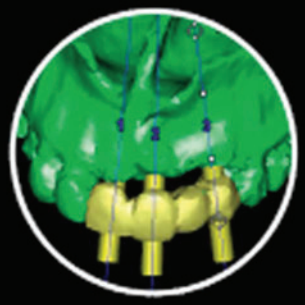
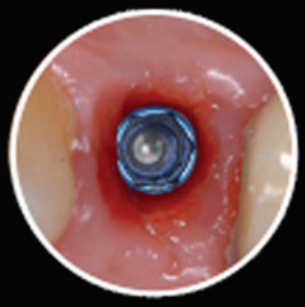
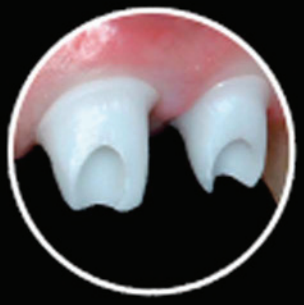
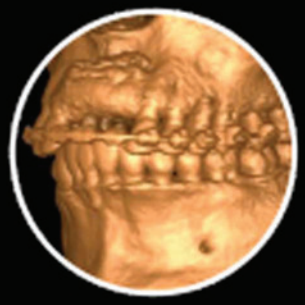
Michael S. Block

Color Atlas of Dental Implant Surgery

Third Edition

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Color Atlas of

Dental Implant Surgery

Third Edition

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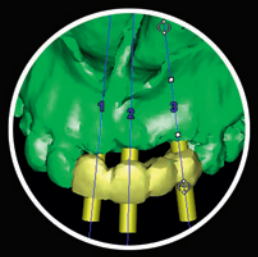
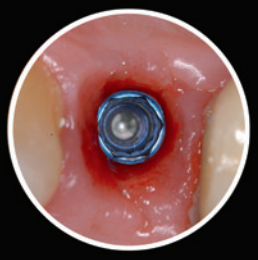
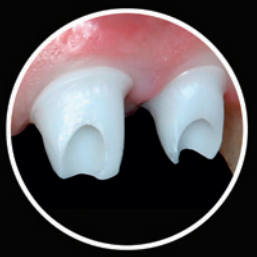
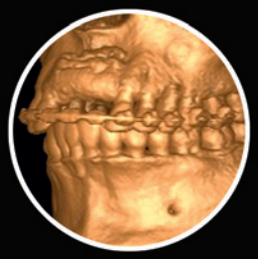
Third Edition

Color Atlas of Dental Implant Surgery

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This third edition of the Color Atlas of Dental Implant Surgery is dedicated to my family and to all of the clinicians who dedicate their daily activities for the care of the patient.

My wife, Colleen, and daughters, Courtney and Celeste, have encouraged me to spend time on this book. They are inspirational and incredibly supportive. I am very blessed.

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Foreword

At the end of our scalpel is the patient. If we treat our patients the same way we would like to be treated, then their care will be well thought out, based on evidence and foundations of knowledge, prepared according to their situation, and orchestrated to the best of our ability. Often the acquisition of new procedures can be difficult.

This edition includes multiple videos of the procedures discussed in the text. Dentists perform mechanical tasks in an artful manner on their patients. New methods can be difficult to perform without seeing the actual procedure. The editorial staff at Elsevier recognized this and suggested that this edition include videos, which is constantly requested by readers. Great idea.

This edition also includes significant updates on procedures including immediate loading, immediate provisionalization, the use of guided surgery methods (both model-based and CT-generated), and the management of the esthetic situation. Case examples are presented to provide the reader with clinical scenarios that we all see on a daily basis. These cases are not the rare ones, but the common ones. Each has a variant, which makes the preoperative evaluation and diagnosis critical to the development of the optimal treatment plan. The reader should be able to extrapolate these cases directly to their practice.

I have had the opportunity to provide continuing education to many oral and maxillofacial surgeons, dental specialists, and general dentists on implant-related procedures. The quest for knowledge amongst dentists is very strong. One of the most rewarding aspects of teaching and translating knowledge to its reduction to practice is seen with the residents in our Oral and Maxillofacial Surgery Program. When I see the clinical accomplishments of Dr. Michael Casadaban, Dr. Ronald Achong, Dr. Mark Ryser, Dr. Clay Chandler, Dr. Tony Panossian, Dr. Chris Haggerty, Dr. Daniel Cook, Dr. Waheed Mohamed, Dr. David Bulot, Dr. Vernon Burke, and so many others, it is easy to understand why this book is written.

The restorations in this book were placed by a large group of great practitioners. They work side-by-side with surgeons—for *the team.* Team New Orleans has positively influenced the long term successful restoration of our patients. On behalf of these patients, I would like to thank you.

It is the hope that this book will provide all clinicians with the knowledge base to move forward using the described techniques to provide patient care that is the same as they would want performed on themselves.

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Preface

Understanding how to perform a surgical technique often requires background reading, watching the procedure being performed, doing the procedure under supervision, assessing the results, and then teaching the method to others. The "see one, do one, teach one" saying is used repetitively in all training programs. From a book, the clinician can see *moments in time* from photograph to photograph, but seeing the actual movement of the periosteal elevator, the method of retraction, and the angle of the cutting instruments, is a very important part of the education when a clinician is learning to utilize a new method.

The third edition of the *Color Atlas of Dental Implant Surgery* has been written to include the critical advances in the field *and* to provide videos for certain procedures as they are performed on patients. Plus, as with the previous editions, each chapter features step-by-step descriptions that include diagnostic methods and algorithms for treatment planning the esthetic case or the perceived difficult case. The inclusion of such a wealth of information on surgical procedures helps the clinician provide the patient with the most chair-efficient therapy possible.

About the DVD

Videos

This new edition provides 14 videos of different surgical procedures:

Video 2-1 Horizontal Ridge Augmentation Using the Tunneling Technique
Video 2-2 Posterior Mandibular Vertical Augmentation Using Interpositional Osteotomy
Video 3-1 Horizontal Ridge Augmentation Using Particulate Graft with a Membrane
Video 3-2 CT-Guided Maxillary Surgery
Video 4-1 Laser-Assisted Intraimplant Site Sinus Elevation Surgery
Video 4-2 Sinus Augmentation Using Bovine Morphogenetic Protein and Laser Assistance
Video 4-3 Placement of Implants into Augmented Sites 6 Months After Grafting with Bone Morphogenetic Protein
Video 6-1 Piezotome-Assisted Premolar Extraction with Immediate Implant Placement
Video 6-2 Placement of Implant in Compromised Central Incisor Site
Video 6-3 Extraction with Immediate Implant Placement
Video 6-4 CT-Guided Surgery for Central Incisor with Custom Healing Abutment
Video 7-1 CT-Guided Anterior Maxillary Surgery with Immediate Provisionalization
Video 8-1 Palatal Approach for Implant Placement
Video 8-2 Anterior Maxillary Interpositional Osteotomy for Vertical Ridge Augmentation

The video narratives, which appear in both the text and on the DVD, are distinguished in the text by a specially-designed box and icon:

Horizontal Ridge Augmentation Using the Tunneling Technique

Before watching the video, please read the following narrative. The narrative describes in detail the procedure performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

A local anesthetic was infiltrated along the edentulous ridge to the lateral aspect of the external oblique ridge up to the posterior tooth. Care was taken to limit periosteal hydropic dissection to the desired location of the augmentation. Two carpules of 2% lidocaine (Xylocaine) with 1:100,000 epinephrine were used. Ten minutes were allowed for absorption of the local solution and vasoconstriction to occur.

The narrative for the procedure follows the actions being performed in the video, and you are encouraged to read the narrative before watching the video. These videos allow the clinician to stop and reassess any step in the

procedure multiple times in the comfort of their office or home.

Image Collection

EXAMPLE

Over 450 additional photos appear as part of an image collection on the DVD. These photos are referenced by an icon that appears in the margin of the text, making it easy to identify what topics feature additional photos. In some instances, there will be additional photos to cases that are presented in the book, whereas others will be cases that appear only on the DVD.

New to the Third Edition

Digital Imaging

The use of digital methods to enhance treatment planning and the orchestration of the treatment plan are balanced with traditional analog procedures. For example, the use of CT imaging to accurately assess bone volume and morphology can be combined with model-based or computer-based guided surgery. The use of digital imaging can provide insight into the need for hard tissue augmentation or the use of soft tissue connective tissue grafts to fully change the thin gingiva patient to a thicker and more stable gingiva patient with less gingival migration to preserve an ideal result long term. As we enter the next decade, all clinicians have a familiarity with digital technology in order to use it as an adjunct for treatment.

Refined Cutting Tools

Another addition to this edition are descriptions on how to use refined cutting tools such as the piezotome and water-cooled laser for bone and soft tissue procedures. These refined cutting tools provide the patient with a gentler and more precise treatment method to achieve the needed result.

Resorbable Membranes

The use of long-lasting resorbable membranes combined with bone graft substitutes, autogenous bone, and fibrin glue has minimal morbidity and is a predictable technique for ridge augmentation.

Enjoy the new book and its educational components. Do not hesitate to contact me if you have questions.

Michael S. Block, DMD

Contents

Section

I

Mandible

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Surgery of the Anterior Mandible

Chapter 1

Chapter Outline

Placement of Two to Five Implants in the Anterior Mandible

General Considerations

Patients who are totally edentulous in the mandible may not be able to consume a normal-textured diet because of mobility of their denture. As the jaws continue to lose alveolar height, the dislodgement forces from the perioral musculature become greater than the retentive aspects of the prosthesis, and the denture moves on the edentulous ridge, causing discomfort, sores, and trauma to the mental nerve. The placement of endosseous implants into the anterior mandible is an excellent therapy for reconstruction, restoring the ability of these patients to consume a normal-textured diet. An improved diet results in normal nutritional intake, improved health, and greater self-confidence.

The options for the patient include (1) a conventional denture; (2) a tissue-borne, implant-supported prosthesis; or (3) an implant-supported prosthesis. The conventional denture is a viable option for many patients, especially those with no prior experience with a removable prosthesis. After an initial attempt to wear a conventional denture, many patients look forward to receiving implants; as a result, they become easier to treat because they are confident about the decision to spend the money, dedicate the time, and deal with the morbidity of implant surgery.

The tissue-borne removable prosthesis can be placed over one to five implants. Most often, two or four implants are used for a tissue-borne prosthesis. The implant-borne prosthesis usually requires the placement of five implants in the anterior mandible, anterior to the mental foramen. For selected patients, four or six implants also can be used. Some patients and clinicians prefer the placement of three implants in each posterior quadrant with four implants in the anterior mandible, resulting in a three-unit, precision-attached crown and bridge restoration; however, adequate bone must be available superior to the inferior alveolar nerve. Surgical placement of implants for a full-arch crown and bridge prosthesis with individual porcelain teeth requires meticulous planning and placement of the implants to locate them within the confines of the crowns, avoiding the embrasure spaces.

Based on the recommendations of the implant team and considering his or her desires and interests, the patient makes the decision after being informed of the advantages of the different types of prostheses and the financial responsibilities associated with each. Once an informed patient has made the decision, surgery is scheduled.

Evaluation of anatomy—physical examination of the patient without teeth

After reviewing the patient's medical and dental history, the surgeon performs a physical evaluation, focusing on the anatomy of the mandible. The range of opening of the patient's mouth is recorded. Limitations in opening may affect the treatment plan in extreme conditions. The general health of the intraoral soft tissues is evaluated. Any undiagnosed pathologic condition or dental infection, as well as mucosal infections, must be treated to completion before implant placement.

The soft tissue attachments of the floor of the mouth and the mentalis musculature are noted. The width of the band of *keratinized gingiva* (KG) on the alveolar crest is documented. The distance from the crest to the junction of the attached and unattached mucosa is recorded (Figure 1-1, A-F). Examination of the soft tissues is important to determine the need for vestibuloplasty, either before or at the time of implant placement.

The locations of the submandibular ducts are evaluated to ensure that they will not be violated during the procedure. The locations of the mental foramina are palpated and, if necessary, transferred to a diagnostic cast for further planning.

The slopes of the labial and lingual cortices are palpated. The height of the mandible is estimated by palpation of the anterior mandible. The location of the genial tubercles is noted. In a relaxed vertical position of the jaws, the relationship of the anterior mandible to the maxilla is observed to determine the benefits of positioning the implants to correct or mask a Class II or Class III skeletal jaw relationship. Occasionally, orthognathic surgery is necessary to correct severe skeletal discrepancies before implants are placed. The physical examination of the slopes of the lingual and labial cortical bone is confirmed by radiographic evaluation when necessary.

At the conclusion of the physical examination, the surgeon should have a good appreciation of the height and

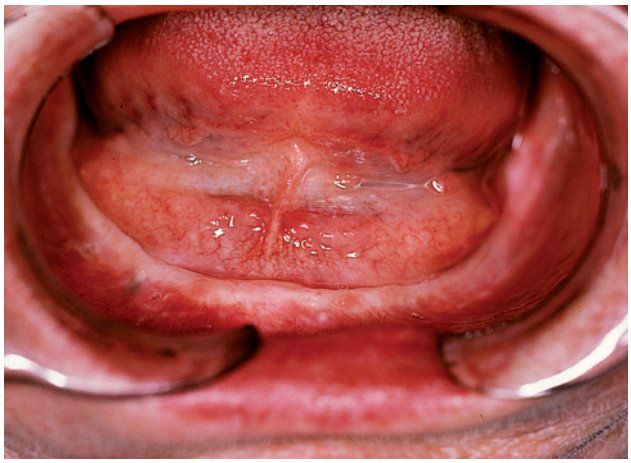


FIGURE 1-1 **A,** Preoperative view of the mandible. The unattached, mobile gingiva is more than 5 mm from the crest.

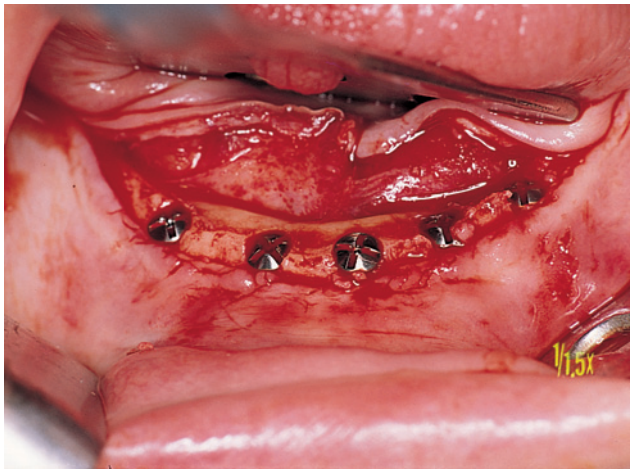


FIGURE 1-1 **B,** Crestal incision with no vertical release is used to place the implants. The implants are placed slightly countersunk to allow the cover screws to be level with the bone; this prevents potential supracrestal pressure points.

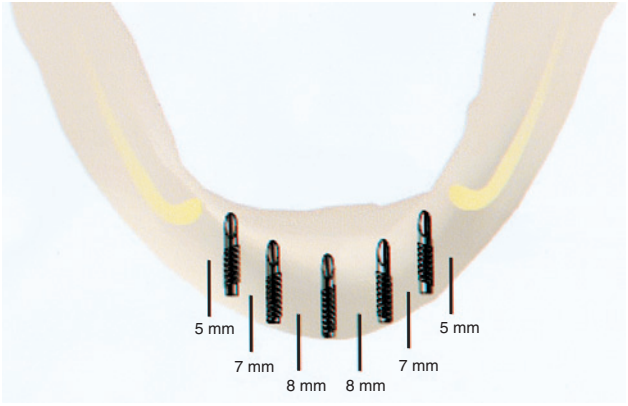


FIGURE 1-1 **D,** Drawing of ideal location and spacing of implants in the anterior mandible demonstrates the distance from the mental foramen.

width of the anterior mandible, as well as the slopes of the cortices. The surgeon should be able to discuss with the patient the planned location of the implants and the need for an adjunctive soft tissue procedure, such as a simultaneous vestibuloplasty.

Evaluation of anatomy—radiologic examination of the patient without teeth

Radiologic evaluation of the patient before the placement of implants focuses on determining the vertical height and slopes of the cortices in relation to the opposite arch. A baseline *panoramic radiograph* typically is used to evaluate the patient considering an implant. Because this

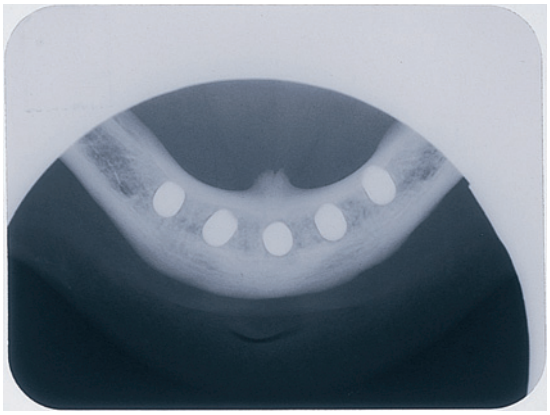


FIGURE 1-1 **C,** Radiograph shows proper positioning of the implants. The most posterior implants are approximately 5 mm anterior to the mental foramen. Note the 3-mm spaces between the bodies of the implants.

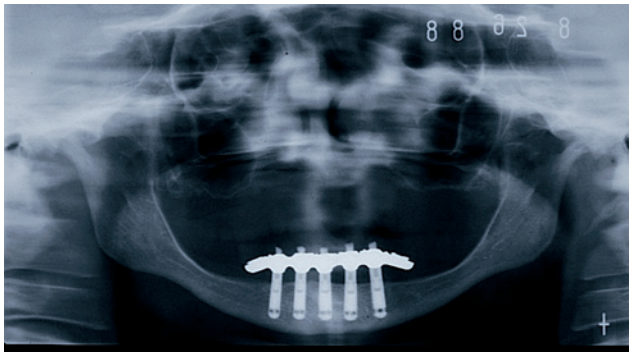


FIGURE 1-1 **E,** Panoramic radiograph shows suprastructure on the implants for the hybrid denture–type prosthesis.

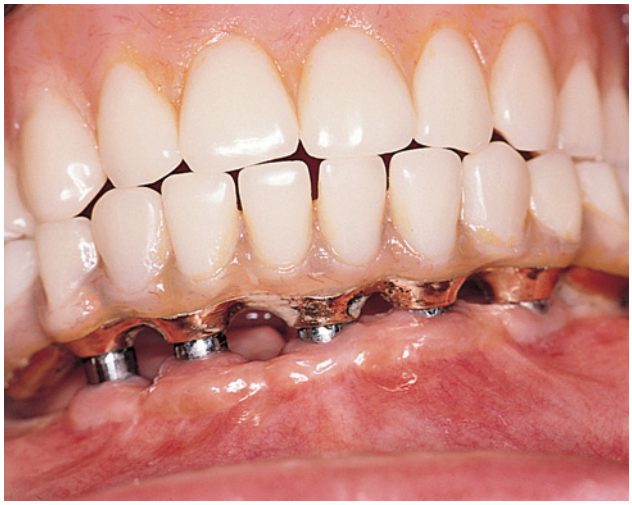


FIGURE 1-1 **F,** Frontal view of the mandibular hybrid denture opposing a conventional maxillary prosthesis. (Prosthetics by Dr. Luis Guerra.)

radiograph usually is magnified more than 20%, accurate vertical measurements of the anterior mandible cannot be determined from it. Ball bearings of known diameter can be placed in a stent in the positions prescribed to receive implants, and then the magnification error can be determined and the correct vertical dimension calculated. When the mandible is greater than 15 mm, the panoramic radiograph is the only film needed, because the height of the mandible clearly exceeds the length of a long implant.

A second radiograph, the *lateral cephalogram,* is very useful and inexpensive, and it provides an image with minimal magnification (Figure 1-2, A-D; the complete case is presented in DVD Figure 1-1, A-E). The lateral cephalogram demonstrates the slopes of the cortices of the mandible and the skeletal ridge relationships of the mandible to the maxilla. It also provides a simple, inexpensive radiographic assessment of anterior height. If desired, foil can be placed over the anterior teeth in a set of dentures during exposure of the lateral cephalogram; this technique can demonstrate clearly the relationship of the teeth to the ridge and the ridge relationships. It also provides insight on the angulation of the implants, so that they can be placed in the ideal locations for the implant-supported or tissue-supported prostheses.

DVD Images 1-1, A-E

Additional radiographic techniques include complex motion tomography or reformatted computed tomography (CT). Complex motion tomography is based on the Grossman technique and has a consistent 26% magnification error. Rulers with the 26% correction are used to measure bone height. CT scans have a less-than-0.5-mm error when reformatted, cross-sectional images are examined. However, both techniques involve more radiation exposure for the patient. Most surgeons agree that, as clinical experience increases, less need exists for these more expensive radiographic techniques in preparing for the placement of implants into the anterior mandible.

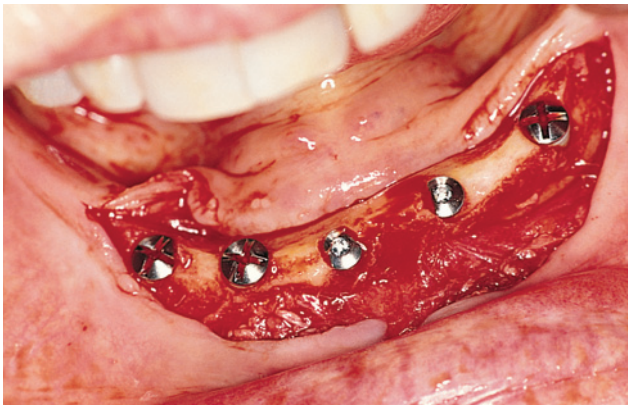


FIGURE 1-2 **A,** Incision is made slightly anterior to the band of keratinized gingiva (KG) to facilitate dissection, because the original ridge is narrow and sharp. The sharp ridge is reduced with rongeur forceps, and the implants are placed.

Surgical treatment

Incision Design Considerations. At the consultation visit, the surgeon notes the following when examining the patient:

1. Level of junction of attached and unattached gingiva
2. Level of attachment of mentalis muscle to the alveolar crest
3. Width of attached KG on the alveolar crest

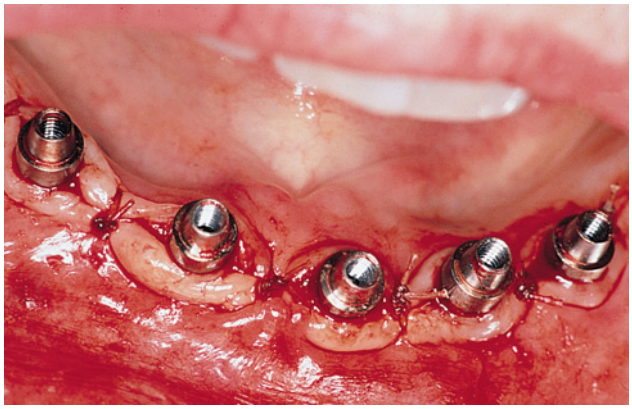


FIGURE 1-2 **B,** At the time of exposure, the band of KG is bisected, and a full-thickness conservative flap is elevated. The cover screws are removed, and for this patient, abutments are placed. The KG is repositioned around the abutments.

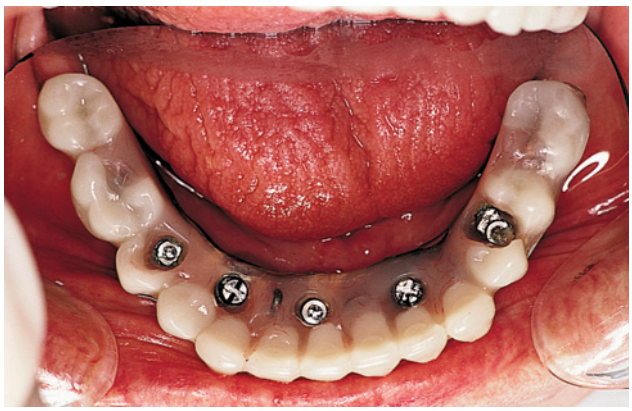


FIGURE 1-2 **C,** Occlusal view shows the slightly lingual position of the implants, secondary to a Class II skeletal profile.

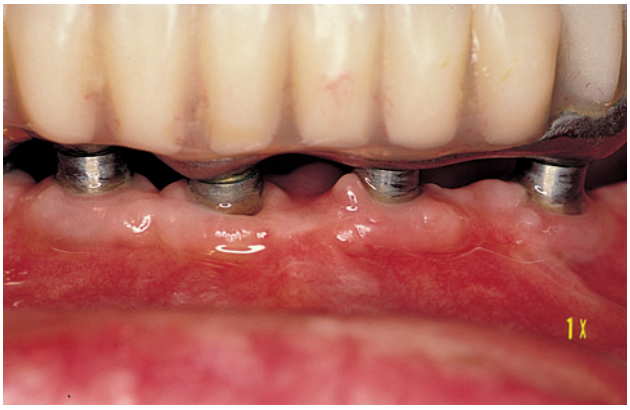


FIGURE 1-2 **D,** Patient has suffered a stroke and has had difficulty with oral hygiene. However, even with the presence of plaque, protection from the retained KG prevents adverse bone loss.

4. Position of the genial tubercles in relation to the alveolar crest
5. Inclination of the lingual and labial cortical plates of bone
6. Skeletal relationship of the anterior mandible to the maxilla

Based on these findings and the height of the mandible, the surgeon decides which incision to use to expose the bone and subsequently to place implants into the edentulous mandible.

If the attachment of the mentalis muscle is 3 mm or more labial to the location of the attached gingiva on the alveolar crest, a *crestal* incision can be used (Figure 1-3, A-F). If the mentalis muscle is located adjacent to the alveolar crest, which would result in mobile, unattached gingiva directly against the implant abutment when restored, a *vestibular* incision is used. A type of lipswitch vestibuloplasty is performed to reposition the muscle attachments inferiorly, resulting in nonmobile tissue on the labial surface of the implant abutment complex.

When the mandible is 12 mm or less in height, an incision placed labial to the thin band of KG allows for easier dissection. However, it cannot be accompanied by a lipswitch vestibuloplasty, because displacement of the mentalis musculature in an atrophic mandible results in a drooping, "witchlike" chin deformity. For the atrophic mandible with 8 to 12 mm of vertical bone height, the locations of the incisions and implants and

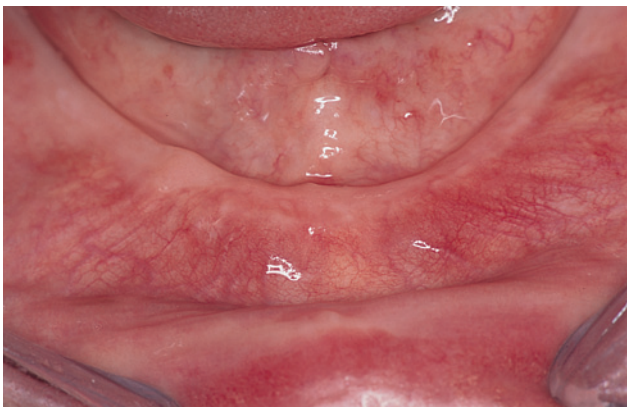


FIGURE 1-3 **A,** Implant placement for a tissue-borne overdenture is demonstrated in a mandible 12 mm tall. The lip musculature is more than 5 mm from the crest.

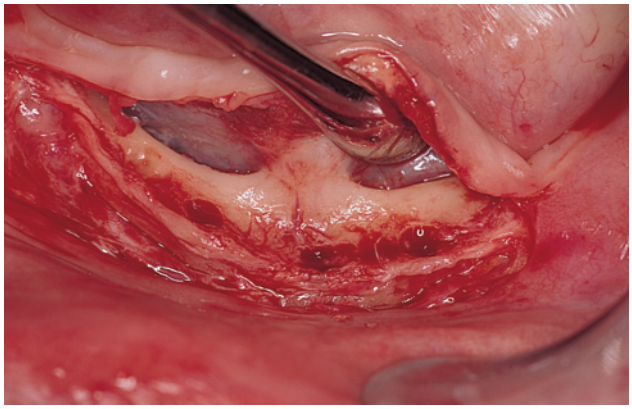


FIGURE 1-3 **B,** Incision is made bisecting the KG. The subperiosteal reflection reveals the facial border of the crest and exposes the lingual bone. The expected presence of the genial tubercles is noted. The anterior position of the mental foramen is demonstrated on the left.

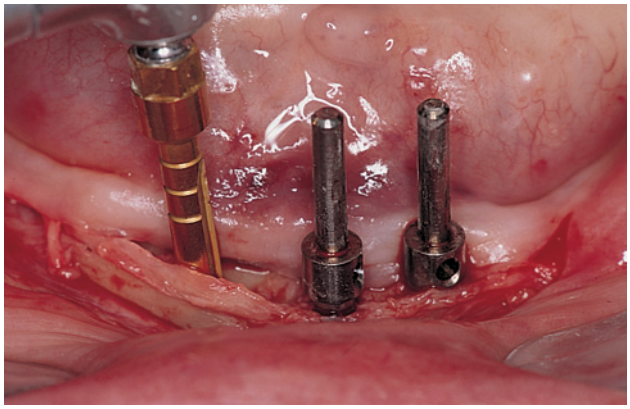


FIGURE 1-3 **C,** Round bur is used, followed by a 1.25-mm pilot drill. Parallel pins are placed to facilitate parallel placement of the implants. Parallel guide pins are used to guide the drilling as the diameter of the drills increases.

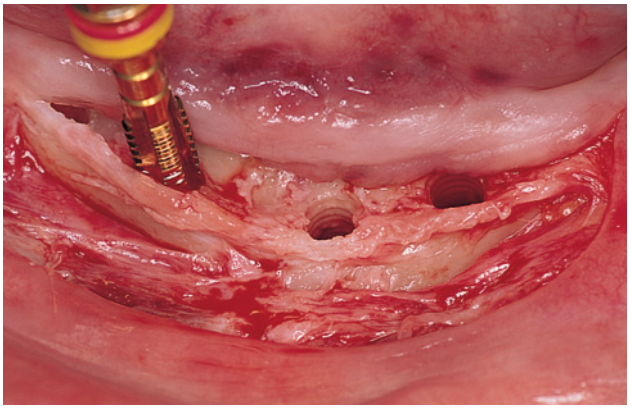


FIGURE 1-3 D, After the final-diameter drill is used, a thread-former is used to create threads in the bone for placement of hydroxylapatite (HA)–coated, threaded implants.

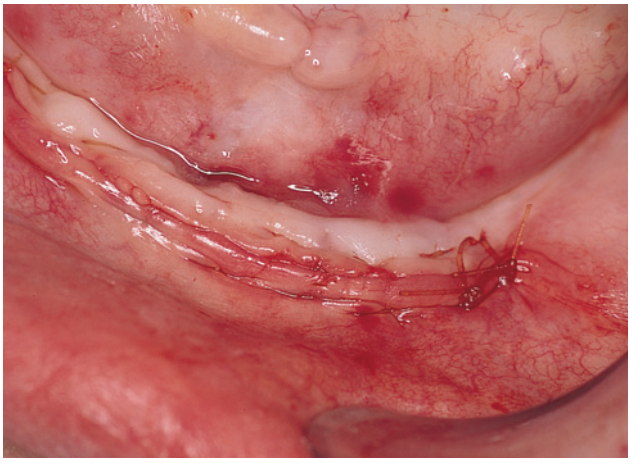


FIGURE 1-3 F, Incision is closed with resorbable sutures using a horizontal mattress suturing technique.

the location of the incision for second-stage surgery are critical for successful restoration. The incision for placement should be made in such a way as to avoid loss of KG. Therefore, an incision placed at the anterior border of the mandibular alveolar crest, typically labial to the KG, allows for adequate dissection. Often in the patient with an atrophic mandible, the thin band of KG is positioned lingually. Attempts to enlarge the band of attached KG have not been greatly successful, because the lip muscles tend to displace the graft from the host bed. The implants must be placed slightly lingual to the crest of the ridge, thus lingual to the attachment of the muscles. If they are flared toward the labial, chronic irritation from the labially flared implants will be a constant source of

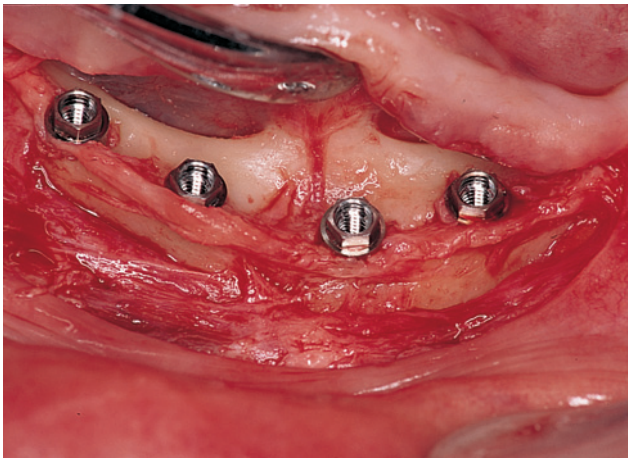


FIGURE 1-3 E, Implants before placement of the cover screws. The implants are placed such that the most facial surface of the implant is slightly lingual to the crestal bone. In an atrophic mandible, this prevents excessive lip irritation from unattached tissue.

soreness and will result in an unhappy patient. At the time of exposure, the thin band of KG should be bisected and transposed labially, resulting in KG along the labial surface of the abutments.

For mandibles with a vertical bone height greater than 12 mm, the incision for placement may be made either on the crest or in the vestibule, depending on the location of the muscle attachments. An incision bisecting the KG allows the surgeon the luxury of knowing that the KG will remain on the labial surface of the implant abutment if the incision breaks down prematurely. Premature breakdown of the incision can occur for several reasons, including excessive pressure from the removable prosthesis; a supracrestal profile of the implant with the cover screw in place; surgical trauma to the tissues; or poor tissue quality and poor healing. If the alveolar crest is thin, with the band of KG over the thin portion of the crest, bisecting the KG may make dissection of the flaps difficult, because the gingiva will be thin over the thin crest. Careful planning of the incisions and technical dissection without trauma promote long-term gingival health.

A local anesthetic, typically 1% or 2% lidocaine (Xylocaine) with 1:100,000 epinephrine, is infiltrated into the labial and lingual tissues. Infiltration includes the labial aspect of the inferior border of the mandible, the lingual cortical plate (to anesthetize branches of the mylohyoid nerves), and along the crest. Infiltration anesthesia on the crest creates a hydropic dissection, which aids in the subperiosteal dissection. Bilateral inferior alveolar nerve blocks are not necessary.

After several minutes have elapsed to allow the anesthetic to take effect and to be absorbed in the tissues to reveal the preinjection anatomy, an incision is made. Typically, a 15 blade is used.

Crestal Incision and Dissection. The crestal incision should bisect the band of KG. Bisecting the KG is important, because this prevents a potential soft tissue problem if the incision should open during the healing period. The incision should extend along the alveolar crest posterior to the mental foramen. When the mental foramen is on top of the crest, secondary to severe bone resorption, the incision should be stopped anterior to the foramen. After the periosteum has been reflected, the mental foramen is visualized, and the crestal incision then can be extended posteriorly along the lingual crest; this prevents trauma to the nerve. Occasionally, vertical release incisions can be used posteriorly. This author does not use a midline vertical release incision, because it causes increased patient discomfort during the first 2 weeks of healing.

After the incision has been made through the periosteum to the bone, a periosteal elevator is used to reflect subperiosteal flaps both labially and lingually. A clean subperiosteal dissection is important, because it results in minimal bleeding and lingual blood vessels can be avoided. If muscle attachments are found inserting into the crest, the surgeon severs them cleanly with a scalpel rather than tearing them, which can increase bleeding and trauma to the soft tissues.

Reflection of the labial tissues can be tedious because of the firm attachment of the dense, fibrous alveolar crestal tissue or if the ridge is narrow. Great care must be taken to raise an intact flap without multiple tears.

A lingual reflection is performed to allow the surgeon direct visualization of the lingual cortex, which also allows proper angulation of the implant parallel to the lingual cortex, if appropriate, and avoids implant perforation of the lingual cortex. The labial reflection includes reflection of a portion of the mentalis muscle to allow for proper visualization of the contours of the labial cortex. A limited reflection prevents the surgeon from seeing the bone contours and results in implants placed through the cortical plates rather than within them. The surgeon should be able to look directly over the alveolar crest, seeing both cortical plates. It is useful to visualize the implant surgery and anticipate any adverse problems. After the bone is exposed, the implants are placed according to manufacturer recommendations.

Vestibular Incision and Dissection. Vestibular incision and dissection is the approach recommended to relocate the mentalis muscle from the alveolar crest, anticipating the ultimate location of the prosthesis and abutments (Figure 1-4, A-L; the complete case is presented in DVD Figure 1-2, A-R). The incision typically is placed 5 to 10 mm from the junction of the attached and unattached gingivae. The incision is made through mucosa, not into the underlying muscle. The incision extends from the approximate location of the mental foramen in the vestibule. The incision is made with a 15 scalpel blade and is kept superficial to identify branches of the mental nerves. Direct visualization of the branches of the mental nerve allows a meticulous dissection superficial to these nerves and prevents paresthesia.

DVD Images
1-2, A-R

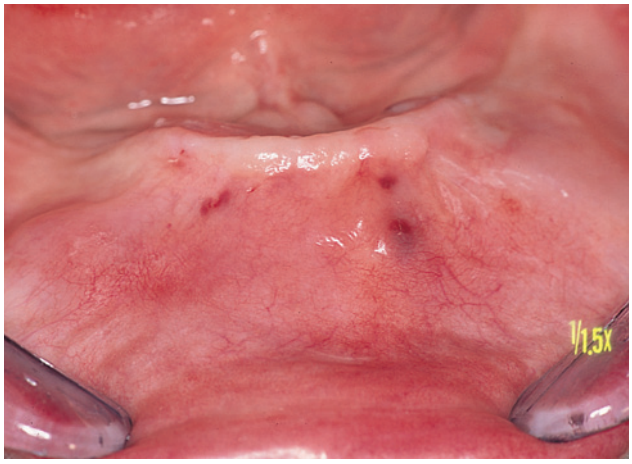


FIGURE 1-4 A, This 65-year-old woman was referred for a vestibuloplasty and placement of two implants. The high muscle attachments to the crest are noted.

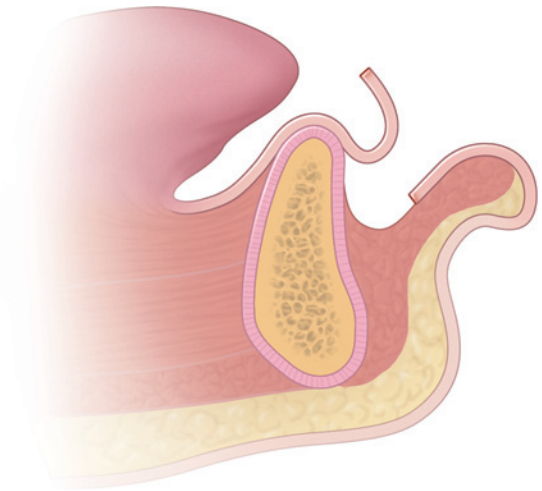
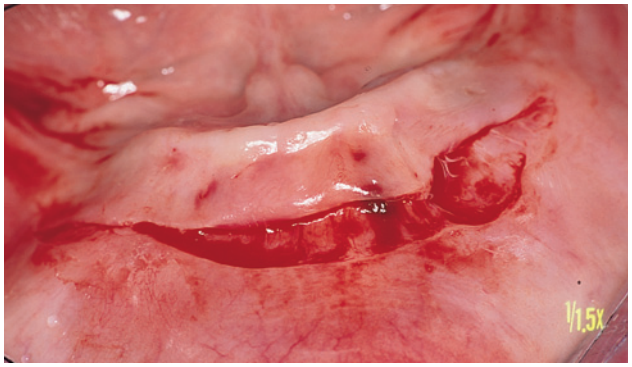
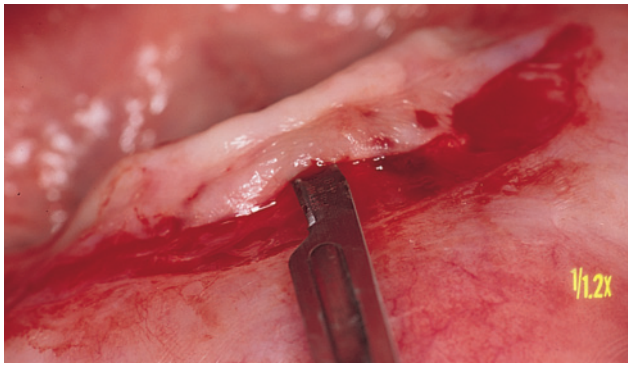


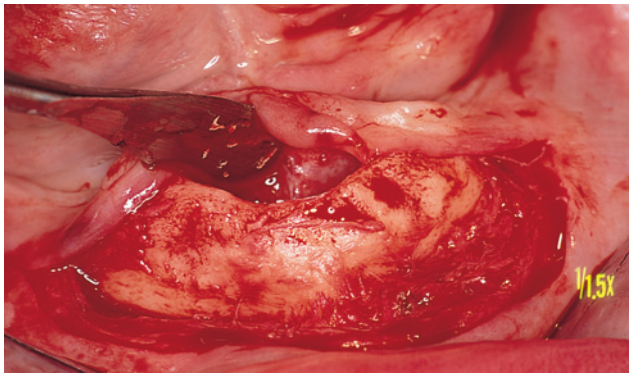
FIGURE 1-4 B, Incision for ridge extension for removable dentures is made far out into the lip. For implant-retained overdentures, the goal is to move the mobile, unattached gingiva from the abutments, not from the ridge extension. The incision is made, and a mucosa-only flap is raised superficial to the underlying mentalis muscle.



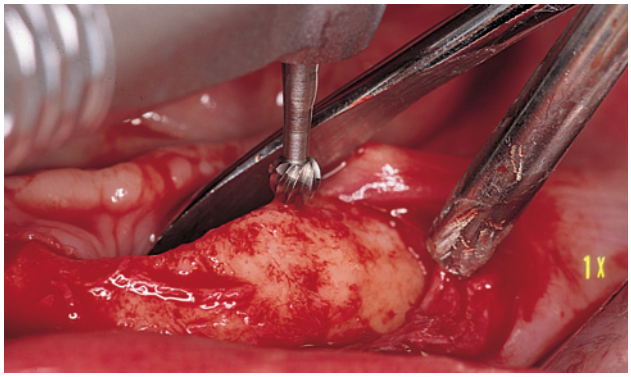
● **FIGURE 1-4** **C,** Incision is made with a 15 blade through the mucosa-only flap without incising the underlying mentalis muscle.



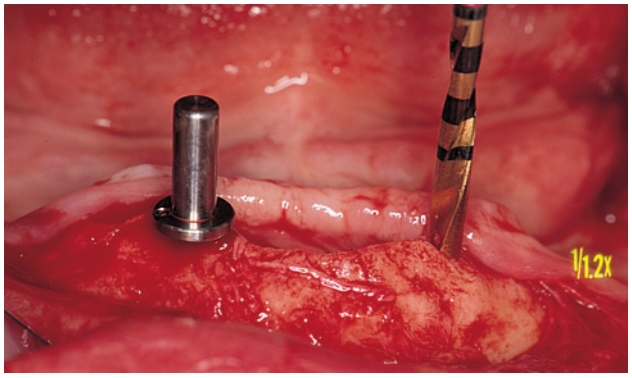
● **FIGURE 1-4** **D,** Scalpel blade is turned parallel to the muscle fibers, and a mucosa-only flap is raised sharply.



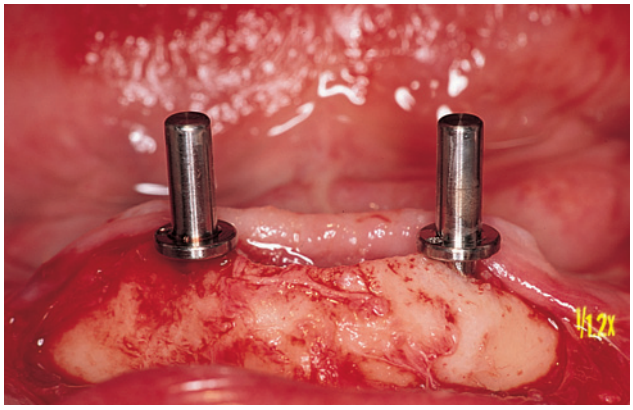
● **FIGURE 1-4** **E,** After the mucosa-only flap has been elevated to the crest, a scalpel is used to sharply incise the periosteum on the crest. The periosteum is elevated toward the facial, exposing the facial aspect of the anterior mandible. It is important to maintain 10 to 15 mm of mentalis attachment to the mandible to prevent chin droop. The lingual edge of the periosteum is raised over the genial tubercles.



● **FIGURE 1-4** **F,** Rongeur forceps are used to mark the implant site. A round bur is used to create the first dimple in the cortex to allow for easy initiation of the pilot bur hole.



● **FIGURE 1-4** **G,** Pilot bur is used to initiate the implant site. Parallel guide pins are placed to aid in parallel implant site preparation.



● **FIGURE 1-4** **H,** Parallel pins indicate the position of the implants. The next-sized drill is used with a guide pin in place.

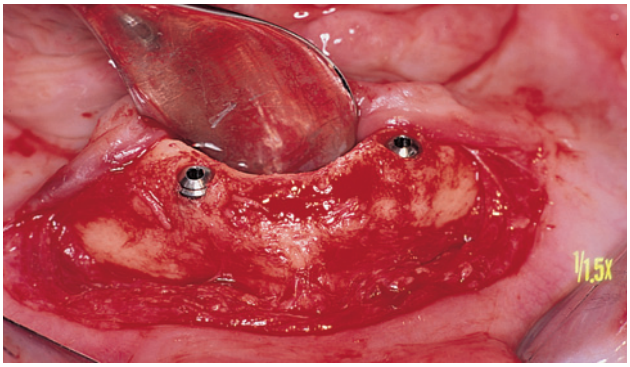


FIGURE 1-4 I, Implants are in position.

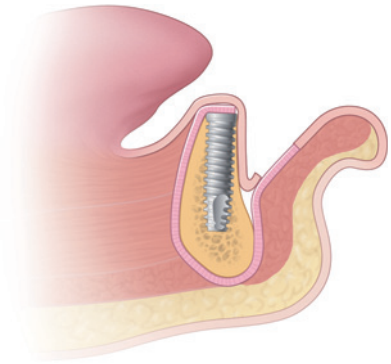


FIGURE 1-4 J, After the implants have been placed, the anterior edge of the mucosa-only flap is sutured in the depth of the vestibule. The sutures are placed to reapproximate the lip mucosa over the implants and to provide a barrier to the migration of muscle superiorly.

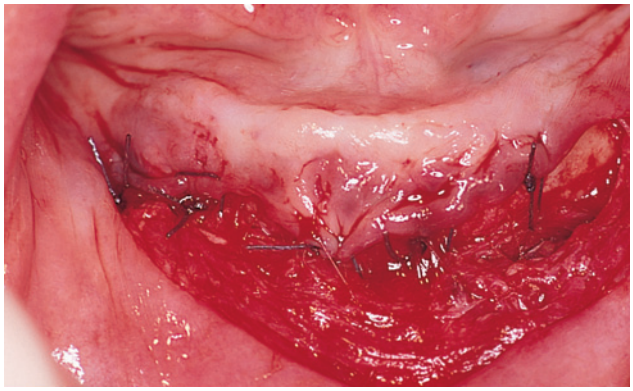


FIGURE 1-4 K, Slow-resorbing sutures can be used in a horizontal manner to retain the lip mucosa to the depth of the vestibuloplasty site.

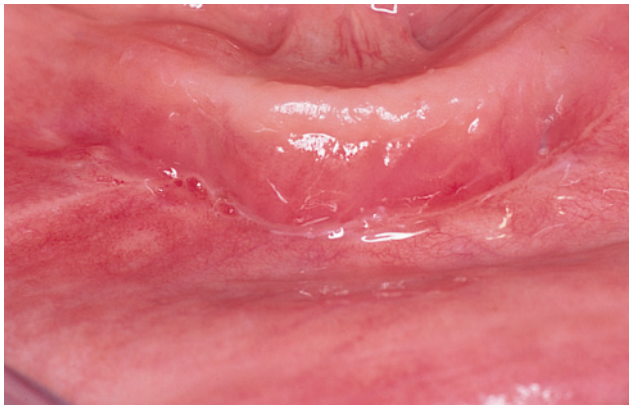


FIGURE 1-4 L, Three-week follow-up photograph shows healing of the site.

After the mucosa has been incised, a mucosa-only flap is carefully dissected from the underlying muscle using either a scalpel or small scissors. The mucosa-only flap is elevated until it reaches the junction of the attached and unattached gingivae. At this location, an incision is made through the periosteum to the alveolar crest. The periosteum is reflected toward the lingual, with the overlying mucosa-only flap attached to the periosteum to expose the lingual aspect of the mandible. The mucosal flap is kept attached to the lingual mucosa and therefore is lingually based. The labial periosteum then is elevated from the bone with a periosteal elevator to expose the labial cortex. The extent of reflection is similar to that described previously for the crestal incision. After the bone has been exposed, the implants are placed according to the manufacturer's recommendations.

Placement of Implants

Two Implants. In general, when two implants are to be placed for an overdenture, the surgeon should consider the potential need for additional implants at a later time; for example, the patient may decide to change from a tissue-borne prosthesis to an implant-borne prosthesis. Some patients prefer the overdenture prosthesis, but they may complain of food being caught under the denture and the mobility of the prosthesis when they are speaking, swallowing, or chewing. They also may want to eliminate the need to change clips or O-rings. For patients who desire the retention of a fixed or fixed-removable prosthesis, three additional implants may be placed, resulting in five implants in the anterior mandible, which will sufficiently support an implant-borne prosthesis. In light of this consideration, when placing two implants into the anterior mandible, the surgeon locates the implants 20 mm apart (each 10 mm from the midline of the mandible) to allow for later implant placement if needed. A caliper is set at 20 mm, and these locations are marked with rongeur forceps or a round bur (see Figure 1-4, F-G; also Figure 1-5, A-C).

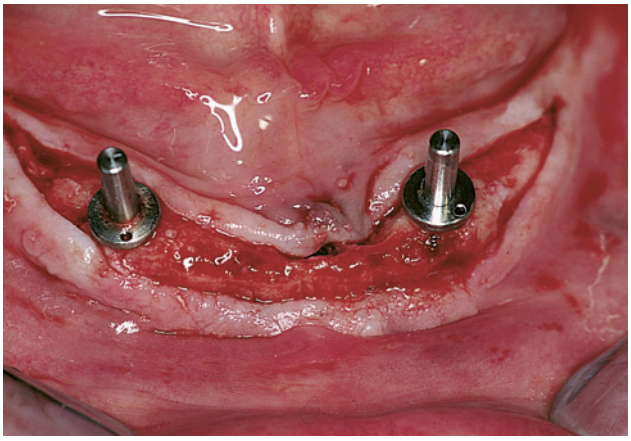


FIGURE 1-5 A, Two implants for O-ring retention of an overdenture prosthesis are planned. A crestal incision is made, bisecting the KG. The locations of the implants are determined by using a surgical stent, which is a duplicate of a denture setup approved by the patient.

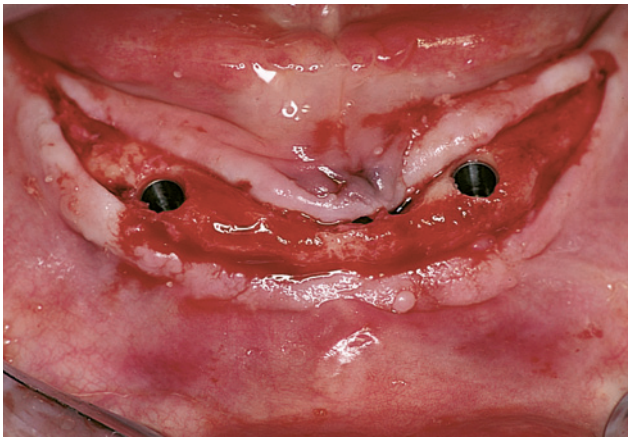


FIGURE 1-5 C, Implants in place. O-ring attachments will be placed after the implants have integrated.

The labiolingual location of the implants in the crest is critical to the patient's long-term comfort. The implants must be located so as to prevent soft tissue irritation, which can occur if the implants are placed too lingual into the mobile tissue of the floor of the mouth or too labial, causing the mobile mentalis musculature to rub continually against the abutments of the implants, creating chronic problems. Ideal placement of the implants, in the center of the crest, is essential to ensure that the restoration is comfortable for the patient (Figure 1-6, A-B).

The ridge of the mandible may be uneven or may have sharp contours. This author uses rongeur forceps to reduce the crestal bone when it is thin, sharp, or uneven. The use

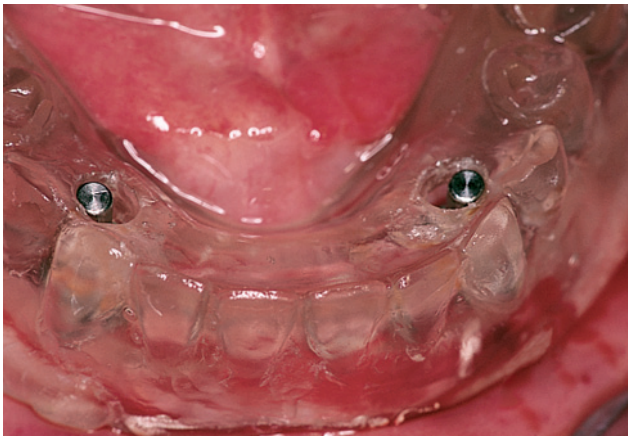


FIGURE 1-5 B, Parallel pins can be seen through the holes made in the surgical guide stent.

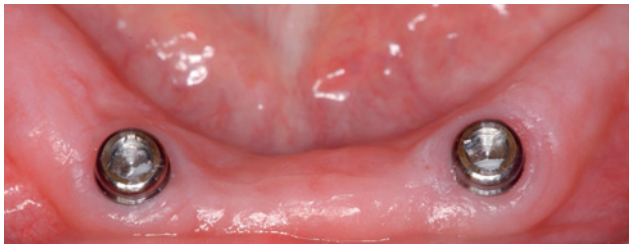


FIGURE 1-6 A, Locator-type attachments have a low profile yet provide retention of the patient's tissue-borne denture. (Biomet 3i, Palm Beach Gardens, Florida.)

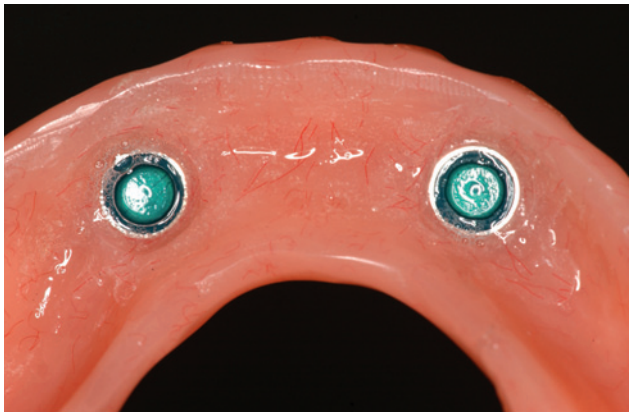


FIGURE 1-6 B, Patient's denture has inserts, which can be picked up by the dentist using a relatively simple protocol. Matching the parts in the denture to the attachments in the mouth, which are screwed into the implant, provides retention as an implant-assisted overdenture. The attachments can be retrofitted into an existing denture.

of rotating burs to reduce the ridge crest may result in bone trauma, with resultant bone loss around the implants. In addition, the rongeur forceps can be used to take a small "bite" from the ridge, creating a small depression that can be easily engaged with the round bur and subsequent pilot drills. Adjacent bone can be removed with the forceps, creating a smooth transition from the implant site to the crest without an unusually tall segment of bone between the implants. The round bur then is used to mark the implant locations, which are placed after the caliper measurements have been confirmed.

After the round bur has been used to mark the sites, the initial drill (typically 1.25 to 2 mm in diameter) is used to create the first site; the surgical guide stent, if available, is used for the surgery. A parallel or guide pin is placed into the prepared hole, and the angulation is checked to ensure that the anteroposterior and medial-distal inclinations are appropriate. The surgical guide, if available, is placed into the mouth to confirm that the implants are within the eventual denture base. If the patient has maxillary teeth or a denture, the mandible is closed gently to ensure that the implants are placed within the contours of the incisive edges of the maxillary teeth, not labially. After parallelism has been confirmed (or after any necessary changes have been made), the second site is prepared with the small-diameter bur in the proper axis.

A second guide pin is placed. Careful examination should confirm that the implants will be satisfactory when placed in these positions at these inclinations. The remaining sequence of burs is used as recommended by the manufacturer. If angulation changes are necessary, the next bur, which typically is 2.7 or 3 mm in diameter, can be directed to correct the angulation of the implant.

It is important to place the implant at the correct height in relation to the alveolar crest. If the implant is placed such that the cover screw is superficial to the adjacent bone, creating a small bulge under the gingiva, incisional dehiscence or mucosal breakdown may occur if the patient chews with a temporary prosthesis. An advantageous technique is to place the implants into the anterior mandible so that they are countersunk sufficiently to allow the height of the cover screw to be considered; this results in a flush relationship with the adjacent alveolar bone. This placement, however, may be contraindicated for specific types of implants. The surgeon should follow the guidelines for the specific implant system. For one-stage implants, temporary healing abutments are placed as recommended by the manufacturer.

The anterior mandible may have a dense cortical plate with abundant marrow space, or it may have minimal marrow with an abundance of cortical bone. A smaller mandible has more cortical bone and less cancellous bone. When dense bone is encountered, it is important to clean the drills often during the drilling sequence to keep the cutting surfaces clean and unclogged during preparation of the implant site. For coated implants, a type of thread-former bur is used to create threads in the bone. For self-tapping implants, the surgeon may need a slightly larger bur than customarily used in other areas of the mouth. For example, rather than using a 3-mm drill before self-tapping a 3.75-mm implant, the surgeon may need to use a 3.25-mm drill to achieve greater ease of implant insertion into dense bone.

If a crestal incision has been used, the incision is closed with atraumatic needles. Sutures may be resorbable or non-resorbable, depending on the clinician's choice. If a vestibular incision has been used, the edge of the vestibular mucosa is sutured into the depth of the vestibule on the edge of the periosteum. This leaves a denuded portion of the lip vestibule, which must heal by secondary intention. A resorbable suture can be used, but it should be longer in retentive strength; therefore, a polyglactin suture is recommended.

Four or More Implants. When four or more implants are to be placed into the anterior mandible, the incision design is the same as that used for two implants. The subperiosteal reflection should be sufficient to expose the lingual and labial cortices and the mental foramen bilaterally. After completion of the periosteal reflection, the surgeon has an excellent view of the operative site, the contours of the bone, and the location of the mental foramen.

The mental foramen is used as the landmark for locating the distal implants. A caliper is used to mark the alveolar ridge no less than 5 mm anterior to the mental foramen. This distance usually is the anterior extent of the nerve as it loops forward in the bone before exiting at the mental foramen. It is critical to examine the radiographs carefully to confirm that the patient does not have an anterior loop of the nerve within the bone. A small nerve probe can be placed into the mental foramen; however, this procedure is reserved for clinicians with experience in handling sensory nerves.

A small, round bur is used to make a depression in the bone to locate the implant site on one side of the mandible. A similar mark is placed on the opposite side of the mandible no less than 5 mm anterior to the mental foramen. The caliper then is set to 7 or 8 mm, and the next implant locations are marked in a similar manner anterior to the two distal locations. If a fifth implant is to be placed, a mark is made in the midline of the mandible. Using the caliper, the surgeon places the implant bodies a sufficient distance apart to ensure adequate space for restoration and hygiene (Figure 1-7, A-J, and DVD Figure 1-3, A-E).

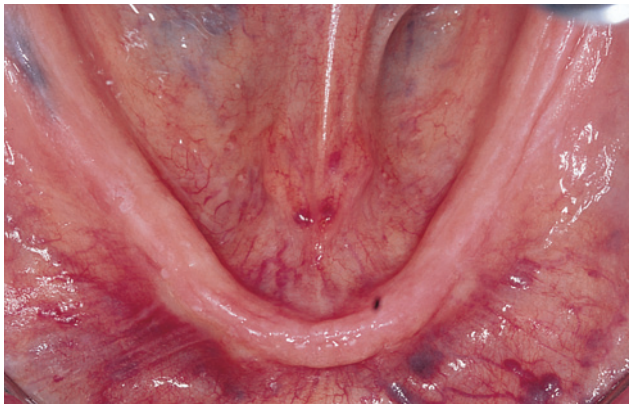


FIGURE 1-7 **A,** Surgical guide directs the placement of five implants for a hybrid denture.

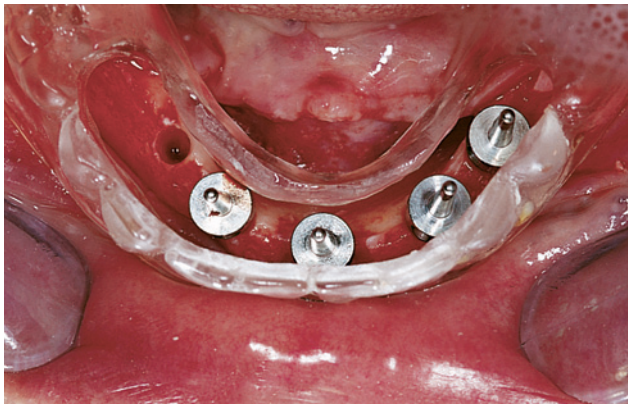


FIGURE 1-7 **B,** Crestal incision is made through the KG. Implant sites are prepared. Guide pins are placed in holes 3 mm in diameter.

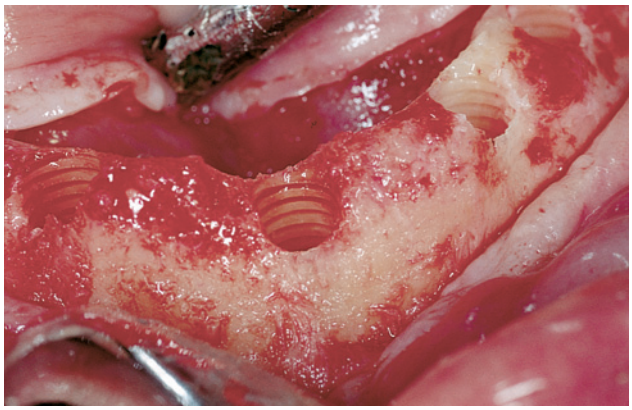


FIGURE 1-7 **C,** Thread-former is used to create threads in the bone. This procedure is performed when HA-coated, threaded implants are used.

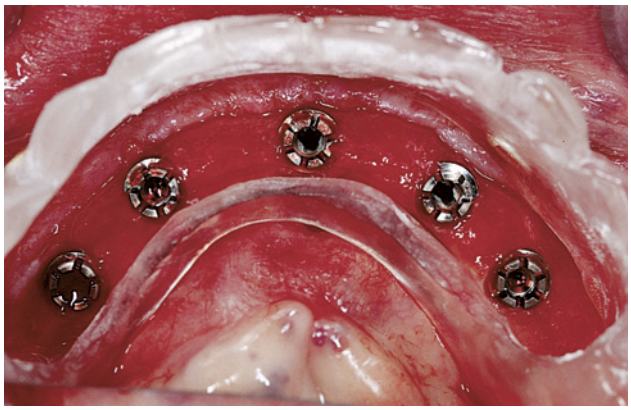


FIGURE 1-7 **D,** Implants are placed. Driving mounts are removed, showing the implants in position. For a hybrid denture, the implants can be placed in the embrasure spaces because of the nature of the prosthesis. The implants are placed slightly lingual to the crest.

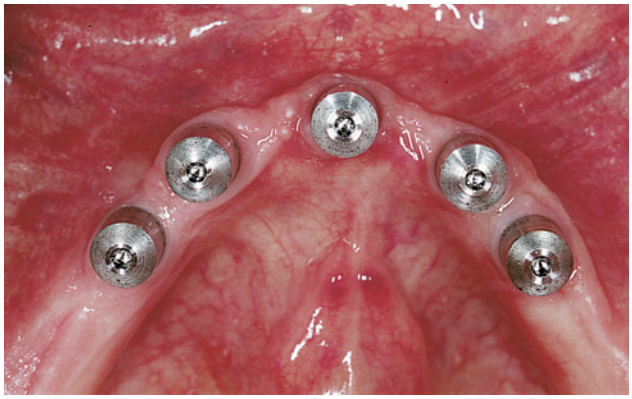


FIGURE 1-7 **E,** After 4 months of healing, the implants are exposed by bisecting the KG and transposing them labially. These healing abutments are shown 3 weeks after exposure.

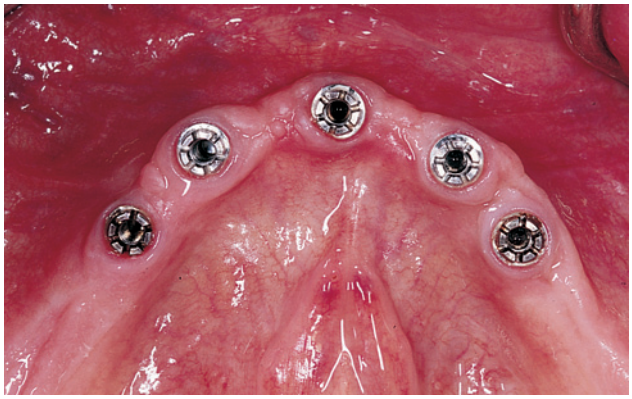


FIGURE 1-7 **F,** Soft tissue around the implants is ready for final impressions and fabrication of the final prosthesis.

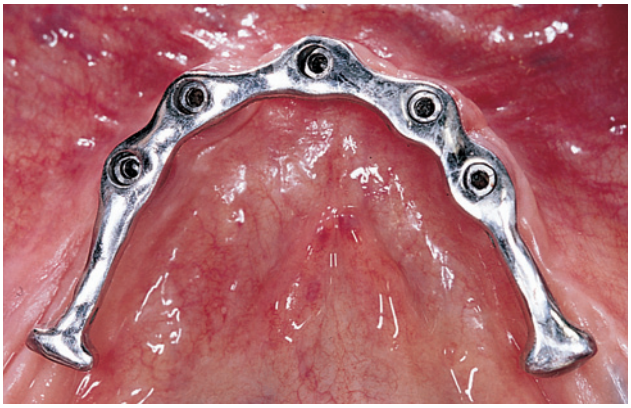


FIGURE 1-7 G, Occlusal view shows the bar that connects the implants and the cross-arch that stabilizes them.

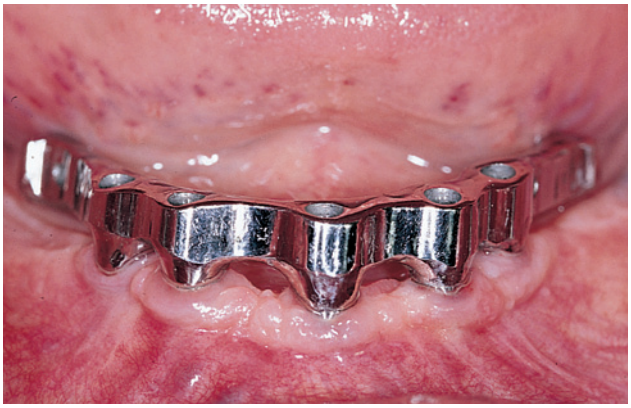


FIGURE 1-7 H, Frontal view of the bar, which is thick and rigid. Posteriorly, small holes are shown in the bar, which will be engaged by a type of plunger-locking mechanism (i.e., SwissLoc NG).

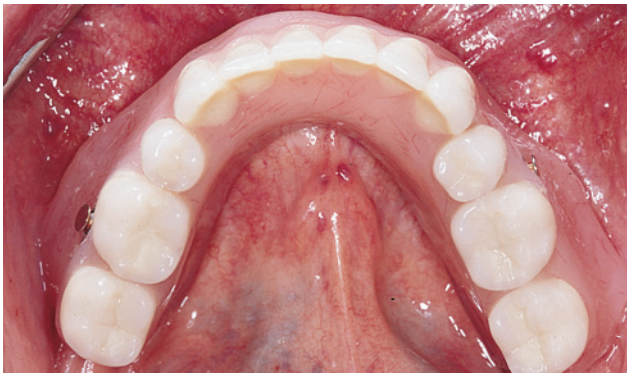


FIGURE 1-7 I, Occlusal view of the restoration; note the natural contour of the restoration.

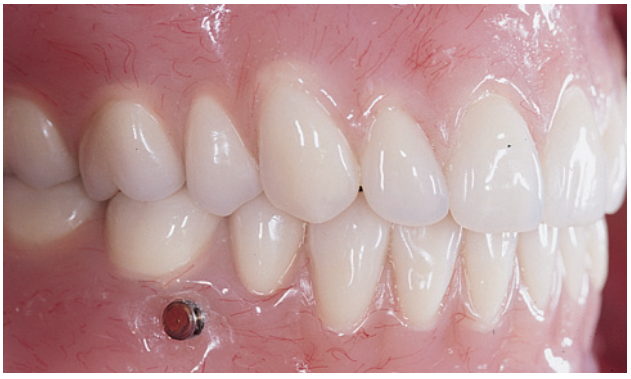


FIGURE 1-7 J, Lateral view shows the final restoration with the SwissLoc NG engaged into the bar, resulting in a restoration that is fixed, removable, and implant borne. (Prosthetics by Dr. Sean McCarthy and Dr. Tom Salinas.)

After the implant locations have been identified, the first drill in the implant drilling sequence is used. If available, a surgical stent is placed to locate the implants correctly in relation to the teeth. For Class III mandibles, the implants can be angled slightly lingual; for Class II mandibles, the implants can be angled slightly anteriorly; for Class I mandibles, the implants are placed vertically in relation to the inferior border of the mandible. Regardless of the angulation of the implants, the crestal location of each is the same: the implants exit the crest midcrestally without excessive labial or lingual location.

Parallel, or guide, pins are placed after each pilot drill has been used to confirm the angulation of the implants in the anteroposterior and left-to-right planes. Small errors can be handled during the progression to the next-sized drills.

Common Clinical Situations. It is common practice to place implants in the anterior mandible soon after dental extractions. Waiting until the bone has healed within the extraction site is one option. However, patients often prefer to wear a transitional removable denture for the shortest time possible. Consequently, implants are placed approximately 8 weeks or sooner after extraction of the teeth. In general, however, most clinicians agree that placing implants immediately after extracting teeth is contraindicated if exudate or active infection is present. This author extracts the infected teeth and places an immediate denture. The implants are placed 8 weeks later in a healthy, uninfected jaw. This delay allows the surgeon to close incisions primarily to prevent infection and to provide the patient with a period of adjustment to the immediate denture.

Dissection of the periosteum may be tedious 8 weeks after extraction, especially if the extractions involved a few remaining teeth (e.g., only the canines). The soft tissue invaginations into the extraction sites must be carefully elevated. The crestal bone irregularities then are reduced to

ensure that all implants exit the crest at the same vertical level. Some canine teeth may be larger than the diameter of the implant; in these cases, the bone may have to be reduced, a larger-diameter implant may need to be placed, or defects between the implant and the remaining bone may need to be grafted. Reducing the bone with rongeur forceps is a simple method of dealing with this problem. The implants also may need to be countersunk an additional 1 to 2 mm because of expected crestal bone loss from normal remodeling of the extraction site (Figure 1-8, A-K).

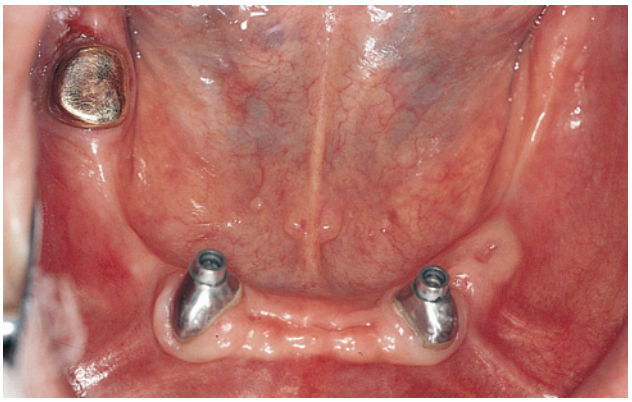


FIGURE 1-8 **A,** Treatment for this patient includes a four-implant, bar-retained denture. Because the teeth have secondary decay below the crest, the plan includes their extraction and simultaneous placement of four implants in a one-stage approach. The preoperative panoramic radiograph shows sufficient bone for 15-mm implants.

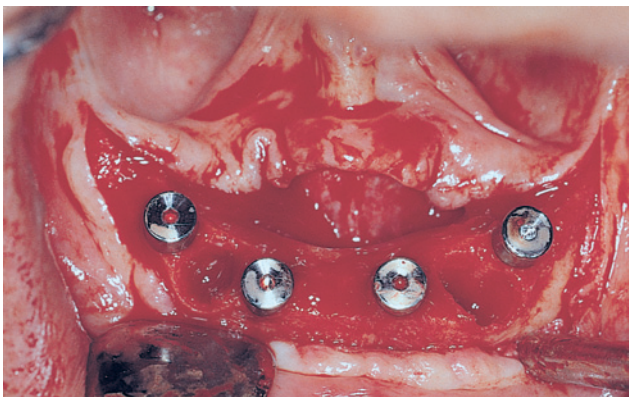


FIGURE 1-8 **B,** Crestal incision is made, and the teeth are extracted. Because of the size of the root and the large defects after the extraction, four implants are placed, avoiding the extraction sites. Bone removed from the drills is placed into the extraction sites. One-stage implant systems are placed to allow for closure around the implants without covering them.

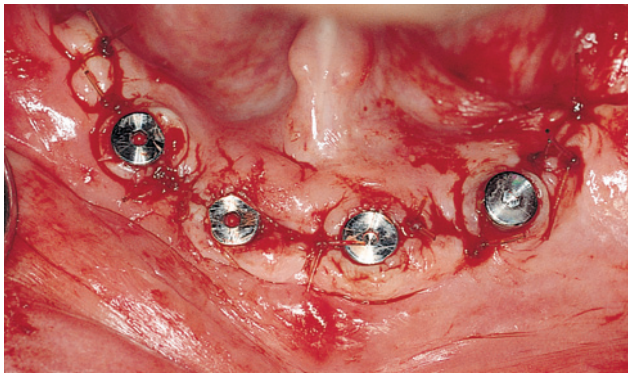


FIGURE 1-8 **C,** Incision is closed around implants.

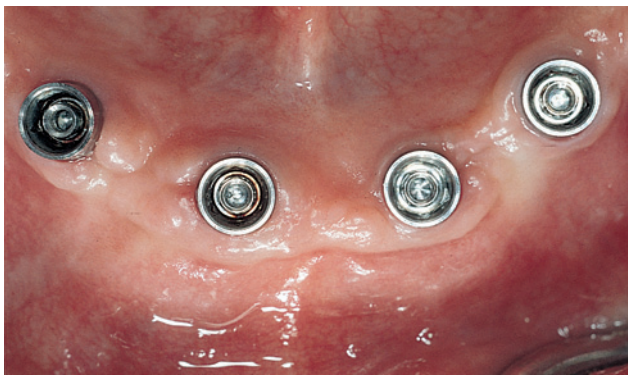


FIGURE 1-8 **D,** After healing, the prosthetic abutments are placed. Excellent soft tissue contours are shown.

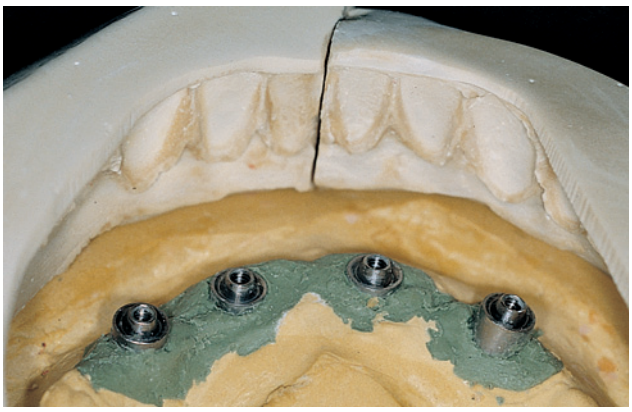


FIGURE 1-8 **E,** Impression is made, and the implants are transferred to a master cast. The planned tooth setup is used to wax the bar, avoiding encroachment of denture space. The bar then is fabricated on the model.

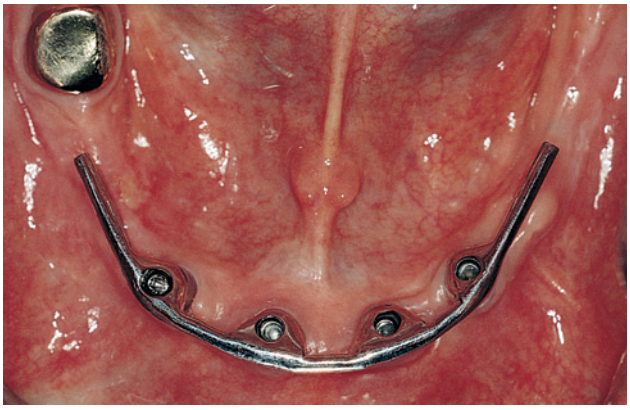


FIGURE 1-8 **F,** Bar is tried in the mouth and, if necessary, cut and soldered to ensure a passive fit. A titanium CAD/CAM milled bar can also be used.

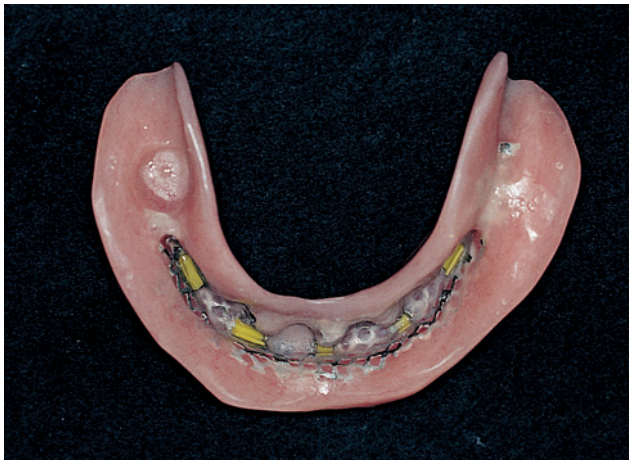


FIGURE 1-8 **G,** Denture is completed with clips placed to engage the bar.

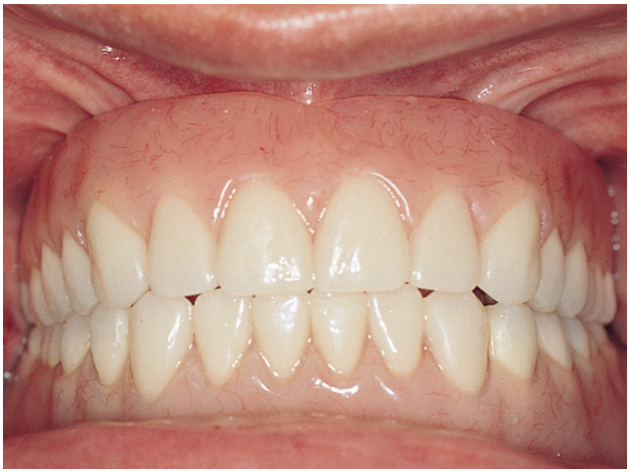


FIGURE 1-8 **H,** Mandibular prosthesis in the mouth and the occlusion are shown.

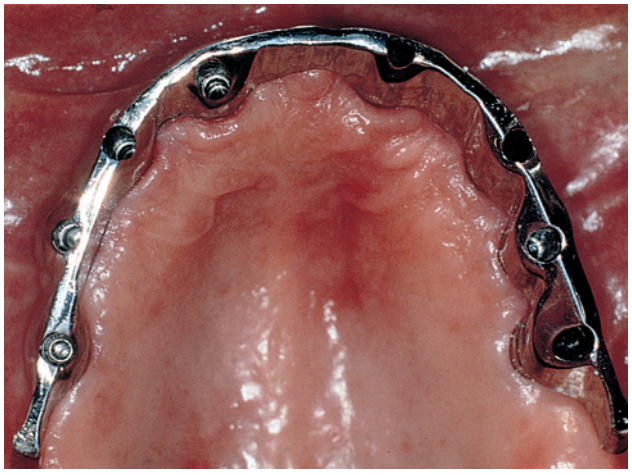


FIGURE 1-8 **I,** Spark erosion bar for the maxillary prosthesis.

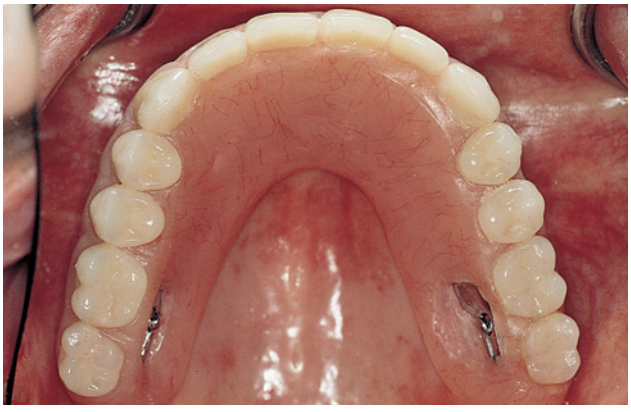


FIGURE 1-8 **J,** Maxillary prosthesis in place with the clips engaging the bar.

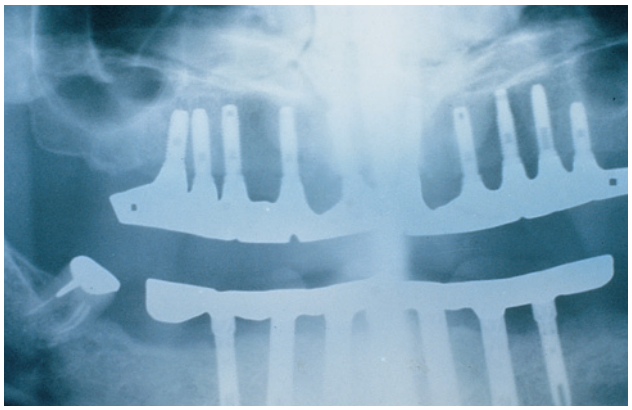


FIGURE 1-8 **K,** Final panoramic radiograph. (Prosthetics by Dr. Israel Finger.)

Another common clinical situation is the isolated bone defect secondary to excessive bone loss from periodontal disease on one or more teeth. The flap is raised, and a definitive bone defect is noted. The thin ridge can be reduced in height until sufficient bone width is available, or a small-diameter implant can be placed in an isolated site with wider implants placed in the other sites. Documentation is necessary so that the restorative dentist can understand the unique location of the implant. For an isolated vertical defect, the implant can be placed at the level of the bone defect; the remaining implants also can be placed at that depth, which requires removal of crestal bone. Placement of one implant should not be several millimeters lower than the remaining implants, because this causes difficulty with restorative procedures. The depth difference is limited to 2 mm, which can be easily handled by using abutments of different lengths. Another option is to place the implant at the base of the polished collar, with the remaining implants more countersunk; in this way, the differential height differences can be relatively reduced (DVD Figure 1-4, A-F). If the site is excessively deficient in height, the ridge can be augmented with distraction osteogenesis or an onlay bone graft.

DVD Images 1-4, A-F

Prior Hydroxylapatite Augmentation. Patients who have had previous hydroxylapatite (HA) augmentation can receive implants (Figure 1-9, A-E, and DVD Figure 1-5, A-F). The preoperative evaluation of these patients should attempt to determine the amount of native bone inferior to the HA. If more than 10 mm of native bone is present, the HA can be removed if it is not impregnated with bone. If the HA ridge augmentation was performed 5 or more years before the proposed implant surgery, the HA ridge may be totally encased in bone. If the HA augmentation is more recent, the HA particles may be removed easily, because mostly fibrous tissue will be holding the particles in place.

DVD Images 1-5, A-F

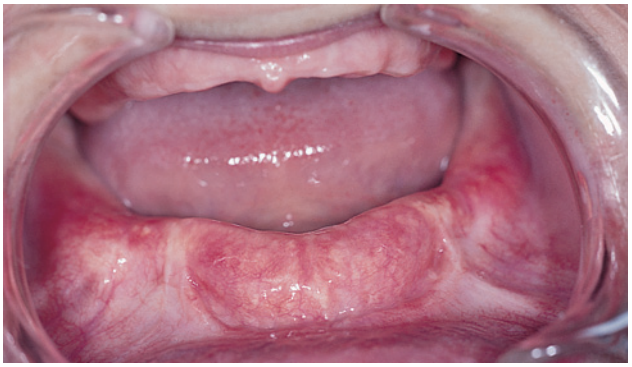


FIGURE 1-9 A, This 50-year-old woman had a full-arch HA augmentation 4 years before seeking additional retention of her mandibular denture. The treatment includes removal of the anterior HA augmentation and placement of four implants for a tissue-borne overdenture.

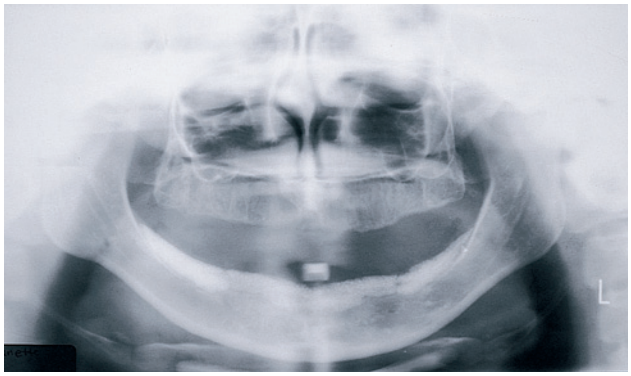


FIGURE 1-9 B, Preoperative panoramic radiograph shows sufficient bone available without the need to retain the HA augmentation. A crestal incision is made, the HA augmentation is removed with rongeur forceps, and the implants are placed.

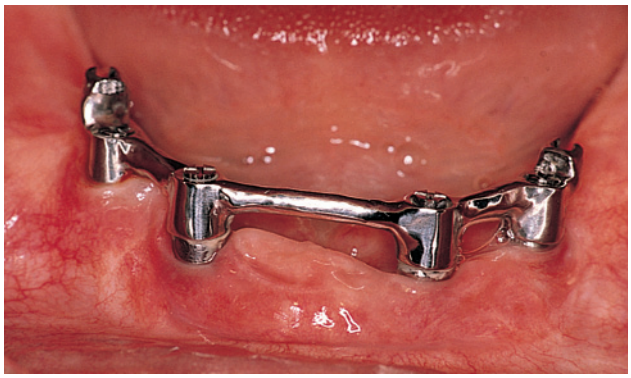


FIGURE 1-9 C, Four months after placement, the implants are exposed, and a bar is made using ASC52 vertical stress-breaking attachments.

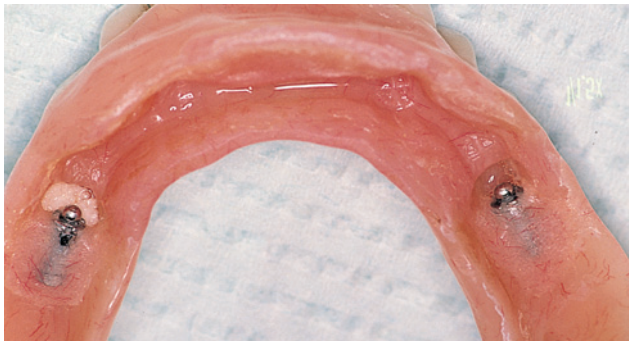


FIGURE 1-9 D, Inner aspect of the denture has the attachments for the ASC52 stress-breaking attachments.

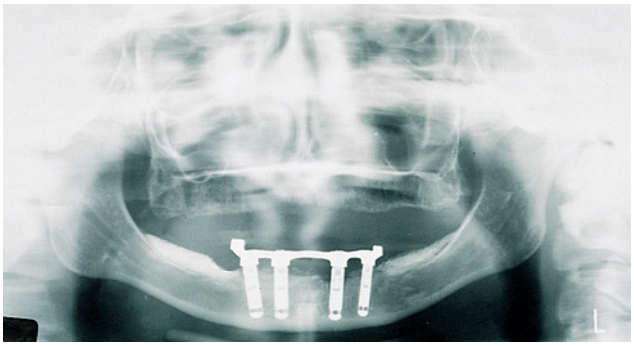


FIGURE 1-9 **E,** Patient has complained of difficulty cleaning her implants on the right side. To alleviate this problem, additional HA is removed to provide adequate space for cleaning. The radiograph shows a 12-year follow-up image. (Prosthetics by Dr. Larry McMillen.)

A crestal incision is made, and the tissues are reflected at the level of the HA augmentation. Care must be taken to avoid branches of the mental nerves that may be within the augmentation in the region of the mental foramen and slightly anterior to it. As necessary, the HA particles can be removed with rongeur forceps; if encased with bone, however, the implants are placed through the HA and bone mass into the native mandibular bone. A diamond bur must be used to create the implant sites until the final-diameter drill is needed. After the implant has been placed, a normal or slightly longer healing period is recommended.

Augmentation of the Atrophic Mandible

General Considerations

Augmentation of the atrophic mandible for eventual placement of dental implants begins with an assessment of the patient's general health and an accurate assessment of the height of the anterior mandible. Patients who are debilitated and would not do well with bone graft harvesting from the iliac crest should not have the mandible augmented. If the patient is satisfactorily healthy for the procedure of harvesting the bone graft, 8 mm of bone height indicates the need for bone augmentation of the anterior mandible. Patients with a bone height greater than 8 mm can do well with implants without bone augmentation.

The decision to perform bone augmentation in the patient with 8 to 12 mm of bone height (Figure 1-10, A-H) is subject to other factors, such as the patient's age and the opposing dentition. The patient with a long life expectancy is more likely to have a long-term benefit from restoration of the mandible to 15 mm of vertical height. However, this has not been proved by clinical prospective studies. Some

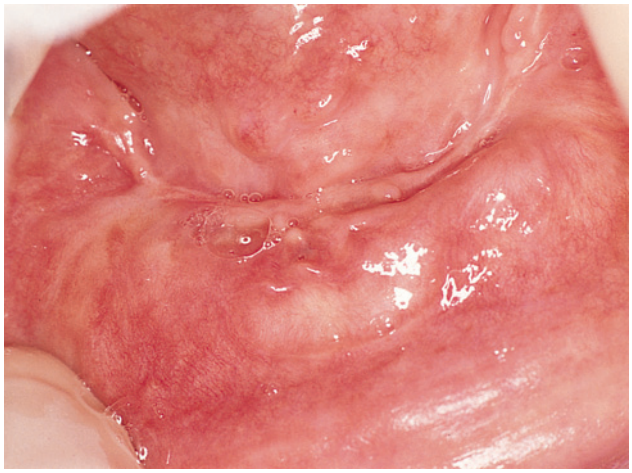


FIGURE 1-10 **A,** This 69-year-old woman had four threaded, titanium plasma–sprayed, one-stage implants fail in the anterior mandible, requiring their removal. She now has difficulty retaining her mandibular denture.

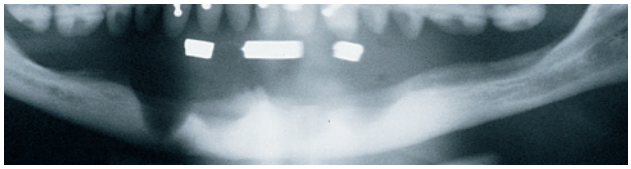


FIGURE 1-10 **B,** Panoramic radiograph shows significant loss of bone structure 1 year after removal of the implants.

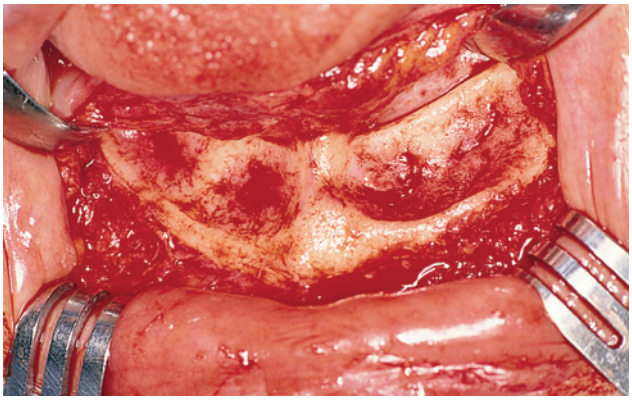


FIGURE 1-10 **C,** Incision is made in the vestibule, and the anterior bone is exposed. The goal is to graft the defects, restore the strength of the mandible, and provide the patient with sufficient bone volume either for better denture retention or for implants.

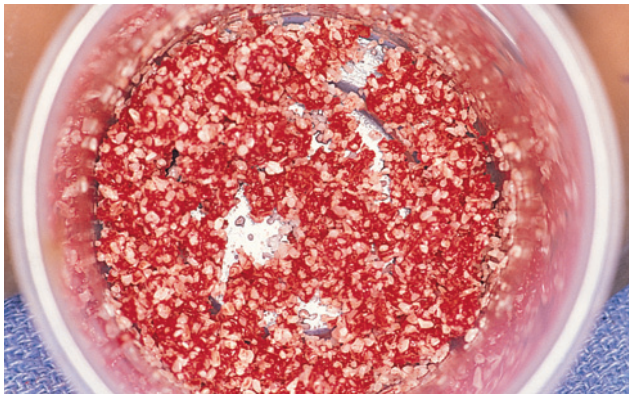


FIGURE 1-10 **D,** Bone is harvested from the iliac crest, and the autogenous cancellous bone is combined with particulate HA as a graft expander.

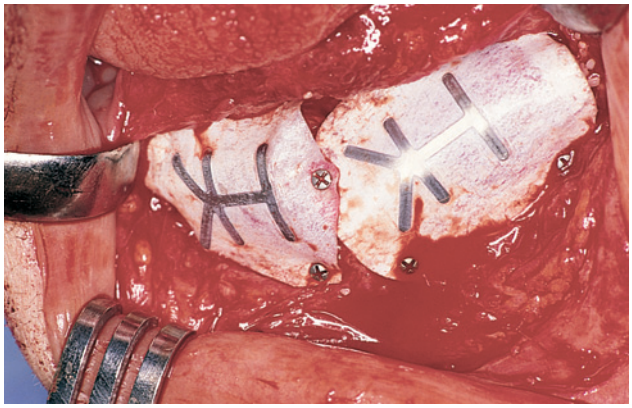


FIGURE 1-10 **E,** Bone is placed into the defects and then covered with a titanium-reinforced membrane of expanded polytetrafluoroethylene. The membrane is retained with small screws.

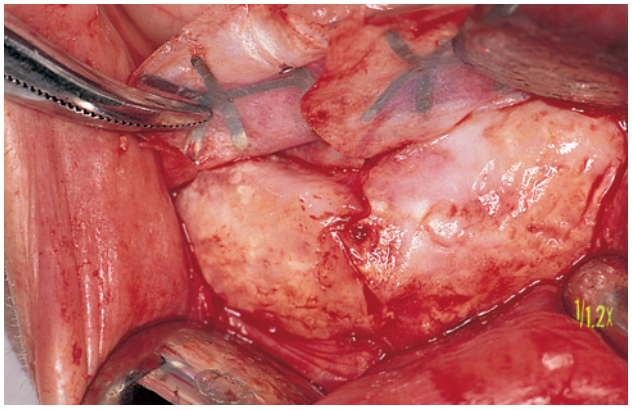


FIGURE 1-10 **F,** After 5 months, an incision is made to expose the membrane. The screws are removed, and the membrane is elevated and removed, exposing a new ridge that is "bone hard."

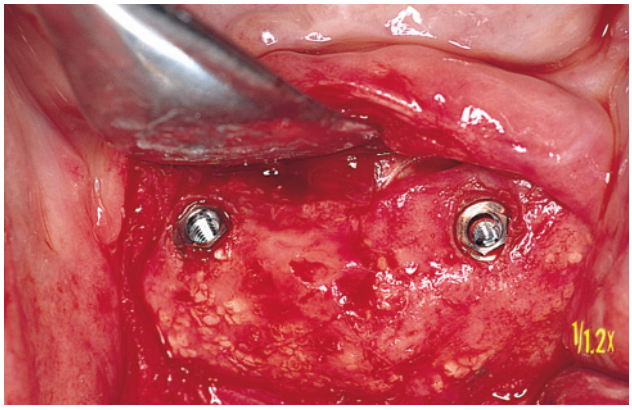


FIGURE 1-10 **G,** Two implants are placed.

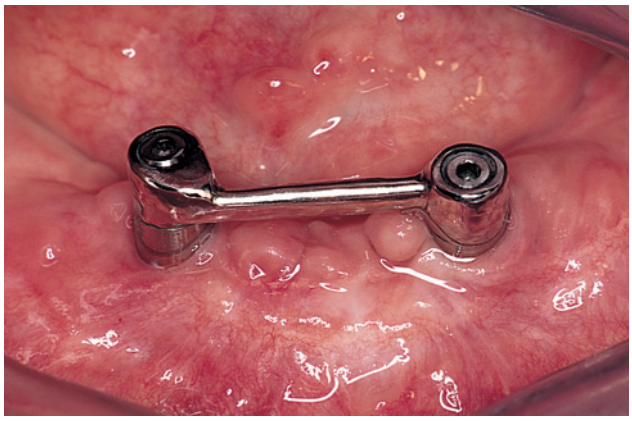


FIGURE 1-10 **H,** Bar is fabricated after the implants have integrated. (Prosthetics by Dr. Luis Guerra.)

clinicians believe that the patient with an intact, natural opposing occlusion may place more force on the mandible than a patient with opposing dentures. Therefore, for a patient with an opposing natural dentition, clinicians may be more prone to perform bone grafting in the atrophic mandible. However, the rationale is anecdotal and not well studied in clinical trials.

Most clinicians use iliac crest corticocancellous blocks to augment the anterior mandible. The procedure can be performed either through an intraoral incision or through an extraoral incision, depending on the clinician's preference. Placement of implants at the time of bone graft placement is also clinician dependent and offers several advantages: (1) the patient's time to restoration is shortened; (2) the graft can be secured to the mandible with threaded implants; and (3) the shorter time to functional loading may prevent graft resorption. The disadvantages

of placing implants at the time of bone graft placement include the following: (1) possible partial resorption of the graft and exposure of portions of the implants, which is difficult to treat; (2) malposition of the implants because of the lack of proper angulation at placement; and (3) the potential for lack of integration secondary to poor graft remodeling. Technically, the grafting procedures are the same, with the exception of the surgical preparation of the sites for the implants.

Intraoral Incision and Placement of Autogenous Corticocancellous Bone Grafts

Intraoral incisions for the placement of blocks of bone can be made either crestally or within the vestibule. The *crestal* incision places the incision over the bone graft, but it also offers the surgeon a better chance of preventing incisional dehiscence secondary to vascular insufficiency. A *vestibular* incision places the incision away from the bone graft; however, blood supply to the edge of the vestibular incision travels through the dense, fibrous tissue over the crest and thus may be prone to breakdown secondary to vascular insufficiency. Both intraoral incisions and their subsequent release result in obliteration of the vestibule, which then requires secondary soft tissue grafting. It should be noted that the mental foramen often is palpable on the alveolar crest, with some portion of the inferior alveolar nerve dehisced from the mandible secondary to resorption of the alveolar crest bone (DVD Figure 1-6, A-J).

1-6, A-J

After infiltration of the local anesthetic, a crestal incision is made, with care taken to avoid the mental foramen. Because the atrophy of the bone resulted in the positioning of the mental foramen on the alveolar crest, the initial incision is made only to the foramen. A subperiosteal reflection is performed to identify the exact location of the mental foramen and nerve. The crestal incision then can be extended posteriorly and most likely slightly lingual. The subperiosteal reflection is continued to allow for adequate visualization of the neurovascular bundle. If necessary, the nerve can be displaced laterally; however, excessive mobilization of the inferior alveolar nerve from the canal can result in alterations of sensation. The anterior subperiosteal reflection should extend over the genial tubercles and facially to the anterior border of the mandible, exposing the superior aspect of the alveolar crest.

After the superior aspect of the alveolar crest has been exposed, length and width measurements of the graft are taken before harvesting. These measurements also can be taken from presurgical diagnostic casts, with the location of the mental foramen transferred to the casts. In general, the grafts are placed anterior, not posterior, to the mental foramen.

The bone grafts are harvested and trimmed as necessary. The goal of the graft should be to restore the mandible to approximately 15 mm of vertical height. However, for a 3-mm mandible, gaining this amount of bone may be excessive. For the extremely small mandible (e.g., 1 to 5 mm), restoration to 10 to 13 mm is considered a great success. Two or three pieces of corticocancellous bone block are trimmed and placed over the superior aspect of the mandible. The edges are smoothed, and the grafts are stabilized in position with screws placed through the grafts, engaging the inferior border of the mandible. If implants are placed simultaneously with graft placement, the clinician must weigh the possibility of partial graft resorption and subsequent implant failure. Implants can be placed 4 months after graft placement and combined with a simultaneous vestibuloplasty.

After the grafts have been placed and secured in position, the soft tissue flaps need to be released to allow for tension-free closure. The periosteum is incised deeply, and a supraperiosteal dissection is performed until the incision can be closed without tension. A two-layer closure can be attempted, but this closure may be difficult to perform because of the thin nature of the anterior gingiva. The mucosa is closed with atraumatic needles and nonresorbable sutures.

Extraoral Incision and Placement of Autogenous Corticocancellous Bone Grafts

The disadvantages of using an extraoral approach are scarring and difficulty placing implants at the time of graft placement. Most implants are flared to the labial when placed into a bone graft performed through an extraoral incision. The advantages of using an extraoral approach to graft the atrophic mandible are (1) prevention of intraoral incision breakdown; (2) prevention of an intraoral communication with the bone graft and potential infection; (3) maintenance of the vestibular attachments, which may eliminate the need for vestibuloplasty; and (4) ease of reflection of the inferior alveolar nerve from the alveolar crest without incising over the nerve (Figure 1-11, A-H).

Before general anesthesia is induced, a marking pen is used to mark an esthetic submental crease, preferably with the patient in a sitting position. Most patients with atrophic mandibles have several creases from which to choose. After an adequate level of general anesthesia has been reached, the skin is prepared with an appropriate skin preparation scrub and solution and then draped. The incision is made, after which a blunt and sharp dissection is made to the inferior border of the mandible. The periosteum is incised at the inferior border of the mandible and elevated carefully over the alveolar crest

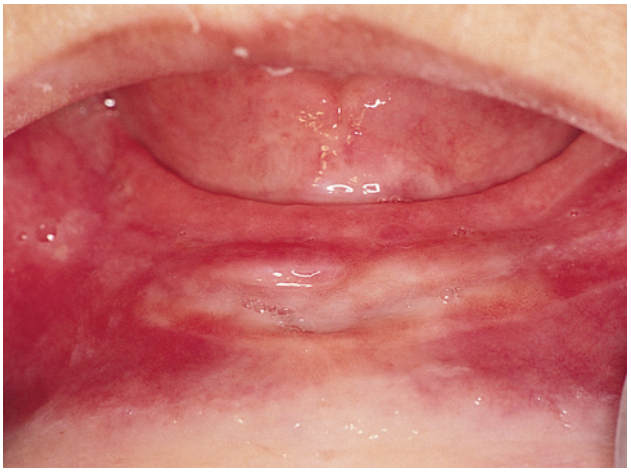


FIGURE 1-11 **A,** This 50-year-old woman wants added retention for her mandibular denture. Her restorative dentist has asked the surgeon to perform a bone graft because of displacement of the denture from the tongue and floor of the mouth tissues.

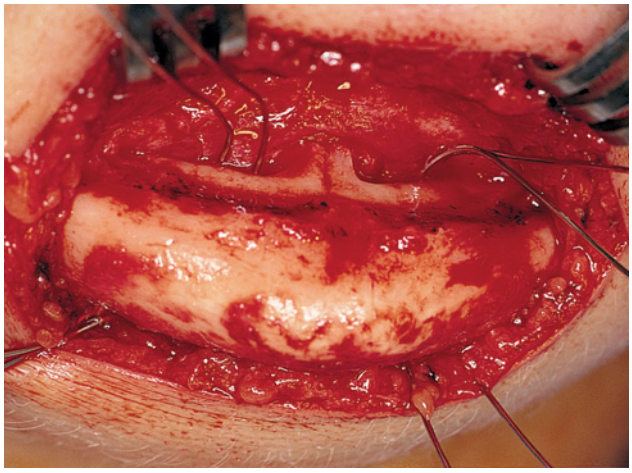


FIGURE 1-11 **B,** Extraoral approach is used. An incision is made in a submental crease, and the dissection continues to the inferior border of the mandible. The periosteum is raised carefully to avoid intraoral communication. From the extraoral approach, the superior surface of the mandible and the genial tubercles are observed.

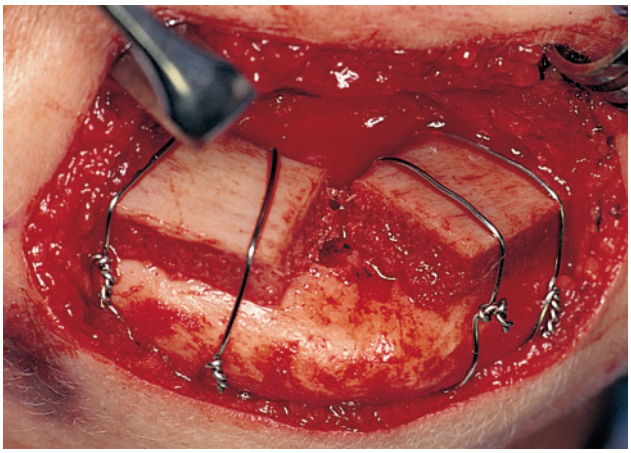


FIGURE 1-11 **C,** Three blocks of corticocancellous bone are harvested from the iliac crest. Two are trimmed to fit onto the superior surface of the mandible and are held in position by circummandibular wires.

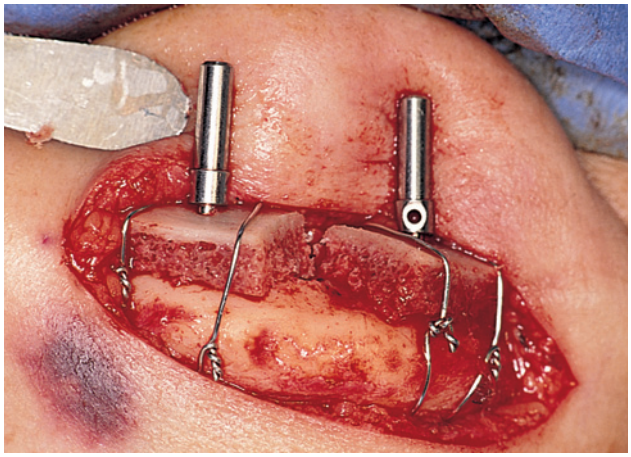


FIGURE 1-11 **D,** Two threaded implants are to be placed. The parallel guide pins are placed through the extraoral incision with appropriate retraction.

and genial tubercles. The subperiosteal dissection is carried posteriorly to expose the superior aspect of the posterior mandible. Great care must be taken to avoid making intraoral perforations while performing the flap elevation. After the periosteum has been elevated, the bone graft is harvested and positioned as previously described. The tissue is relocated to its original position and, if necessary, released. The incisions are closed in multiple layers, with care taken to perform a plastic closure of the skin.

Implant Placement into Augmented Mandible

Most clinicians allow 4 months for healing of the iliac crest corticocancellous bone graft before placing implants. Iliac crest corticocancellous grafts heal well, but they start resorbing after 3 to 4 months. Consequently, the surgeon may need to place the implants at 3 months, depending on consolidation and remodeling of the bone graft, which is determined radiographically. If necessary, a split-thickness dissection can be made intraorally, and a palatal or split-thickness dermis or skin graft can be placed to restore some semblance of a vestibule. At vestibuloplasty, the rigid

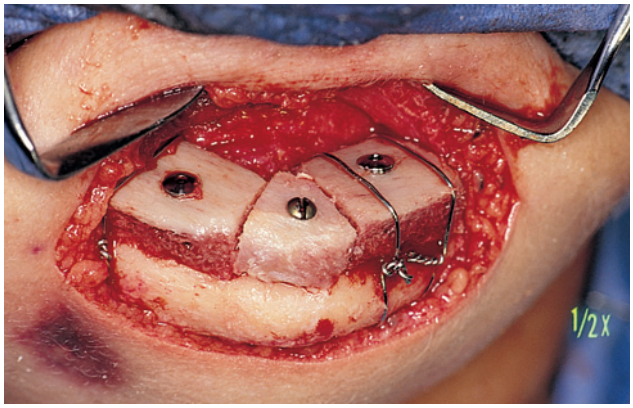


FIGURE 1-11 **E,** Thread-former is used to create threads in the graft and native bone. Two implants are placed. The third block of bone is placed anteriorly. Only one wire is needed to secure one graft.

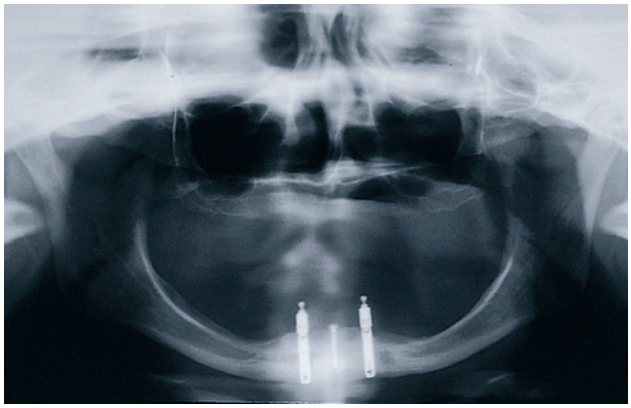


FIGURE 1-11 **F,** Postoperative panoramic radiograph.

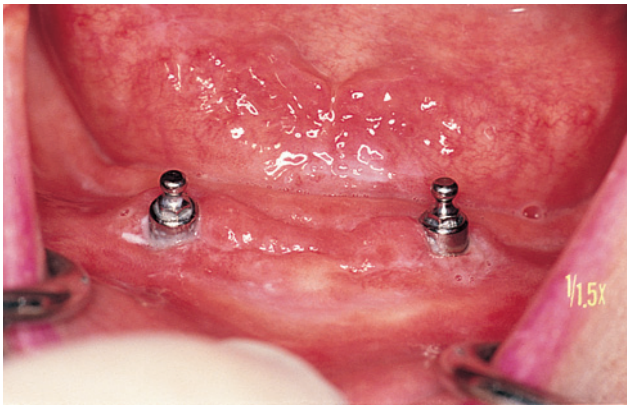


FIGURE 1-11 **G,** After 6 months, the implants are exposed and restored by O-ring attachments.

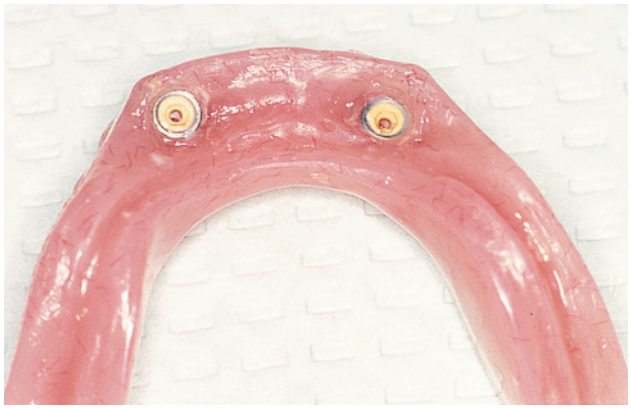


FIGURE 1-11 **H,** Inner aspect of the denture with the O-ring attachments in place.

fixation screws can be removed and implants placed, engaging the inferior border of the mandible. When a vestibuloplasty is performed simultaneously with implant placement, the implants should be countersunk below the level of the periosteum so that the graft can lie flush and is not held off the host tissue bed by the domelike prominences of the implants' cover screws. If meticulous suturing has been performed, a stent may not be necessary; however, if used, the stent should have a soft lining to prevent excessive pressure on the graft and implants.

Placement of Implants into the Atrophic Mandible without Grafting

Some patients with atrophic mandibles with at least 5 to 6 mm of bone height but less than 10 mm are not good candidates for bone grafting because of health-related issues. For these patients, four implants can be placed, with 2 mm of the implant through the inferior border of the mandible and, as necessary, 2 mm supracrestal. It is important to prepare the bone gently and to pretap these bones, because they may be brittle and may have minimal blood supply. The implants should be placed so as to avoid labial protrusion. Long-term follow-up of this method indicates excellent results, with anecdotal evidence that bone formation can occur distal to the implants, presumably in response to tensile and compressive forces on the mandible (Figure 1-12, A-C).

Alveolar Ridge Distraction of the Anterior Mandible

The following case report demonstrates the use of *distraction osteogenesis* to augment the alveolar ridge (DVD Figure 1-7, A-O).

DVD Images 1-7, A-O

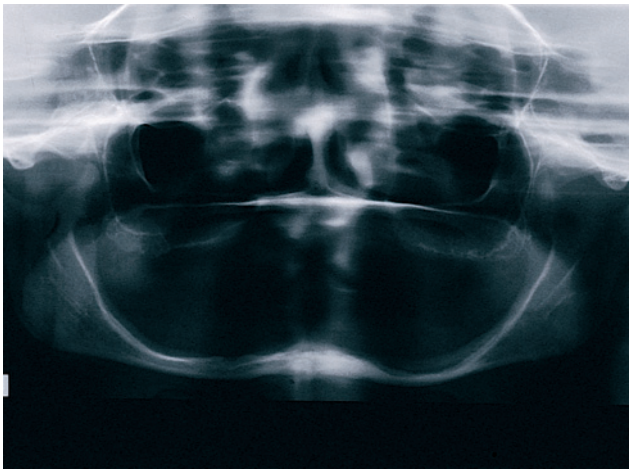


FIGURE 1-12 **A,** This 76-year-old woman has a mandible measuring 7 mm tall. The treatment plan includes four implants and an overdenture.

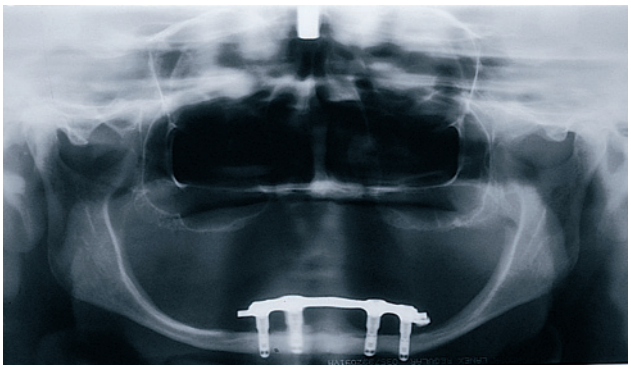


FIGURE 1-12 **B,** Four HA-coated, threaded implants (10 mm long and 3.25 mm wide) are placed with 1 to 2 mm exposed on the inferior border. For two implants, 1-mm implant dehiscence is exposed crestally.

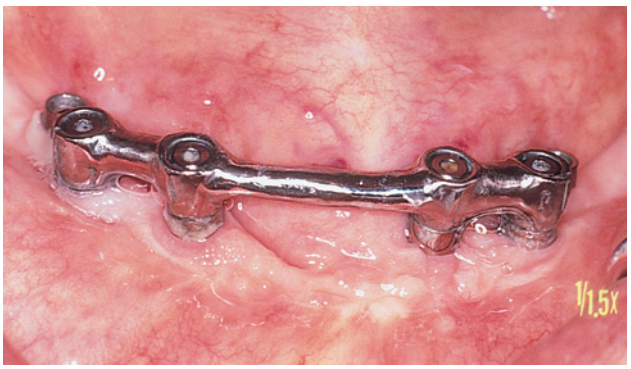


FIGURE 1-12 **C,** Implants have integrated, and a bar has been fabricated for a tissue-borne prosthesis. (Prosthetics by Dr. Larry McMillen.)

The goal of the procedure is to augment the alveolus 10 to 12 mm to obtain a ridge that can receive implants in the ideal location. An incision is made at the junction of the attached and unattached gingivae. A full-thickness dissection is performed, exposing the labial bone. The lingual periosteum is not dissected so as to preserve the vascular supply to the alveolar bone. For this patient, bone plates from prior bone grafts and trauma reconstruction were removed. The distraction device was tried in place, but the distraction vector was too far labial. The bone was flattened to allow for a proper distraction vector. The distraction device then was adjusted to fit the bone. Two screws were placed in each arm of the plates. With the device in place and held in position with the four screws, the horizontal osteotomies were performed using a sagittal saw. The device was removed, and the osteotomies were completed using a thin sagittal saw. Fingers were placed on the lingual bone to feel the saw emerge without traumatizing the periosteum, similar to performing interdental osteotomies in orthognathic surgery. After the cuts were completed, the distraction device was repositioned, and the four screws were replaced. Additional screws were placed, with at least two screws on each arm. The distraction screw was turned to confirm separation of the segments. The segments were returned to their original position and, as possible, compressed slightly. The incision was closed with sutures, leaving the distraction screw exposed along the labial aspect of the ridge.

Seven days were allowed for incision healing; the device then was distracted 0.5 mm, two times each day, for a 1-mm augmentation each day. This procedure was performed daily until the 12-mm augmentation height was reached. Light-cured resin was placed to prevent loss of height that could result from accidental screw turning. After radiographic confirmation of bone fill within the distraction defect (which can take 8 to 12 weeks to form, depending on the patient), as well as confirmation of the extent of distraction and the quality of bone, the device was removed and the implants were placed.

Exposure and the Need for Secondary Soft Tissue Surgery

The patient requiring bone graft augmentation of the atrophic mandible may need vestibular extension or creation of attached KG at the implant sites. A split-thickness dissection can be performed 3 months after the bone graft, and the margins of the dissection can be either sutured to a new position or held inferiorly by circummandibular retention sutures. The soft tissue graft may be harvested from the palate or the skin, according to the clinician's preference. The dissection should be limited in depth, resulting in only keratinized tissue on the alveolar

crest. Excessive dissection results in a "chin droop," which is not esthetically pleasing.

Immediate Loading of the Edentulous Mandible

Restoration of the edentulous mandible has been achieved with the use of dental implants and a variety of prostheses that are removable by the patient, or removable by the dentist, or fixed in position by cement. For dental implants, the traditional two-stage placement with a stress-free healing period and secondary exposure surgery has been well documented.[1-3] When two-stage implant systems are used, with primary gingival closure after implant placement, interim relined dentures are used to restore function for up to 6 months. However, the first several weeks after implant placement are uncomfortable for patients and limit their function during the entire implant integration period. To minimize the patient's discomfort and functional disability, treatment options using immediate implant-borne prostheses have been developed. The decision to provide the patient with improved function immediately after implant placement is patient driven. The overall success rate for immediate rehabilitation of the edentulous patient is similar to that for the traditional two-stage method.[4-7]

Clinicians decide whether to rehabilitate the edentulous patient immediately based on evidence that this method is as successful as traditional delayed techniques. Clear evidence has justified immediate loading of implants placed between the foramina of the edentulous mandible.[4-17]

The initial reports on immediate loading of mandibular implants used extra or expendable implants that were placed into function with a temporary fixed restoration at surgery.[18] The immediately loaded implants integrated. Following the same approach, Schnitman et al.[6] later reported failure of 4 of 28 implants; these four implants were placed in the posterior mandible and were 7 mm long. Tarnow et al.[5] used a provisional approach to restore six mandibles and four maxillas. They reported a high rate of success, with 67 of 69 loaded implants integrating. All of these loaded implants were cross-arch stabilized immediately upon placement to reduce the isolated load on a single implant; the cross-arch connection disperses the load to all the implants.

To minimize treatment time, the final prosthesis can be delivered on the day or within days of the surgery. Branemark et al.[7] used three implants in the anterior mandible and a screw-retained hybrid prosthesis; they reported a 92% to 98% success rate. Castellon et al.[19] used another approach: a premade bar and final denture were delivered the day of surgery or within a week after surgery.

Table 1-1 summarizes classic papers on the immediate loading of mandibular implants; these reports verify that sufficient evidence exists that this procedure is acceptable and no longer should be considered experimental. The 14 authors listed results of 240 mandibles involving more than 1277 implants, all supporting immediate restoration of the mandible. The success rates ranged from 84.7% to 100%, indicating that immediate loading of the edentulous mandible is a viable treatment. The lower success rates from Balshi and Wolfinger[4] and Schnitman et al.[6] have clear explanations for the failures. The remaining references report success rates greater than 95% in the mandible.[5,7-17] The reasons cited for implant failure in immediate loading of the edentulous mandible include placement of short implants into the posterior mandible, bruxism, poorly fitting prostheses, poor surgical technique, and infection of the implants.[18]

A careful review of the references in Table 1-1 reveals certain criteria that are consistently associated with successful patient treatment, including the following:

1. Adequate density of anterior mandibular bone, with insertion torque greater than 20 Newton-centimeters (N-Cm), often cited to be greater than 30 N-Cm
2. Cross-arch stabilization of the implants with either a rigid metal bar or resin
3. Use of threaded implants at least 10 mm long
4. Sufficient interocclusal space for fabrication of the framework and interim prosthesis
5. Patient dexterity and compliance with hygiene instruction and postdelivery care

When these five criteria are met in the patient, success should be expected if the remaining technical aspects of the implant procedures are performed properly.

The clinician, therefore, has a choice: to deliver an immediate provisional prosthesis at the time of implant placement, with the intention of fabricating the final restoration after the implants have integrated, or to deliver the final definitive prosthesis at implant placement. Table 1-2 compares provisional and final restoration methods (discussed later).

Using the previously listed criteria can help the clinician determine which treatment modality is optimal for each patient: the traditional two-stage method or one-stage immediate loading. For example, if the interocclusal space is inadequate for placement of an interim hybrid-style prosthesis, the delayed approach may avoid vertical dimension problems involving a bar. With a small interocclusal space, the clinician may use a fixed crown and bridge type of temporary prosthesis, which requires less vertical dimension and avoids the use of a bar, which requires more vertical space. If the five criteria are met, the choice between an immediate final or an immediate provisional prosthesis is limited to questions of cost,

TABLE 1-1 Literature Review of Immediately Loaded Mandibular Implants

Authors (Date)	Implant Location	Number of Implants	Time to Implant Loading	Type of Restoration	Length of Follow-Up	Success Rate
Balshi and Wolfinger[4] (1997)	Mandible	130	Immediate (n = 40)	Fixed provisional	N/A	80%
Tarnow et al.[5] (1997)	Mandible (n = 6) Maxilla (n = 6)	107	Immediate (n = 69)	Fixed provisional	1-5 years	97.1%
Schnitman et al.[6] (1997)	Mandible (n = 10)	63	Immediate (n = 28)	Fixed provisional	10 years	84.7%
Branemark et al.[7] (1999)	Mandible (n = 50)	150	Immediate (n = 150)	Fixed final prosthesis	6 months to 3 years	98%
Randow et al.[8] (1999)	Mandible (n = 27)	118	Within 20 days (n = 88)	Fixed final prosthesis	18 months	100%
Horiuchi et al.[9] (2000)	Mandible (n = 12) Maxilla (n = 5)	140	Immediate (n = 140)	Fixed provisional	8-24 months	97.2%
Jaffin et al.[10] (1998)	Mandible (n = 23) Maxilla (n = 4)	149	Immediate or within 72 hours (n = 149)	Fixed provisional	N/A	95%
Chow et al.[11] (2001)	Mandible (n = 27)	123	Immediate (n =123)	Fixed provisional	3-30 months	98.3%
Colomina[12] (2001)	Mandible (n = 13)	61	24 hours (n = N/A) 10 days (n = N/A)	Fixed provisional	18 months	100% 96.7%
Ganeles et al.[13] (2001)	Mandible (n = 27)	186	Immediate (n =161)	Fixed provisional	25 months	99%
Grunder[14] (2001)	Mandible (n = 5) Maxilla (n = 5)	91	Within 24 hours (n = 91)	Fixed provisional	2 years	92.3% Overall Mandible (97.2%) Maxilla (87.5%)
Cooper et al.[15] (2002)	Mandible (n = 10)	54	Immediate (n = 48)	Fixed provisional	6-18 months	100%
Ibanez and Jalbout[16] (2002)	Mandible (n = 5) Maxilla (n = 5)	87	Immediate to 48 hours (n = 87)	Fixed provisional	1 year	N/A
Testori et al.[17] (2003)	Mandible (n = 15)	103	Immediate to 36 hours (n = 103)	Fixed provisional or fixed final	4 years	98.9%

N/A, Not available

TABLE 1-2 Comparison of Methods for Immediate Loading of Mandibular Implants

Method	Preoperative Preparation	Advantages	Disadvantages
Provisional Restoration			
Fixed, hollow-shell crown and bridge adapted to implants	Laboratory fabricates temporary restoration from model Requires surgical guide stent	Easy chairside adaptation of hollow-shell bridge with common materials	Esthetics may not be ideal Chairside time may be excessive Hygiene may be difficult unless embrasures are kept large
Provisional hybrid	Acrylic is added to denture Requires surgical guide stent	Denture easily adapted with common materials Hygiene is easy	Requires constant patient recalls to perform hygiene on lingual side Requires monitoring for overload from chewing May work so well that patient does not return for final prosthesis
Final Restoration			
Use of prefabricated segmented bar and precision attachments	Analogs in model Laboratory-fabricated, segmented final bar for indexing at surgery Requires surgical guide stent	Index easy to perform Patient treatment finished in 2 weeks Minimal adjustments necessary	Laboratory support critical May be difficult to place precision attachments Requires precision surgery
Computed tomography (CT)–generated restorations	Requires: • Final denture for esthetics and tooth position • CT scan • Software virtual surgery • Computer-generated surgical guide stent with absolute accuracy	Final restoration delivered within minutes of placing implants Minimal patient chair time Use of high technology benefits practice's marketing	Final prosthesis may be as good as a delayed final; hybrid method may not be desirable for all Difficult to judge bone quality May require significant occlusal adjustment Early implant failures are difficult to manage

preoperative and postoperative time commitments, laboratory support, and patient considerations.

Several techniques can be used to achieve immediate delivery of a final prosthesis. All these techniques require excellent laboratory support and preoperative fabrication of parts to facilitate indexing and completion of the final prosthesis within 1 to 2 days after implant placement. One procedure uses master casts and laboratory fabrication of a segmented framework that is indexed and delivered the day after a technician finishes the bar.[19] In another method, described by Tames et al.,[20] a premade acrylic template is indexed after implant placement, cast, and finalized within 36 hours as the definitive hybrid prosthesis.

The Novum procedure (Nobel Biocare, Yorba Linda, California) features precision-fitted surgical and prosthetic templates to deliver a hybrid prosthesis in 1 day.[7,21,22] Another technique creates the final definitive restoration from CT-generated models, with the generation of a surgical template for precision implant placement and preoperative fabrication of the final hybrid prosthesis, which is delivered within 1 hour of surgery.[23] Both of these techniques require adequate preprosthetic preparation and intensive laboratory and computer support to fabricate the final prosthesis within a day or minutes of the implant placement surgery.

Immediate Loading with Provisional Restorations

Fixed, hollow-shell crown and bridge adapted to implants

The restorative dentist may prefer to provide the patient with a fixed, cemented, immediate provisional full-arch prosthesis. A *provisional prosthesis* is a temporary set of teeth, not the final, permanent prosthesis. The provisional

prosthesis can be made by modifying the patient's old denture. After the implants have integrated, the design of the final prosthesis can be made, taking into consideration hygiene, esthetics, and functional needs. To provide this service, the laboratory must fabricate a hollow-shell matrix that can be relined after implant placement, as well as a drill guide to provide the surgeon with the specific location of the implants under the teeth. Coordination is essential between the team members with regard to scheduling and responsibility for placement of the abutments, implants, and postoperative management.

Preoperative preparation involves fabrication of an interim prosthesis and a drill guide. The restorative dentist mounts diagnostic casts, and from these models a planned setup is made. If the patient has a satisfactory prosthesis, it can be adapted by the laboratory. Usually the laboratory technician fabricates a one- or two-piece shell, which is relined with resin after the implants have been placed. After duplication of the diagnostic plan on a cast, a surgical drill guide is fabricated in clear acrylic to guide the placement of the implants under the teeth, avoiding excessive lingual, labial, or interproximal positioning of the implants.

Use of Computed Tomography Imaging to Plan for a Fixed Prosthesis. The transition from teeth to implants must take into consideration patient-related concerns. The patient does not want to wear a denture in the interim. Many patients feel that pink acrylic with teeth represents a "denture," which makes the patient feel old and defiled. How do clinicians plan for the replacement of teeth with a fixed crown and bridge type of provisional restoration? Preoperative planning includes fabrication of a mockup of the planned restoration, which can be used to do the following:

- Confirm the plan with the patient
- Evaluate the bone under the planned teeth
- Assess the need for grafting
- Evaluate the specific locations for the implants
- Fabricate a provisional prosthesis preoperatively for reduced chair time

Step-by-Step Method. Restorative dentists commonly have an esthetic waxup made before extensive crown and bridge restorations and also for diagnostic planning. The technique shown in Figure 1-13 uses well-known prosthetic methods but includes CT imaging and implant planning.

The patient presents with a lower dentition in a mixed state of disrepair. She wants a pain-free, esthetic, and functional set of mandibular teeth to replace her current dentition (Figure 1-13, A). Before a CT scan is obtained of her dentition, which must be removed to accomplish her goals, diagnostic planning will be performed to limit her radiation dose.

Models are taken and mounted. A diagnostic waxup is made and later is converted into an acrylic "mask." The mask is used to establish the esthetic and functional goals and as a scanning template for CT software virtual implant planning. The model of the waxup is duplicated in stone. The laboratory technician then uses the models to make the mask. Barium sulfate (20% volume) is mixed thoroughly with A2 shade acrylic to form a solid replica of the waxup (Figure 1-13, B-D). The mask is tried in the mouth to confirm esthetics, function, and intimate fit with the teeth (Figure 1-13, E-F). The CT scan is taken with the patient's mouth slightly open to avoid scatter from the maxilla and interdigitation of the maxillary teeth with the mandibular teeth. Avoidance of interdigitation makes the CT images easier to visualize (Figure 1-13, G).

The scan is taken, and cross sections of the teeth are examined. The cross sections show the teeth and overlying radiopaque mask (Figure 1-13, H-I). These sections are also used to confirm proper seating of the mask to the teeth. The CT scan's DICOM data are loaded into a computer, and virtual implant surgery is performed. The implants can be positioned within bone, emerging just lingual to the plan (Figure 1-13, J-K). The virtual panoramic reconstructed image (Figure 1-13, L) is used to confirm placement of the implants within the tooth sockets. In this plan, the implants will be placed into the first premolar and lateral incisor sites bilaterally. A midline implant may be used if the bone is found to be soft (i.e., has an implant stability quotient [ISQ] of less than 70) upon insertion of the other four implants.

Preoperative instructions to the patient should include counseling about eating a soft, textured diet and the need to perform appropriate hygiene on the temporary prosthesis. A visit with at least one member of the team is necessary the day after surgery so that the occlusion can be checked. The next-day postoperative appointment and the weekly appointments are made in advance to ensure appropriate personal schedule adjustments.

At surgery, the surgeon needs the surgical guide. An escort should be present to drive the patient to the

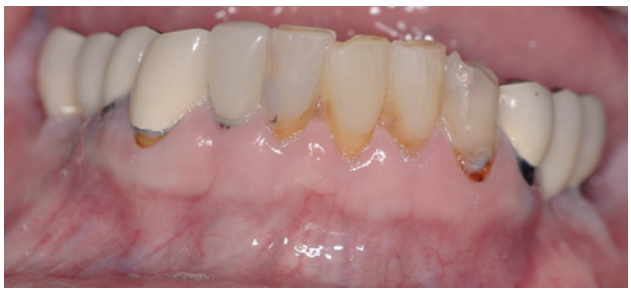


FIGURE 1-13 A, Preoperative appearance of anterior dentition with recurrent decay, bone loss, and mobility. This patient shows her lower teeth when animating, and she wants a fixed restoration that provides function and esthetics. Her dentist and she prefer an implant-supported prosthesis.

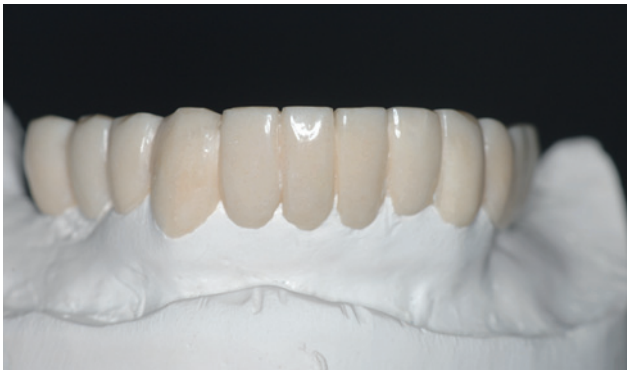


FIGURE 1-13 **B,** Models were mounted, and a waxup was created over the current dentition. The waxup then was converted into a mask, which was made with a combination of barium sulfate (20% by volume) and A2 shade acrylic. This provides the patient and dentist with a visual try-in "mask" that can be adjusted as necessary until all are satisfied.

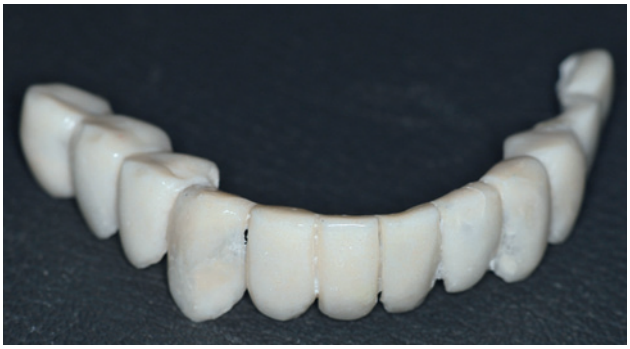


FIGURE 1-13 **D,** The mask is removed from the model before the computed tomography (CT) scan is taken.

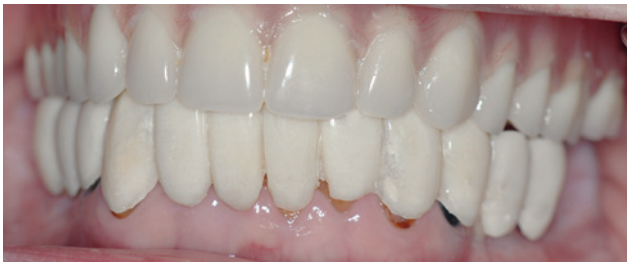


FIGURE 1-13 **F,** The mask is in place, and the patient's teeth are in occlusion. The vertical dimension is confirmed.

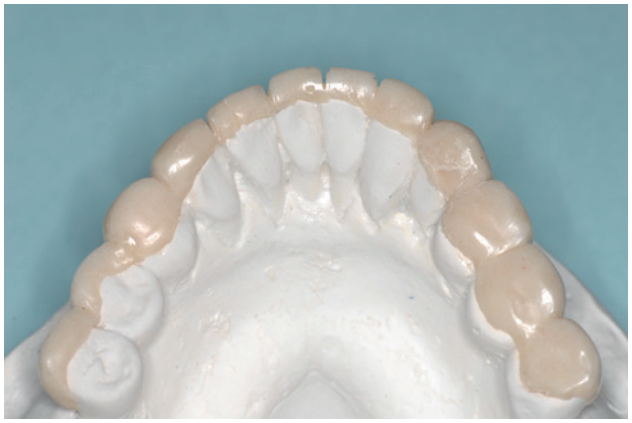


FIGURE 1-13 **C,** Lingual view shows the mask over the current teeth. Note that the positions of the current teeth are very close to the planned location of the new teeth, with minimal embrasure relocation.

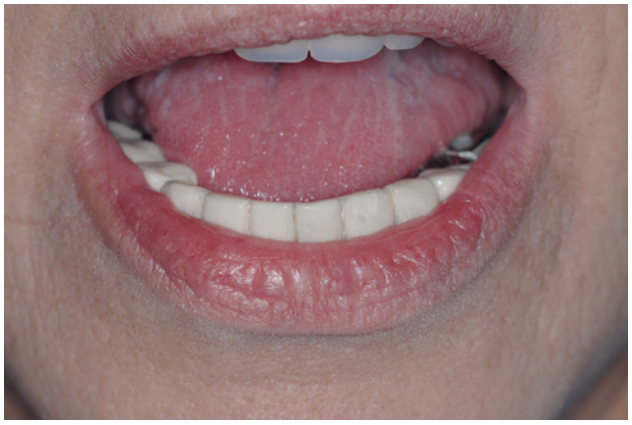


FIGURE 1-13 **E,** The mask is tried in the mouth to confirm esthetics. The patient is very satisfied with this plan.

FIGURE 1-13 **G,** Before the CT scan is taken, cotton rolls are placed to open the mandible a few millimeters. This provides a scan without the presence of the maxillary teeth over the incisal edges of the lower teeth and mask. The result is less scatter, and CT planning software can be used more easily.

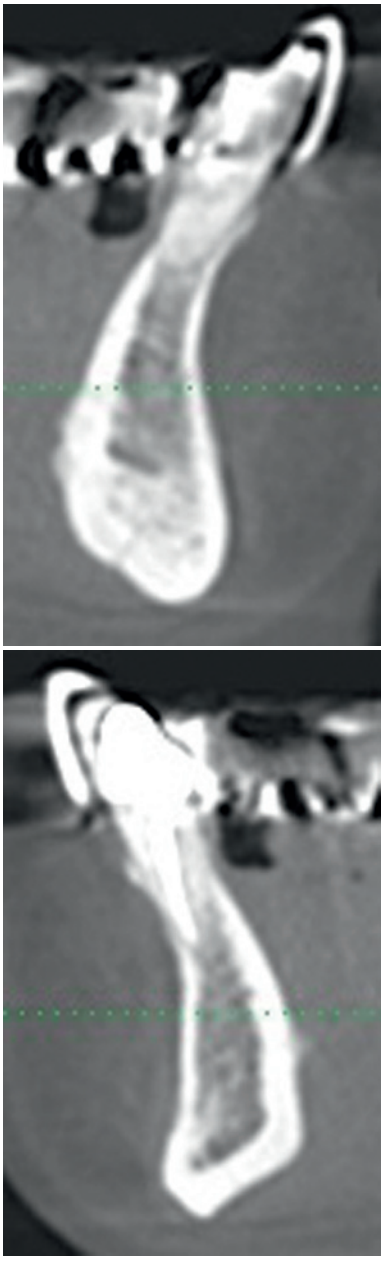


FIGURE 1-13 **H-I,** Two cross-sectional images of the anterior teeth in the left and right canine regions showing the teeth and their relationship to the mask. The barium sulfate–impregnated acrylic is seen as the white line over the incisive edge and labial surface of the teeth.

restorative dentist's office. A local anesthetic is applied, with the understanding that a long-acting anesthetic will be administered after the incisions have been closed to maintain anesthesia during the prosthetic phase on the day of surgery.

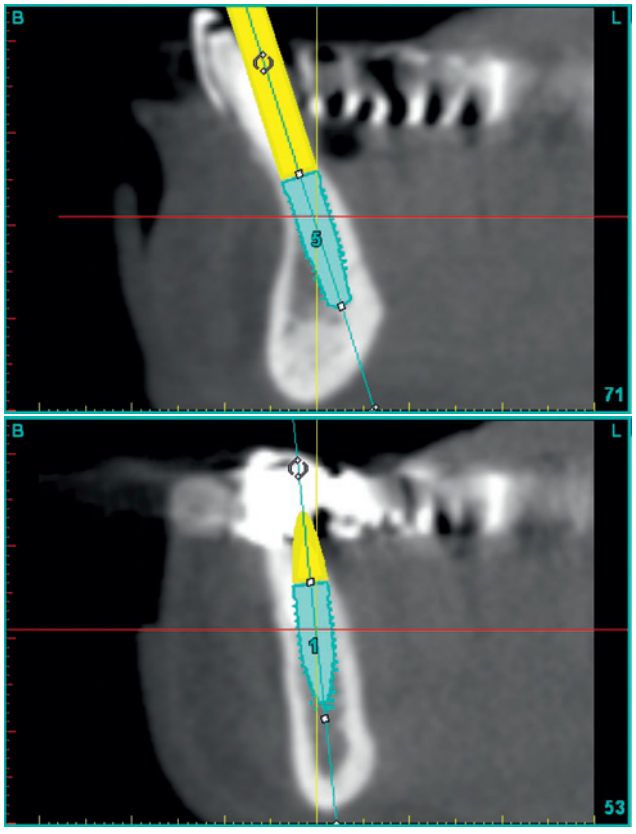


FIGURE 1-13 **J-K,** Images created with the Simplant CT planning software (Materialise, Brussels, Belgium). The CT scan was loaded and converted to allow for virtual implant placement. These implants can be placed within the bone and easily angled to emerge just lingual to the planned incisive edge of the mask.

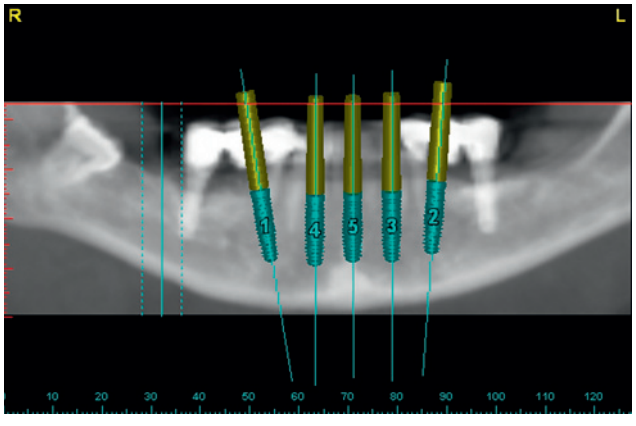


FIGURE 1-13 **L,** Virtual panoramic image showing the planned position of the implants. A surgical template will be fabricated using the mask, with holes to allow the surgeon to place the implants precisely.

After infiltration of the local anesthetic and a hydropic dissection have been performed, the incisions are made. In dentate patients, incisions are made within the sulcus of the teeth, and all KG is preserved. In an edentulous patient, the band of KG is bisected to allow for KG both labial and lingual to the implant abutments. A conservative reflection of the periosteum is performed to preserve the vascular supply to the crestal bone.

Teeth are extracted, and a small alveoloplasty is performed only to remove sharp edges of bone. For a planned fixed restoration, less alveolar bone is removed than when the final plan calls for a bar-retained prosthesis. Fixed crown and bridge restorations benefit from smaller interocclusal space, in contrast to the 12 to 15 mm of interocclusal space required when a procession bar-retained prosthesis is fabricated. If the provisional restoration is fixed but the final prosthesis is planned as a hybrid or a precision bar, the implants are placed in accordance with the final prosthesis. Therefore, if a milled bar prosthesis or a hybrid-type prosthesis is planned, space for the bar may need to be created. In addition, the implants may need to be placed slightly lingual to the incisive edges in the canine and incisor locations.

The implants are placed under the teeth according to the guide. Care is taken to make sure the implants are level across the arch, that large bone cavities are grafted or avoided, and that the implants chosen are long enough to maximize mechanical stability. After the implants have been placed, the surgeon places the abutments and torques them as prescribed. The abutments may involve additional parts that are screw retained to the abutments, or the abutments may be fixed in design and may require small adjustments. The hollow-shell teeth are relined, and the occlusion is checked to detect isolated contacts and ensure that the occlusion is evenly distributed (Figure 1-14, A-O, and Figure 1-15, A-L).

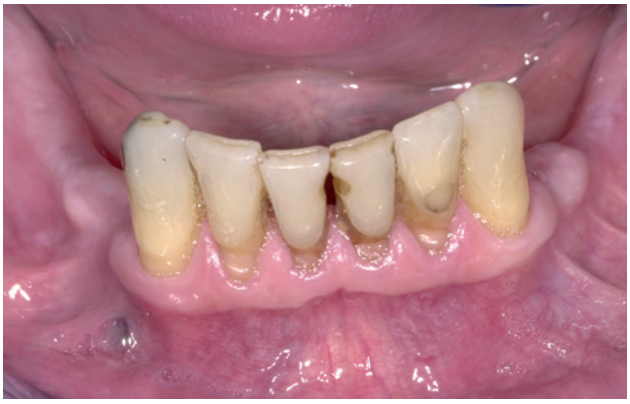


FIGURE 1-14 A, Preoperative view of remaining six mandibular teeth.

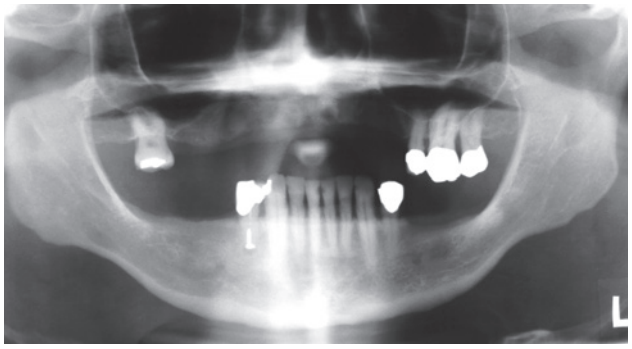


FIGURE 1-14 B, Preoperative panoramic radiograph showing more than 15 mm of anterior mandibular bone height.

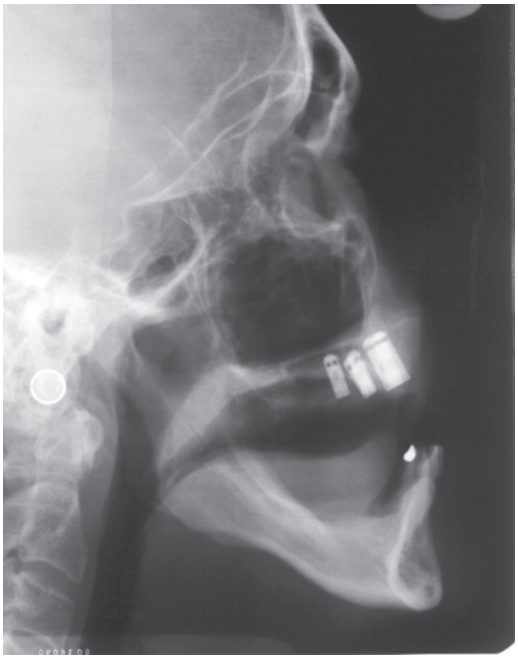


FIGURE 1-14 C, Lateral cephalogram taken before extractions demonstrates that the teeth are slightly protrusive compared with the opposing teeth. Positioning of the implants, therefore, must take into account the required final location of the teeth in the prosthesis.

Provisional hybrid prostheses

Many edentulous patients have a lower denture that does not provide sufficient retention for function without a compromise in diet and comfort. The placement of four or five implants into the anterior mandible allows for immediate occlusal loading. Five implants are ideal, because if one implant is lost, the prosthesis can be salvaged without

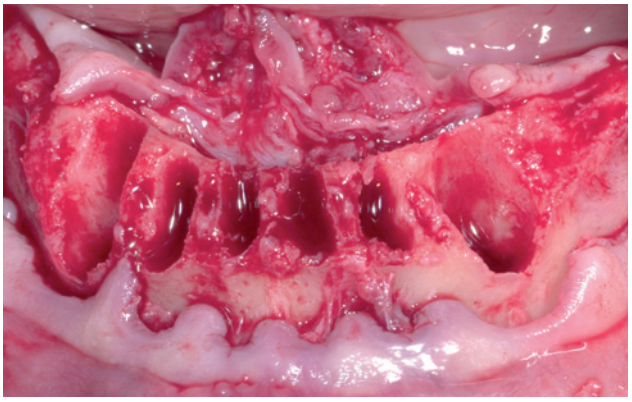


FIGURE 1-14 D, Incision is made in the sulcus of the teeth, and an envelope flap is raised full thickness. The teeth are removed, and the sharp edges of the crestal bone are removed before the implant sites are prepared.

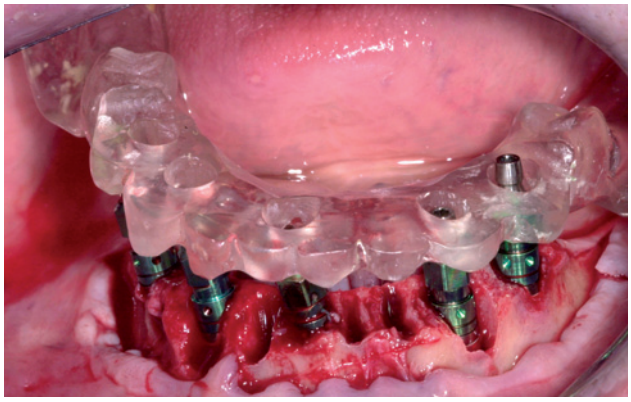


FIGURE 1-14 E, Surgical template is placed over the crest, and the implant sites are prepared. A bone trap/sieve has been placed in the suction line to capture bone removed during preparation of the implant sites.

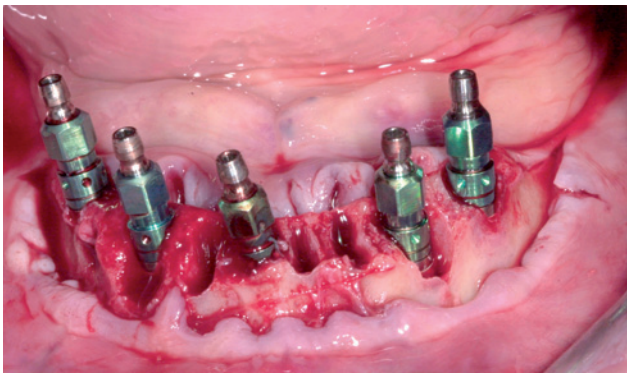


FIGURE 1-14 F, Implants in position. The bone defects are grafted with bone captured from the sieve.

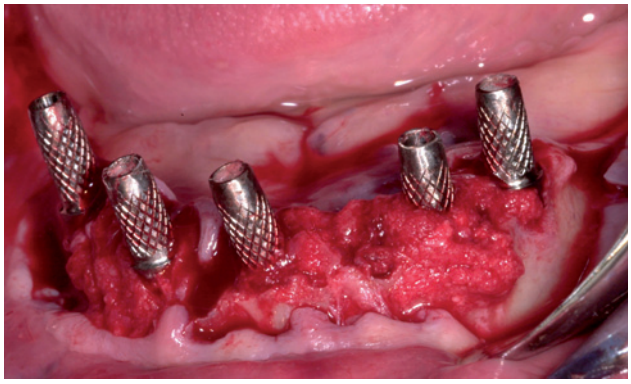


FIGURE 1-14 G, Defects have been grafted and the driving mounts removed. Copings are placed and hand-tightened to the implants with screws.

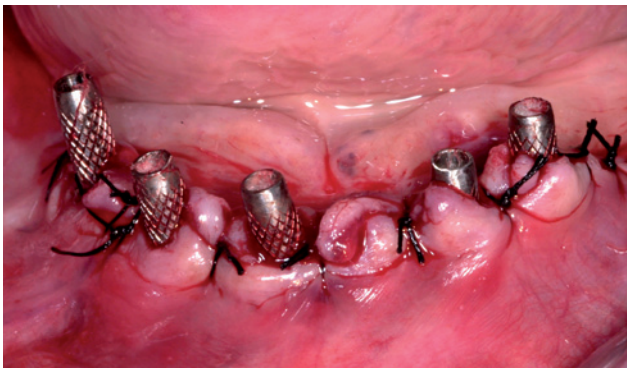


FIGURE 1-14 H, Incision is closed with sutures that return the KG to the labial and lingual aspects of the abutments.

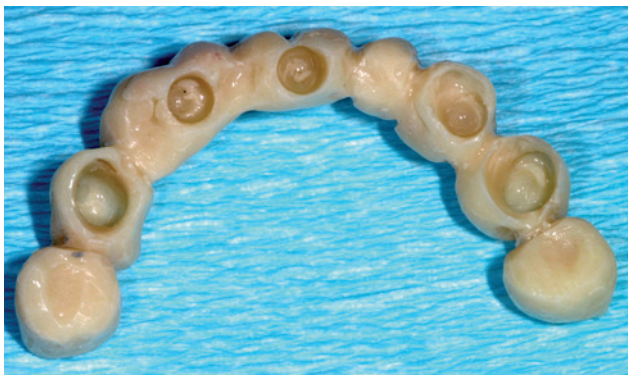


FIGURE 1-14 I, Preoperative preparation includes a diagnostic setup, which takes into consideration the final positioning of the maxillary teeth. A hollow-shell, temporary fixed prosthesis is fabricated and relined at surgery.

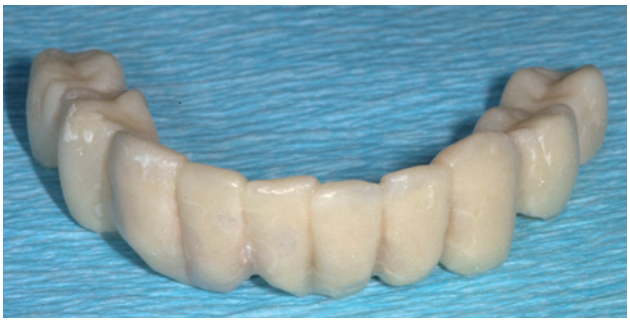


FIGURE 1-14 **J,** Occlusion for the temporary prosthesis is kept level to match the opposing removable prosthesis.

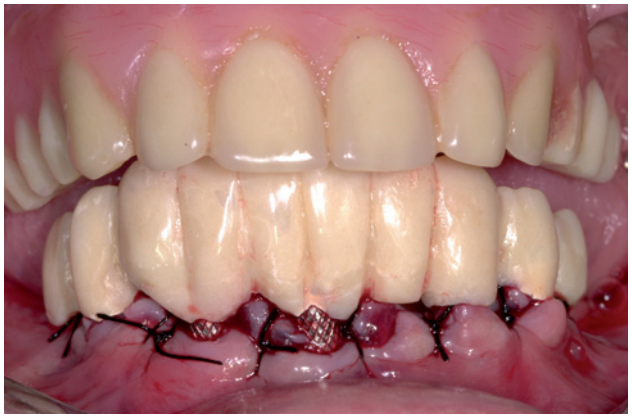


FIGURE 1-14 **K,** After relining with resin, the temporary fixed restoration is positioned over the copings placed on the implants by the surgeon.

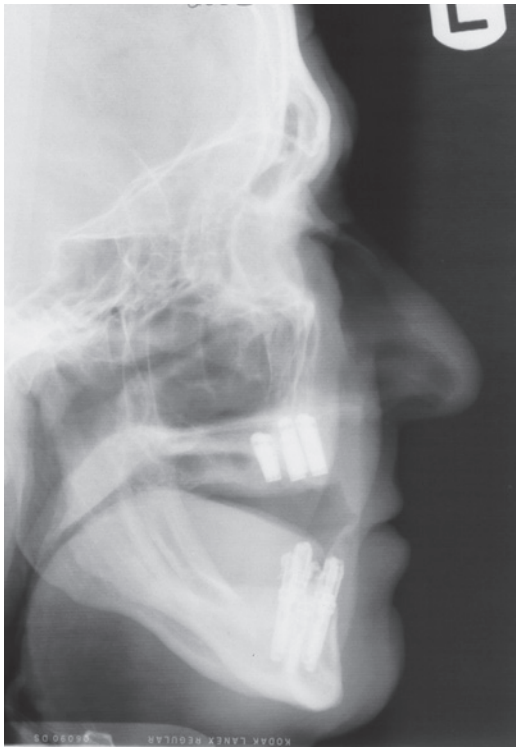


FIGURE 1-14 **L,** Postoperative view showing the angulation of the implants.

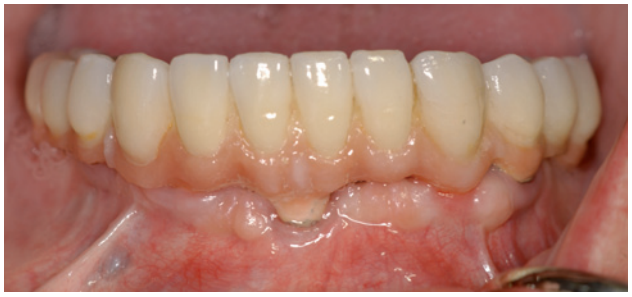


FIGURE 1-14 **M,** Final prosthesis is a hybrid type that is screw retained to the implants. Final impressions were taken 4 months after placement of the implants. The patient did not have a temporary removable prosthesis from the time of implant placement to final restoration.

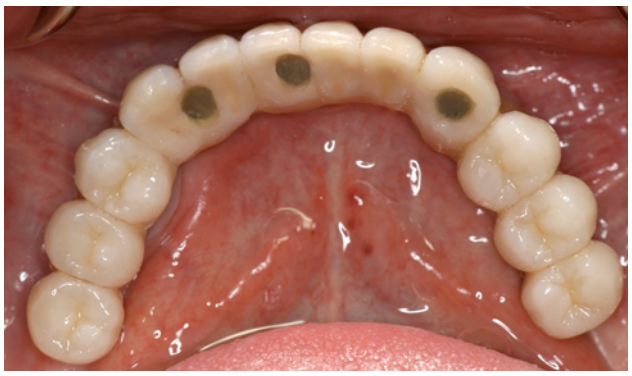


FIGURE 1-14 **N,** Occlusal view shows the position of the implants. The implants could not have been placed in correct position without the surgical guide.

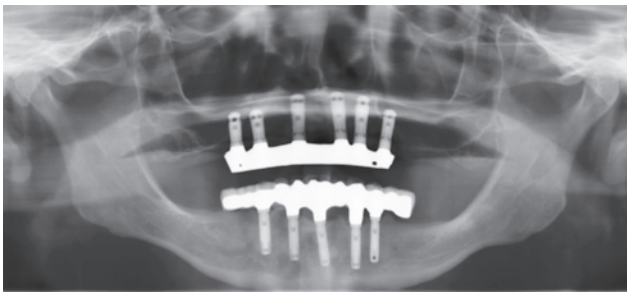


FIGURE 1-14 **O,** Final panoramic radiograph.

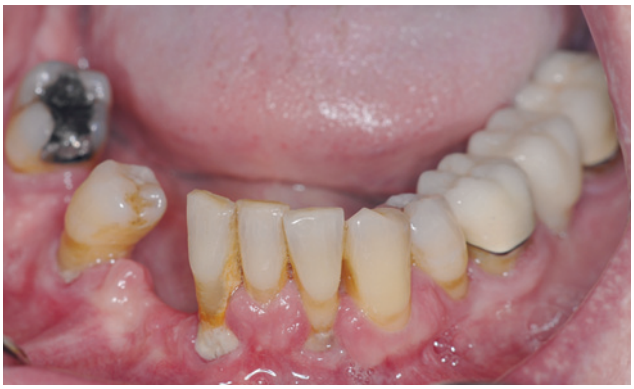


FIGURE 1-15 **A,** Patient desires immediate replacement of his teeth with an implant-supported restoration. Because his prosthetic plan includes a fixed ceramic restoration that is cemented or screw retained, the decision was made to place a similar prosthesis as an immediate temporary.

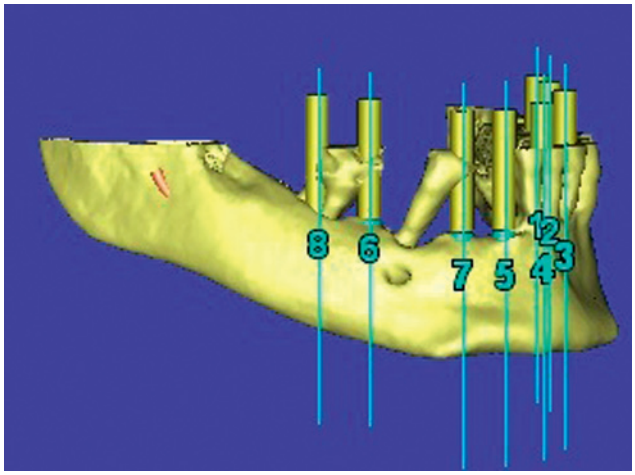


FIGURE 1-15 **B,** CT cone beam scan was obtained, and CT planning software was used to plan the implant positions, choose implant lengths, and predetermine the location of the implants on casts. This three-dimensional virtual image shows the planned implant positions in relation to the teeth to be removed.

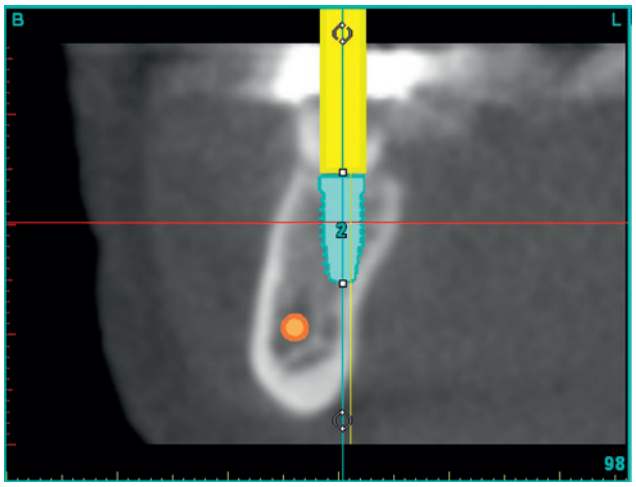


FIGURE 1-15 **C,** Cross-sectional image shows one of the implants in its virtual position. Note that CT planning allows the team to choose the ideal implant sizes and to relate them to avoid vital structures, such as the inferior alveolar nerve, which is seen in orange.

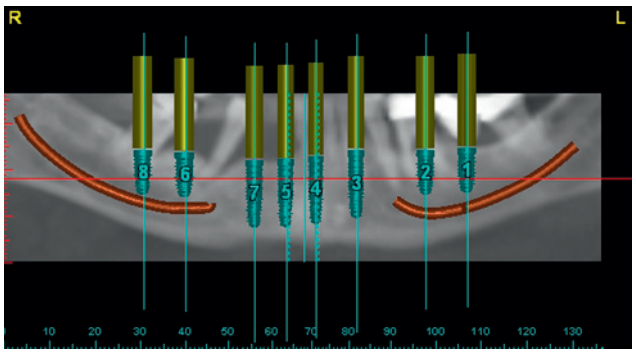


FIGURE 1-15 **D,** Panoramic image on the CT planning software (Materialise, Belgium). Note the locations and lengths of the implants.

the need to redo it. A technique that provides the patient with an immediate, fixed, full-arch restoration uses the patient's old denture and a relatively efficient restorative technique; this allows the patient and the dentist time to decide on the final prosthesis. This method also gives the patient a provisional restoration, which can be used to determine the final occlusal scheme and the patient's hygiene level (Figure 1-16, A-W).

For the patient to receive an immediate, provisional fixed restoration in the form of a hybrid prosthesis, the interocclusal space must be sufficient for the supporting framework and the teeth. Therefore, the clinician needs

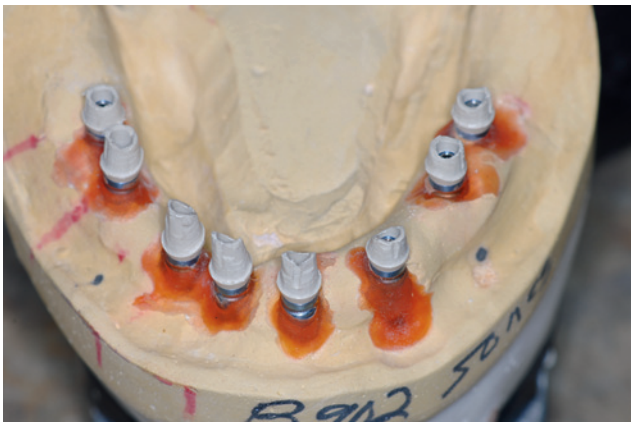


FIGURE 1-15 **E,** Location of the mental foramen is marked on a cast, and implant analogs are placed to match the plan illustrated in Figure 1-15, D. Implant abutments are then placed and prepared lightly.

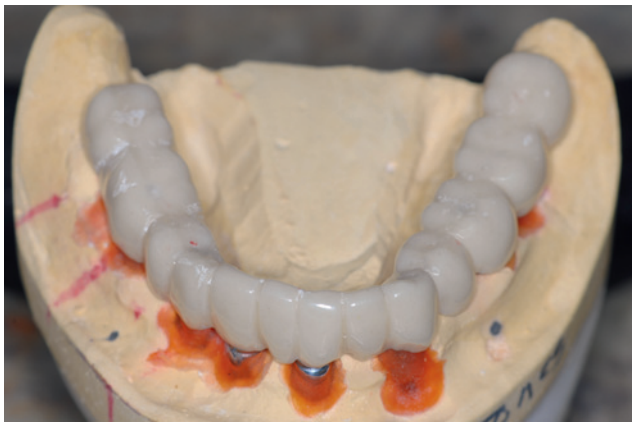


FIGURE 1-15 **F,** Full-arch, one-piece provisional prosthesis is made on these models. Preoperative planning facilitates patient treatment and reduces chair time.

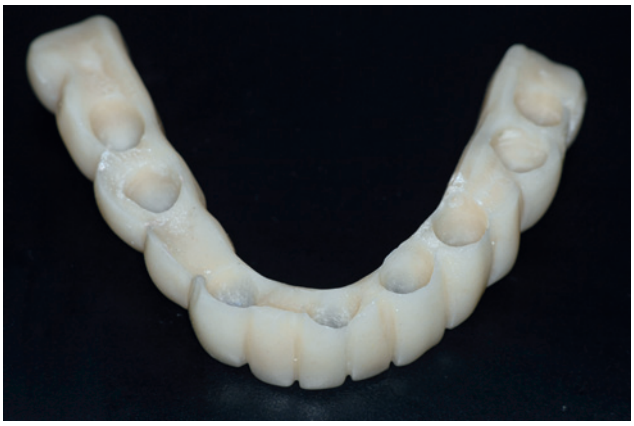


FIGURE 1-15 **G,** Fixed provisional prosthesis is ready for implant placement. Adjustment and relining are expected after the implants have been placed.

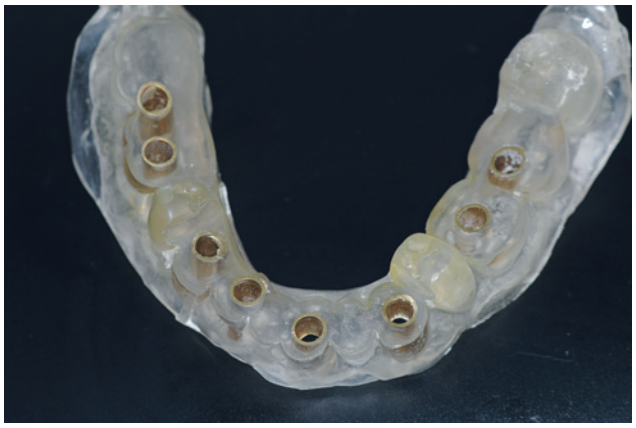


FIGURE 1-15 **H,** Drill guide stent is made, using small brass tubes to guide the surgeon. Another option is the use of CT guide tubes placed over the abutments.

12 to 15 mm from the mandibular crestal bone to the incisal edges of the opposing occlusion. If extraction of teeth is required to prepare for implant placement or if immediate placement after extraction of the teeth is planned, an alveoloplasty should be performed to provide sufficient interocclusal space for the abutments; the bar (typically 3 to 5 mm tall); and the resin, which should be thick enough to maintain the connection of the teeth.

After the implants have been placed, holes are drilled through and through the patient's denture to lute the prosthesis to the implant's temporary cylinders. If the denture has a typical thickness, it most likely will break into two pieces when the holes are drilled in the implant locations. Therefore, the restorative dentist needs to thicken the denture preoperatively in the labial-lingual dimension.

For the surgical guide, the dentist should duplicate the denture in clear acrylic. The implants must be placed lingual to the anterior dentition and within the confines of the premolar teeth, avoiding excessive labial angulation. The *only* way the surgeon placing the implants can understand the planned position of the teeth completely is to use a surgical duplicate of the planned restoration as a surgical guide. These two steps—thickening of the denture and fabrication of the drill guide—are essential for proper patient care.

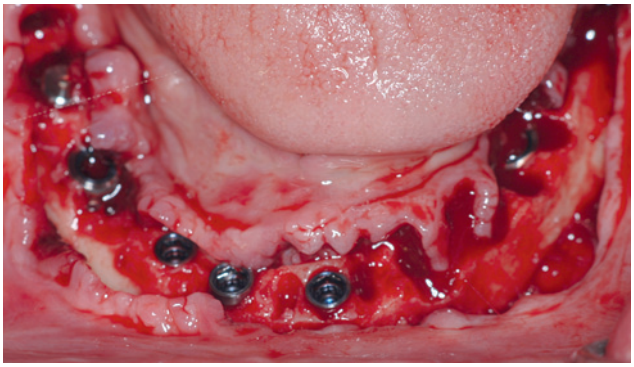


FIGURE 1-15 I, At the time of surgery, the teeth are removed and the implants are placed according to the surgical guide stent. As each site is prepared, a guide pin is placed into the bone site and through the guide tubes of the stent. As more implants are placed, the stent is stabilized with interim guide pins; this facilitates accurate placement of the implants.

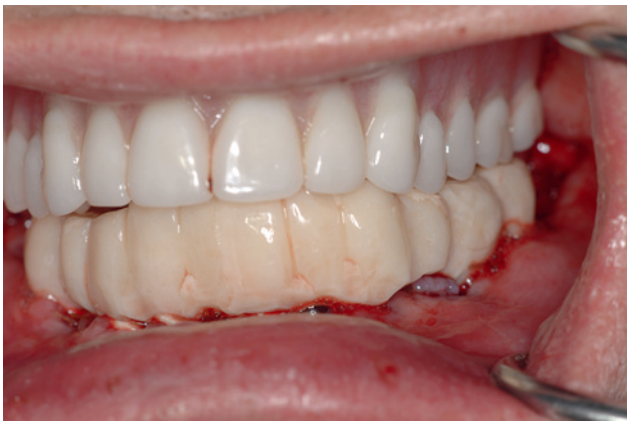


FIGURE 1-15 K, Full-arch provisional prosthesis was cemented after relining and adjustment of the occlusion. (Prosthetics by Dr. Israel Finger).

In the consultation visit with the surgeon, the planned surgical procedure is explained in detail, including the necessary trip to the restorative dentist's office after the implants have been placed. It is imperative that the provisional prosthesis be placed on the same day as implant placement. As mentioned earlier, an escort is needed to drive the patient to the restorative dentist's office. A long-acting anesthetic should be infiltrated after the incisions have been sutured to provide the patient comfort during the 2- to 3-hour restorative phase on the same day as implant placement surgery.

Preoperative Laboratory Procedures. Once an immediate hybrid provisional prosthesis has been chosen as the

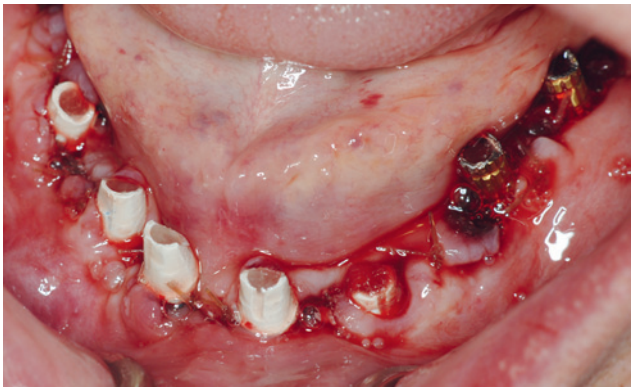


FIGURE 1-15 J, Abutments prepared preoperatively are placed. In this patient, because of a small vertical height discrepancy, taller metal temporary cylinders were placed in the left posterior implants. The implant stability quotient (ISQ) values for all the implants were greater than 70, except for the right posterior implant, for which the ISQ was 61. That one implant was not loaded.

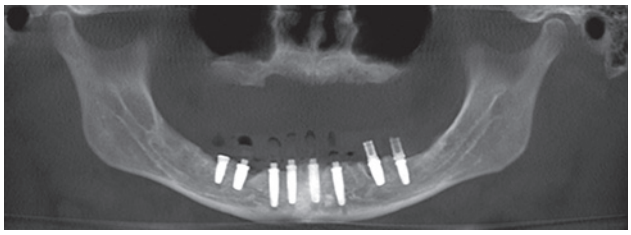


FIGURE 1-15 L, Postoperative panoramic radiograph.

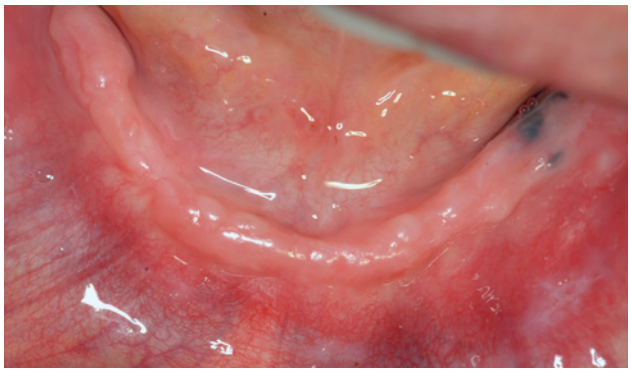


FIGURE 1-16 A, Preoperative view of edentulous mandible before placement of implants. The teeth had been extracted 2 months earlier, and an alveoloplasty was performed to allow adequate space for the final hybrid prosthesis.

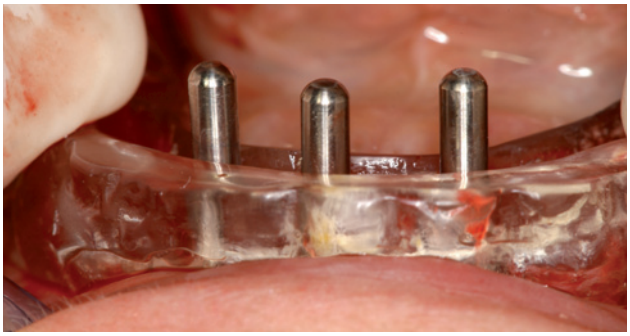


FIGURE 1-16 **B,** Crestal incision is made, bisecting the thin band of KG, and the implant sites then are prepared. The surgical guide stent is used to confirm that the implants are placed slightly lingual to the planned incisive edge of the final prosthesis.

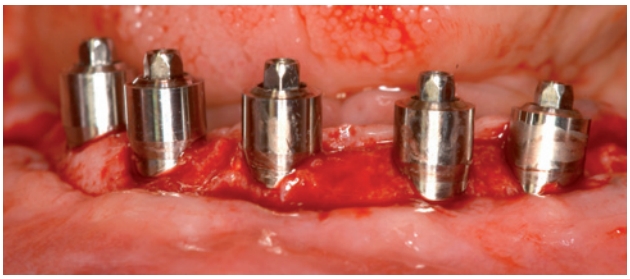


FIGURE 1-16 **D,** Abutments are tightened to the implants with a torque driver to 20 N-Cm of force. The gingival collar height is 4 mm in this case, which places the shoulder of the implant supragingivally to allow for ease of prosthetics and hygiene. The abutments do not need to engage the antirotation feature of the implants, because they will be secured to each other through the prosthesis.

FIGURE 1-16 **F,** Telescopic copings are placed on the abutments, and a rubber dam is placed around the abutments. A material such as "wax of fit checker" is placed into the intaglio surface of the denture to mark the locations of the implants.

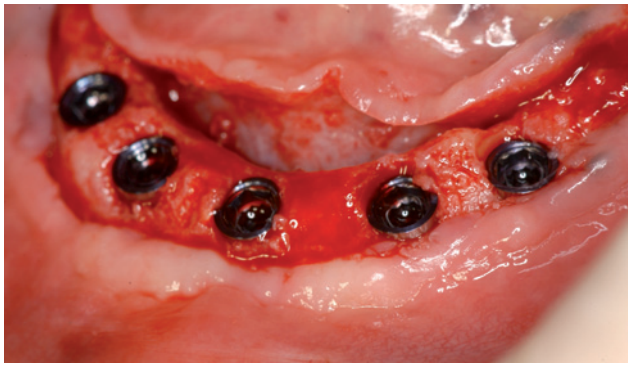


FIGURE 1-16 **C,** Implants have been placed level with the bone with at least 3 mm between the implant bodies to allow for adequate hygiene.

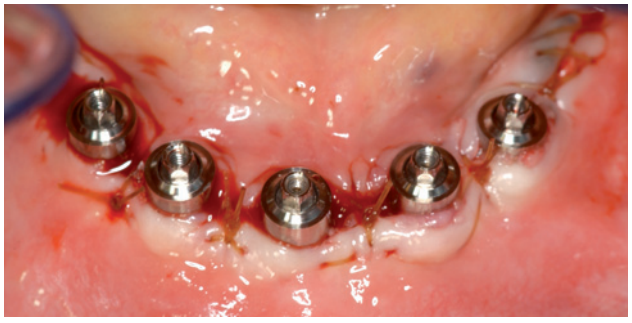


FIGURE 1-16 **E,** After the abutments have been secured to the implants, the gingiva is approximated to the abutments. Typically, a resorbable suture material (e.g., chromic, size 4-0) on a tapered needle is used. After the incisions have been closed, a long-acting local anesthetic is infiltrated, and the patient is escorted to the restorative dentist's office for the prosthetic portion of the procedure.

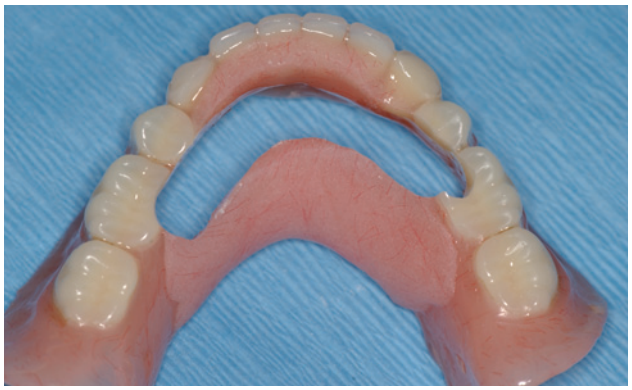


FIGURE 1-16 **G,** In many cases, acrylic should be added to the patient's denture to increase the width before a channel is cut or holes are drilled through it. After the locations of the implants have been identified on the prosthesis, a channel is cut or holes are drilled in the denture. An example of a channel cut into the reinforced denture is shown.

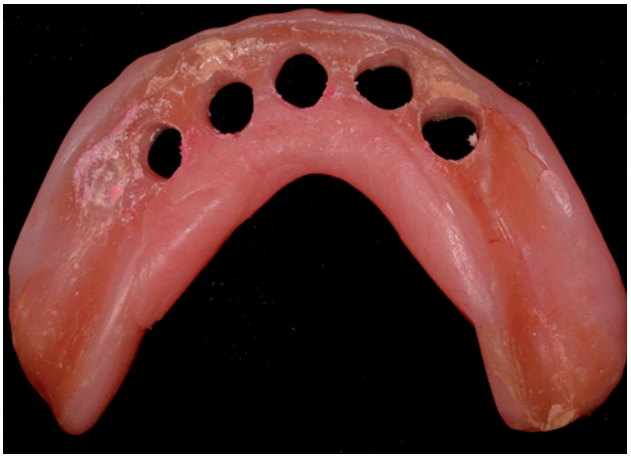


FIGURE 1-16 H, Example of holes drilled in the denture. The intaglio aspect is relieved distal to the implants, approximately 10 mm for the distal extensions.

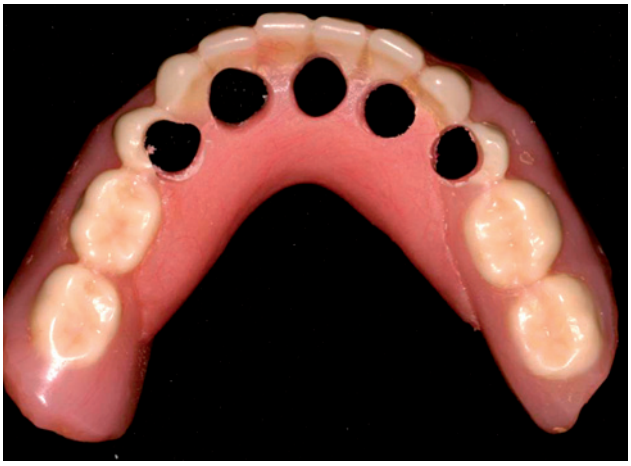


FIGURE 1-16 I, Occlusal aspect demonstrates the rationale for adding resin to the denture. Without the added resin, the denture likely will fracture.

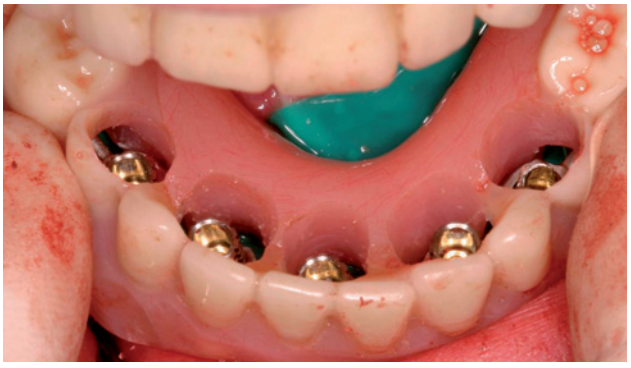


FIGURE 1-16 J, Denture is placed to ensure a passive fit and a stable fit on the residual ridges and to make certain that the occlusion is appropriate and reproducible and the device does not rock in the mouth.

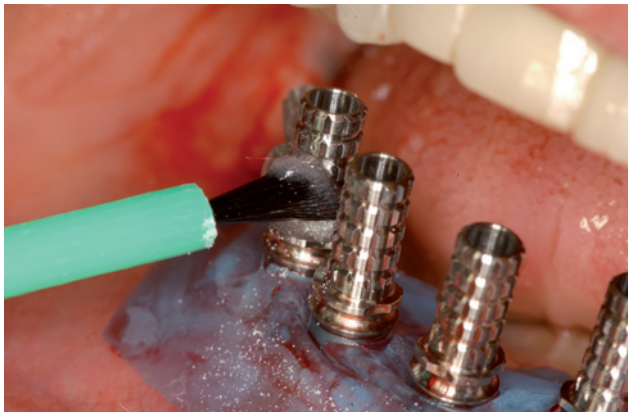


FIGURE 1-16 K, Distal extension is placed over the distal implants and secured to the telescopic coping with resin. This extension prevents fracture of the distal cantilever of the provisional hybrid prosthesis.

planned treatment, a surgical guide stent must be fabricated through duplication of the patient's existing denture in clear acrylic resin. An alternative is to fabricate the surgical guide stent in clear acrylic resin from the wax try-in or a provisional denture. The stent should be prepared by drilling a slot lingual to the teeth to form a channel from first premolar to first premolar, indicating where four or five implants should be positioned to prevent screw emergence from the labial surfaces of the teeth. The screws securing the hybrid prosthesis should emerge lingual to the incisive edge of the teeth or within the fossae of the premolar teeth.

Another option is to use a CT scan to fabricate the surgical guide. This requires a duplicated denture with radiopaque markers to allow for accurate placement of the implants into the CT scan based on planned teeth positions. From the CT plan, the file is transmitted electronically to the manufacturer, which then fabricates a drill guide. This can allow for flapless surgery, but it also increases the cost and the patient's pretreatment time. The benefits of CT planning with prototype stents include complete knowledge of the bone morphology before surgery; use of a flapless surgical technique, which shortens the surgical time and reduces postoperative

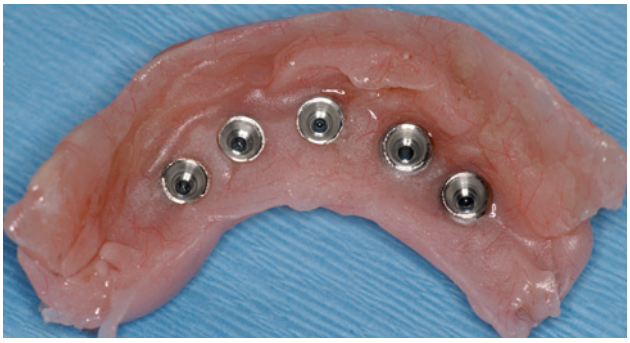


FIGURE 1-16 L, Telescopic copings are cut short to the level of the denture and are replaced onto the abutments. Cotton is placed into the abutment screw sites to prevent acrylic from entering the screw heads. The prosthesis is placed, and acrylic is injected by syringe into the space between the copings and prosthesis. After the acrylic has set, the prosthesis is removed by removing the occlusal screws. This is the intaglio view of the copings after initial luting to the denture. Spaces must be filled and smoothed.

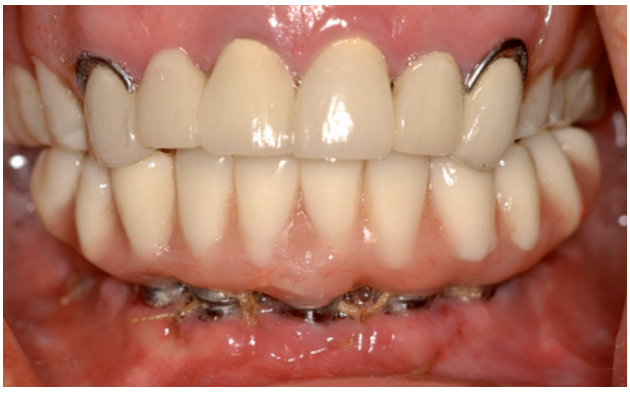


FIGURE 1-16 N, Provisional prosthesis is secured to the implants using hand-tightening. The occlusion is checked and adjusted for balance if necessary.

pain and swelling; and laboratory preparation of the denture based on transferal of the CT plan to a working model.

Before surgery, the denture to be used as the provisional prosthesis *must* be thickened by the addition of denture resin in the buccal-lingual dimension to prevent fracture when the holes are drilled to secure the prosthesis to the implants. This also provides additional strength to the prosthesis. The provisional prosthesis should be relieved internally; however, the distal bases and periphery should not be relieved so that the correct occlusion can be reproduced.

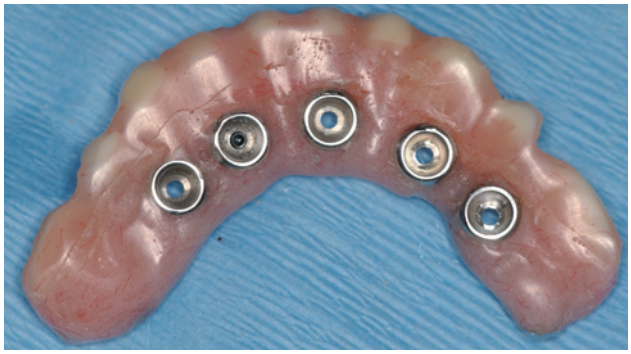


FIGURE 1-16 M, Prosthesis is smoothed, and all the flanges are removed. The distal cantilever is trimmed to 14 mm distal from the posterior implants. The intaglio surface is smoothed to prevent food entrapment during function.

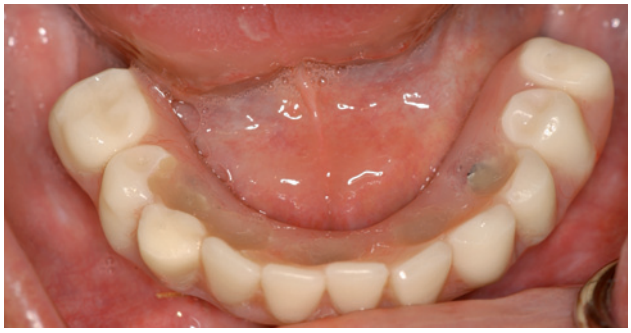


FIGURE 1-16 O, Occlusal screw holes are filled with resin and smoothed.

The provisional denture should be tried-in before surgery is started. If necessary, any remaining teeth should be cut down to the tissue level to facilitate the try-in. The occlusion should be verified carefully. The implants should be placed according to established surgical procedure and with the guide stent used to ensure proper placement.

Surgical Procedure. A topical anesthetic is administered, and a local anesthetic with constrictor then is infiltrated into the labial and lingual tissues from mental foramen to mental foramen. After sufficient time has elapsed for the anesthetic and constrictor to take effect, a crestal incision is made, bisecting the KG. Full-thickness, mucoperiosteal flaps are raised, exposing the labial and lingual cortical bone of the anterior mandible, as well as the mental foramen and nerves.

The incision should bisect the KG so as to place it on the labial aspect of the abutments, as well as the lingual surfaces of the abutments. The implants should be placed level

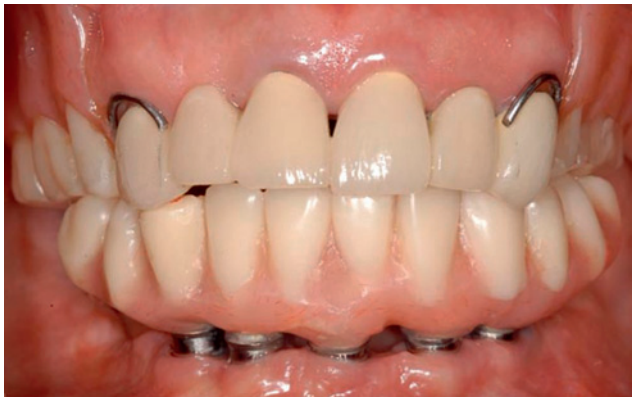


FIGURE 1-16 P, Four months after placement of the provisional hybrid, the patient is ready for fabrication of the final prosthesis. Note the excellent oral hygiene and health of the preserved keratinized gingiva.

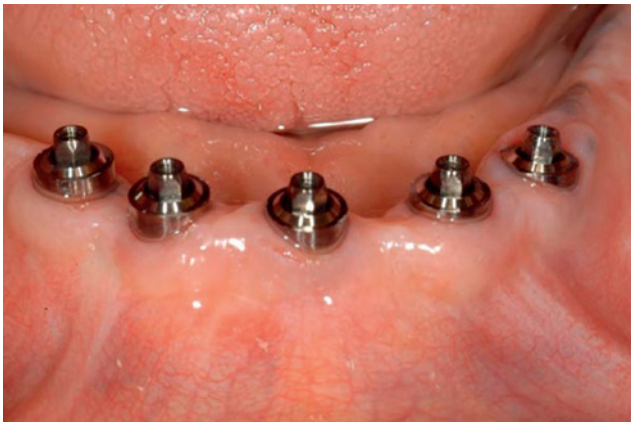


FIGURE 1-16 Q, Provisional hybrid restoration is removed, leaving the abutments in place. An abutment-level impression is taken.

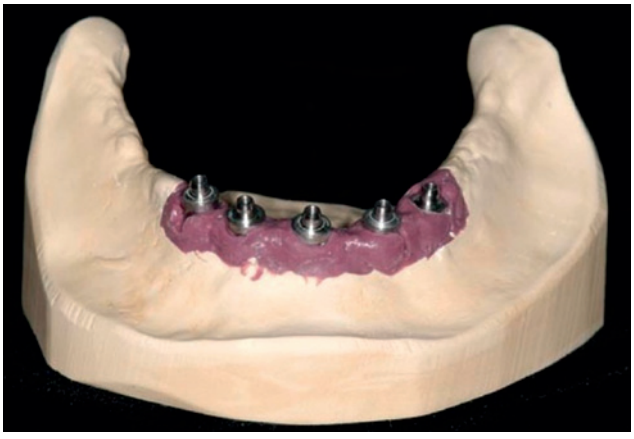


FIGURE 1-16 R, Model will be used to fabricate an implant-borne verification index. When computer-assisted design and manufacture (CAD CAM) is used, the use of titanium milled frameworks is critical to the creation of a perfect impression. Because of normal impression error, a verification index is required.

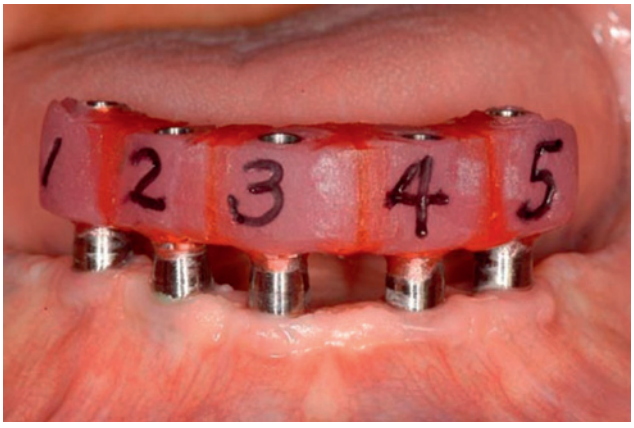


FIGURE 1-16 S, Verification index in the mouth. Areas between the implants have been cut and connected using high-accuracy resin. The index is used to fabricate the milled, one-piece titanium framework.

with the bone, and the gingival collar of the abutments should be long enough (at least 3 mm and more often 4 mm) to allow supragingival location of the abutment to the framework. The implants need not be countersunk. Because the abutments should be placed passively, countersinking may create a problem with bone interference.

Teeth are extracted if present. Sharp edges of bone are removed as necessary. An alveoloplasty is performed to create a smooth shelf of bone. It is important to place the implants in secure bone, and a minimum of 20 N-Cm of torque is required to drive the implants into position. If used, a radiofrequency index of greater than 60 is recommended.

The implant sites are marked on the ridge in a manner similar to that described earlier for the placement of five implants in the anterior mandible. With the help of the surgical guide, the first implant site is prepared. A guide in is placed into the site to confirm proper implant position within the channel as made in the surgical guide. Subsequent implant sites are prepared, and the orientation of

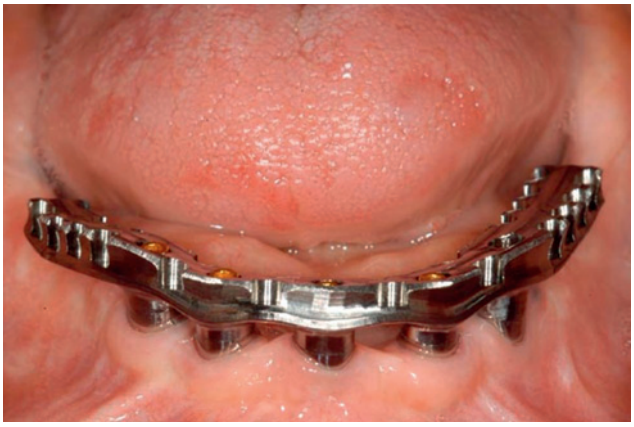


FIGURE 1-16 **T,** Titanium framework is created in the laboratory using CAD CAM technology and milling. The framework is tried in place to verify fit. Usually a try-in of this stage is not necessary.

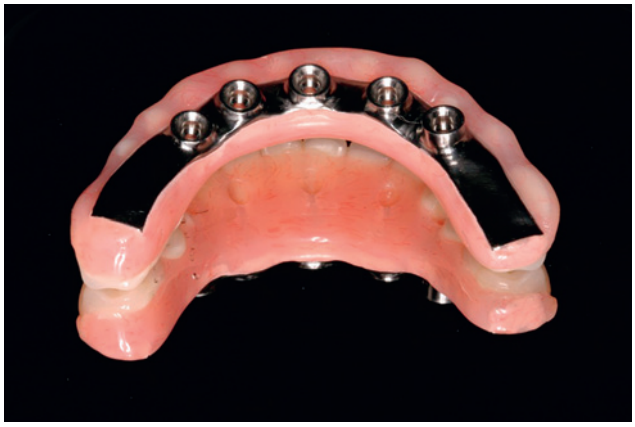


FIGURE 1-16 **U,** Intaglio surface of the final prosthesis is smooth and low profile. This highly polished surface will not collect food debris.

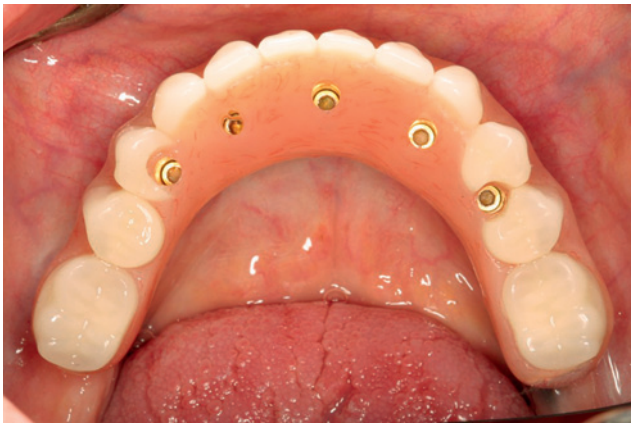


FIGURE 1-16 **V,** Titanium milled framework allows drilling of small access holes for final screw retention. Note the position of the implants as determined by the initial drill guide.

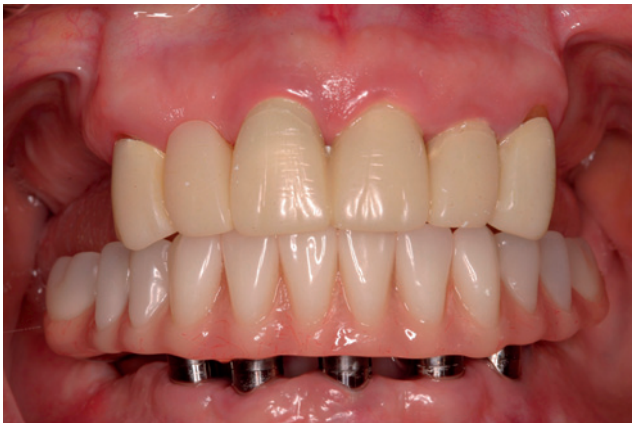


FIGURE 1-16 **W,** Final prosthesis in position. Note the easy access for hygiene. This patient had posterior implants placed and restored at a later time to provide molar occlusion. (Prosthetics by Dr. Israel Finger and Dr. Paulino Castellon).

the implants is confirmed with the use of the stent. It is imperative to place the implants perfectly. If an implant is placed too far labial, the prosthetic problems are enormous, and the case is compromised.

Each implant should be 7 to 8 mm apart from the center of the adjacent implants and placed level with the bone. The implants should be level with each other to prevent difficulty with prostheses. In dense bone, a thread-former can be used to create threads, allowing the implants to be placed without excessive compressive forces. In the author's experience, this does not compromise an immediately loaded case in the anterior mandible.

After the implants have been placed, the abutments are positioned and the screws are torqued to 20 N-Cm for primary stability. The screws must not be overtorqued, or they will strip, fracture, or deform. The abutment should be placed so that the interface is 2 mm above the level of the gingiva. The gingival collar height on the most frequently used abutments is 3 or 4 mm. It is important to use the correct abutment placement tool and to avoid scratching the abutments; this can be accomplished by using needle holders or other clamping instruments. The gingiva is closed with 4-0 resorbable, chromic suture using a tapered needle. Interrupted or horizontal mattress sutures allow for

conformation of the gingiva to the abutments. After closure, a long-acting local anesthetic is placed to provide the patient with anesthesia during the 2 to 3 hours of the restorative phase.

Restorative Phase. After the incisions have been closed, the restorative dentist marks the implant sites, drills holes through the denture, and relieves the area distal to the most posterior implant for the hybrid extensions. Heavy "body putty" or similar material is placed in the intaglio space of the provisional denture to mark the implant sites. The patient is instructed to occlude, and the dentist must confirm that the occlusion is identical to the verified position at the beginning of the procedure. After the putty has set, the provisional denture is removed. The marks in the putty reveal the location of the abutments and the locations where holes should be drilled in the denture. Holes are drilled through the provisional denture with an acrylic bur. The temporary cylinders are placed into the abutments and retained with screws. The denture, with the holes drilled, is placed to ensure passive fit. The heights of the temporary cylinders are marked so that they can be reduced after removal of the denture from the mouth. The temporary cylinders need to be reduced below the plane of occlusion of the denture.

After the height adjustments have been made, the temporary cylinders are screw retained to the abutments, and a rubber dam with holes at the implant locations is placed, fitting over the abutments. On the most posterior abutments, a distal extension support is used to support a 15-mm cantilever. The extension is luted to the distal temporary cylinder with resin. The denture is tried-in over the cylinders, confirming that there is no interference with the cylinders or distal extensions and that the denture is fully seated. If necessary, the denture is further adjusted. It should have positive tissue support with a reproducible occlusion similar to the preoperative occlusion.

The access holes for the temporary cylinders are filled with a removable material, such as cotton, to prevent acrylic resin from entering the retaining screws. Autopolymerizing acrylic resin is mixed, placed into a syringe, and injected to connect the temporary cylinders to the relieved denture. Occlusion is verified by having the patient close into the established vertical dimension, using the bite registration to verify that the denture is in the correct position. Centric occlusion is maintained while the acrylic resin sets.

After the denture resin has set, the prosthesis with temporary cylinders is removed. In the laboratory, the dentist finishes the denture by adding acrylic resin to any areas with voids. Using an acrylic bur, the dentist removes the acrylic resin on ridge contact areas, all excess acrylic from the bottom of the denture between the cylinders, and the posterior cantilever beyond 15 mm (the first molars). It is important to create a space of 3 to 6 mm between the sutured gingiva and the intaglio surface of the prosthesis. This space gives the patient access for cleaning. If the flanges are not generously relieved, food will collect during the healing phase, increasing the risk of infection. All surfaces are polished smooth.

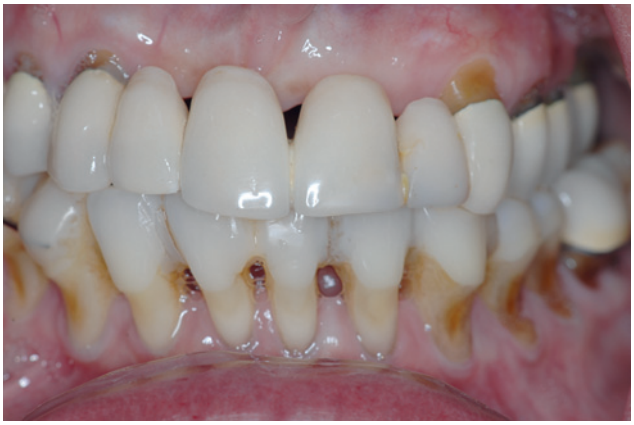
The restoration is placed into the mouth to verify appropriate occlusion and tissue clearance. The retaining screws are hand-tightened only to 20 N-Cm, and the screw access holes are sealed with resin and polished. Final impressions are made after the clinicians are satisfied that integration of the implants is complete.

Immediate provisionalization in a patient with teeth using CT guidance

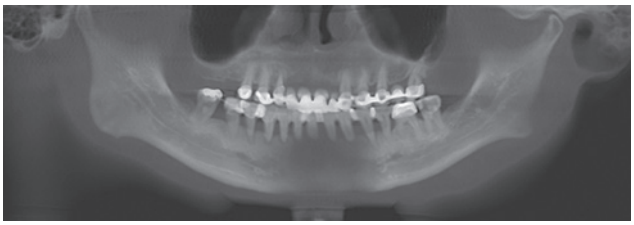
Patients often present with teeth in various states of health and with a generalized poor prognosis. The goal for most patients is to re-establish the teeth to the functional levels present before dental deterioration. Most patients want to have their teeth removed and immediately replaced with a fixed prosthesis so that they do not have to wear removable dentures. The literature supports immediate occlusal loading of implants that are cross-arch stabilized in the mandible. When the cost is acceptable to the patient, this option should be considered routinely if the treatment plan calls for an implant-supported final prosthesis. Pretreatment planning can be summarized as a treatment flow algorithm consistent for all patients about to become edentulated.

Step 1: Determination of the Final Esthetic and Functional Tooth Setup. The patient's preoperative occlusion (Figure 1-17, A-U) must be adjusted so that the restorative dentist knows the final location of the lower teeth. The maxillary occlusal plane may need to be re-established by restoration of the maxillary teeth with a new temporary prosthesis for full mouth rehabilitation cases. If necessary, a new maxillary denture is fabricated. Once the proper position of the maxillary teeth has been established, the position of the planned mandibular teeth can be predicted and created in the laboratory. In this way, the resultant surgical planning is based on the ideal.

Step 2: Planning of the Setup of the Mandibular Teeth. When removal of all or most of the mandibular teeth is planned, an immediate denture may be used to provide the patient with teeth when leaving the office. To establish the location of these teeth, the maxillary teeth positions are critical (thus the need for step 1). If necessary, a mockup of the proposed teeth can be made, but for most patients, the immediate denture setup provides the important information. A cone beam scan is taken with the new maxillary



● **FIGURE 1-17** **A,** Initial presentation. Before the immediate load mandibular prosthesis is fabricated, the maxillary dentition must be provisionalized to establish the final maxillary plane of occlusion.

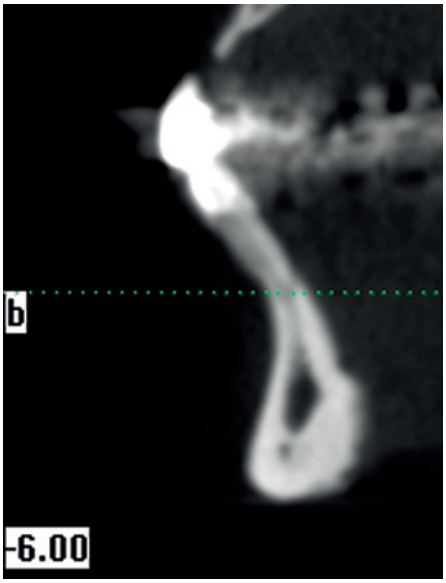


● **FIGURE 1-17** **B,** Preoperative reconstructed panoramic image showing severe bone loss of the mandibular dentition.

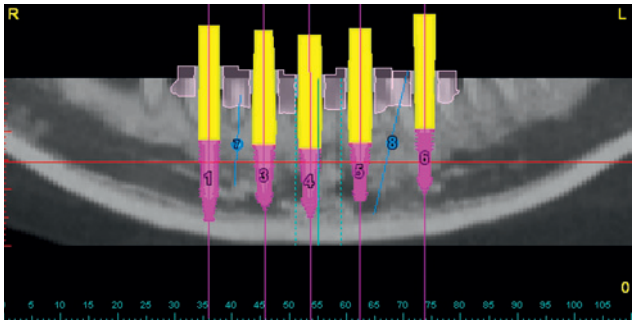
provisional in place, with the teeth together (see Figure 1-17, B-C). The new provisional teeth in the maxilla serve as landmarks for future planning for the new mandibular teeth. When the scan is taken with the teeth together, planning software is used to place implants that are correctly aligned with the opposing teeth. If the patient has malpositioned mandibular teeth, a landmark of the planned ideal location of the teeth is necessary for subsequent planning.

The scan is then evaluated. In the case example (see Figure 1-17, C-D), the crestal aspect of the ridge is narrow, but the ridge then widens sufficiently to require a bone height reduction of 5 to 8 mm. The presence of the opposing teeth in the image allows virtual implant placement with the correct orientation to match the maxillary teeth; this ensures accurate positioning of the mandibular implants.

Step 3: Decision on the Use of CT Guidance for Surgery. CT guidance provides the surgeon with a surgical guide that helps position the implants, that provides information on the implants' angulation, and that can be



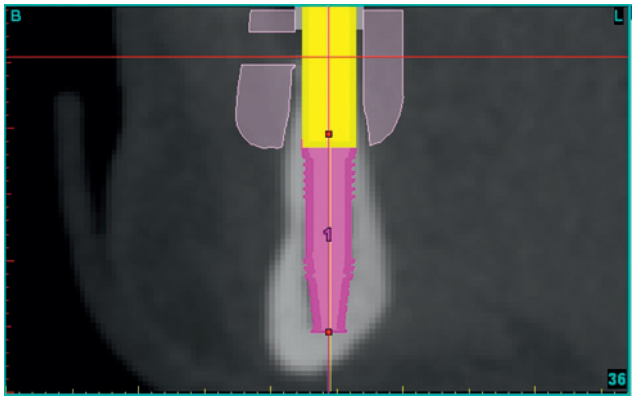
● **FIGURE 1-17** **C,** Cross section through the mandibular canine showing a thin ridge, which becomes wider after 8 mm of ridge reduction. Also note the dental protrusion, which is common in patients with severe bone loss.



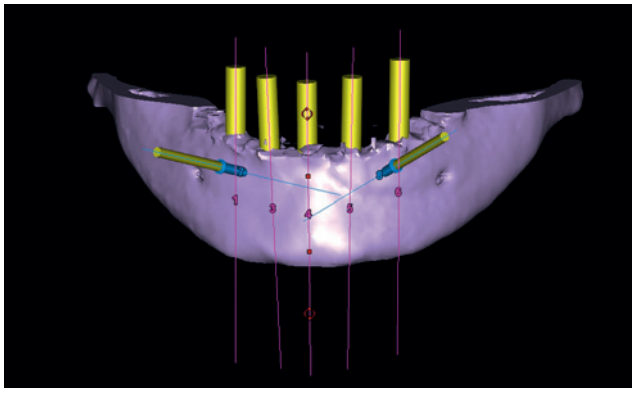
● **FIGURE 1-17** **D,** Reconstructed panoramic image after the implants have been positioned using CT planning software (Materialise, Belgium). The implants are placed inferiorly in the mandible to a depth that allows for 1.5 mm on the labial and lingual aspects of the implants. They are angled to match the maxillary dentition, which has been provisionalized.

used to visualize the final location of the implants. For example, if the mandibular teeth are flared and the position of the maxillary teeth and immediate lower denture shows that the mandibular teeth should be more upright and lingual, the implants on the CT plan can be located as such.

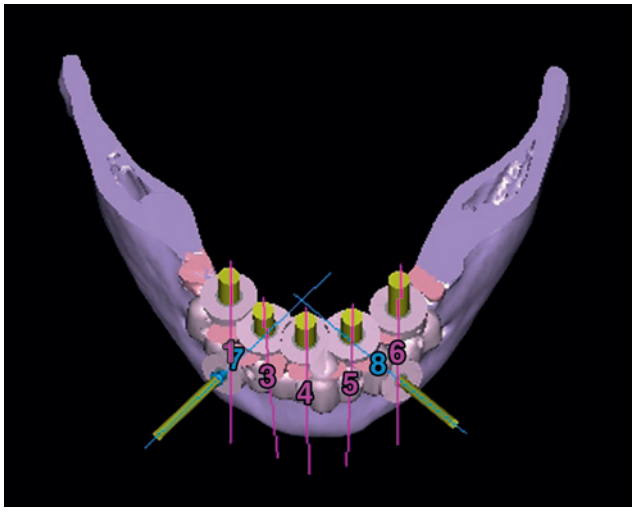
The scan is taken, and CT planning is performed. During the computerized planning, the implants are positioned



● **FIGURE 1-17** **E,** Cross section showing the implant positioned inferiorly in the wide portion of the mandible. The outline around the implant's emergence axis is the virtually designed, bone-anchored guide stent.



● **FIGURE 1-17** **F,** Virtually designed guide stent has been removed from the computer image to show the emergence of the implants and the fixation screws. The implants are placed below the thin bone into the sufficiently thick mandible.



● **FIGURE 1-17** **G,** Occlusal view shows the virtually fabricated guide stent in place with the implant axes visualized.

● **FIGURE 1-17** **H,** Bone-anchored surgical guide stent is fabricated to fit over the alveolar ridge after extraction of the teeth and before the alveoloplasty. The stent, which is secured with two fixation screws, is used to position the implants accurately, avoiding the mental nerve, and to allow for efficient surgery.

within the bone to allow for 12 to 14 mm of space from the bone to the incisive edges of the maxillary teeth, allowing for prosthetic alternatives ranging from a fixed crown and bridge to a fixed-removable spark erosion prosthesis. If a fixed-removable prosthesis is planned, 12 to 14 mm of interocclusal space must be available for the bar (which is 3 to 4 mm tall), acrylic, and teeth.

A bone-anchored surgical guide is needed for extracting teeth and placing implants. A flap is raised so that the alveolar bone can be trimmed to the planned height, resulting in adequate ridge width and providing the required 12 to 14 mm of interocclusal space. After the bone has been exposed, the surgical guide stent is placed on the bone and secured with fixation screws.

Step 4: Fabrication of the Immediate Mandibular Prosthesis. The immediate denture is made with a relatively thick lingual region. This provides sufficient resin to allow holes to be made to engage and connect to the temporary cylinders without fracturing the denture. The temporary cylinders are placed onto abutments screwed to the implants, immediately after implant placement, as discussed in this chapter.

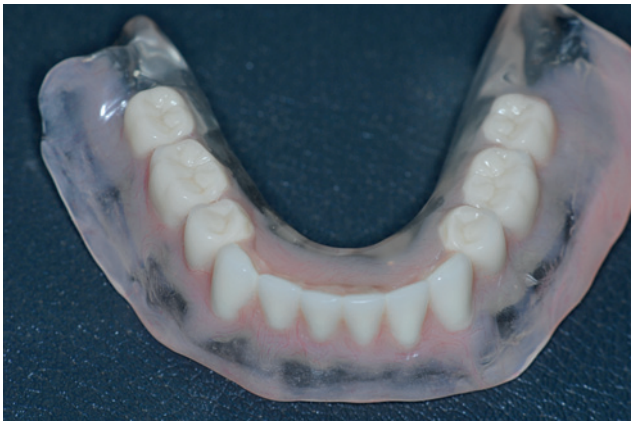


FIGURE 1-17 **I,** Immediate mandibular prosthesis. Clear flanges are used to allow visualization of the temporary cylinders when they are luted to this prosthesis. The lingual aspect has been reinforced similar to other acrylic prostheses.

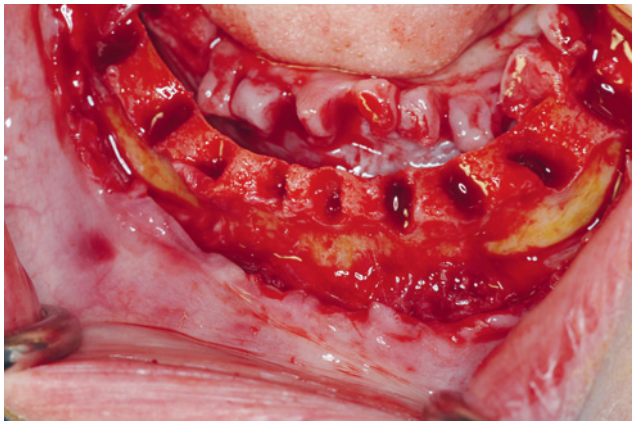


FIGURE 1-17 **J,** Local anesthetic (producing both infiltrative and block anesthesia) is administered. Sulcular incisions are made, and full-thickness flaps are reflected to expose the bone. After subluxation, the teeth are removed with forceps.

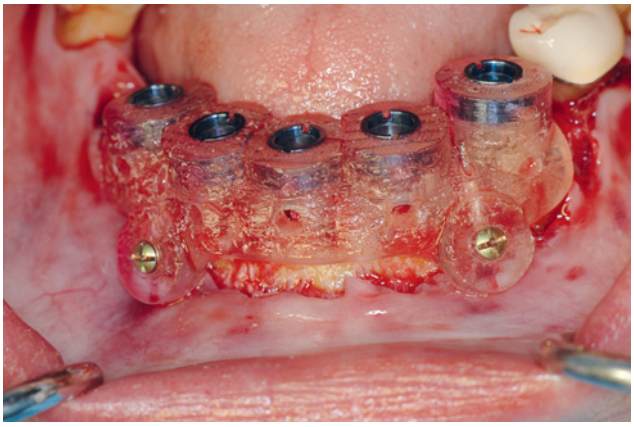


FIGURE 1-17 **K,** Surgical guide stent is placed and found to fit securely with minimal mobility. The 17-mm fixations screws are placed. Intimate contact of the stent and bone is confirmed because of the extensive bone exposure.

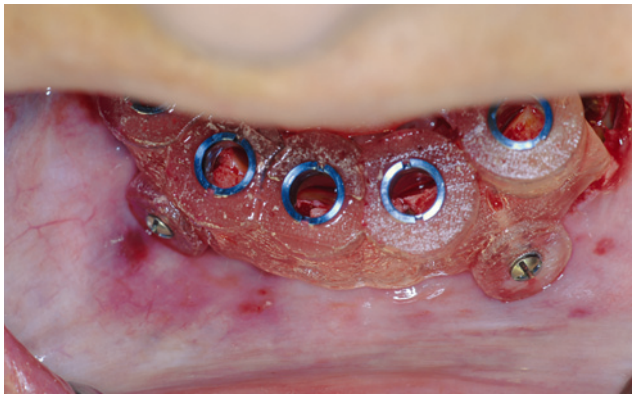
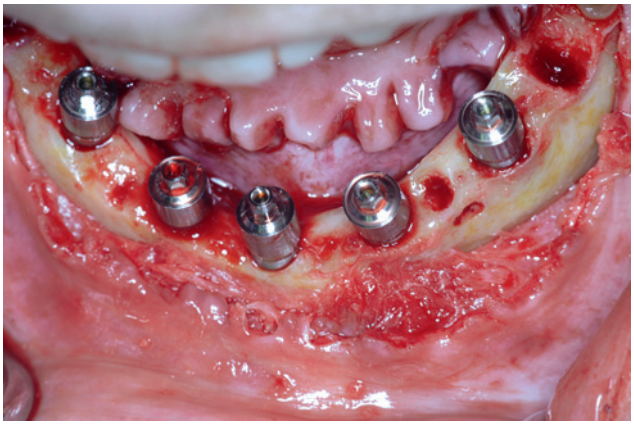


FIGURE 1-17 **L,** Viewed from the occlusal aspect, the initial pilot holes for the middle two implants are noted to be lingual to the midcrestal area. Because of intrinsic error to 1 mm or greater, the surgical guide is not used for these two sites. Direct visualization of the lingual and labial cortices was performed to prevent implant dehiscence through the lingual cortical bone.

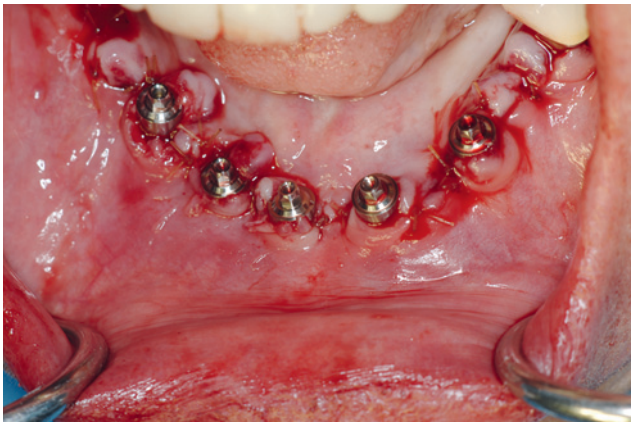
It is critical to lute the denture to the temporary cylinders with the teeth in the ideal occlusion. If posterior edentulism is a factor, the posterior denture base is adequate for stability during the luting process. If not, the denture's labial flanges must be removed to allow acrylic to be placed from the lateral or inferior aspect, securing the prosthesis to the cylinders with the patient in occlusion.

Step 5: Scheduling of Day of Surgery and Ordering of Prosthetic Parts. The patient must sign a consent form, must understand the procedure in detail, must be prepared for a 3-hour session with the implant team, and must take care of financial matters. In addition, the surgeon or restorative dentist must order the parts necessary for immediate provisionalization. On the day of surgery, the patient should be escorted. The patient can be given prescriptions at the final consultation visit.

Implants that match the CT plan and CT guide system must be ordered. Usually the accuracy of CT planning



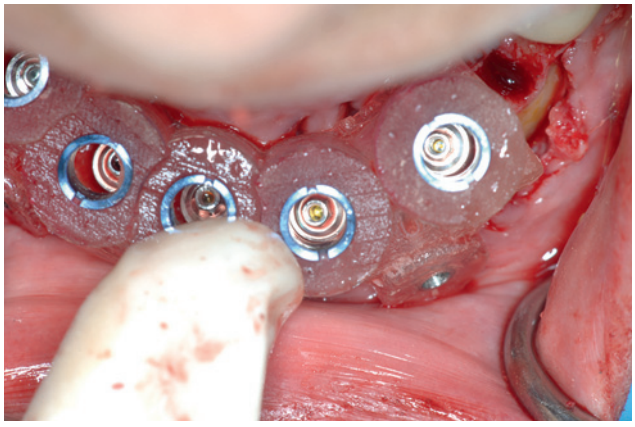
● **FIGURE 1-17 M,** After the implant sites are completed to the planned depth, depth indicators are used to mark the bone, which is reduced in height with a drill. The implants then are placed level with the bone. Gingival height abutments 4 mm tall are placed and torqued to the implants to 30 N-Cm. Here, the IOL abutments (Biomet 3i) have been placed prior to suturing.



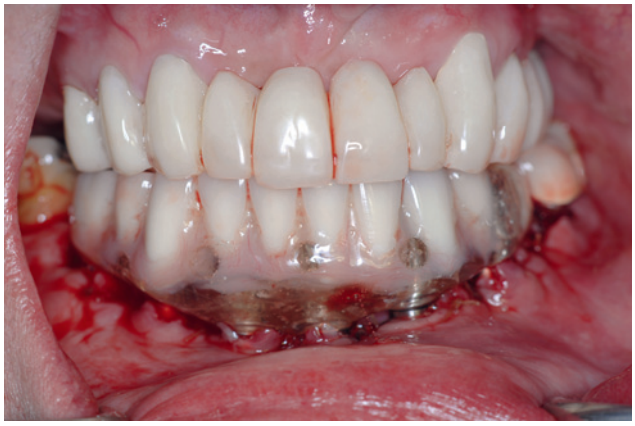
● **FIGURE 1-17 O,** Incision is closed with 4-0 chromic sutures. Care is taken to preserve all the KG around the teeth before their removal. The excess tissue is not a concern, because it shrinks as it reattaches around the abutments within the first few weeks after surgery.

determines the specific implant sizes, and extra implants need not be ordered.

Step 6: Day of Surgery and Immediate Provisionalization. The patient is positioned in the surgical chair in a relaxed posture. After a povidone-iodine (Betadine) preparation, a local anesthetic is infiltrated into the alveolar ridge. When a satisfactory state of anesthesia has been reached, sulcular incisions are made, with distal extensions as needed, and a full thickness flap is raised to expose the



● **FIGURE 1-17 N,** After placement of the implants, the guide stent is fitted over the bone, and the implants are seen to be positioned as planned.



● **FIGURE 1-17 P,** Mandibular prosthesis is converted into an implant-supported, hybrid-type prosthesis, which is screw retained to the implants. The flanges are removed to allow patient hygiene. The occlusion is adjusted, allowing the patient to leave the operatory with teeth in place. (Prosthetics by Dr. Marco Brindis and Dr. Jorge Palavicine.)

labial and lingual bone. The teeth are then removed. The sockets are debrided of soft tissue. This author does not rinse the sockets with solutions other than sterile saline.

The surgical guide stent is placed over the bone, and the secure fit is confirmed. The patient's mouth is closed into occlusion if stops are present on the stent. If stops are not present, the stent is held securely and fixation screws are placed.

The initial drill (usually 2 or 2.3 mm in diameter) is used in all sites. It is important that the surgeon visualize the initial sites in the bone, especially when operating in thin bone. If the bone is thin, the surgical stent is removed

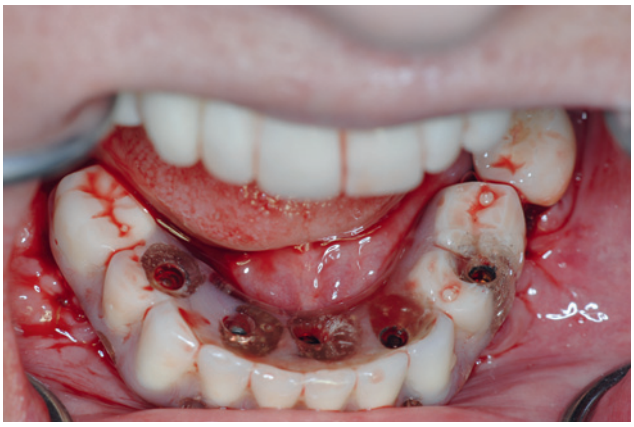


FIGURE 1-17 **Q,** As can be seen in this occlusal view, the axis of the implants is slightly lingual to the teeth and close to the fossae of the premolar teeth in the denture. Use of the CT guidance procedure allows planning to determine the proper depth, the amount of bone that had to be removed to achieve ridge width, the spacing of the implants, and the orientation required to allow the implants to emerge slightly lingual to the teeth. Without the guide stent, accurate location of implants in the face of such a large ridge reduction would have been more difficult.

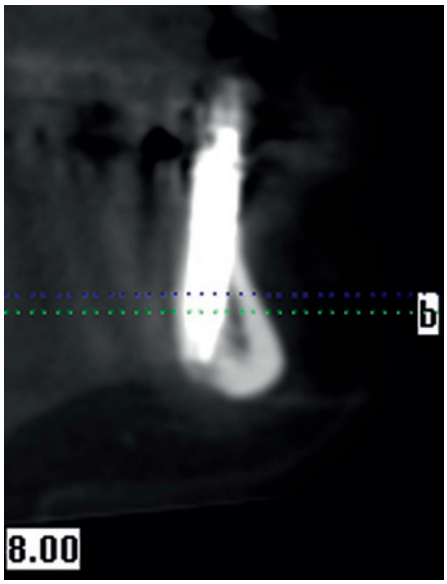


FIGURE 1-17 **R,** Cross-sectional view obtained after implant placement shows the 15-mm implant placed within the confines of the bone of the mandible.

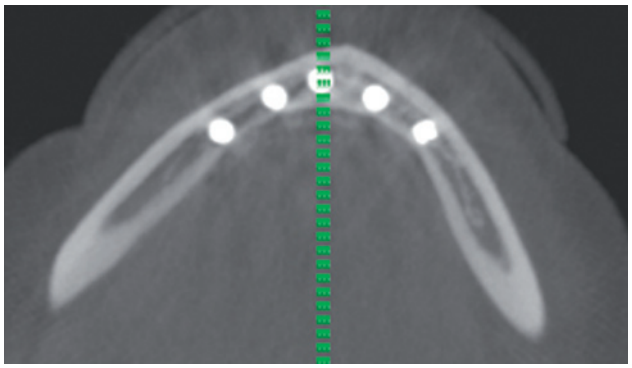


FIGURE 1-17 **S,** Axial view reconstructed from the cone beam scan shows the symmetric and evenly distributed implant positions.

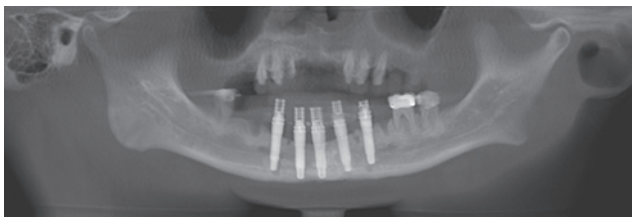


FIGURE 1-17 **T,** Postoperative panoramic image from the cone beam scan shows the implants engaging the inferior border of the mandible as planned.

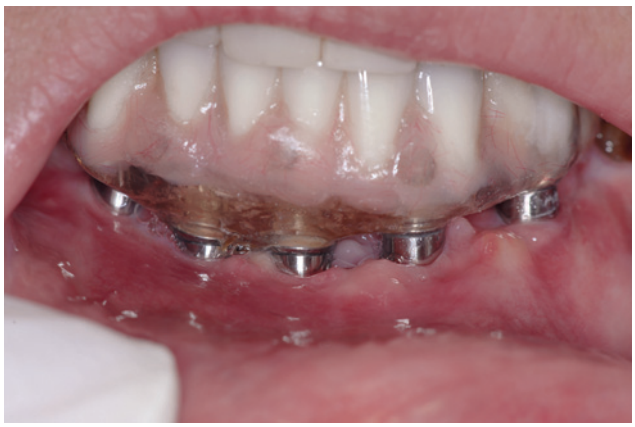


FIGURE 1-17 **U,** Frontal view taken 3 weeks after surgery shows that the gingiva has healed with sufficient space to allow patient access for hygiene.

and, as necessary, the implant sites are modified to ensure that the implant will not be placed with bone dehiscence.

Error can occur in surgical guide stents; the CT scan has a 0.5-mm error factor. The error factor is unclear when surgical planning is done on the computer and followed by guide fabrication. A factor of 0.5 mm of error must be assumed in that process. Conceivably, the specific crestal location of the implant may deviate 1 mm from the planned location. In a thin ridge, which has minimal space for error, the surgeon should check and confirm accuracy before completing the implant site preparation. If a bone dehiscence develops after the implant site has been completely prepared, placement of the implant may not be possible. In the case example, the pilot drill holes for two of the implants were within 1 mm of the lingual cortical bone plate; therefore, if the graduating-sized drills were used, a huge lingual bone dehiscence would be present, resulting in implant failure. In this case example, the surgical guide stent was removed, and two implant sites were moved to the middle of the ridge.

The implants are placed into the correct position, with the depth dictated by the surgical guide stent. After the implants have been placed, the cover screws can be placed to protect the bone, and the alveolectomy is performed. The cover screws are removed, and the abutments are torqued into the implants at 20 N-Cm.

The gingiva is sutured to approximate the KG around the abutments. A resorbable suture can be used either in interrupted or mattress style. When teeth are extracted and alveolar bone height is reduced, excessive tissue may appear to be present. However, the KG should not be removed, because it settles over the next 2 to 4 weeks, and it provides appropriate protection for the implants over time. A long-acting anesthetic is injected to provide patient comfort over the next 2 hours of prosthetic care.

The temporary cylinders are placed over the implant abutments. The immediate denture then is placed, and holes are made to allow passive placement over the abutments. The flanges are removed and denture resin is injected to lock the temporary cylinders to the denture. After the resin has set, the prosthesis is removed. In the laboratory, the flange is removed completely, additional acrylic is placed, and the intaglio and occlusal surfaces are polished. The distal extension of the prosthesis can be shortened if necessary. The immediate hybrid prosthesis is then screw retained to the abutments and hand-tightened. The occlusion is adjusted to obtain balanced contacts.

The patient is sent home with antibiotics, an antibacterial rinse, and pain medication. The individual also is instructed in the appropriate hygiene methods and encouraged to consume a liquid diet.

At the postoperative follow-up visit, the occlusal is checked and adjusted as needed, and irrigation is used if the patient's hygiene efforts have not been adequate. (Patients often are reluctant to use proxy brushes during the first week after surgery.)

After the implants have integrated, the final prosthesis can be made.

Immediate Loading with the Final Restoration

Use of a prefabricated segmented bar and precision attachments

In the late 1970s and early 1980s, Straumann's "Swiss Screw" system (Straumann Holding AG, Basel, Switzerland) was a popular choice for implant restorations. It used four implants, which were placed into the anterior mandible. Immediate impressions were taken for overnight fabrication of a bar and immediate loading of the prosthesis. The prosthesis was tissue borne and had three clips to retain the denture. Gold copings were available that fit onto the one-piece implants, and gold bars were soldered to the gold copings using the transfer impression taken at surgery. The success rate for postimplant placement transfer with immediate loading was greater than 88% at 7 years.

After implants have integrated, fabrication of precision bar structures from transfer impressions often requires cutting of the gold casting and providing the laboratory with a solder index. Soldering of multiple sites on a large gold casting is customary and expected.

Using the success of the immediately loaded bar and the common indexing of cast restorations, the following procedure was developed that involves indexing a segmented, precision-type bar on the day of surgery and placing the final precision bar the same day or the day after surgery, after the segmented bar has been soldered or laser-welded (DVD Figure 1-8, A-Q).

1-8, A-Q

For this procedure, a segmented bar is fabricated in the laboratory and placed onto the implants on the day of surgery. The surgeon uses a prefabricated surgical guide to position the implants, which are spaced according to the plan developed. After the implants have been placed, the surgeon places the abutments, which were chosen before the surgery. The abutments are torqued to 20 N-Cm, and the incisions are closed. The restorative dentist places the segmented bar and indexes the segments with resin. The indexed bar is removed and soldered or laser-welded in the laboratory and placed over the implants on either the same day or the day after surgery. The final prosthesis then is relined with soft material.

After the soreness has resolved and the patient's jaw movements are reproducible (approximately 7 to 14 days after surgery), the final precision attachments are picked up, and the prosthesis finalized. The benefit of this approach is that the final prosthesis is delivered within

2 weeks of implant placement and, depending on laboratory support, the same day as implant placement. If a CT-generated stent with precision drill guides is used, the final bar requires minimal or no indexing; therefore, the final prosthesis delivery can be performed at the time of implant placement, depending on the treatment decisions and the patient's needs and desires.

Preoperative Laboratory Procedures. The mandibular arch is evaluated for implant placement. From the denture setup and the use of a mandibular master cast, the locations of the implants are marked on the cast with an indelible pen. Care is taken to identify the location of the mental foramen after assessment of the locations on a panoramic radiograph and palpation of the patient's mouth.

The clear acrylic duplicate of the denture is placed over the master cast. Either a drill press or a handheld drill is used to create the holes through the stent, entering the crest of bone previously marked. The size of the drill entering the stone is increased to accommodate the analog of the implant system being used. Use of the shouldered abutment analogs is helpful. The gingival shoulder of the abutment analog is placed at least 1 mm superficial to the gingiva on the model. The analog is secured to the cast with fast-setting glue, stone, or plaster.

If the implants and abutments are placed too deep in the model, clearance for the bar above the gingiva will be inadequate. In addition, if the abutments chosen are too tall, they may interfere with the vertical space, resulting in thin prostheses that are prone to fracture. Typically, abutments that are 4 mm tall are used to place the margin supragingivally.

Metal tubes are placed into the holes that have been drilled into the acrylic duplicated denture. This provides accurate implant placement at surgery.

The laboratory technician fabricates the segmented bar on this model with the analogs in place. At surgery, the abutments, implants, segmented bar, retaining screws, and surgical guide stent are available.

The bar is made parallel to the existing cast of the ridge. For a bar-supported final prosthesis, the bar is made in a segmented manner to be indexed at surgery. The bar is waxed and cast in four pieces. The spaces between the segments should be small to ensure ease of soldering or welding. If the implants are placed too far apart from the planned position, the spaces between the segmented bars may be large and may result in strength deficiency after the space has been filled with solder.

After the implant analogs have been secured in the cast, a type IV gold bar is constructed in four sections. The two distal extension segments consist of a 2-degree plastic premilled (PPM) bar, which has a 1.5-mm hole drilled through it to receive a retentive attachment. The PPM bars should be placed over the crest of the mandibular ridge with no more than a 15-mm cantilever. The two middle sections have extensions toward the distal abutment that are luted together with pattern resin after the incisions have been closed with sutures.

After the four segments have been cast, two metal sleeves that will house the retentive attachments are fabricated. The sleeves are used to provide support to the denture and help position the attachment at delivery. The sleeves are cast in nonprecious metal. An anterior attachment is fitted to the anterior segment when the sleeves are completed to provide anterior stability.

When picking up the clip in the mouth, the dentist must ensure an adequate blockout beneath the bar to prevent resin from being trapped beneath the bar, which would make removal of the denture difficult. After the bar and sleeves have been completed, the bar is blocked out to accept the final denture. Once the denture has been processed and finished, it is seated onto the original cast with the bar. At this point, the preoperative workup is complete, and surgery can be performed.

Surgical Technique. At surgery, a local anesthetic is applied to the anterior mandible. An incision then is made bisecting the band of KG. Posterior vertical release incisions may be necessary to visualize the bone. After the full-thickness flap has been raised, sharp edges of crestal bone are removed with rongeur forceps.

The drill guide is positioned over the ridge. One drilling sequence is completed through one hole, and a guide pin is placed. A second implant site is developed, and a second guide pin is placed. After each drill step has been performed, the stent is removed to verify correct positioning and placement of the implant without bone perforation. After placement of the second guide pin, the stent is locked in position and the final two implant sites are prepared. The implants are placed level with each other, because the segments of the segmented bar must be close to each other without excessive vertical mismatch.

Each implant should be placed with at least 20 N-Cm torque for primary stability. As mentioned, the implants should be placed level in the bone to avoid significant vertical discrepancies. An appropriate abutment should be placed for each implant so that the interface is 2 mm above the level of the gingiva. The most frequently used abutments have a gingival collar height of 3 or 4 mm. The abutments are secured to the implants and torqued to 20 N-Cm. The incisions then are sutured with resorbable sutures to approximate the gingiva to the abutments.

Indexing the Bar. When implant placement is complete, the sections of the bar are luted together with either light-cured material or autopolymerizing resin. The bar is removed from the patient's mouth and taken to the

laboratory for soldering. When finished, the bar is delivered, and the denture is relined with soft liner in occlusion. The inner aspect of the denture is adjusted as necessary.

Depending on the preference of the implant team, final placement of the attachments into the prosthesis can be done on the same day as implant placement, after resolution of the local anesthesia, or after soft tissue swelling has resolved. The attachments are fitted over the bar, and the denture is tried-in, verifying occlusion. The attachments then are picked up using autopolymerizing resin material. The occlusion is verified. The denture is taken to the laboratory for a final polishing. The anterior stabilizing attachment also is placed. The completed bar and denture are delivered to the patient.

CT–generated final mandibular prosthesis

The main reason surgeons make incisions to place implants is to visualize the bone and the mental foramen and to make soft tissue adjustments if necessary. The accuracy of CT allows the implant team to perform virtual surgery and prosthodontics, which in turn allows the creation of CT-generated models, the generation of surgical guide stents, and the fabrication of provisional or final prostheses.

The generic technique requires a setup of the planned restoration, taking into account esthetics and function. The planned setup then is converted into a radiographic stent, with metal markers embedded for software superimposition of images. A CT scan is taken with the radiographic stent in the patient's mouth, and usually, the radiographic stent then is scanned by itself. The CT scan data are transferred to a CD (DICOM format). The implant team then performs virtual surgery on the computer by placing the implants, with the final restoration imaged. The final plan is sent electronically to the manufacturer, which fabricates the surgical guide and teeth.

The fusion of the CT scan of the prosthesis and the bone image was developed to allow planning not only of the position of the implants, but also of the final prosthesis.[24-29] The software and flapless surgery were further developed and popularized by Nobel Biocare (Goteborg, Sweden) under the name "Teeth in an Hour."[29-31] Since the initial presentation of this technique in Europe, the process has been launched extensively, and subsequent clinical reports have been summarized by Parel and Triplett.[32] Currently, the surgical guide with tubes is used by the laboratory to retrofit analogs into a model, from which prostheses can be generated.

General Methods for CT-Generated Immediate Loading of the Mandible. The surgeon and restorative dentist must be confident that the CT scan is sufficiently accurate to allow placement of the implants without incisions or with minimal subperiosteal flap reflection. The CT scan also must be sufficiently accurate to allow fabrication of a provisional or the final prosthesis by using the surgical stent to place implant analogs into a model without the need for taking impressions in the patient.

All CT-generated implant guides begin with duplication of the planned restoration in clear acrylic. For the edentulous patient, a new denture is completed to confirm esthetic support of the lips, proper positioning of the teeth, and adequate speech, with approval by the patient. This new denture then is duplicated in the laboratory in clear acrylic. For most of the current programs, CT scanning is performed with the duplicated denture in the patient's mouth, in occlusion with a bite registration, and a second CT scan is taken of the duplicated denture by itself. Before the CT scan is taken, radiographic markers are placed according to the specific CT protocol to allow computer planning software to superimpose the duplicated denture over the bone and soft tissue (Figure 1-18, A-S, and Figure 1-19).

CT Scanning Protocol. CT protocols require the scanner to make axial sections at least 1 mm thick and often 0.7 mm thick. A gantry angle of 0 degrees is common. For each CT software program, the manufacturer provides specific CT scanner parameters, which must be followed to ensure optimal accuracy of the scan and subsequent stent.

At the time of the scan, the surgeon or restorative dentist should be present to make sure the duplicated denture is properly positioned in the correct bite registration. Most CT technicians are not educated in the techniques for placing these templates in the mouth properly. The orientation of the intaglio surface of the duplicated denture must be the same when the denture is scanned alone as it is when the denture is in the mouth. The duplicated denture usually is taped to a Styrofoam or cardboard box with clear, nonradiopaque tape. The patient then leaves, and he or she returns for the implant surgery after the surgical guide and prosthesis have been fabricated.

After the scan has been taken, the radiology technician is asked to place the CT scans on a CD in the DICOM format, a standard format for CT scan readers and the software for the virtual implant planning. Depending on the software used by the clinician, the CT data may need to be sent or uploaded to a distant site for reformatting, after which it can be used on the clinician's office computer.

Preoperative Process and Surgical Technique. The scan is processed in the treatment team's personal computer, and the virtual plan is uploaded to a site for fabrication of the surgical guide. At this point, the surgical restorative team has several options:

- The CT-guided stent can be used to place the implants with minimal flap reflection.

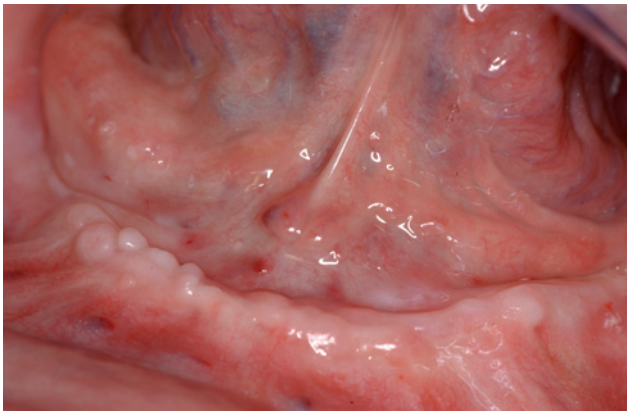


FIGURE 1-18 **A,** This woman had her mandibular teeth extracted and an alveoloplasty performed to smooth the crestal portion of the ridge. Approximately 8 weeks later, she presented for CT-guided immediate restoration of the mandible.

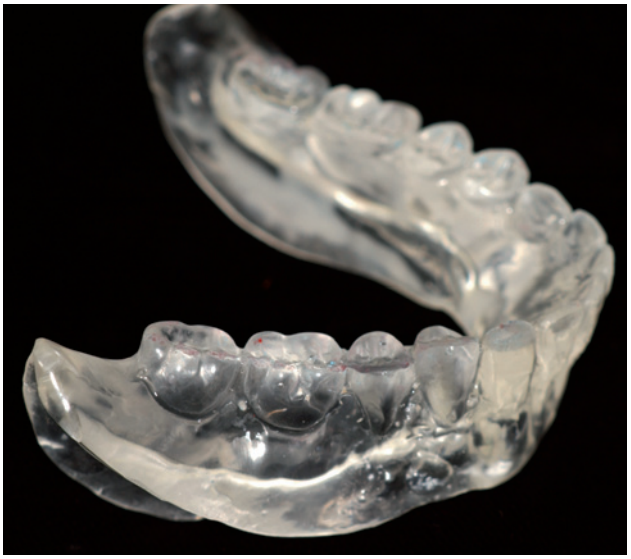


FIGURE 1-18 **B,** New denture is fabricated, providing excellent esthetics and positioning of the teeth. The denture then is duplicated in clear acrylic.

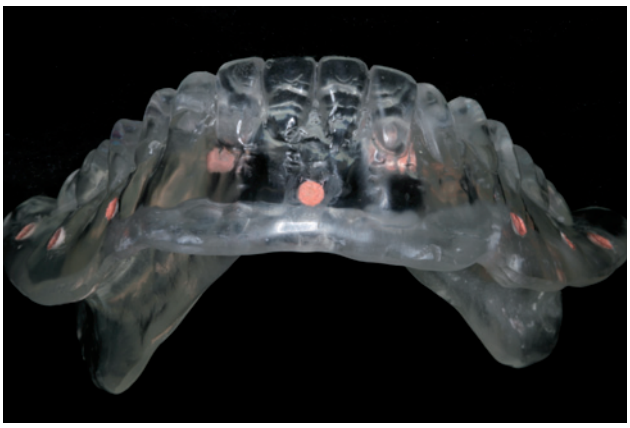


FIGURE 1-18 **C,** A small round bur is used to make nine small holes in the flanges of the duplicated denture. Gutta percha is placed into the holes as positional reference points.

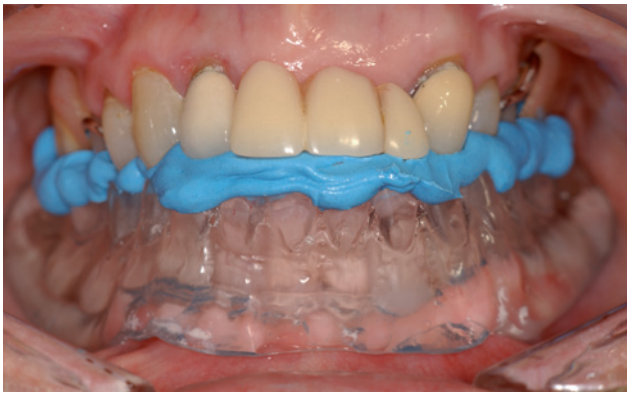
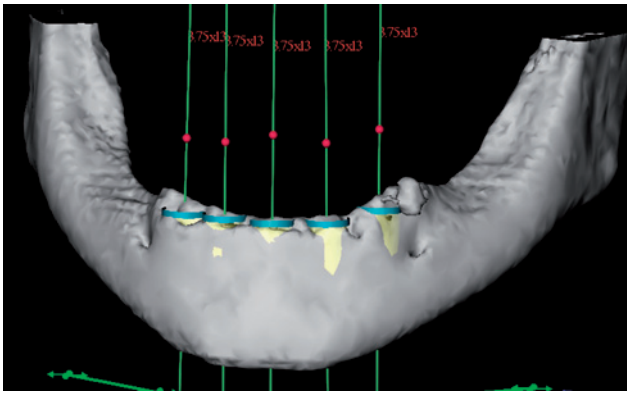


FIGURE 1-18 **D,** Bite registration is made to ensure that the duplicated denture is positioned accurately when the CT scan is taken.

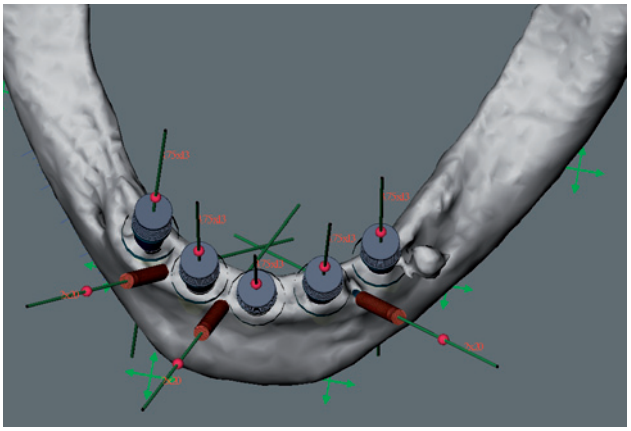
- The implants can be covered and exposed later, after integration, for final restoration.
- The surgical guide can be used to pour a model, with the undersurface of the guide simulating the patient's ridge. The model then is mounted to the opposing jaw using the surgical guide or base rims. Implant analogs can be placed into the model using the same techniques as for implant placement. Analogs are placed and prepared if necessary, depending on the final treatment plan. A provisional or final prosthesis can be fabricated on this model.

At surgery, a local anesthetic is applied to the edentulous jaw in the areas of the planned implant sites. Only infiltration is necessary, and it can be limited to the sites involving the implants because minimal or no flaps will be raised. The surgical guide is positioned with a bite registration to ensure that the guide is accurately placed. It is important to confirm that the posterior aspect of the surgical guide is properly seated; otherwise, the final restoration may have an open bite anteriorly, which would require occlusal adjustment.

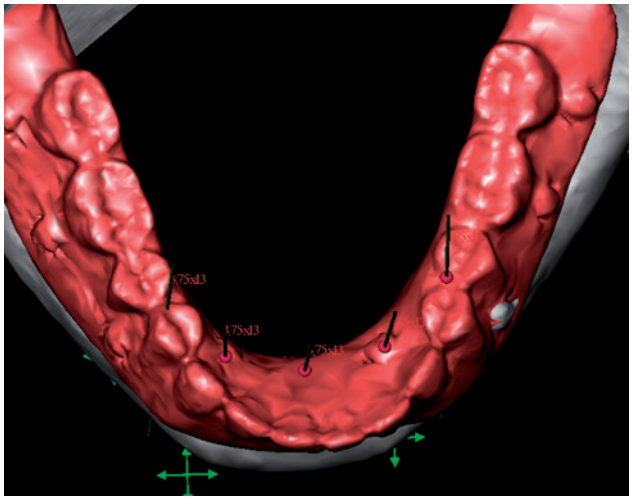
Pin fixation of the surgical guide aids accurate placement of the implants. Three pins are placed to lock the



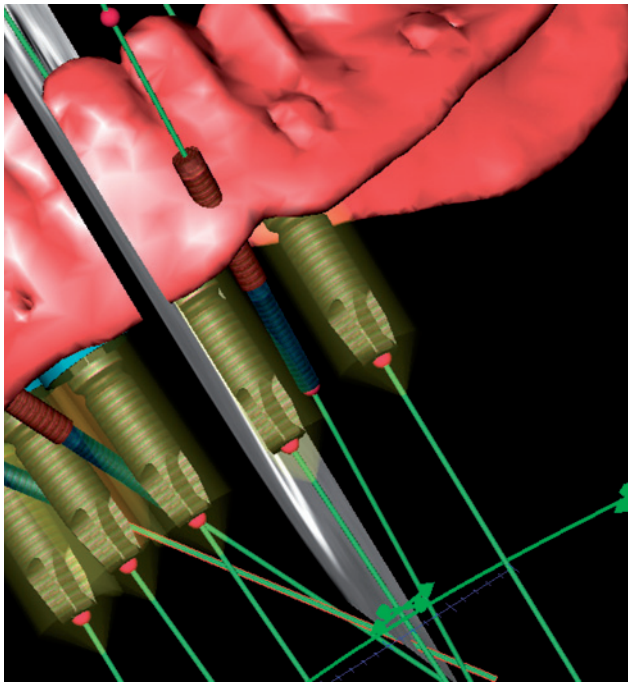
● **FIGURE 1-18** **E,** CT scan is taken with the duplicated denture in the mouth, and then a second CT scan is taken of the duplicated denture by itself. The CT data are transferred by compact disc (CD) to a computer and processed using software provided by Nobel Biocare (Goteborg, Sweden). Here, the three-dimensional reconstruction of the mandible is shown. Implants are placed in the mandible using the software.



● **FIGURE 1-18** **G,** Three-dimensional reconstruction depicting the implants on the crest of the bone in correct position.



● **FIGURE 1-18** **F,** Denture is reconstructed by the computer and placed over the bone to direct the placement and angulation of the implants so that they emerge appropriately.



● **FIGURE 1-18** **H,** Computer reconstruction showing the implants and their relationship to the prosthesis, with the bone removed. The angulation and parallelism of the implants can be confirmed easily from these views.

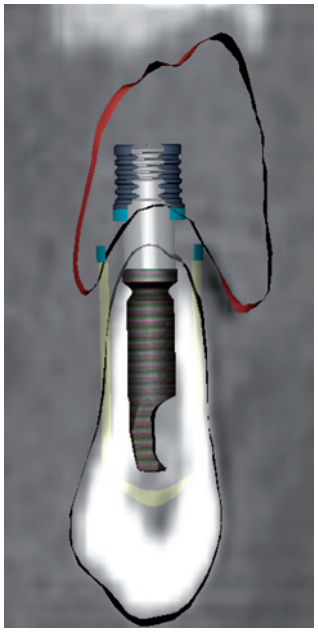


FIGURE 1-18 I, Cross section of the mandible with the implant and abutment in place and the outline of the prosthesis present. The computer program allows all parts to be located before surgery.

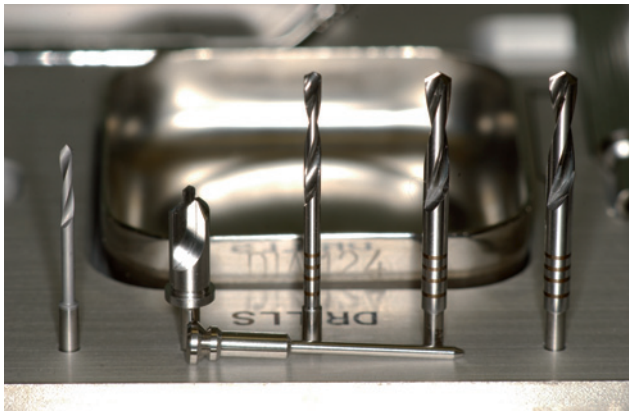


FIGURE 1-18 K, Surgical drills required to place the implants. *From the left,* A 1.5-mm-diameter drill for the pins that secure the surgical guide to the jaw, a drill for removing the gingiva over the implant sites, and a series of twist drills for preparing the implant site. Lines on these drills provide depth reference for the surgeon, taking into account the length of the tubes in the surgical guide stent. A fixation pin is lying horizontally.

surgical guide to the jaw. One implant site is prepared, and the implant is placed. The driver mount is removed and replaced with an expandable part that secures the guide to the implant and jaw, further stabilizing the surgical guide. The implant is secured to the surgical guide

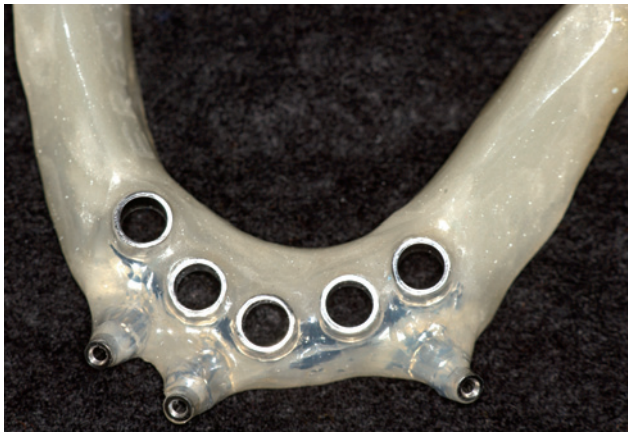


FIGURE 1-18 J, After virtual planning is completed, the plan is uploaded to the company, and the surgical guide stent is fabricated. Specific guide tubes are placed, which aid the surgeon in placing the implants.

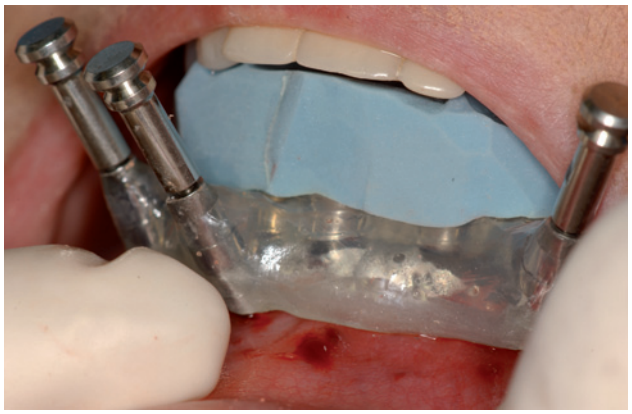


FIGURE 1-18 L, After administration of a local anesthetic into the planned implant sites, the surgical guide is placed with the bite registration made in the laboratory. Osseous pins are placed to secure the guide to the jaw.

with a special mount, providing additional retention of the surgical guide to the jaw. When the implant sites are prepared, a specific sequence of drill guides is used to provide accurate hole preparation. It is important to follow the sequence of drills and guides meticulously to position the implants properly.

After the first implant has been secured to the surgical guide, a second implant is placed and secured to the guide with a special mount. The remaining implant sites then are prepared, and the implants are placed.

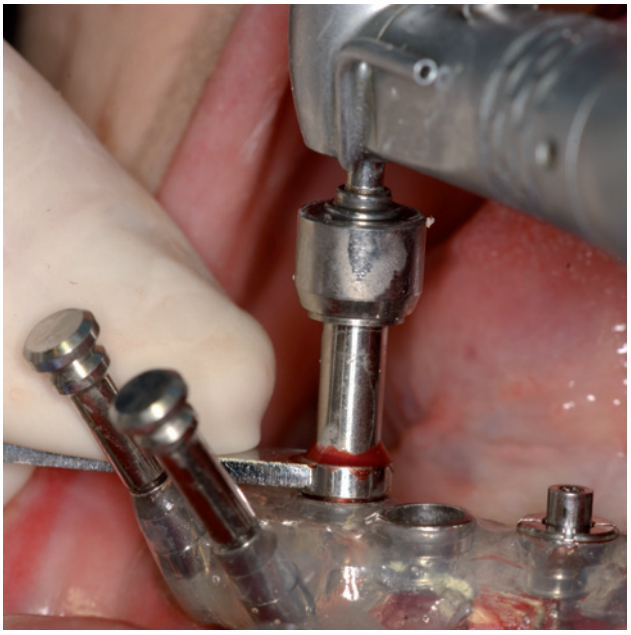


FIGURE 1-18 M, Gingival removal drill is used to remove the gingiva in the implant site.

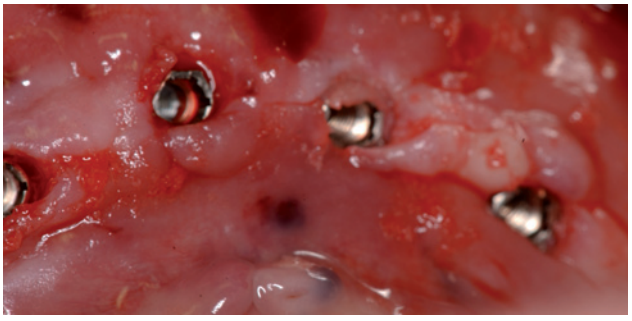


FIGURE 1-18 O, Surgical guide stent is removed, allowing visualization of the implant sites. Excess soft tissue can be removed, if necessary, to allow passive seating of the prosthesis.

While the final implants are placed, the restorative dentist places the abutments into the final prosthesis in preparation for placing the final prosthesis immediately after removal of the surgical guide stent. It is important to place the prosthesis and abutments promptly to prevent soft tissue collapse.

The surgeon loosens the retaining screws from the implant mounts, and the surgical guide is removed. The implant sites are irrigated, and soft tissue is removed as necessary to facilitate abutment seating. The prosthesis with abutments is

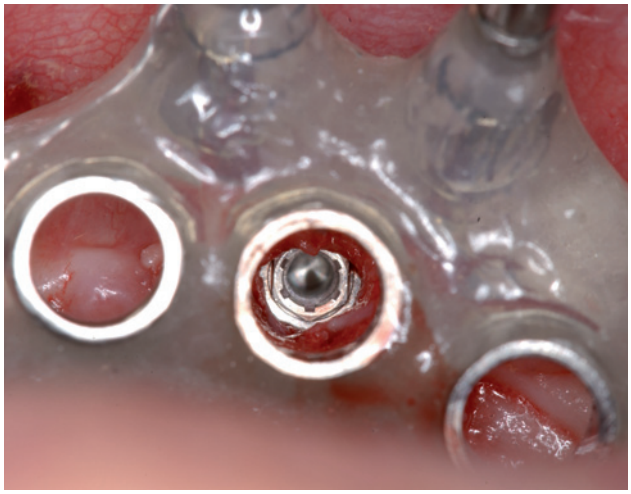


FIGURE 1-18 N, Implants are placed according to the manufacturer's protocol. After all the implants have been placed, the driving mounts are removed. Here, the implant is shown under the tube in the surgical guide stent.

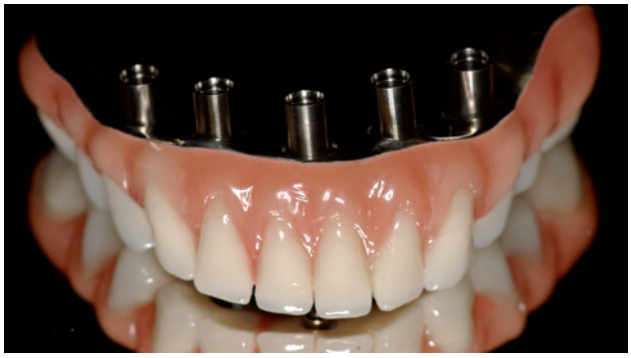


FIGURE 1-18 P, Abutments are placed into the final prosthesis.

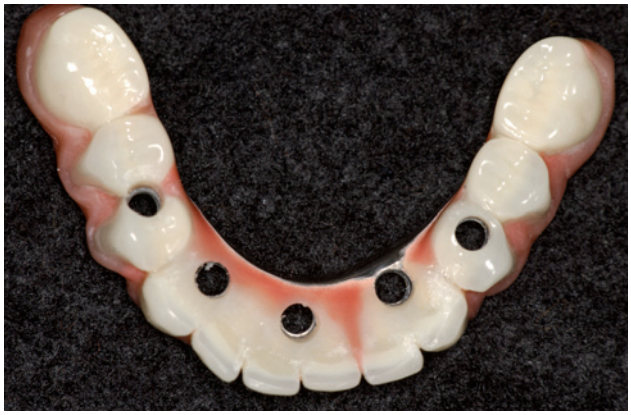
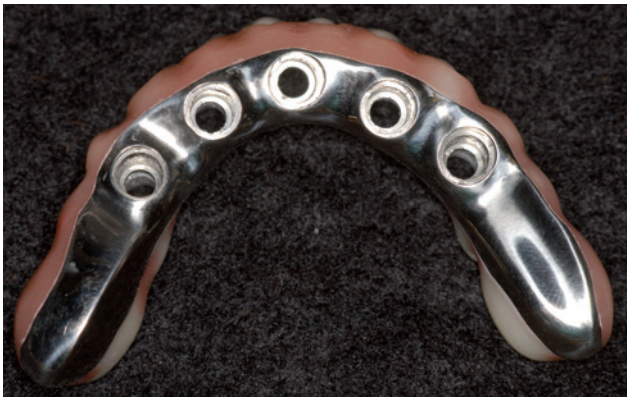
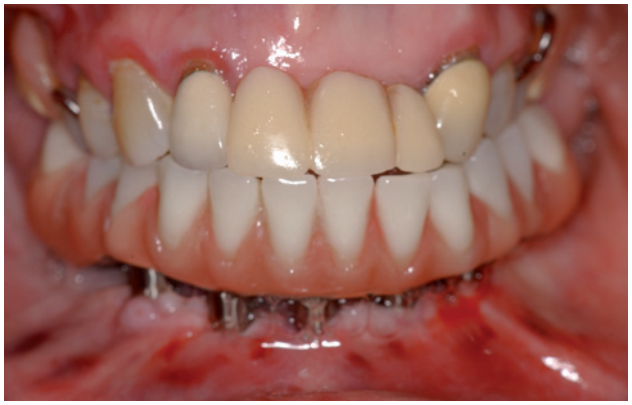


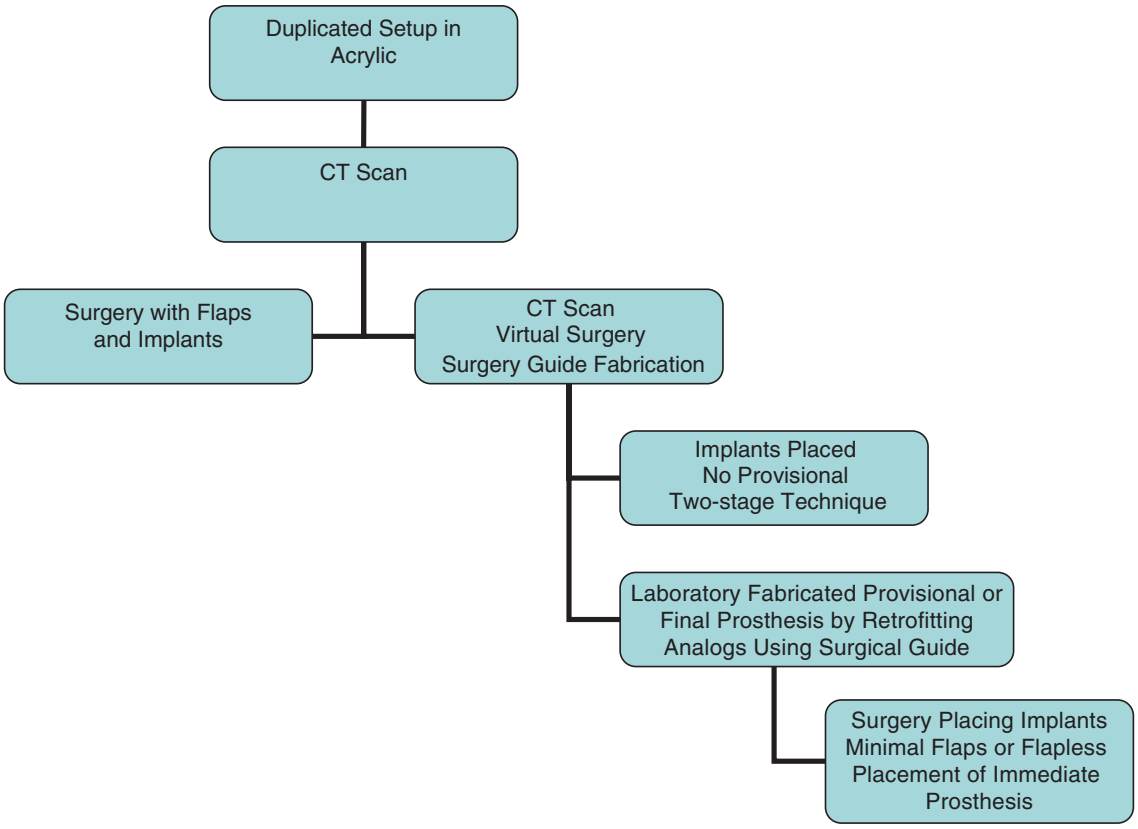
FIGURE 1-18 Q, Occlusal view showing the excellent symmetry of the implants, the result of the computer planning process.



● **FIGURE 1-18** **R,** Intaglio surface of the prosthesis is milled titanium. The surface near the soft tissue is smooth and can easily be cleaned by the patient.



● **FIGURE 1-18** **S,** Prosthesis is delivered and secured with screws. The occlusion is adjusted if necessary. This photograph was taken within 1 hour after implant placement. The prosthesis is a hybrid type, totally implant borne, that provides the patient with excellent function within hours of surgery. (Prosthetics by Dr. Paulino Castellon.)



● **FIGURE 1-19** Options when using CT scans.

seated and secured to the implants with screws, which are torqued to 20 N-Cm. Radiographs are taken to verify seating. The occlusion is checked and adjusted.

Adjustment of the occlusion is an important step in the immediate loading process. The occlusion should be even in all movements and should not have isolated areas of premature contacts.

Postoperative care includes routine antibiotics and a soft diet. These patients do not develop excessive swelling because of the flapless design of the surgery. They have mild to moderate pain, depending on their level of pain tolerance. The treating clinicians should reinforce hygiene habits and instruct the patient on the locations of the implants and how they should be maintained.

Discussion

As can be seen from the literature review in Table 1-1, immediate loading of the edentulous mandible with an implant-borne prosthesis clearly is no longer an experimental procedure. Therefore, few reasons exist to avoid immediate loading of edentulous patients for whom an implant-borne and implant-supported prosthesis is planned. Some valid reasons are a patient's inability to pay for the provisional materials; a limited vertical dimension, which prevents fabrication of a prosthesis; lack of availability for the preoperative workup on the part of the patient or the clinician; lack of laboratory support; and operator inexperience.

Benefits for the patient with the immediate loading protocol include reduced time from edentulism to function; elimination of the uncomfortable period with mobile removable dentures after implant placement, which is a part of a two-stage protocol; improved self-esteem; and improved nutrition as a result of re-establishment of a normal diet soon after implant placement surgery.

Some problems have been encountered with the immediate loading protocols. However, most of these are the result of the learning curve involved for performing the procedures or of pretreatment planning and preparation that are less than optimal.

Laboratory support may be excellent or also may include a learning curve. The laboratory technician must know how to solder or laser-weld, without strength concerns, and must be able to fabricate a bar with the correct taper and form. In addition, the laboratory technician requires special training in the fabrication of the CT-generated surgical template that guides the model surgery and final prosthesis fabrication.

Problems can occur if implants are not placed accurately. A duplicate of the patient's old or new denture must be made to construct the surgical guide. Without this, the technique cannot be used; the duplicate denture serves as a basis for communication between the restorative dentist and the surgeon, and without it, the implants may be placed in a position that is too labial, compromising the final result.

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Surgery of the Posterior Mandible

Chapter 2

Chapter Outline

Placement of Implants in the Posterior Mandible

General Considerations

All patients evaluated for the placement of implants require a thorough medical and dental history. The medical health of the patient reveals systemic problems that can affect wound healing. The dental history of the patient provides critical information about patients who have lost teeth and retained other teeth. Why did they lose their teeth? Did they have severe periodontal disease secondary to poor oral hygiene, parafunctional habits, or pathogenic bacteria? Did they have chronic problems with a tooth with multiple endodontic procedures, periodontal grafts, and repeated restorative care? The answers to these questions relate to the preoperative assessment of the patient.

Patients with long-standing poor or marginal oral hygiene are not good candidates for implants; therefore, the placement of implants is not recommended because of the increased incidence of implant infection. Patients must demonstrate an ability to clean and maintain their teeth. This criterion is vital for the long-term success of implants placed into the posterior mandible, because poor oral hygiene can adversely affect the soft and hard tissues supporting endosseous implants. Patients with parafunctional habits can be treated with implant restorations; however, special attention should be given to providing an occlusion that can protect the implants from excessive forces (DVD Figure 2-1, A-B).

2-1, A-E

Consultation with restorative dentists reveals their understanding of patients' desires and motivation. The restorative dentist, who likely has followed the patient for years, can help the surgeon gain a better understanding of the characteristics of the patient. Patients who smoke cigarettes or consume alcohol daily are advised that they are not ideal candidates for dental implant restorations. They are counseled to eliminate these habits and often are sent to their internist to confirm adequate clotting times, liver function, and the absence of other systemic problems related to these habits.

Typically, a patient seeks the extraction of a single molar that is causing chronic pain, is refractory to periodontal treatment, or requires multiple restorative care for a fractured tooth (DVD Figure 2-1, C-E). After the tooth has been extracted, the patient should wait until the socket has healed, the site is covered with mature keratinized gingiva (KG), and the pain has been absent for at least 6 weeks. When the implant is finally placed, the surgeon will have gained increased confidence in the success of implant restoration in this edentulous site. However, if the molar tooth has been retained for an extended period, with active infection and bone resorption, extensive loss of facial bone may have occurred. If antibiotics are administered both systemically and topically to gain control of the infection, the area can be grafted with a slow-resorbing alloplast or xenograft, such as anorganic bovine bone. In this situation, implant placement should be delayed 3 months or longer to allow for bone replacement of a significant portion of the graft.

The use of membranes to cover the graft material is not recommended because of the relatively high incidence of incision breakdown and membrane exposure. The method of choice for this author is to place a xenograft of slow-resorbing calcium phosphate material, release adjacent tissue for primary closure without the use of a membrane, and place the implant 3 to 4 months later, with 4 to 5 months allowed for integration of the implant. This technique has resulted in predictably high rates of success for implants placed into a molar location that has had extensive local bone resorption secondary to tooth fracture or after multiple endodontic failures.

Treatment Planning and Diagnosis

After the medical and dental histories reveal that the patient is an acceptable candidate for implant surgery, the treatment planning and diagnostic sequence of events can be initiated.

Physical examination

A screening panoramic radiograph is obtained. After the radiograph is reviewed, an oral examination is performed to document the following:

1. Jaw opening
2. Masticatory muscle tenderness, if present
3. Presence or absence of teeth
4. Presence of pathologic disorders of the soft tissues of the mandible and maxilla
5. Location of the mental foramen
6. Contour of the edentulous posterior mandible
7. Interarch space between the edentulous ridge and opposing occlusion
8. Width of the KG on the edentulous region
9. Health of remaining dentition
10. Palpation of the ridge, to identify:
    - Contour of the labial cortical bone
    - Contour of the lingual cortical bone
    - Location of the mylohyoid ridge
    - Estimated width of the crestal bone
    - Height of the bone superior to the inferior alveolar nerve

Based on this examination, the surgeon should be able to make an accurate assessment of the amount of available bone. Once the mental foramen has been identified through palpation, the radiographs are used to increase the surgeon's understanding of the location of the inferior alveolar nerve. The course of the inferior alveolar nerve should be visible on the panoramic radiograph or on CT scanning images. Is the canal lying along the inferior border of the mandible? Is it in the middle of the alveolus along the apical regions of

the remaining teeth? Does the canal loop inferiorly and anteriorly before exiting at the mental foramen?

Often the nerve is inferior to the mental foramen and loops slightly anterior to the foramen before exiting. By exposing the location of the mental foramen at surgery and with knowledge of the course of the nerve based on radiographs, the surgeon can place implants without disturbing the neurovascular bundle. If necessary, a computed tomography (CT) scan can be obtained to allow further evaluation of the distance from the inferior alveolar nerve and the crest.

The relationship of the bone to the proposed restoration must be established before the implants are placed. Ideally, the implants should be placed under the surface of the tooth that is receiving the forces of mastication (Figure 2-1, A-C). For the posterior mandibular teeth, these are the fossae and buccal cusps. The surgeon should gain an understanding of the relationship of the available bone to the working cusps of the teeth to be restored. With an understanding of the functional loading relationship of implants and bone, the implants can be placed to withstand the forces of chewing. After the posterior mandibular teeth have been extracted, it is common to lose a portion of the thickness of the facial bone. Implants placed too far lingually result in a lingualized occlusion or buccal cusp cantilevers, which may cause abutment fracture after loading. The surgeon may need to graft to allow placement of implants under the cusps or fossae. Adequate thickness of facial bone allows for a mechanically stable restoration. If grafting is not absolutely indicated because of near-adequate bone position, the implant-supported restoration may be fabricated with a smaller occlusal table to distribute the forces of chewing evenly. To assess whether the patient has a satisfactory amount of bone for the placement of implants into a proper location, a diagnostic setup of the planned restoration is necessary.

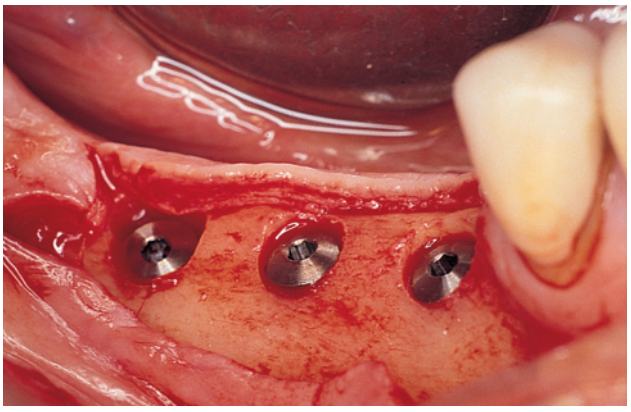


FIGURE 2-1 **A,** Right posterior quadrant of a 65-year-old man who wants a fixed prosthesis to replace a removable partial denture. The clean subperiosteal reflection and the placement of three implants to replace three teeth are shown. The attached gingiva is maintained without elevation on the premolar natural tooth. The implants were placed with the aid of a surgical stent.

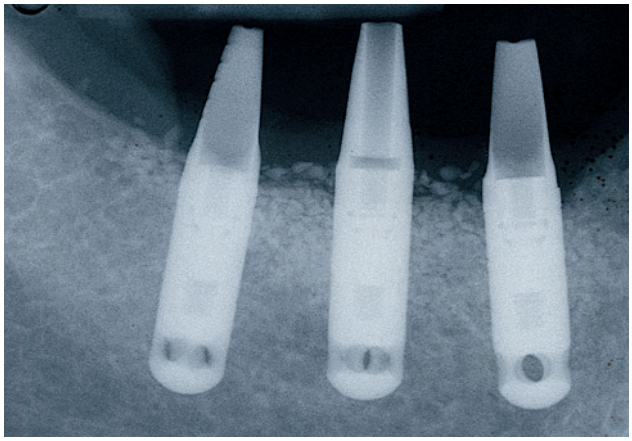


FIGURE 2-1 **B,** Radiograph showing the placement of the abutments before placement of the final restoration. A radiograph is necessary to confirm that the abutments are completely seated before final cementation of the prosthesis.

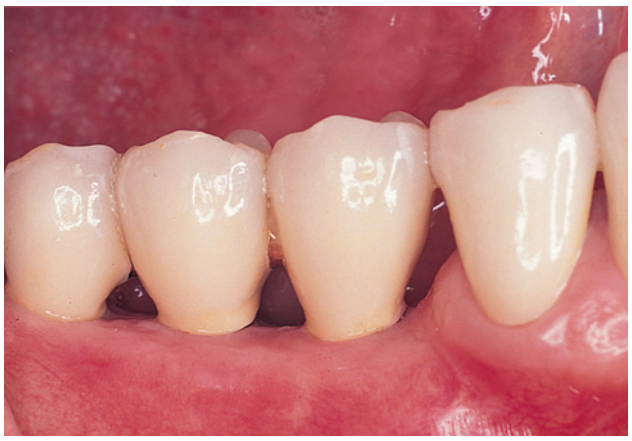


FIGURE 2-1 **C,** Final prosthesis. Premolar-shaped teeth are used to optimize the transfer of occlusal forces to the implants. The large embrasures allow ease of cleaning. (Prosthetics by Dr. Gerald Chiche.)

Stent fabrication

Two methods can be used to fabricate a surgical guide stent for implant placement in the posterior mandible: (1) the patient's current removable partial denture can be used, or (2) a new diagnostic setup can be made.

Often the patient has been wearing a removable prosthesis, either as a temporary or a long-term device. If the occlusion is adequate and the teeth approximate the planned anatomic form for the prosthesis, the removable prosthesis can be used as a template for the stent. Two impressions are taken, one with and one without the removable prosthesis in the mouth. A thin, plastic vacuform is made over the stone model of the prosthesis in the mouth. It is removed and trimmed to fit onto the entire remaining dentition. The locations of the implants are identified by removing a portion of the stent to allow direct visualization for placement of the implants within the corpus of the teeth, not in the embrasures. If the clinician requires a more rigid stent, acrylic can be placed into the hollow cavities of the teeth, as shown in Figure 2-2 and Figure 2-3, A-D.

Diagnostic models can be mounted on an anatomic articulator, and teeth can be set or waxed on the models. An acrylic copy of the teeth with an acrylic overlay of the remaining dentition then can be made in the laboratory. The implant locations can be determined, and pilot holes can be made through the acrylic. A thin, clear vacuform also can be made over the model, allowing visualization of the location of the teeth and their orientation to the residual mandible.

If the clinician has doubts about the location of the bone in relation to the fossae of the mandibular teeth, CT can be used. With CT, a radiopaque set of teeth can be created in the stent by filling the teeth locations of the clear vacuform with clear resin combined with barium sulfate (30% by weight). If 30% or greater barium sulfate is used, the tooth form will be chalky; if less than 20% is used, the tooth form will lose some of its radiopaque properties. With the

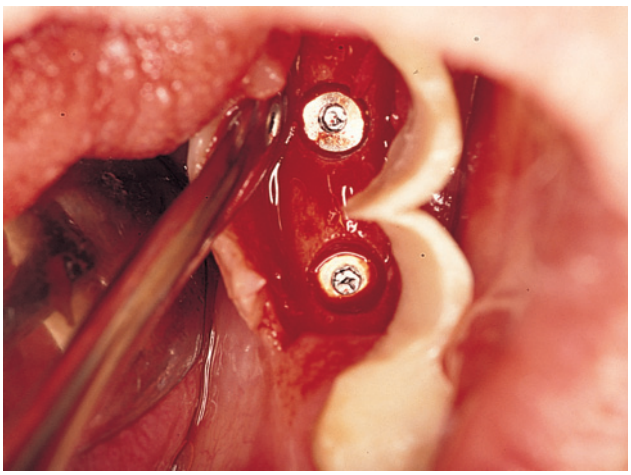


FIGURE 2-2 Occlusal view shows how a surgical stent helps the surgeon place the implants in the ideal location. The surgeon centers the implants within the confines of the teeth and avoids the embrasure spaces.

FIGURE 2-3 **A,** After the restorative dentist has made the final preprosthetic plan on models, a surgical stent is fabricated. A stone model is made from the model with the planned or denture teeth waxed in place. An acrylic copy is made of the planned teeth, with the acrylic or vacuform covering the anterior teeth for stability of the stent during surgery. A round bur is used to drill a hole through the stent into the stone cast. After the path of the round bur has been confirmed as ideal, a wider bur (typically the last bur in the drilling sequence) is used to create a precise hole in the stent.

FIGURE 2-3 **B,** After the hole has been cleaned of acrylic spurs, the occlusal height of the stent is reduced to allow the bur to engage bone. The stent should be approximately 3 mm thick to allow the hole to be used in a precise manner.

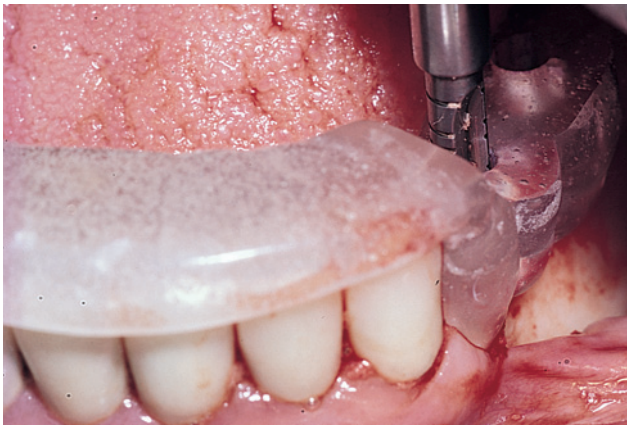


FIGURE 2-3 C, At surgery, the drilling sequence is performed using the stent for guidance.

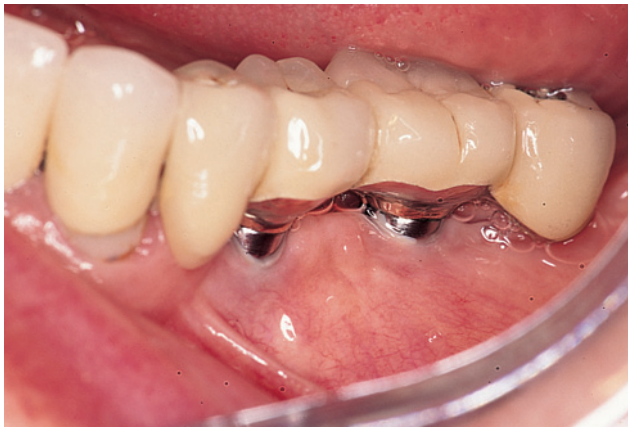


FIGURE 2-3 D, Result is a prosthesis that demonstrates the correct implant-to-crown orientation. (Prosthetics by Dr. Gerald Chiche.)

CT scan or complex motion tomography, the resulting cross sections locate the bone in relation to the planned restoration. The information revealed includes the height of bone superior to the inferior alveolar canal; the amount of bone available in relation to the working cusps and fossae of the planned crowns; and, depending on the quality of the scan, the quality of the bone in relation to trabecular bone density.

Determination of the number and size of implants

How many implants should be placed? What are the appropriate diameters and lengths of the implants? What type of implant is indicated? These questions must be answered before implants are selected and ordered for surgery. The type of implant (e.g., manufacturer and type [cylinder, threaded, tapered, flared]) is decided after a consultation between the surgeon and restorative dentist. In the posterior mandible, a flared, tapered, or threaded implant may be used because of cortical bone thickness and the presence of abundant cancellous bone. The diameter of the implant is based on the diameter of the teeth to be restored, the width of available bone, and the philosophy of the restorative team. A single molar may be restored with one wide-diameter implant or two small-diameter implants, depending on available space. It is important to allow 3 mm between implants and between the implants and natural teeth to promote bone healing, natural tooth form development, and access for oral hygiene maintenance.

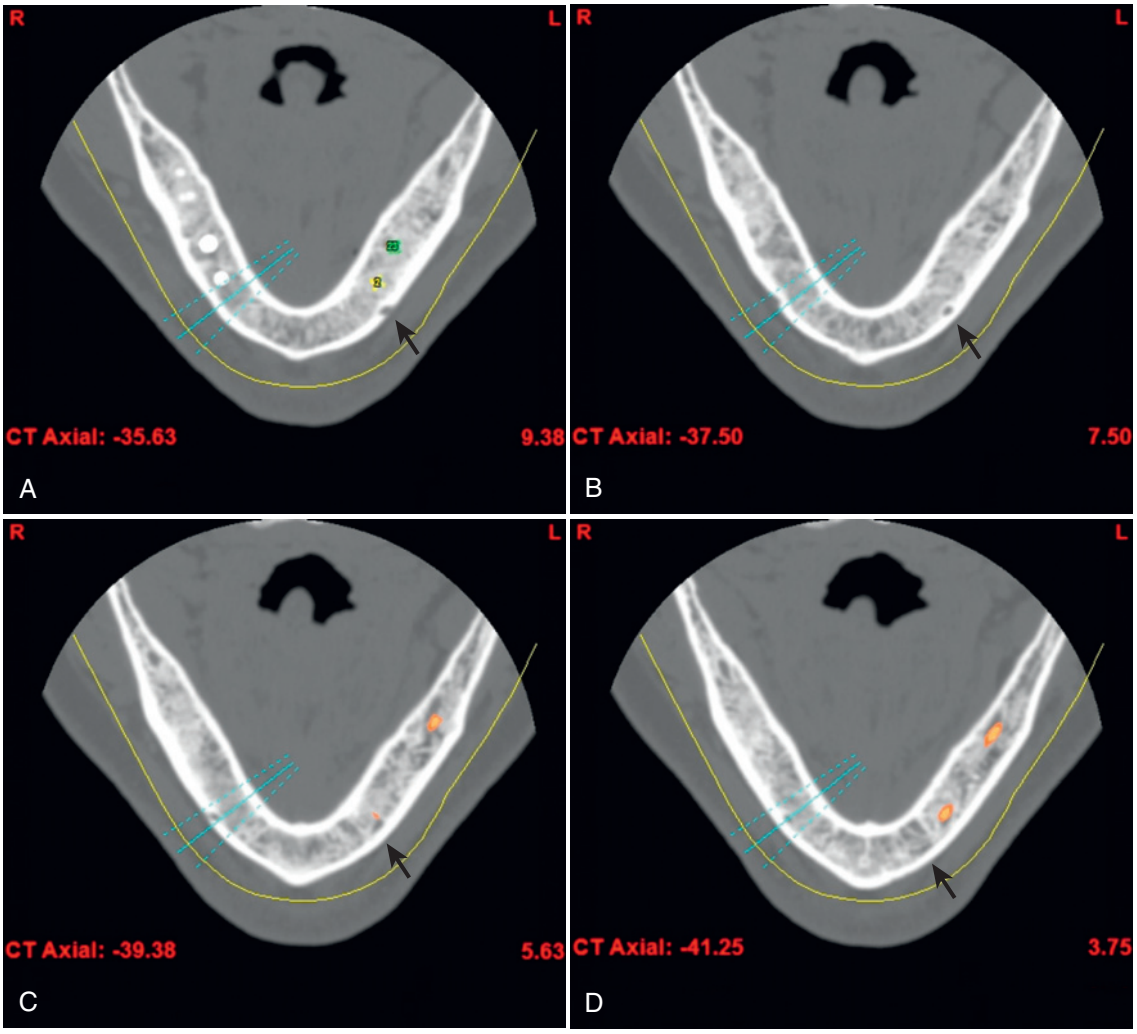
Two premolar teeth can be restored with two implants of regular diameter or small diameter. Two molars can be restored with two wide-diameter implants. In general, the diameter of the implant should be the same or slightly smaller than the diameter of the tooth at the cementoenamel junction. Failure occurs when too few implants are placed, and excessive forces of occlusion destroy the bone-implant interface. Implants can be attached to natural teeth, but this has been associated with fracture of the natural teeth or intrusion of the natural teeth. Therefore, the experienced clinician restores the posterior mandibular implants with freestanding, implant-borne restorations, avoiding the attachment of implants to the natural teeth.

Once the surgical plan has been developed and approved by the patient and restorative dentist, implant placement surgery can be performed. Appropriate consent forms must be signed, and a surgical template is fabricated to allow the surgeon to place the implants in line with the fossa or working cusp and to avoid the embrasure spaces of the proposed restoration.

Use of CT imaging to assess bone prior to implant placement

CT imaging allows the surgeon to assess vital structures accurately and to gauge bone shape and height. It is critical that the surgeon know the location of the inferior alveolar nerve before drilling holes for implants. Axial sections can be scrolled to follow the nerve as it enters and exits the mandible (Figure 2-4, A-D). The nerve may loop forward or move into the mandible without an anterior extension. This knowledge can be used to better position implants in both an edentulous and a partially edentulous patient.

The shape of the alveolar bone also can be assessed by direct observation after reflection of the periosteum; this was the method used before CT imaging. CT images produce



● **FIGURE 2-4** **A-D,** Axial sections starting at the superior aspect of the mental foramen. Note the hole in the bone on the left mandible (near the implant placed by the CT software; see *arrows*). As the sections move inferiorly, the clinician can follow the nerve canal in the mandibular body and observe whether it moves anteriorly as a loop or enters and moves posteriorly. This is important when implants are placed near this anatomic location.

very accurate pictures of the shape of the alveolar bone. Using these pictures, the surgeon can note the inclination of the alveolar cortical bone or the shape of the ridge itself (Figure 2-4, E-H).

The posterior mandible is evaluated both radiographically and by palpation. Palpation of the ridge often results in the conclusion that the ridge is too narrow for implant placement. However, CT images may result in more accurate measurement of the alveolar width and subsequent implant placement (Figure 2-4, I). If the ridge is narrow, augmentation can be performed and the ridge reassessed after bone consolidation has occurred. This can be done using surgical procedures with less morbidity, because preoperative knowledge of the location and width of the nerve reduces tissue reflection (Figure 2-4, J-K).

Cross-sectional images can be used to assess not only the location of the inferior alveolar nerve canal (Figure 2-4, L), but also the location of the anatomy of the concavity from the mylohyoid ridge. This factor affects the choice of implant length, which can be refined to engage but not protrude through the bone (Figure 2-4, M-N).

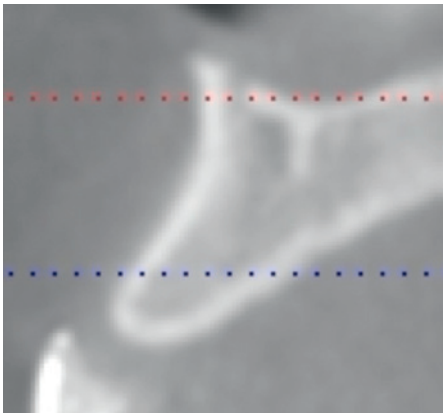


FIGURE 2-4 E, Cross section of the anterior maxilla at the lateral incisor site, which in this patient never developed. The angle of the alveolus is easily seen. The implant should be positioned slightly palatal for ideal emergence of the crown. Knowledge of the anatomy of the bone at the time of surgery improves the angulation of the implant at placement.

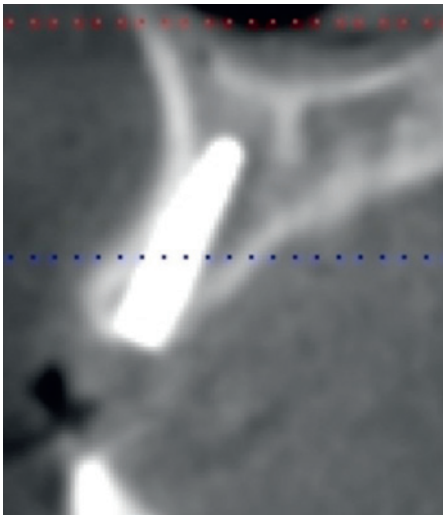


FIGURE 2-4 F, Postoperative section showing the implant ideally positioned. The surgeon recognized that the implant should be placed more retroclined than the palatal cortical bone and should start its entry palatal to the crest.

In patients who do not have all of their teeth because of agenesis, the anatomy of the facial and palatal crestal bone may differ from the expected. The lack of permanent tooth development and eruption can result in a thinner crestal bone that requires grafting (Figure 2-4, O-R). The palatal mucosa may be thick in these patients, and unless it is probed, the clinician may not appreciate the presence of very thin bone. CT imaging reveals such problems.

Different materials can be used for grafting in the jaws. When materials that undergo different rates of bone formation are used, accurate assessment of bone density and presence may be difficult with conventional panoramic radiographs. CT imaging with cross-sectional analysis can be coupled with CT planning software to allow the practitioner first to identify bone and assess its density and then to choose the best implant length and width.

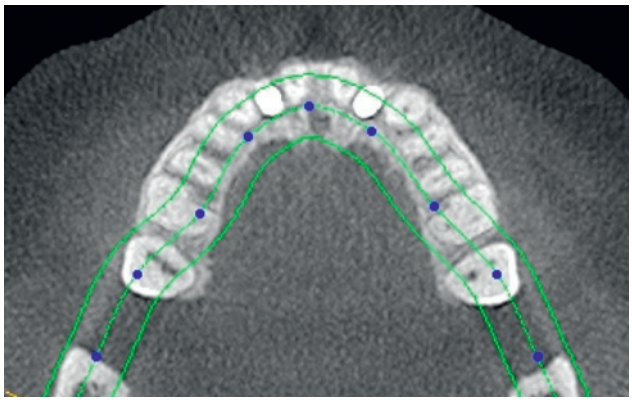
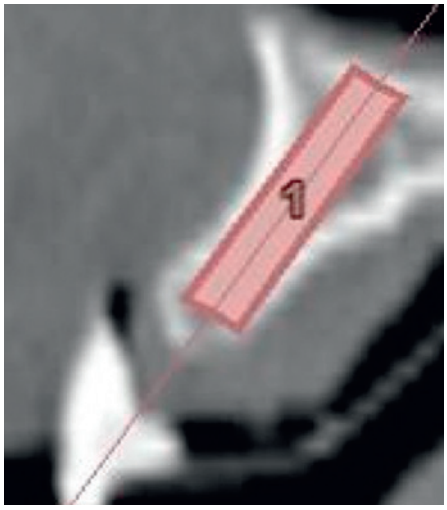


FIGURE 2-4 G, Axial cross section showing ideal placement of the implant in the cross section in Figure 2-4, F. CT imaging definitely provides important information that the surgeon can use to improve implant placement.

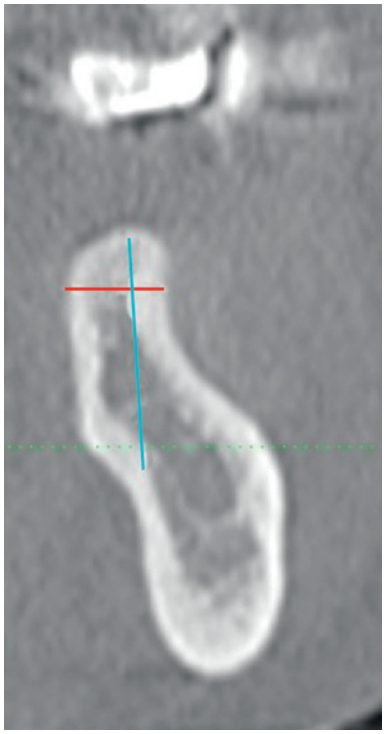
Surgical Treatment

Placement of implants into adequate bone

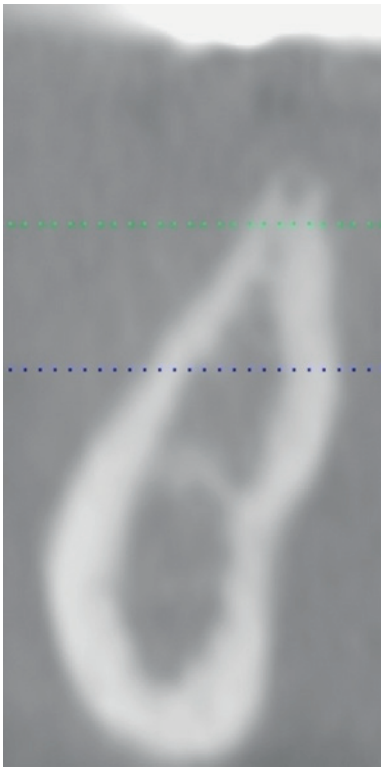
At the time of surgery or within a few days of surgery, an antibacterial solution is used to reduce the flora in the mouth. A chlorhexidine solution can be used at home or at surgery, or a povidone-iodine (Betadine) solution (not the scrub solution) can be applied at surgery. Infiltrative anesthesia should be used rather than inferior alveolar block anesthesia. Infiltrative anesthesia does not anesthetize the inferior alveolar nerve. The periosteal tissues are anesthetized to provide patient comfort during surgery. The endosteal portion of bone does not have sensory innervation. However, if the drill gets close to the neurovascular bundle, the patient will feel discomfort and can alert the surgeon. This technique provides an additional safety measure for preventing inadvertent trauma to and permanent sensory impairment of the inferior alveolar nerve. The anesthetic solution is infiltrated lingually and labially, as well as directly over the



● **FIGURE 2-4** **H,** Planning image created by using a radiopaque pontic using barium sulfate–impregnated acrylic, followed by virtual implant placement. The surgeon knows that placing the implant parallel to the labial cortex will result in proper implant placement.



● **FIGURE 2-4** **I,** Cross section created by CT imaging demonstrates a ridge of sufficient width and height above the nerve for implant placement. The clinical examination recorded a narrow ridge that might require lateral augmentation, but this was not accurate.



● **FIGURE 2-4** **J,** Posterior mandibular ridge with a narrow crest and buccal bone resorption. Based on this radiograph, a lateral augmentation using the tunneling technique was performed.

alveolar crest. The local anesthetic solution is placed in a subperiosteal plane to perform a hydropic dissection of the tissues, allowing for relatively bloodless and efficient reflection of the tissues.

Multiple incision designs have been reported in the literature. One incision design can be used in most cases. The incision is placed so as to bisect the band of KG (Figure 2-5 and Figure 2-6, A-D), because an incision in the posterior mandible occasionally may break down. Thus, if breakdown occurs, KG is present on the lingual and labial aspects of the implant. If the incisions are made either lingually or labially to the KG and incision breakdown occurs, the KG is not present on one aspect of the implant. Bisecting the KG also is used for a one-stage implant, whether the implant is so designed or when a one-stage technique is used intentionally to allow placement of the temporary healing abutment into the implant.

The crestal incision is released vertically posterior to the planned posterior implant location. Anteriorly, vertical releases are made to the labial and lingual aspects and are

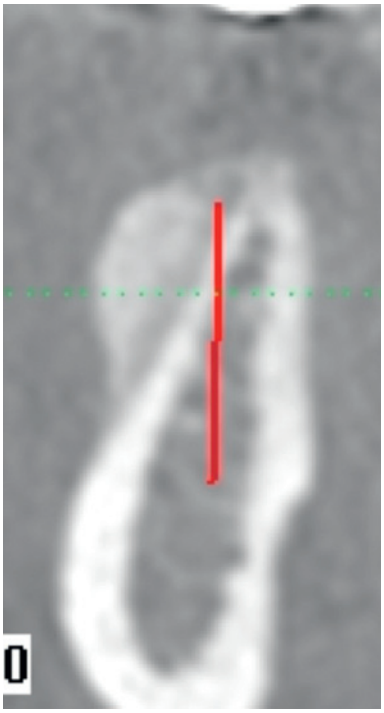


FIGURE 2-4 **K,** Cross-sectional image prior to implant placement showing adequate bone formation in the augmentation for ideal implant placement. The CT image provided information that allowed implant placement without excessive periosteal reflection, because the surgeon knew that the bone width was sufficient and the nerve was far from the crest.

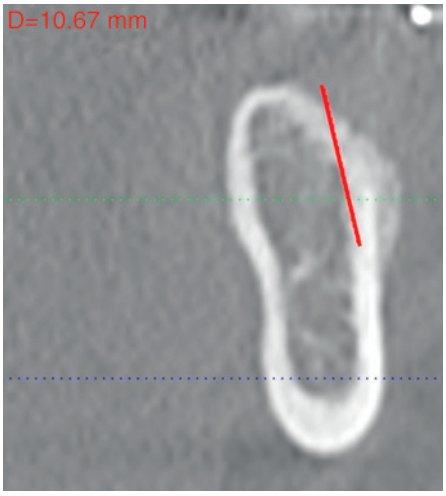


FIGURE 2-4 **L,** Cross sections from CT imaging provide information on the location of the inferior alveolar nerve canal, which in this patient is 11 mm from the crest.

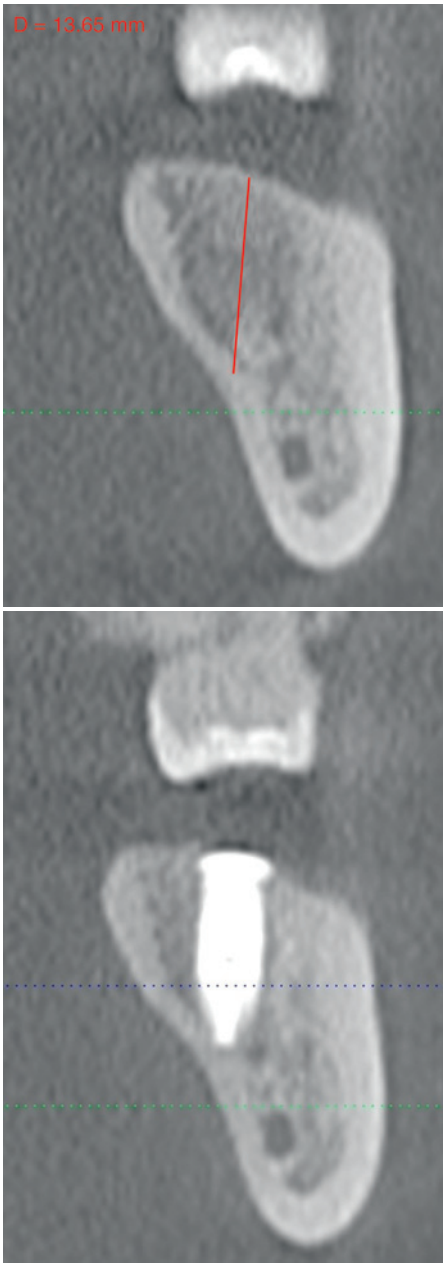


FIGURE 2-4 **M-N,** Cross section at the second molar location shows that the nerve is 18 mm from the crest; however, the mylohyoid ridge required placement of a 13-mm implant.

placed approximately 1 to 1.5 mm away from the distal surface of the natural dentition. The benefits of avoiding elevation of the attached gingiva of the natural dentition are less postoperative discomfort and less chance of disturbing a healthy periodontal apparatus. The incisions also are easy to close without contaminating the periodontal ligament space of the adjacent natural dentition.

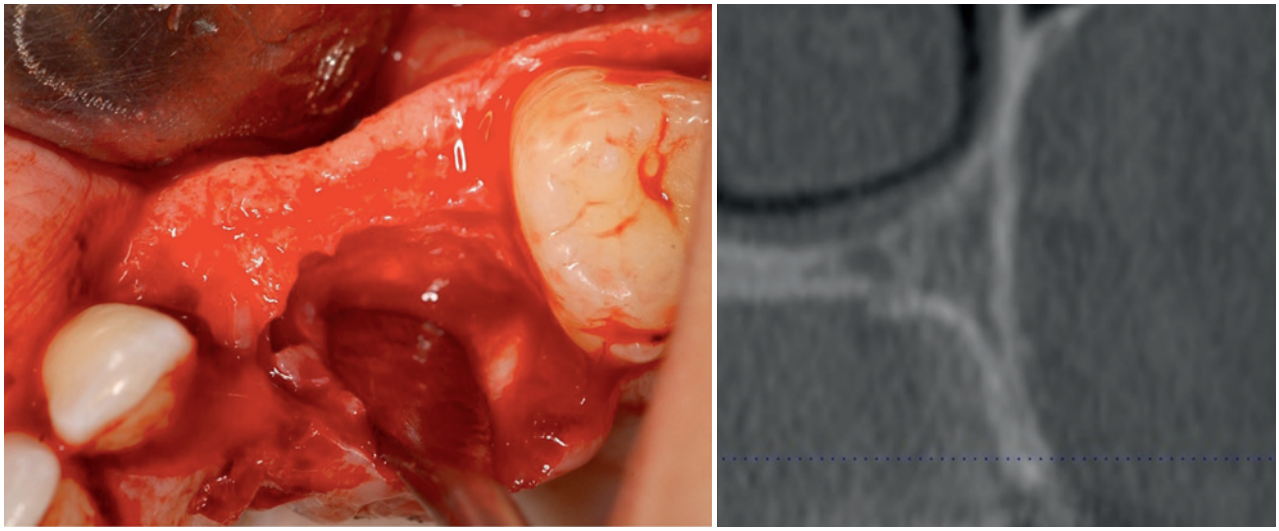


FIGURE 2-4 **O-P,** Patient who had agenesis of the maxillary canine and first premolar. Note the thin ridge seen on the CT cross section, which was confirmed after flap elevation. Preoperative knowledge of this ridge resulted in plans to graft the site, which was difficult to identify from palpation alone.

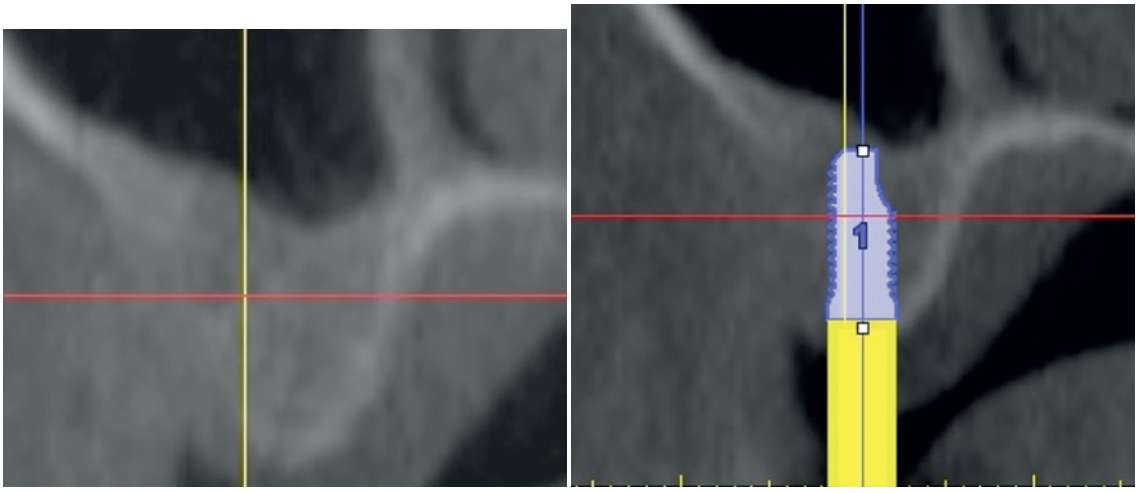


FIGURE 2-4 **Q-R,** Cross section of a posterior maxilla 5 months after grafting with bone morphogenetic protein. Note that bone is available for implant placement. CT images allow the surgeon to choose the most appropriate implant length and width before surgery. The same accuracy is difficult to achieve with routine panoramic radiographs.

The incisions are made, and a full-thickness reflection is performed. It is important that the periosteum be reflected inferiorly and anteriorly so that the surgeon can identify the mental foramen and confirm the amount of bone available superior to the inferior alveolar canal. A panoramic radiograph, a CT scan, or both can be used to increase the surgeon's understanding of the potential for working too closely to the inferior alveolar nerve. A panoramic radiograph can show whether the nerve runs at the approximate level of the canal or inferior to its position. Occasionally, the panoramic radiograph is not sufficient, in which case CT is useful. As mentioned previously, infiltrative

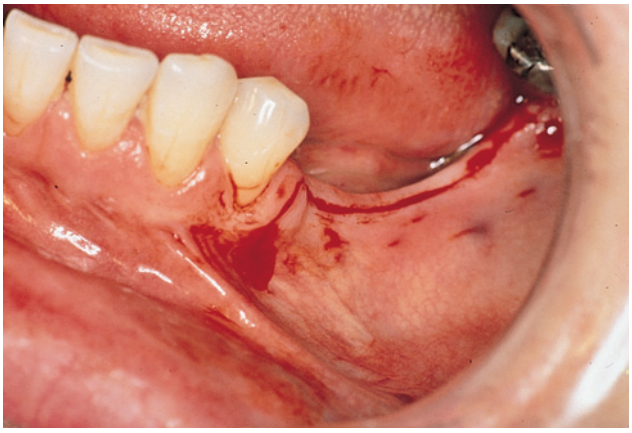


FIGURE 2-5 Incision design for the posterior mandible is simple and efficient. After the labial and lingual tissues have been infiltrated with a local anesthetic, a crestal incision is made, with vertical release incisions made anteriorly and posteriorly. Often the posterior lingual release is not necessary. If an extensive posterior lingual release incision is not made, the chances of inadvertent trauma to the lingual nerve are reduced.

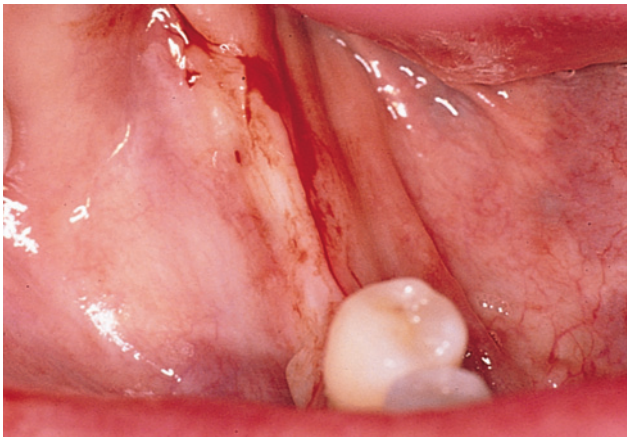


FIGURE 2-6 B, At the time of exposure, an incision is made to bisect the KG. A tissue punch is not used, because it would remove the KG, which typically is thin in the edentulous posterior mandible.

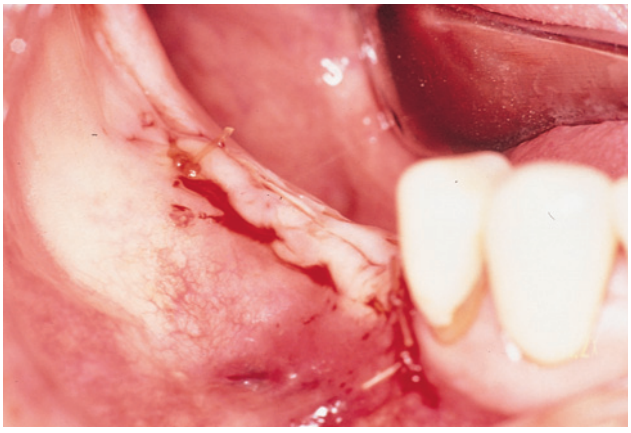


FIGURE 2-6 A, Horizontal mattress suture technique everts the edges of the incision, eventually resulting in flat scars. If the incision inverts, the functional amount of keratinized gingiva (KG) around the final restoration will be reduced.

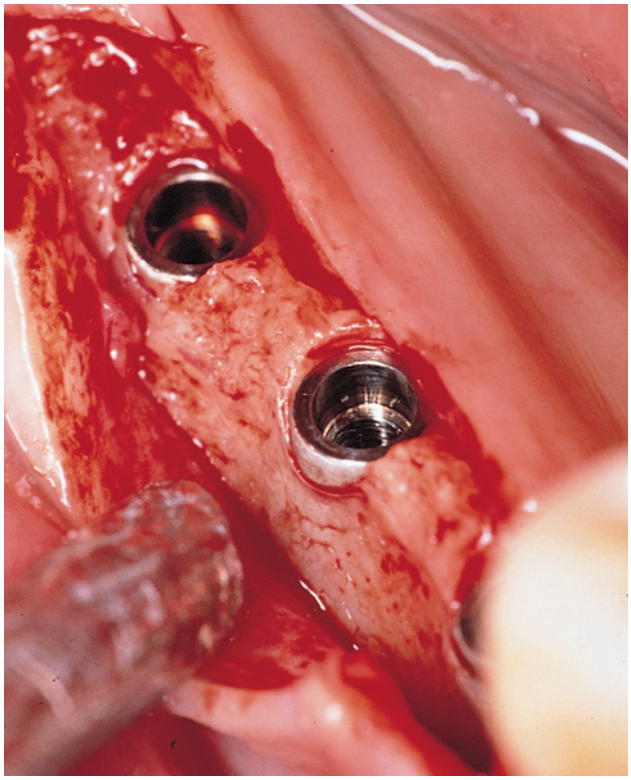


FIGURE 2-6 C, Flap is elevated, and the cover screws are removed.

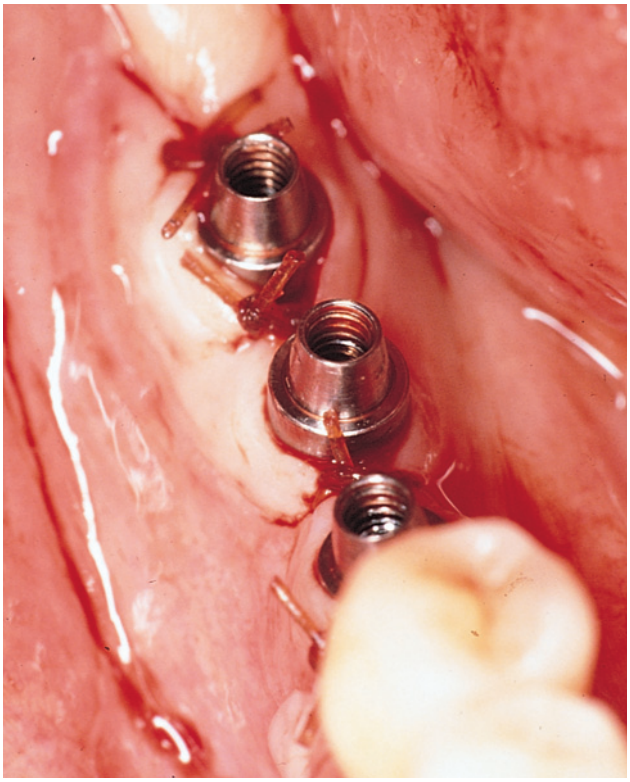


FIGURE 2-6 **D,** Temporary or final abutments are placed, depending on the clinician's preference. The gingiva is sutured to approximate the KG around the abutments. To preserve the KG, trimming or other procedures that would reduce the width of the KG are not performed.

anesthesia does not block nerve impulses from the inferior alveolar nerve in the canal. Consequently, if the surgeon drills close to the nerve, the patient will feel the drill, as well as heat- or vibration-induced pain, and alert the surgeon, preventing inadvertent trauma to this sensory nerve.

The specific locations for entry of the implants are marked with the surgical guide stent in place (Figure 2-7, A-F). These marks often are made with a round bur. The stent is removed, and the locations of the drill sites are examined. The center of the implant site should allow the body of the implant to be at least 2 mm from the natural tooth. The surgeon should note the angulation of the roots of the adjacent teeth to avoid apical trauma to the natural tooth. A space of 3 mm should be maintained between the implants to allow for ideal emergence of the crowns from the implants, maintenance of bone between the implants, and adequate healing of the bone to the implant. If the implants are placed too closely together, problems can develop, including difficulty placing the transfer copings and prosthetic abutments, difficulty creating an appropriate

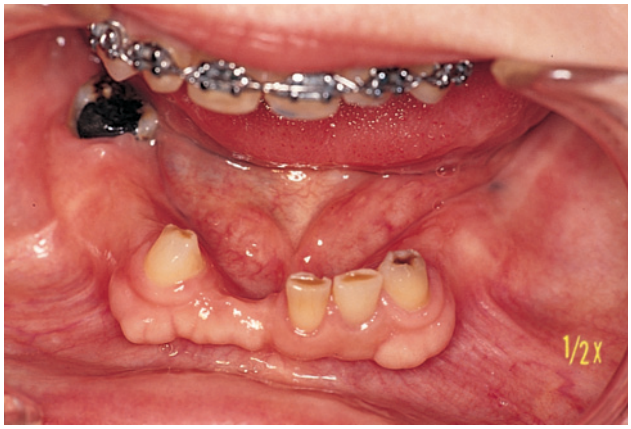


FIGURE 2-7 **A,** Occlusal view of a 54-year-old woman who wanted implant-borne, fixed restorations to replace her removable partial denture. She had orthodontic treatment to align her teeth before the implants were placed.

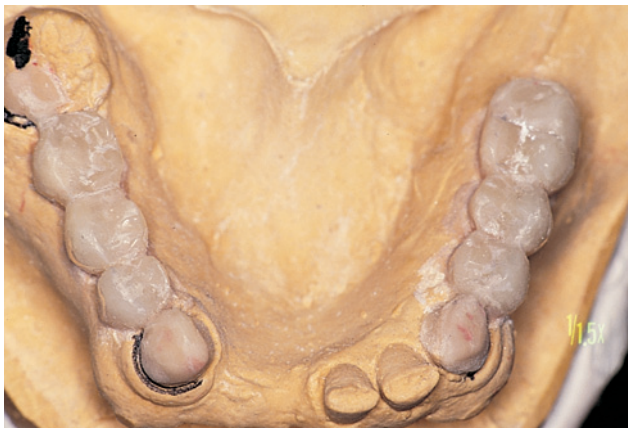


FIGURE 2-7 **B,** Planned restoration is created in the laboratory. A surgical stent is made to help place the implants accurately.

hygienic embrasure space, and crestal bone loss from inadequate bone adjacent to the implant.

The round bur is used first, followed by the pilot drill. Most implant systems have a graduating-sized drill set. The pilot bur is taken to the expected depth of the implant chosen for placement. The surgeon acknowledges patient comfort and lack of excessive bleeding from the drill site to confirm further that the drill is superior to the inferior alveolar canal. The drills are angled within the surgical stent to locate the implants opposite the working cusp of the opposite arch or, for cemented restorations, under the working cusp of the mandibular teeth. These positions are important, because they locate the implants in the correct

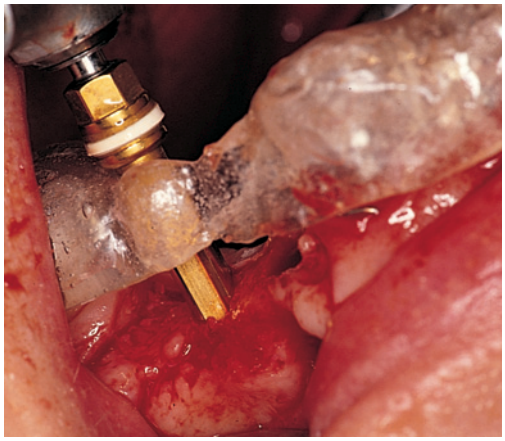


FIGURE 2-7 C, Use of a pilot drill and the surgical stent. The drill is within the confines of the labial tooth form.

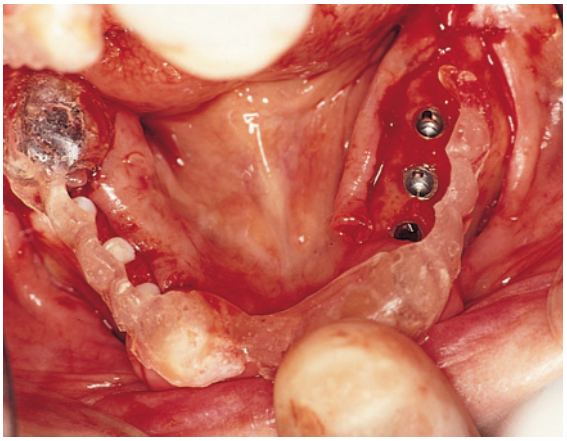


FIGURE 2-7 D, All implants have been placed. Their position was dictated by the stent. The implants in the right posterior mandible have been placed to ensure that the centers of the implants are lined up with the fossae of the planned restoration. The incision bisects the KG, which is lingual to the final positioning of the implants.

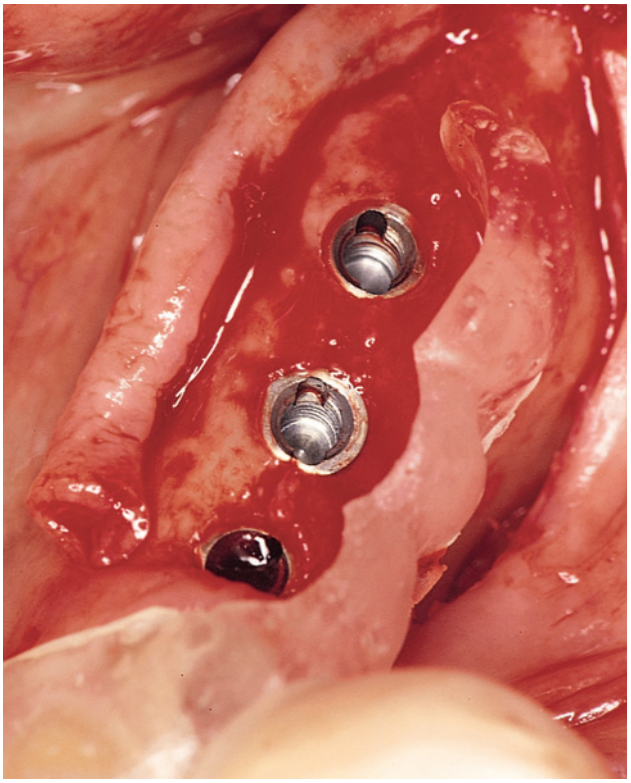


FIGURE 2-7 E, Close-up view shows the implants in relation to the stent for the left side. Placement of the implant in the ideal orientation for the restorative dentist results in a simpler prosthetic phase and long-term success.

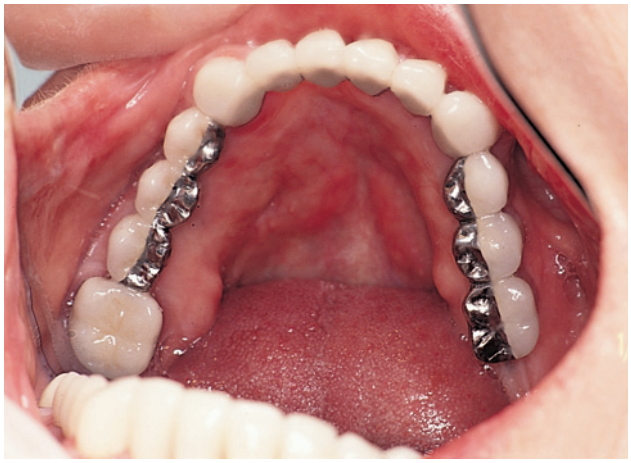


FIGURE 2-7 F, Final restoration. (Prosthetics by Dr. Richard Gruner.)

restorable location for the mandibular dentition. Parallel or guide pins are used to verify correct angulation. These pins are placed into the pilot hole. The patient is instructed to close very slowly to bring the parallel pin close to but not in contact with the maxillary teeth. The pin should be angled to meet the working cusps of the opposite arch, which are the maxillary palatal cusps. Once this relationship has been verified, the drilling sequence can be continued. If angulation changes are necessary, the next-sized drills can be used to correct the angulation. This simple

maneuver allows the surgeon to place the implants in a restorable position, which ensures ultimate success.

In the second molar region, the surgeon may perforate the lingual cortex within the mylohyoid concavity; this should be an expected event, because the physical examination should have revealed this concavity. The implant chosen should be long enough to engage the lingual cortex without extending into the mylohyoid concavity.

After the drilling sequence has been completed, the implants are placed. The goal is to place the longest implant possible without trauma to the inferior alveolar nerve. The polished collars of the implants can be placed supracrestally, placed at the level of the crest, or countersunk 1 mm. This decision is based on the availability and quality of bone and the philosophy of the implant team. For a two-stage system, the cover screws are then placed; for a one-stage system, a healing abutment is placed. If the implant is placed with the cover screw more than 1 mm supracrestally, incision breakdown may occur, exposing the implant cover screw. If this occurs, hygiene with topical chlorhexidine solution is recommended. The implant-gingiva interface should heal uneventfully, as has been well documented with one-stage implant systems and in this author's experience.

Incision breakdown is proportional to the tension placed across the incision line. For most situations, a periosteal release is necessary to achieve a tension-free closure. Scissors can be used to cut the periosteum only, not the muscle or long buccal nerve. After the periosteum has been relieved, the incision can be closed without tension using atraumatic needles.

Placement of implant into thin bone

In the regions where teeth have been lost secondary to chronic decay, periodontal disease, or both, the buccal width of bone may be limited. In these cases, bone grafting should be performed to allow placement of the implant in the ideal location. Placement of the implant too far lingually creates a cantilever from the buccal working cusps of the mandibular teeth or requires the creation of a cross-bite occlusal scheme.

If the implant is placed and the labial bone is thin after placement, the facial surface of bone may resorb either during the healing period or shortly after functional loading. During implant surgery, the superficial surface of the facial bone usually is stripped of periosteum during surgical flap reflection. The endosteal surface of the thin bone is altered by the drilling sequence, with removal of a significant portion of the endosteal blood supply between the implant and bone. This creates the potential for resorption of thin labial bone during the healing period and the future possibility of implant surface dehiscence from the bone.

What can the surgeon do to prevent fenestration when placing implants into thin bone? If bone grafting is not an option because of clinical reasons or patient preference, several technical factors must be considered. Exposure of the thin crest should be sufficient to allow the surgeon to visualize directly the labial and lingual cortical bone contours from above and to appreciate any undercuts. The round bur should be placed accurately in the middle of the crest. The pilot bur should be used with appropriate retractors in place to allow three-dimensional visualization and to prevent cortical plate perforation. Often, a small-diameter implant (3.25 mm) is chosen rather than a 3.75-mm implant. Osteotomes are not routinely useful in the posterior mandible, because the dense cortical bone of the alveolus is not as easily expanded as maxillary bone. If osteotomies are planned, the periosteum must be maintained. Limited clinical trial reports are available on the use of cortical osteotomies to widen a thin mandibular ridge.

After the pilot drill has been used and if the position of the implant is satisfactory, the next-diameter drill is used. The next-sized drill is designed to remove 1 mm of bone. The drill will follow the course of least resistance and may remove more facial bone, which is thinner than the lingual bone, resulting in facial dehiscence. At this time, slightly more pressure on the lingual surface of bone is applied to prevent excessive removal of labial bone. After the final diameter has been prepared, the site may be tapped, or a self-tapping implant may be placed.

After the implant has been placed in the moderately thin ridge, the surgeon may be concerned about potential resorption of this labial cortical bone and implant exposure through the bone. In this situation, the following technique is recommended. Because the incisions must be sutured without tension and because an alloplastic graft—typically dense, nonresorbable hydroxylapatite (HA)—will be placed, the periosteum should be released to allow a tension-free closure. These procedures are performed before the nonresorbable material such as bovine bone is placed on the thin labial bone. After the supraperiosteal dissection and flap release have been performed and hemostasis has been achieved, the particulate graft is placed. Typically, less than 1 ml of graft is needed. Graft particles 500 μm in size are used, because smaller particles tend to flow with the blood. The dense, nonresorbable graft is placed over the thin bone with a syringe to cover and enhance the thickness of the thin bone. The graft particles are positioned in the desired location, and the incision is closed with nonresorbable suture (Figure 2-8, A-F). If a graft is used at the time of implant placement, a nonresorbable suture is used to close the incision sites. Additional 4-0 resorbable sutures can be placed to reduce tension on the initial sutures. Follow-up evaluations indicate that the graft remains in position and becomes infiltrated with bone over time. The removable

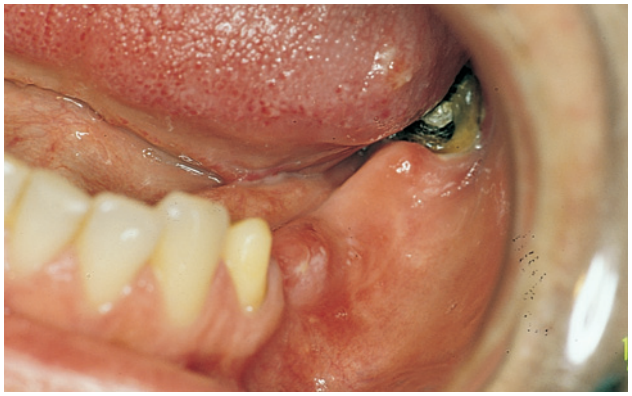


FIGURE 2-8 A, Typical clinical situation in which the patient and restorative dentist decide to replace the missing three teeth with implants. As a result of recent extractions and asymmetric resorption, the bone is 5 mm wide.

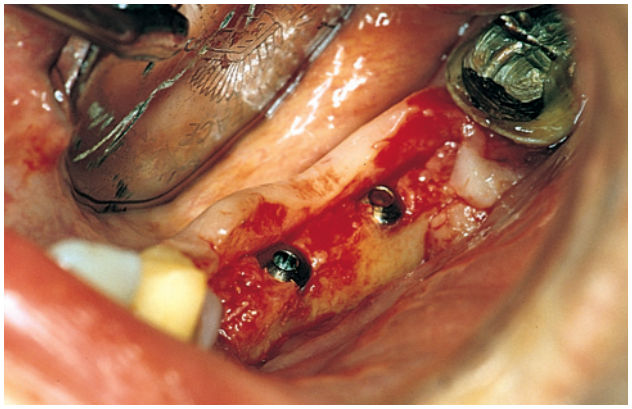


FIGURE 2-8 C, Placement of the implants. The labial bone is no more than 1 mm thick.

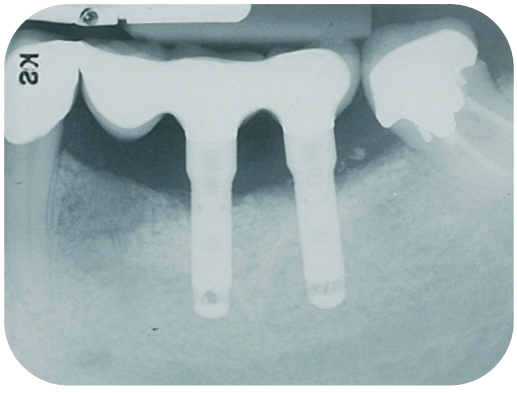


FIGURE 2-8 E, Six-year follow-up radiograph shows maintenance of crestal bone levels.

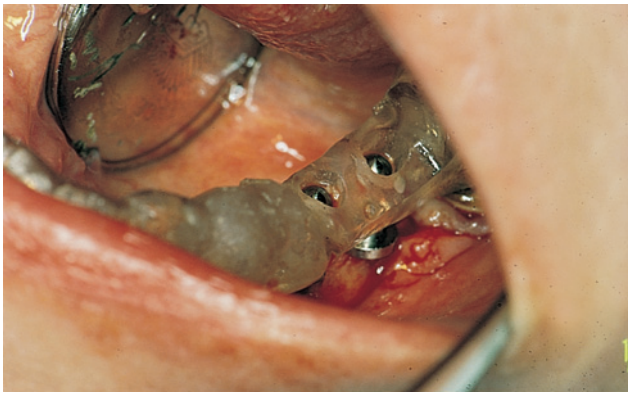


FIGURE 2-8 B, Parallel guide pins are placed into the pilot holes in the bone and exit through the stent, confirming the direction and placement of the implants.

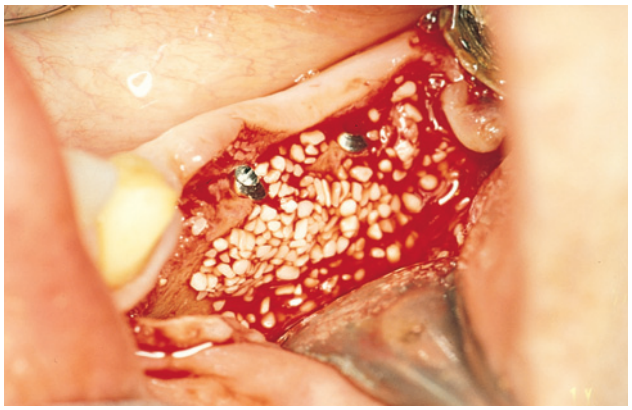


FIGURE 2-8 D, Augmentation of the ridge width with hydroxylapatite (HA) particles has proven to be an effective therapy for enhancing the long-term health of the restoration when implants are placed into thin bone.

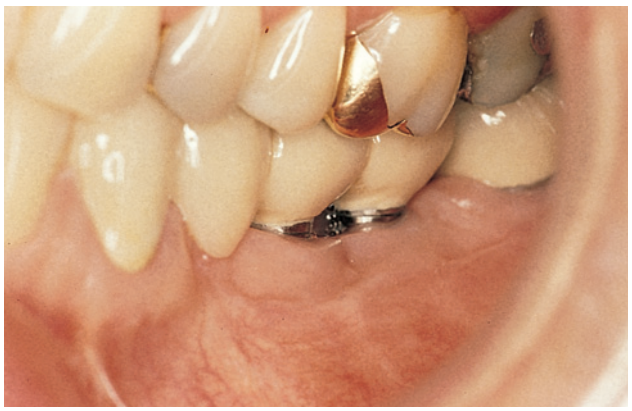


FIGURE 2-8 F, Final restoration preserves the KG and anatomic form and provides adequate embrasure space for oral hygiene. (Prosthetics by Dr. Patrick Wade North.)

prosthesis is not replaced into the mouth for at least 10 days and not until it has been relieved and soft-lined to prevent excessive trauma to the implants.

Augmentation of thin or vertically deficient posterior mandibular ridges

The posterior mandible may have thin alveolar bone that prevents appropriate engagement of an endosseous implant (Figure 2-9, A-I). After teeth have been lost, the facial cortical bone resorbs more than the lingual cortical bone, resulting in a ridge that may have sufficient vertical height but is 3 mm wide or less. Thin ridges also are common in patients who have worn removable partial dentures for many years.

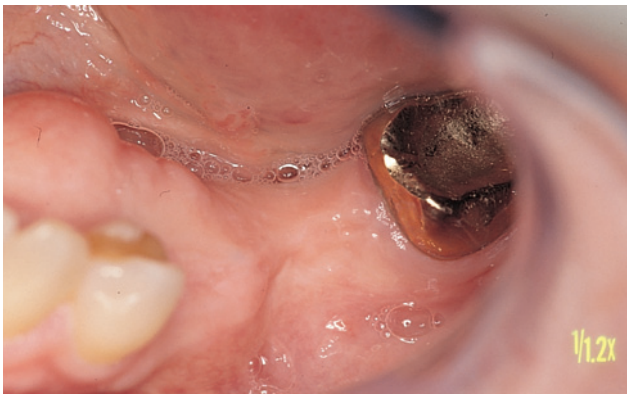


FIGURE 2-9 **A,** Forty-year-old woman with a two-tooth edentulous space. Her dentition is in excellent health. Examination shows adequate bone height for potential implant locations, but the posterior implant site is thin at the crest. Treatment includes external oblique ridge bone grafting and placement of two implants after the graft heals.

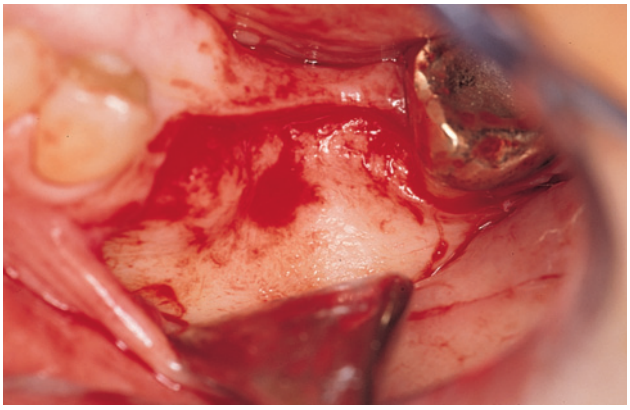


FIGURE 2-9 **B,** At graft surgery, a crestal incision is made with vertical release. The thin bone crest is easily visualized.

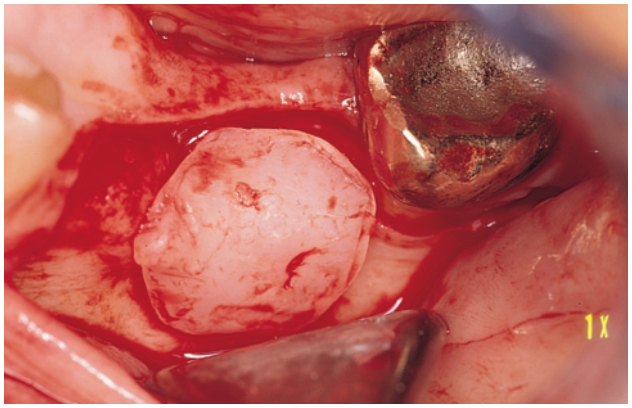


FIGURE 2-9 **C,** A piece of sterile bone wax is molded to fit the site and act as a template for the graft.

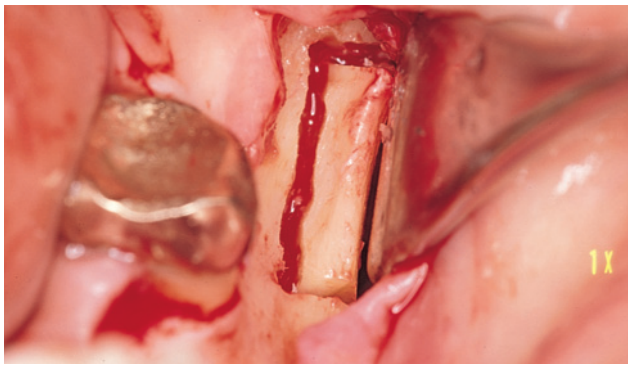


FIGURE 2-9 **D,** Crestal incision is extended posteriorly and angled superiorly along the external oblique ridge. After full-thickness reflection, the external oblique ridge is exposed. A thin fissure bur is used to outline the graft site, taking into consideration the final dimensions of the graft as determined by the wax pattern. The graft is delivered with the aid of thin osteotomes.

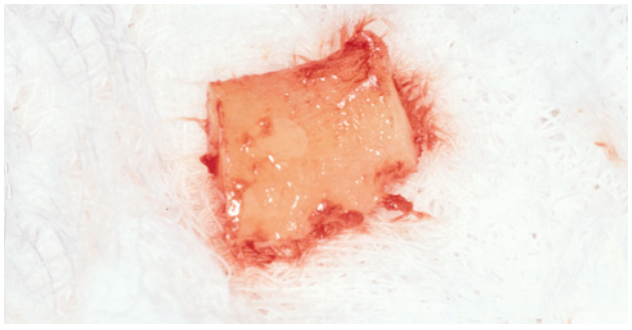


FIGURE 2-9 **E,** Graft is placed on a saline-dampened sterile gauze. Round, pear-shaped, or oval burs and copious irrigation are used to shape the graft to match the wax pattern.

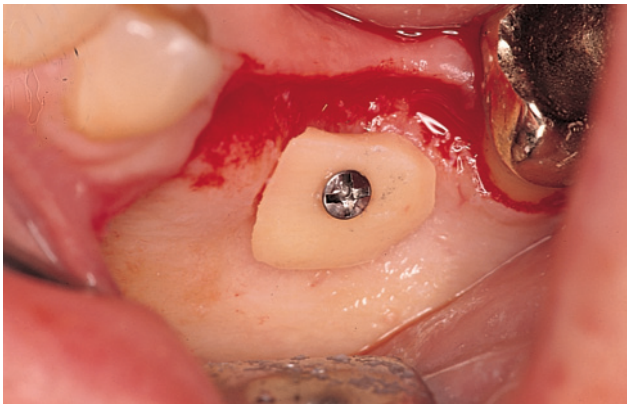


FIGURE 2-9 F, Graft is trimmed to mortise in position without movement at the host site. A screw is placed to hold the graft firmly in position.

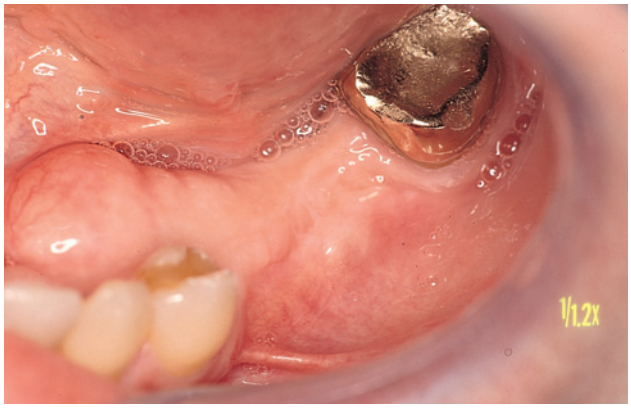


FIGURE 2-9 G, Same site as in Figure 2-9, F, shown 4 months later but before placement of the implants.

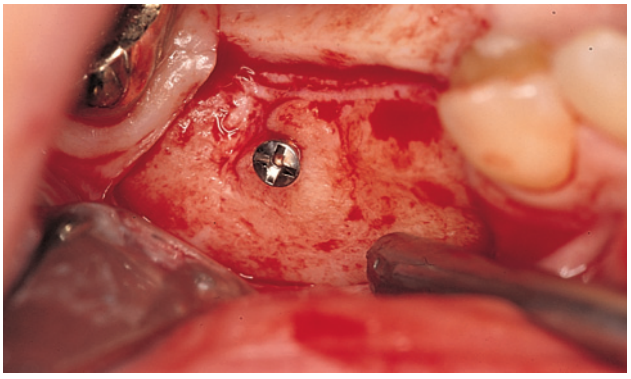


FIGURE 2-9 H, Crestal incision and full-thickness reflection have been performed, exposing the graft. The screw is removed.

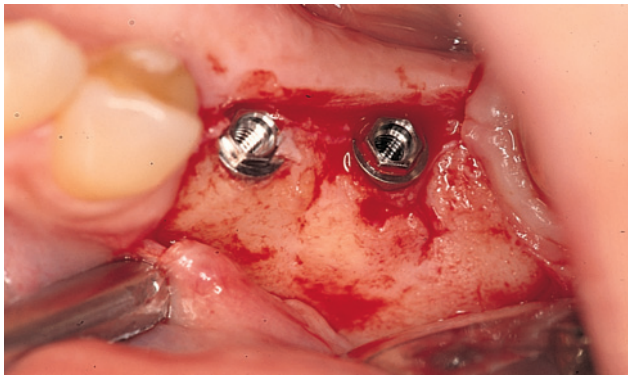


FIGURE 2-9 I, Two implants are placed.

Patients who have lost their teeth for other reasons, such as periodontal disease or chronic endodontic problems with exudate, may have thin ridges and vertical ridge deficiency. Ridges 4 to 6 mm wide are marginal for implant placement, but they usually are sufficiently wide to allow placement of the implant with simultaneous labial grafting, as described previously and illustrated in the figures.

Patients with thin ridges may have lost all or some of their posterior teeth. They may have an intact anterior dentition that has been used to support a removable partial denture. For the patient who is missing molars and perhaps premolars, the following restorative options may be considered:

1. New removable partial denture to improve comfort and function
2. Extraction of remaining anterior teeth and placement of five implants for an implant-supported prosthesis
3. Bilateral placement of two or three implants in the edentulous posterior quadrants for a fixed prosthesis

The cost of performing a bone graft to restore the thin or vertically deficient ridge and the placement of six implants for the bilateral edentulous situation often is greater and potentially less effective than the second option listed. For patients who will not entertain losing their anterior teeth and in the unilateral situation, grafting a thin alveolar ridge is an excellent option. However, clinical outcomes from long-term prospective studies on the performance of cortical grafts to the posterior mandible are lacking.

Treatment planning for the patient receiving an onlay bone graft, which includes a diagnostic setup of the planned restoration, is the same as that for any patient receiving an implant. This diagnostic setup includes diagnostic models and several preoperative visits with the restorative dentist. In selected patients, the removable partial denture can be

used to provide information to the surgeon concerning graft size. A clear surgical guide stent is made to provide the surgeon with the location of the working cusps, the position of the fossae of the planned teeth, and the level of the proposed gingival margin. This guide stent is used during the bone grafting surgery to ensure that the bone is placed appropriately to allow ideal implant placement after graft consolidation and healing.

If the desired graft is 4 mm or less, the external oblique ridge of the mandible can be used as the source of the graft. An alternative site is the chin, which may provide more cancellous bone attached to the cortical bone and is useful for thicker grafts. Other sources include the iliac crest and calvaria.

Incision Design. For bone graft placement onto the posterior mandible, incisions may be made either on the crest or in the vestibule. Vestibular incisions are thought to be useful, because they place the incision away from the graft and not directly over it. However, a vestibular incision with vertical release and reflection over the lingual cortex, which allows access to the thin alveolar ridge, solely relies on the lingual tissues for its blood supply. The lingual mucosa may be thin in many patients. The blood must pass through the crestal band of attached, fibrous gingiva. Because of the thin lingual mucosa, which often is traumatized by the dissection and manipulation, and the potentially reduced blood supply that passes through the scarred gingival crestal tissue, a vestibular incision may break down in some patients, resulting in graft failure.

A crestal incision with anterior and posterior releases, which often is placed one tooth mesial or distal to the graft site, relies on the lingual tissue and facial tissues for its blood supply. After the graft has been placed, the facial periosteum can be incised and released, allowing tension-free closure. This author prefers the crestal incision for bone graft augmentation of the posterior mandible.

After intravenous sedation for patient comfort, an antibacterial solution is used to prepare the patient's mouth. Local anesthetic is infiltrated into the facial and lingual tissues to allow for a hydropic dissection and to anesthetize the periosteum. This technique provides a comfort zone for the surgeon; if the inferior alveolar nerve is approached, the patient will respond, and the surgeon can reposition the drills.

After confirming the effect of the local anesthetic, the surgeon uses a scalpel to make a crestal incision that bisects the KG. Anterior vertical release incisions are placed at the junction of the attached and unattached gingivae of the teeth to avoid disturbing the gingivae, or they can be placed intrasulcularly with vertical release one tooth away from the graft site. Posteriorly, the incision is carried from the attached gingiva in the third molar region and extends obliquely superior along the ramus. After a full-thickness, mucoperiosteal reflection has been performed, the lateral mandible and the external oblique ridge are exposed and available for bone harvest.

The recipient site is examined for pathologic conditions (e.g., pieces of amalgam, small pieces of soft tissue in prior tooth sites) and for general bone contour. The surgical guide is placed to enable the surgeon to measure the size of the graft. Sterile bone wax may be sculpted into the defect to show accurately the size and shape of the graft. This wax template then can be used to measure the graft size accurately and to modify the graft after it has been harvested.

External Oblique Graft Harvesting. If the graft's necessary thickness is less than 4 mm, it may be harvested from the external oblique ridge (see Figure 2-9). A local anesthetic is administered in the retromolar region. After the anesthetic takes effect, an incision is made starting from the distal facial aspect of the second molar and extending obliquely along the ramus. A full-thickness reflection is performed to expose the external oblique ridge and the lateral aspect of the ramus. Either a thin fissure bur or a thin saw can be used to outline the graft. The inferior horizontal cut along the lateral surface of the ramus can be made with a round bur or other cutting instruments that may require a contra-angled handpiece. After the cortical cuts into the marrow space have been completed, osteotomes are used gently to split the bone graft from the ramus. Care must be taken to avoid the inferior alveolar nerve, which may be surprisingly superficial in this region.

Chin Graft Harvesting. If the graft's design or the clinician's preference requires the bone graft to be thicker than 3 to 4 mm, the graft may be harvested from the chin. Preoperative assessment of the amount of marrow in relation to cortical bone thickness is important. A lateral cephalogram can reveal the thickness of the facial cortical bone, the presence or absence of a cancellous marrow space, the location of the apices of the teeth, and the thickness of the symphysis.

After a local anesthetic (which should include mylohyoid nerve anesthesia) has been administered, a vestibular or sulcular incision may be made to approach the symphysis. Care must be taken to identify the location of the mental foramen and branches of the mental nerves so as to avoid them. A thin fissure bur can be used to outline the dimensions of the graft, which may include a portion of the inferior border to form an L-shaped graft for vertical and horizontal ridge reconstruction. For symphyseal graft harvesting, the cortical cuts are made deeper than in the external oblique area, because the nerve is not present in the symphysis. The graft is removed with the aid of osteotomes, with care taken to prevent excessive trauma to the chin. The defect is irrigated; additional bone can be harvested, if desired, from the internal aspects of the chin; and hemostasis is achieved. The defect can be left empty if it is confined to the lateral aspect, or it can be grafted with a resorbable hemostatic material or a bone graft substitute (e.g., alloplast, allograft, xenograft) and covered with a

resorbable membrane. The incisions are closed to reapproximate the mentalis muscle and the mucosa aspect of the incision. An appropriate chin dressing should be placed to ensure the natural return of the mentolabial form and submental form of the soft tissues of the chin.

Graft Preparation and Placement. The graft is taken to the recipient site, which may require modification if the contour of the bone is uneven. The bone at the recipient site should be smooth in contour and shaped to allow intimate mortising of the graft to the recipient site. Attention to detailed mortising of the graft to the recipient site is critical to the success of the procedure. If the recipient site is covered with dense, nonbleeding cortical bone, small holes are made through the cortex into the marrow space to promote graft healing. The graft is handled carefully and is kept wet with saline. The shape of the graft must be modified to match the shape of the wax template. The modifications should be atraumatic and should be made with either cutting rongeurs or burs under copious irrigation. The marrow on the graft should be maintained. The graft is positioned with the aid of the stent to ensure the correct size. It is secured in place with screws that are 1.5 mm in diameter.

After the graft has been secured in position, the edges are smoothed to produce a smooth transition with the adjacent bone. The incisions are closed after release of the periosteum to allow for a tension-free closure. Tapered, atraumatic needles and nonresorbable sutures should be used for this purpose. The sutures may be left for 10 to 14 days postoperatively. Antibiotics and pain medication are prescribed. Antiinflammatory analgesics also are recommended. An antibacterial rinse and a liquid, nonchewing diet are recommended for 2 weeks. The patient's temporary prosthesis is left out of the mouth until the incisions and swelling allow its replacement and after a soft liner has been positioned that allows only minimal pressure on the graft site.

Postoperative graft failure or small pieces of loose graft may not cause infection until 3 weeks after surgery. If swelling is observed approximately 3 weeks after graft placement or after implant placement into a graft, necrotic bone may be present. Gram staining of the purulence may not necessarily indicate the presence of bacteria. These sites must be re-exposed by conservatively raising full-thickness flaps, and necrotic, mobile pieces of bone must be removed as soon as possible. If the bone graft is compromised after implant placement, removal of small necrotic bone pieces, with retention of a large portion of the graft, may allow integration of the implants after the infection has resolved, unless the infection has invaginated into the implant site between the implant and the bone. Loss of the graft also may occur.

Harvesting of an Iliac Crest Block Graft. The iliac crest is another source of onlay blocks of corticocancellous bone for grafting (Figure 2-10, A-G, and DVD Figure 2-2, A-L). The iliac crest corticocancellous graft can be harvested from the anterior or posterior iliac crest, depending on size of the graft, the patient's and the clinician's preferences, and financial considerations.

2-2, A-L

Why choose the iliac crest, rather than the symphysis or external oblique, as the source of bone? The amount of cancellous bone and transplanted, viable endosteal osteoblasts

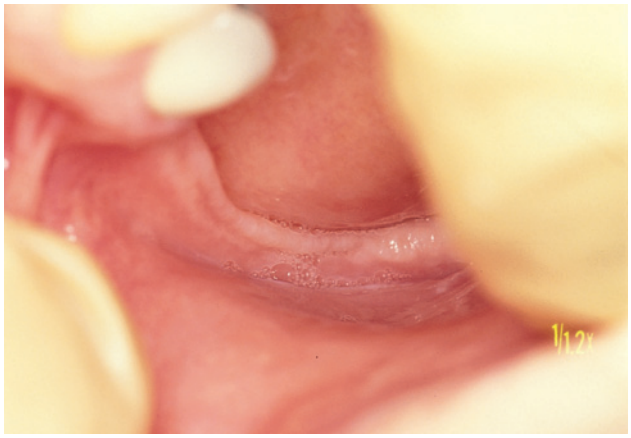


FIGURE 2-10 **A,** Treatment for this 62-year-old woman includes an implant-borne prosthesis. The posterior mandible on both the right and left sides is thin. Because of the patient's small chin and a thin external oblique ridge that requires 5 mm of graft thickness, the decision is made to augment the mandible with corticocancellous bone from the iliac crest.

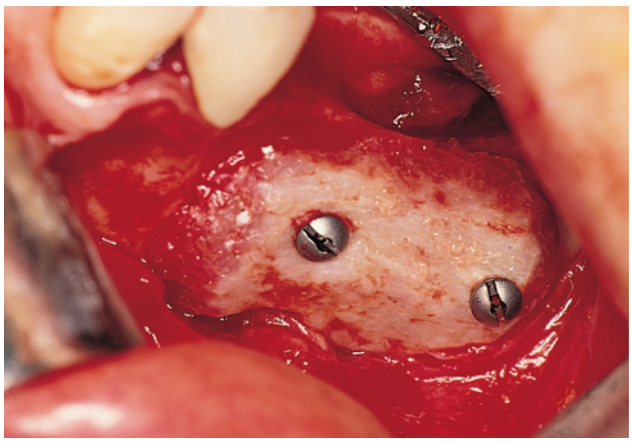


FIGURE 2-10 **B,** Bone is harvested from the iliac crest. The superior cortical portion of the iliac crest is used as the new alveolar crest, the medial cortex is used as the new labial surface, and the cancellous bone is placed against the host cortical bone. Small holes are made in the cortical bone to augment graft revascularization and healing.

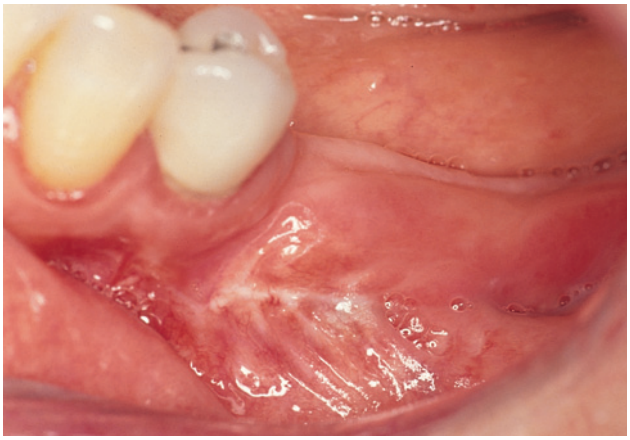


FIGURE 2-10 **C,** Left side of mandible after 4 months of healing. A small piece of bone sequestered from the most posterior portion of the graft at 3 weeks after surgery, with rapid closure of the mucosa.

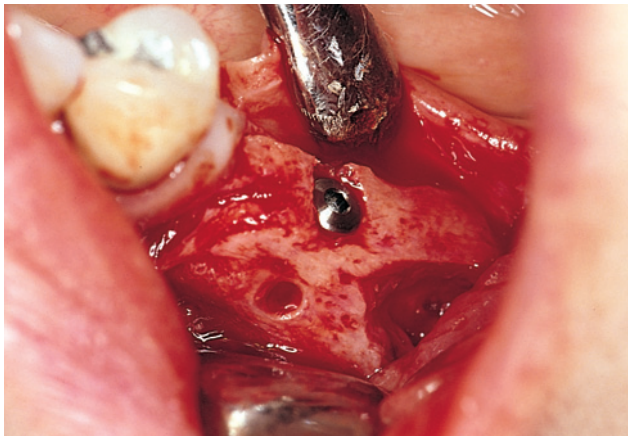


FIGURE 2-10 **D,** Graft is exposed by a crestal incision after 4 months, and one implant is placed. The treatment plan includes attachment of the posterior restoration to the anterior natural tooth.

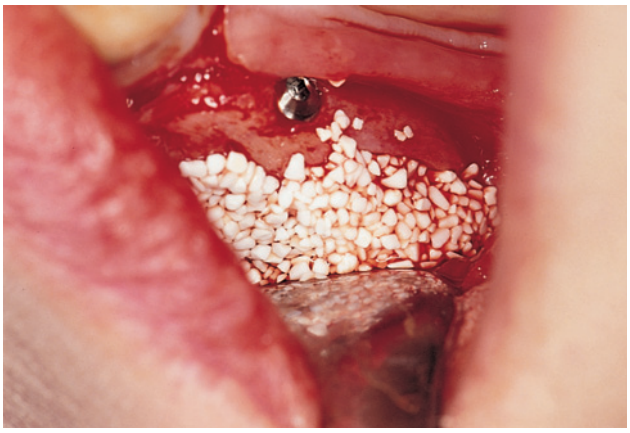


FIGURE 2-10 **E,** Hydroxylapatite particles are used to graft the bone defects.

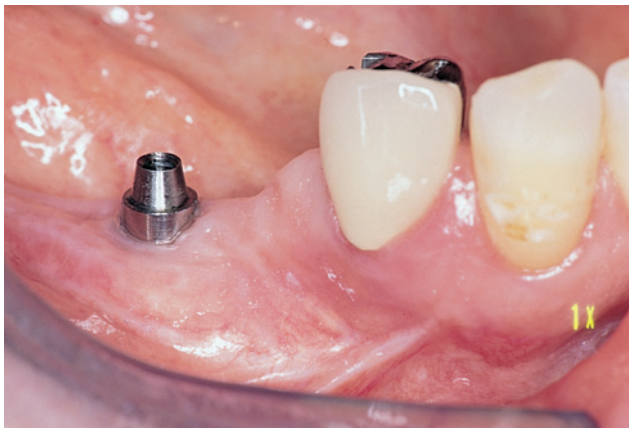


FIGURE 2-10 **F,** Implants are exposed 4 months after placement. The abutment is shown before final delivery of the prosthesis.

is unquestionably greater with iliac crest corticocancellous bone than with mandibular cortical blocks of bone. In addition, revascularization of the bone graft is more accomplished sooner with iliac crest corticocancellous bone than with the predominantly dense cortical bone harvested from the mandibular chin or ramus. The dense cortical bone of symphyseal or external oblique bone grafts undergoes resorption before revascularization is complete, with the natural remodeling and healing process of creeping substitution replacing the dense cortical bone. The iliac crest corticocancellous graft, with its volume consisting predominantly of cancellous bone and thin, less dense cortical bone, is revascularized before resorption and remodeling.

The ease of initial stabilization, the maintenance of graft bulk in the early phase of healing, and the ease of harvesting the dense cortical graft are advantages of the mandibular graft. However, the long-term consequence of remodeling by creeping substitution of the dense cortical graft is not known. Failure of the dense, predominantly cortical graft from the jaws can occur after the implant has been placed at the interface of the graft and mandible. Implant placement may jeopardize the limited vascular supply to the dense cortical bone, and thus the cortical bone may become necrotic after the implant has been placed. Although this phenomenon is rare, it is an adverse event that the patient does not appreciate.

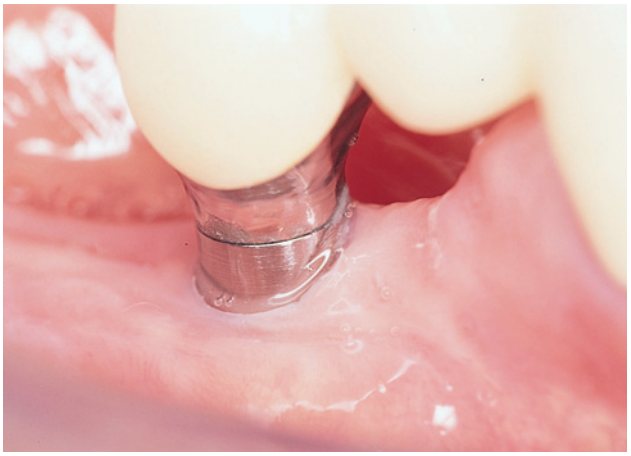


FIGURE 2-10 **G,** Close-up view of the final prosthesis. Healthy gingiva adjacent to the abutment can be seen, and the design of the prosthesis allows maintenance of oral hygiene (5-year follow-up). (Prosthetics by Dr. Israel Finger, Dr. Arturo Mendez, and Dr. J. Hochstedler.)

Iliac crest corticocancellous grafts revascularize early in the healing response, but they lose bulk faster than mandibular grafts during the initial consolidation phase. Therefore, the surgeon should be prepared to place implants at 3 to 4 months after placement of iliac crest grafts; by 6 months, the graft's bulk may be very small. The surgeon also should be prepared to place additional grafts when the implants are placed, because resorption of the bulk of the graft may be significant, and the pattern of resorption may be irregular. Long-term data from onlay grafts using iliac crest in the maxilla and mandible indicate that implant loading maintains the graft's volume and bulk. Long-term data are not readily available for dense cortical grafts taken from the chin or external oblique ridge. If a small area of incision dehiscence occurs with iliac crest corticocancellous grafts, only a small portion of the graft may be lost, because the cancellous bone is revascularized quite early. The small, exposed portion is kept clean with antibacterial rinses for as long as possible; as mobile pieces sequester, they are removed, which preserves most of the remaining graft. A large area of incision breakdown, however, may be associated with loss of most of the graft.

The iliac crest corticocancellous block of bone usually is harvested with an intact medial and superior cortex. The superior cortex will be the most superficial aspect of the graft when it is placed into the recipient site, and the medial cortex will be the facial aspect of the graft. The marrow of the corticocancellous bone graft is placed against the bone in the recipient site. If the recipient bone is dense and without evidence of perforating blood vessels, a small round bur is used to create small cortical perforations to promote healing. Rigid fixation of the graft to the recipient site is achieved with screws that are 1.5 mm in diameter after the graft has been modified so that it can be mortised to the recipient site. After the fixation screws have been placed and the graft is secure, the edges of the graft are trimmed gently to produce a smooth interface between the graft and native bone.

Graft Healing and Timing for Implant Placement. Opinion varies concerning the optimal time for implant placement after bone grafting. The graft must be allowed to heal and, through remodeling, attach itself firmly to the recipient bone. Many of the grafts from the chin or external oblique appear to have bone formation at the junction of the graft and recipient site with minimal visual changes along the graft's outer cortex. The cortical bone looks similar to its original appearance when placed because it has not yet been remodeled, which indicates that revascularization and graft replacement represent a long process and that continues for an extended period after implant placement.

General recommendations for implant placement after grafting depend on the size and source of the graft. Larger grafts may need 6 months or longer before implants can be placed. Small grafts can be exposed for implant placement at 4 months. Iliac crest grafts demonstrate resorption with lack of bulk earlier than chin or ramus grafts; therefore, for most iliac crest corticocancellous onlay block grafts, this author places implants at 3½ to 4 months after hip grafts to the jaws.

Implant Placement into Grafted Bone. The preoperative assessment should include the standard restorative workup, which should have been performed before the graft procedure. In addition to performing the usual preoperative examination, the surgeon should palpate the graft site to confirm graft stability, lack of graft mobility, and the position of the screws, as well as to anticipate the potential need for additional grafting if graft bulk has diminished.

At the time of implant placement, a local anesthetic is infiltrated in a manner similar to that for the ridge with adequate bone. Often the screws are easily visualized before the local anesthetic is administered. Because of prior surgery and the presence of scar tissue, administration of the local anesthetic may be slightly more painful at the graft site than previously noted before graft placement. After the anesthetic has taken effect, a crestal incision is made with adequate vertical release incisions to allow reflection of the gingiva, removal of the rigid fixation screws, and inspection of the graft. The graft is exposed, and the screws are removed. Any soft tissue in the screw sites also should be removed.

The technique for placing the implants is similar to that used for a nongrafted ridge, except that the use of osteotomes to expand the ridge is contraindicated. The implant site is prepared, the implants are placed, and the incisions are closed. After the normal period for integration has passed, the implants are exposed and restored.

Augmentation of a thin ridge with particulate materials

Rationale for Minimally Invasive Surgical Technique. Thin alveolar ridges prevent the placement of dental implants. A variety of autogenous,[1-11] allograft,[12,13] xenograft,[14,15] and alloplastic[16-18] onlay grafts, alone or in different combinations, has been used to provide sufficient ridge width for proper positioning of endosseous implants. Onlay grafts of block bone from the ramus or symphysis often are used to augment a thin ridge. These grafts require a second surgical site, which adds morbidity to the procedure. Patients complain of discomfort at the harvest site. In a small number of patients, damage to the inferior alveolar nerve occurs, resulting in lip and chin sensory deformity or numbness of the anterior dentition. The ideal procedure would be simple to perform, involve no secondary sites for bone harvesting, and allow the patient to return to daily activities the day after graft placement.

The use of a particulate material "from the shelf" eliminates the need for a second surgical harvest site. Particulate HA, when used as an onlay graft, increases the vertical and horizontal ridge dimensions for improved denture retention. In several studies,[16,17,19] when adequate denture retention was not achieved, treatment was planned to include implant-retained overdentures. Typically, these patients were treated more than 5 years after HA ridge augmentation. The HA-augmented ridge was entered to place implants, and bone consistently was found within the HA ridge. If space is maintained under the periosteum with an osteoconductive particulate graft, bone ingrowth occurs within the graft material. The osteoconductive material must be present for a sufficient time for bone infiltration to occur. If the shape of the ridge resembles a two-wall or three-wall defect, this affects bone formation within the particulate graft.

Tunneling procedures are simple to use and have a long history with HA augmentation. However, an open technique is useful because it allows complete visualization of the thin bone to be augmented; creates space between the periosteum and bone; and allows the use of a combination of graft material, with membranes used for larger or more complex defects.

When an open technique is used, some method must be added to maintain the particulate augmentation material in the ideal position. Membranes can be used with tenting screws, or the particulate mass can be held together as a composite using tissue-derived adhesive. In one study reporting on augmentation of thin ridges using an open technique, the osteoconductive material chosen was bovine bone combined with particulate bone shavings from the ramus, held together by tissue sealant (fibrin glue).[20] The composite graft was molded to the thin ridge, and the incision was closed without tension. Long-term results included excellent bone formation that allowed the placement of implants into the augmented ridge.

A review of the literature shows common themes for successful bone formation within a particulate graft used to augment a thin ridge. If the periosteum is raised and the space is maintained with an osteoconductive material, bone ingrowth into the space can occur. For dental implants, the best result is a high density of bone formation within the augmentation without excessive loss of volume during the remodeling phase of the augmentation material. The ideal material for ridge augmentation used in implant reconstruction has the following characteristics:

1. The graft material should be able to maintain space for the interval necessary to achieve bone ingrowth and implant healing. Bone ingrowth should be rapid and of sufficient density for implant stabilization.
2. The resultant ridge augmentation should be stable over the period of graft consolidation and implant integration, which may be 6 to 8 months.
3. The resultant ridge augmentation should be stable after the implants have been restored, without evidence of bone loss.
4. The graft material should be able to promote osteoconduction of the neighboring cells to form bone within the augmentation.
5. The bone augmentation material should be able to be remodeled eventually into long-lasting bone based on the functional matrix theory.[21]
6. The augmentation material should be easy to place, preventing patient morbidity.
7. The graft material should have predictability, with an incidence of success at least equal to that for onlay grafts.

Human mineralized bone can be used as the bone augmentation material for horizontal ridge augmentation of the thin mandibular ridge, because this material satisfies the criteria previously listed. The technique used is similar to the ridge augmentation methods described for HA augmentation of the edentulous ridge.[16,17] Because of the bone ingrowth found within HA-augmented ridges, without the use of membrane barriers, and the evidence of the osteoconductive nature and slow resorption of mineralized bone particles, a subperiosteal tunneling approach, with placement of the particulate graft material directly on bone, is performed in patients whose alveolar ridges had sufficient

height but insufficient width for implants.[22] The open approach, as described[20] can be a useful alternative.

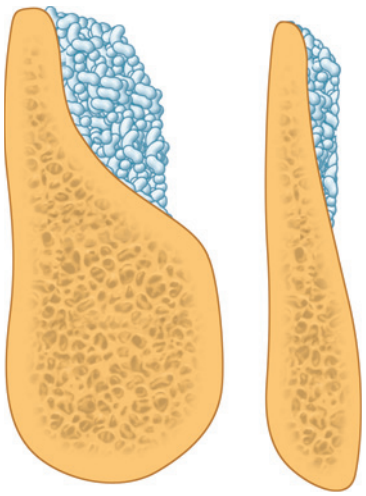
Realistic Expectations. All grafts undergo similar wound repair during the healing process. To be successful, a particulate graft must become vascularized by ingrowth of new blood vessels; must recruit bone cells from the periphery; must form woven bone; and then, during the remodeling process, must form lamellar bone and resorb the graft particles. In a solid piece of bone consisting predominantly of cortical bone (e.g., ramus and symphyseal bone in adults), the interface is slowly revascularized, which is followed by creeping substitution of the block graft and replacement with new bone. Loss of bone volume occurs with all grafts. With the particulate graft, the volume of new bone formed is less than the volume of the original graft.

In this author's patient series, the particulate graft augmentation procedure has been predictable and has provided patients with a less morbid alternative for augmentation of the thin ridge. This procedure is useful for augmentation of the thin mandibular posterior ridge, single-tooth concave ridge forms, and anterior maxillary combined deformity. As with all onlay procedures, the amount of augmentation has limitations, and all patients do not form bone equally. The clinician should plan on 25% to 50% resorption of the augmentation's width, which usually results in sufficient bone for implants. For example, if a 2-mm ridge is augmented to a width of 8 mm, the resultant ridge will be 5 mm, which is adequate for implant placement. Graft resorption can be unpredictable, therefore patients need to be followed during the first 2 years after graft placement for monitoring of the graft.

Patient Selection Criteria. Patients are selected for this procedure if they have a satisfactory vertical ridge height but less than 4 mm of bone width, which prevents the placement of small-diameter implants. A prosthetic plan for future implant restoration must be confirmed so that the clinician knows where to place the graft and the final restoration can be realized.

The ridge form may contribute to augmentation success. If the thin ridge is isolated to the superior aspect of the jaw, with the body of the jaw wide, a two-wall defect is present. The augmentation material will "sit" on the wider area, and the graft therefore will have less tendency to migrate. A thin ridge that does not have a wide "seat" platform is less likely to be augmented successfully (Figure 2-11).

Posterior Mandibular Edentulism. Patients in whom the molars and premolars are missing often have a thin alveolar ridge. Augmentation of the width of this thin ridge can be accomplished either by an onlay of bone harvested from the mandible or by subperiosteal placement of a particulate graft. The subperiosteal particulate graft technique can reduce patient morbidity; provide a minimally invasive surgical technique; and reduce the incidence of sensory nerve damage to the lips, chin, and teeth.



● **FIGURE 2-11** Ridge form affects the success of onlay particulate grafts. A ridge with a wider inferior aspect reliably holds a graft in position. If the ridge is thin and without a wider inferior aspect, the resultant graft width at the crest is not as predictable.

Surgical Technique. A topical anesthetic is applied to the edentulous ridge. A local anesthetic with constrictor is infiltrated under the periosteum of the edentulous ridge, creating a hydropic dissection. Administration of the anesthetic solution is carefully limited laterally to the external oblique ridge and posteriorly to the retromolar pad, avoiding the peripheral muscle attachments. It is critical to define the augmentation by the anesthetic solution and dissection so as to prevent migration of the augmentation material. Ten minutes are allowed before the start of surgery.

The location of the incision is designed to promote easy closure, provide access to the ridge, and limit loss of the graft if incision breakdown occurs. The incision locations described in the previous edition of this text were adjacent to the tooth closest to the edentulous site. This incision was easy to close and provided ease of access for the thin ridge. However, if incision dehiscence occurred, loss of the graft occasionally prevented implant placement adjacent to the tooth. A modification of the original incision location, which now is recommended, is to make the incision anterior to the most distal tooth from the junction of the attached gingiva inferiorly. The periosteum is incised, and a subperiosteal tunnel is made starting one tooth anterior to the thin ridge. This way, if the incision breaks down,

minimal loss of graft occurs, and the chances are better of being able to place an implant adjacent to the most distal tooth (see Video 2-1).

The vertical incision is made in the gingiva in the area of the interdental gingiva of the tooth anterior to the edentulous ridge. The incision to access the thin ridge is made starting at the junction of the attached and unattached gingivae, running inferiorly and anteriorly from the planned augmentation site in a vertical manner (Figure 2-12, A-J). The incision should not cross the crest to the lingual mucosa. If the lingual mucosa is cut, closure of this tissue is difficult and prone to breakdown.

A small periosteal elevator is used to develop a subperiosteal tunnel posteriorly to create a well-defined pocket. When creating the subperiosteal tunnel, the surgeon should maintain lateral external oblique and retromolar pad tissue attachments. Care must be taken to avoid excessive dissection; the dissection must be limited to the external oblique ridge and anterior to the retromolar pad, without violation of the peripheral muscle attachments.

At the crest of the ridge, the periosteum is elevated slightly over the ridge to release the periosteal attachment of the lingual mucosa at the crest. At the site of the incision, the tissue also is reflected anteriorly to allow a tension-free closure.

After the subperiosteal tunnel has been formed, the particulate material is placed. The volume needed ranges from 0.5 to 1 ml for two tooth sites to 1.5 ml for missing premolars and molars. Delivery of the particulate graft is simplified by using a 1-ml plastic syringe with the tip cut on a bevel, similar to the syringes used in the past for subperiosteal placement of particulate HA for ridge augmentation. The human mineralized bone graft material is hydrated and mechanically placed into the 1-ml syringe. The recommended particle size is 350 to 500 μm, and the source is either cortical or cancellous mineralized freeze-dried bone. For larger augmentations (1.5 ml), two syringes are used to facilitate

Horizontal Ridge Augmentation Using the Tunneling Technique

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for horizontal ridge augmentation using the tunneling technique, which is performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

A local anesthetic was infiltrated along the edentulous ridge to the lateral aspect of the external oblique ridge up to the posterior tooth. Care was taken to limit periosteal hydropic dissection to the desired location of the augmentation. Two carpules of 2% lidocaine (Xylocaine) with 1:100,000 epinephrine were used. Ten minutes were allowed for absorption of the local solution and vasoconstriction to occur.

The incision is made anterior to the distal tooth, in the unattached gingiva and through periosteum, taking care to avoid the mental nerve, which is anterior and inferior to the planned incision site. A small periosteal elevator is used to create a subperiosteal tunnel. The periosteal elevator elevates the anterior edge of the incision to facilitate later closure. The periosteal elevator is introduced with the bevel directly against the bone, subperiosteally. The periosteum is elevated *only* in the planned area of the augmentation. A finger is kept on the lingual aspect to prevent the surgeon from being overaggressive with the tissue elevation. The periosteal elevator continues the tunnel creation to the posterior tooth. The subperiosteal tunnel is formed to the posterior tooth and limited laterally to the muscle attachments of the external oblique ridge. The crestal tissue is elevated carefully from the crest, with a very slight elevation of the lingual tissue, perhaps only 1 to 2 mm from the crest. Care is taken to avoid tearing the crestal tissue. This allows for a flat ridge form from the crest, because the augmentation material can be placed at the level of the crest.

After creation of the tunnel, the tip of a 1-ml plastic syringe is cut off, and a bevel is created using a scalpel blade. The graft material (here, human mineralized cortical bone particles 350 to 500 μm in diameter) is placed in the syringe. The syringe is introduced into the tunnel. Occasionally the incision may need to be enlarged slightly to accommodate the syringe; however, if the wide portion of the number 7 periosteal elevator can be introduced into the tunnel, the incision typically does not have to be enlarged. The syringe is placed into the subperiosteal tunnel to the most posterior portion, and a pumping action with the syringe is used to introduce the graft material firmly into the site. Usually 1 ml of graft material must be placed for a full posterior thin ridge. A second syringe is introduced to finish the augmentation. The incision is then closed; here, 4-0 chromic suture is used with a tapered SH needle. The fingers are used to mold the augmentation.

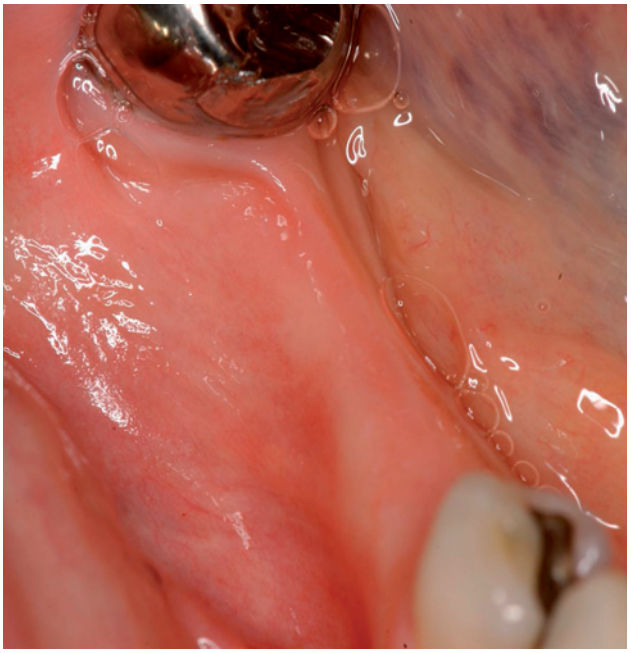


FIGURE 2-12 **A,** Unilateral thin mandibular ridge. Note that the thin ridge widens at the level of the external oblique ridge. A local anesthetic is administered only in the area of the planned augmentation.

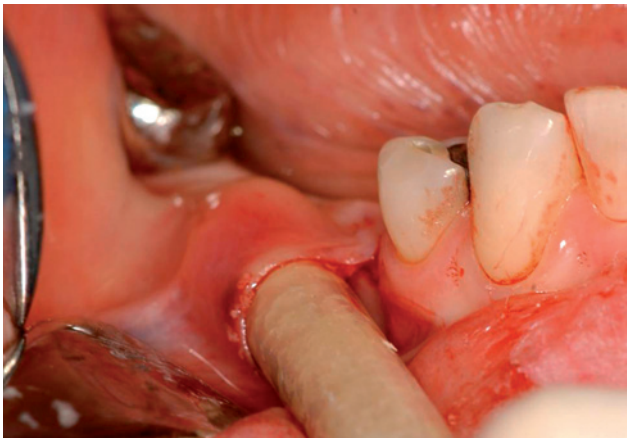


FIGURE 2-12 **C,** Syringe (1 ml) is used to deliver the particulate graft over the bone in the subperiosteal tunnel. It is important to avoid excessive dissection so as to keep the augmentation material confined to the planned augmentation area.

the surgery. Gentle retraction is provided by a small periosteal elevator, and the syringe is inserted into the subperiosteal tunnel with the bevel against the cortical bone, with care taken to place it directly onto bone. The syringe is advanced to the posterior extent of the dissection without tearing the gingiva at the incision site. The graft material is injected into

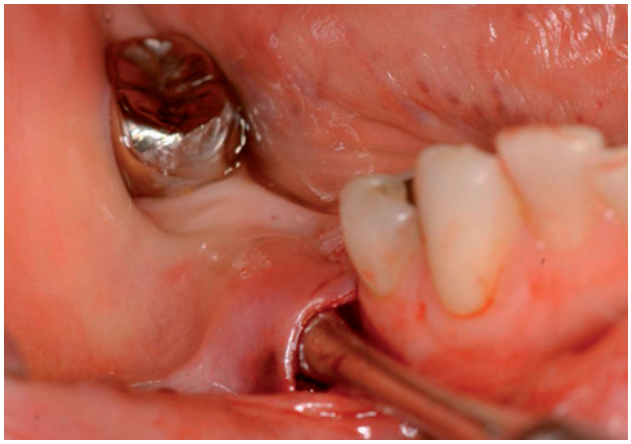


FIGURE 2-12 **B,** Incision is made through periosteum vertically near the remaining tooth, with care taken to prevent incision of the lingual crestal tissue. A subperiosteal tunnel to the posterior tooth is created, and the tissue attachments over the external oblique ridge are maintained.

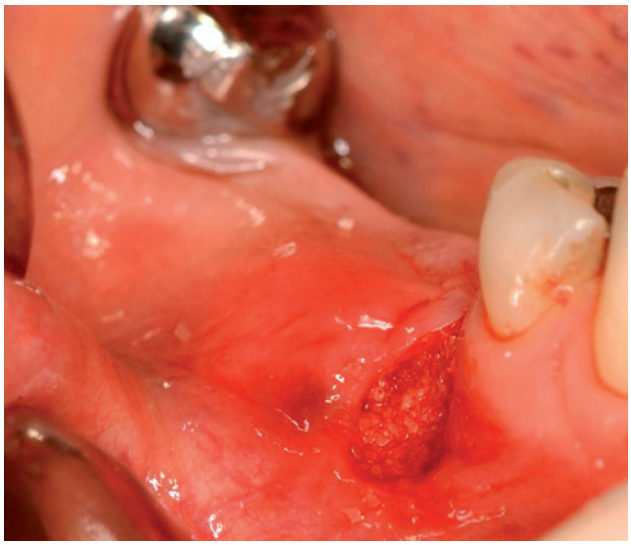


FIGURE 2-12 **D,** As the syringe is removed, the graft is pushed and compacted firmly in the tunnel.

the tunnel and compacted firmly to form a dense graft. The desired augmentation width is doubled by the augmentation; this allows for graft consolidation and resorption while achieving the planned ridge augmentation.

Digital pressure is used to mold the graft along the thin ridge to achieve the desired shape of the lateral ridge augmentation. The incisions are closed with minimal tissue trauma using resorbable sutures on tapered needles in

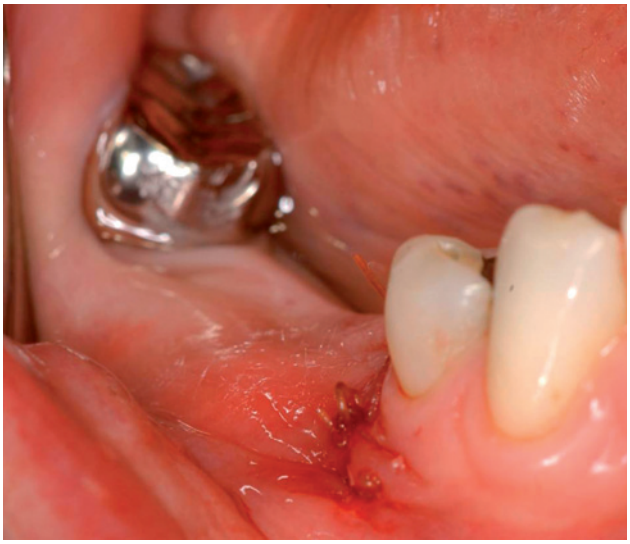


FIGURE 2-12 **E,** Resorbable sutures are used to close the incision without tension. Occasionally the mucosal margin may need to be elevated anteriorly to gain a tension-free closure.

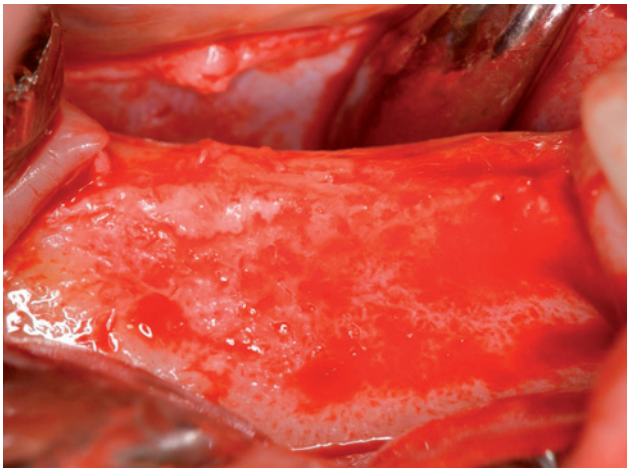


FIGURE 2-12 **G,** Crestal incision is used to bisect the KG, exposing the new bone.

either an interrupted or a running pattern, depending on the clinical situation and ease of closure.

The patient is given antibiotic and analgesic therapy. No prostheses are allowed over the grafted sites for 4 months. The patient is instructed to eat a soft diet, without chewing on the grafted side. The individual is followed weekly and then monthly. Clinical observation indicates that at least 5 to 8 mm of lateral ridge augmentation is common immediately after placement of the material, with subjective evaluation indicating maintenance of at least 50% of the augmentation

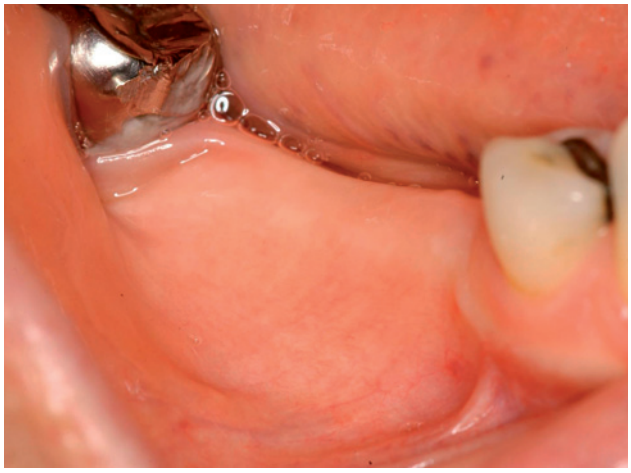


FIGURE 2-12 **F,** After 4 months the ridge should feel "bone hard" and should be well defined.

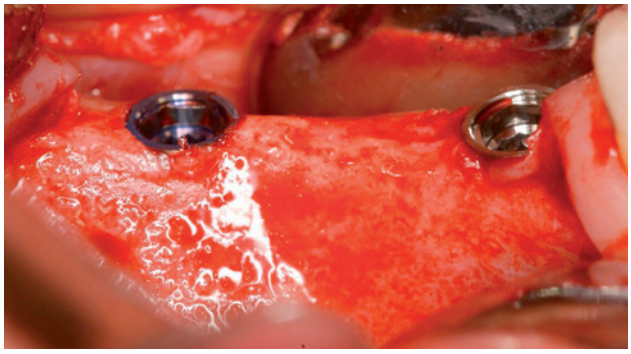


FIGURE 2-12 **H,** Two implants are placed. The new bone is clearly visible.

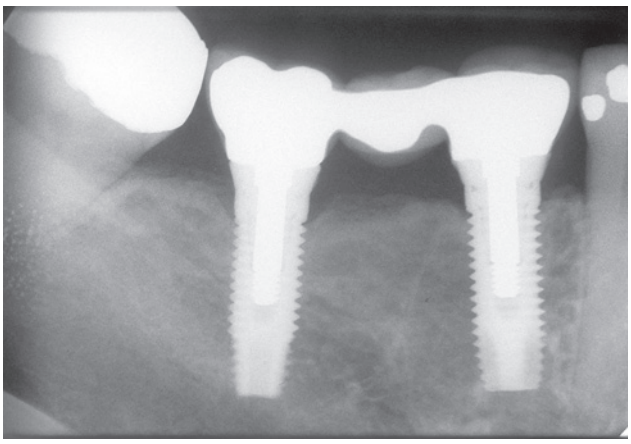
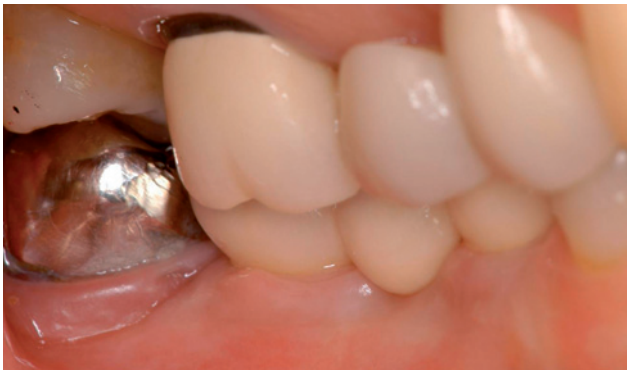


FIGURE 2-12 **I,** Radiograph 2 years after restoration shows excellent bone health around the implants.



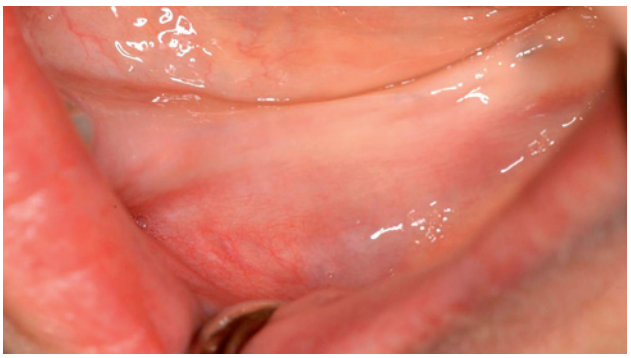
● **FIGURE 2-12** **J,** Two-year follow-up of the final restoration. (Prosthetic by Dr. Israel Finger.)

DVD Images 2-3, A-F

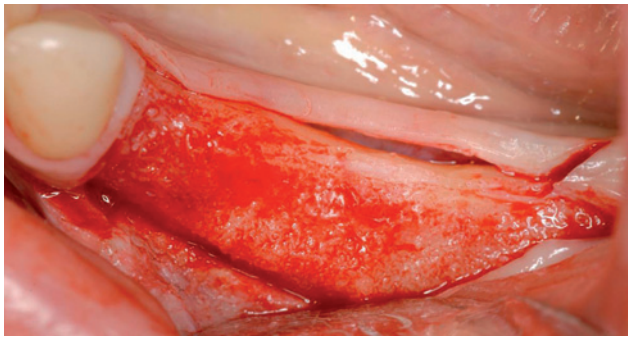
4 months later (Figure 2-13, A-D [the complete case is presented in DVD Figure 2-3, A-F], and Figure 2-14, A-H).

Case Example. Preoperative evaluation of this woman's right posterior mandible revealed a thin ridge with adequate bone height. A preoperative CT scan cross section showed the thin ridge with the labial bone resorbed in the desired implant locations (Figure 2-15, A). (See Video 2-1 for a demonstration of the surgical technique.)

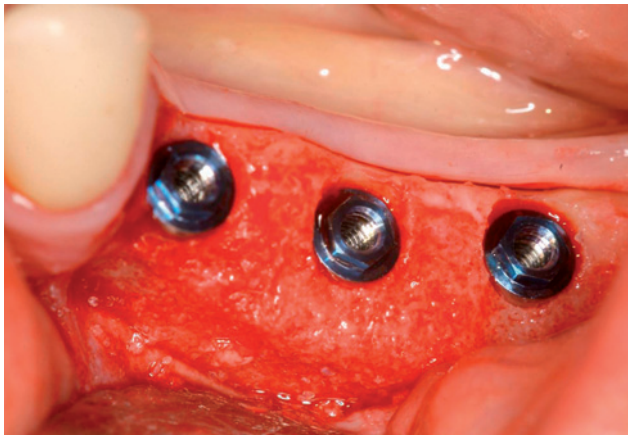
A local anesthetic was infiltrated along the edentulous ridge to the lateral aspect of the external oblique ridge up to the posterior tooth. Care was taken to limit periosteal hydropic dissection only to the desired location of the augmentation. Two carpules of 2% lidocaine with 1:100,000 epinephrine were used. Ten minutes were allowed for absorption of the local solution and vasoconstriction. The incision was made anterior to the distal tooth, in the unattached gingiva, through the periosteum. Care was taken to avoid the mental nerve, which is anterior and inferior to the planned incision site. A small periosteal elevator was used to create a subperiosteal tunnel. The lingual mucosa was elevated gently to



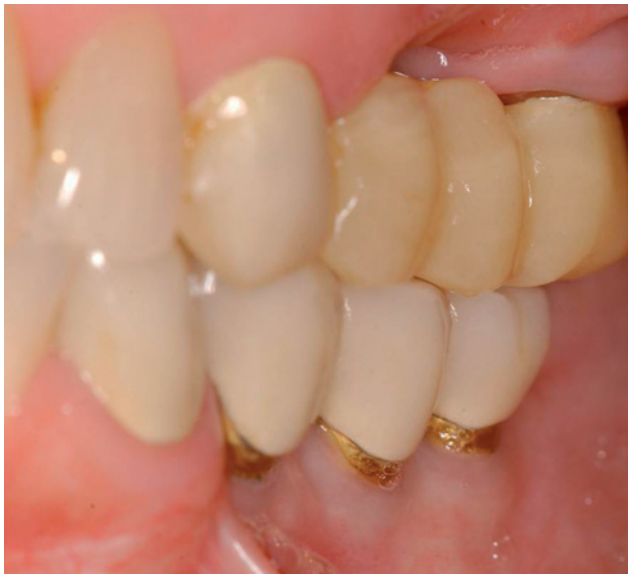
● **FIGURE 2-13** **A,** Preaugmentation view, with 2 mm of ridge width in the posterior mandible. The thin ridge, which is bilateral in this patient, is augmented using the tunneling technique.



● **FIGURE 2-13** **B,** Postaugmentation view of the left posterior mandible. The most superior 2 mm of the crest is narrow, but the ridge then widens to an appropriate width for implants.



● **FIGURE 2-13** **C,** Three implants are placed into the left posterior mandible.



● **FIGURE 2-13** **D,** Final restoration at 2-year follow-up. (Prosthetic by Dr. Mary Beilman.)

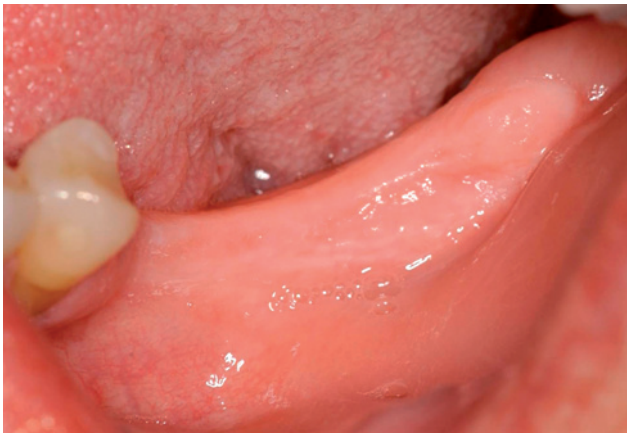


FIGURE 2-14 **A,** Preoperative photograph of thin left posterior mandible. The external oblique ridge is palpable and is felt to widen inferiorly approximately 6 mm from the crest.

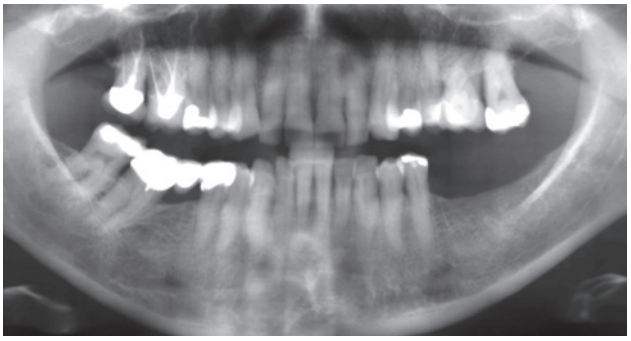


FIGURE 2-14 **B,** Preoperative panoramic radiograph showing the external oblique ridge inferior to the crest of the mandible.

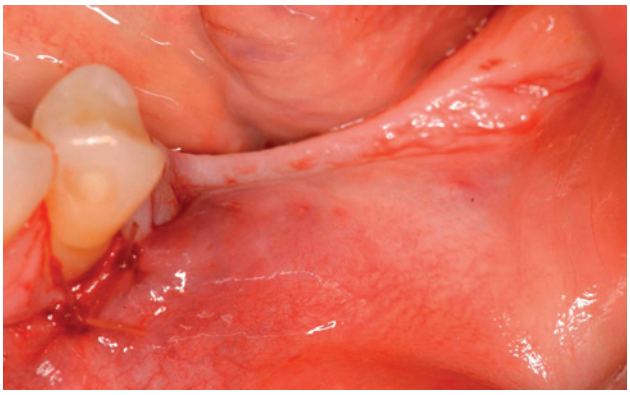


FIGURE 2-14 **C,** Thin left posterior mandibular ridge has been augmented and is shown here immediately after closure of the incision.

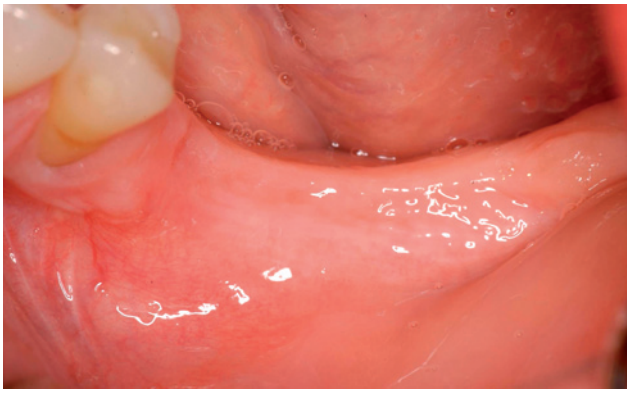


FIGURE 2-14 **D,** Four months after augmentation, palpation of the ridge form determines that it is wide enough for implants.

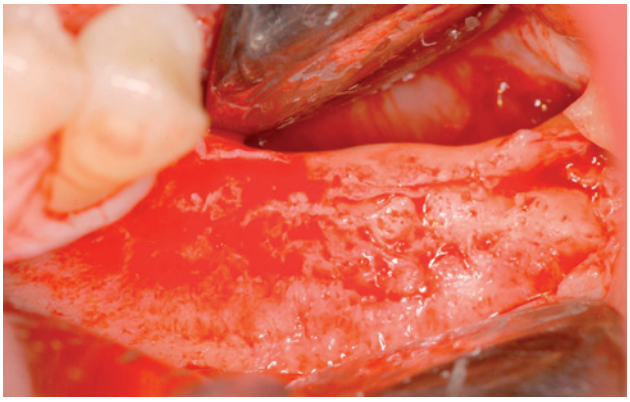


FIGURE 2-14 **E,** Crest is exposed, and the augmentation is confirmed.

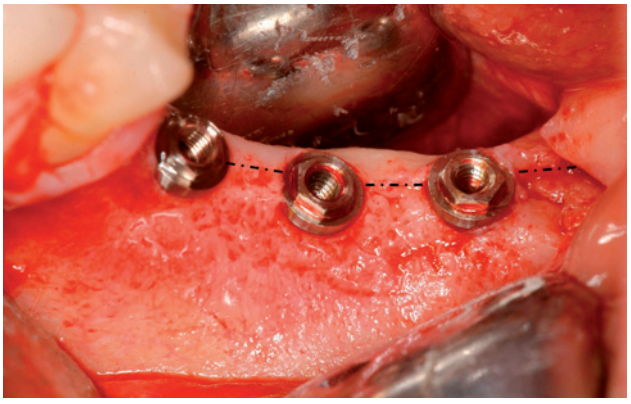
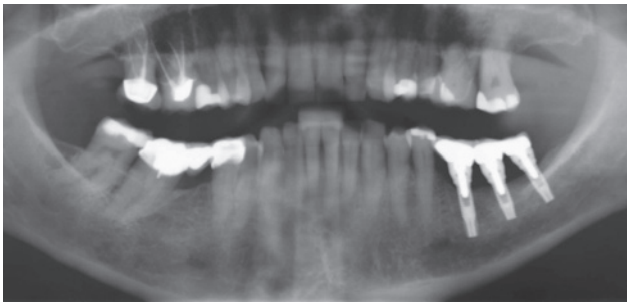
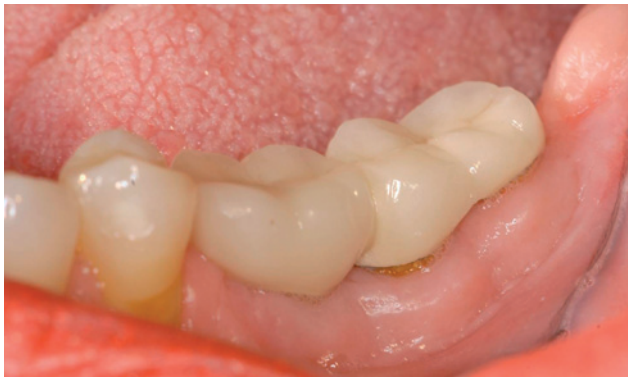


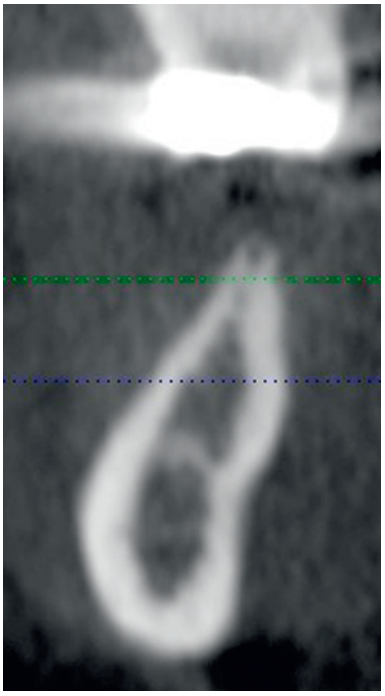
FIGURE 2-14 **F,** Three implants are placed in appropriate position for a freestanding, three-unit, implant-supported restoration. The *line* denotes the graft interface.



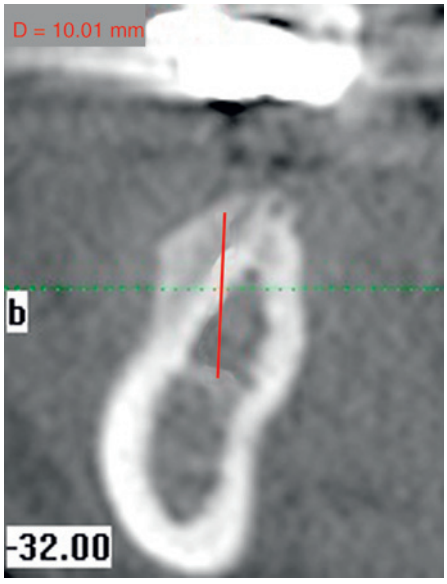
● **FIGURE 2-14** **G,** Panoramic radiograph taken 2 years after completion of restoration.



● **FIGURE 2-14** **H,** Photograph taken 2 years after completion of restoration. The soft tissue probing is less than 3 mm around the implants.



● **FIGURE 2-15** **A,** Preaugmentation cross section of the posterior mandible shows a narrow crestal area with widening approximately 7 mm from the crest. The ideal implant location is just labial to the most coronal aspect of the crest.



● **FIGURE 2-15** **B,** Augmentation has been performed as described in the text and portrayed in Video 2-1. Here, a cross section from a cone beam scan taken 4 months after augmentation shows the lateral ridge augmentation, for which particulate mineralized bone and a tunneling approach were used. The *red line* denotes the planned location of the implant.

allow for adequate crestal augmentation. Care was taken to avoid tears in the crestal tissue. The subperiosteal tunnel was formed to the posterior tooth and limited laterally to the muscle attachments of the external oblique ridge. The particulate mineralized bone graft was placed into the tunnel directly against the cortical bone. The bone was not scored. Adhesive factors (e.g., platelet-rich plasma or fibrin glue) were not used. The graft was compacted within the tunnel with the delivery syringe. After the graft had been compacted in place and form, the incision was closed with resorbable suture on a tapered needle. The ridge augmentation was shaped into the desired form by digital manipulation.

Postoperative care included avoiding pressure on the ridge and routine antibiotic coverage. After 4 months, a CT scan was obtained to confirm the graft's presence and adequate ridge augmentation. The implants then were placed (Figure 2-15, B-G).

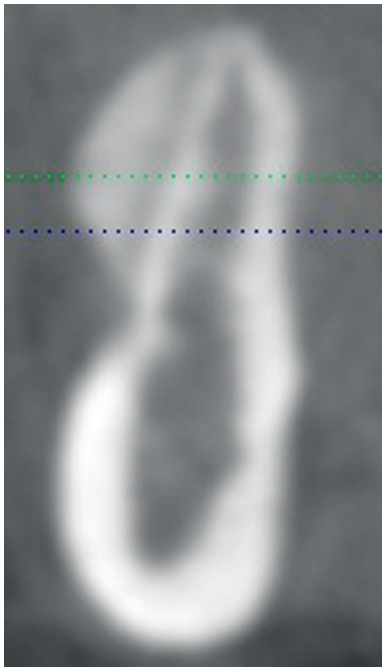


FIGURE 2-15 **C,** Cross section in the area of the mental foramen 4 months after augmentation. Note the well-positioned augmentation, which avoids the nerve.

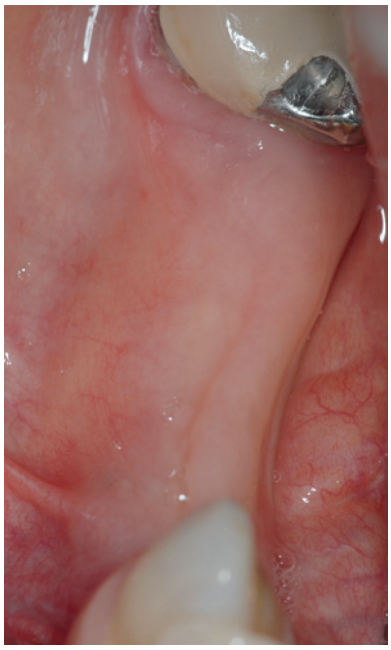


FIGURE 2-15 **D,** At 4 months, the ridge form now is broad and satisfactory for implant placement.

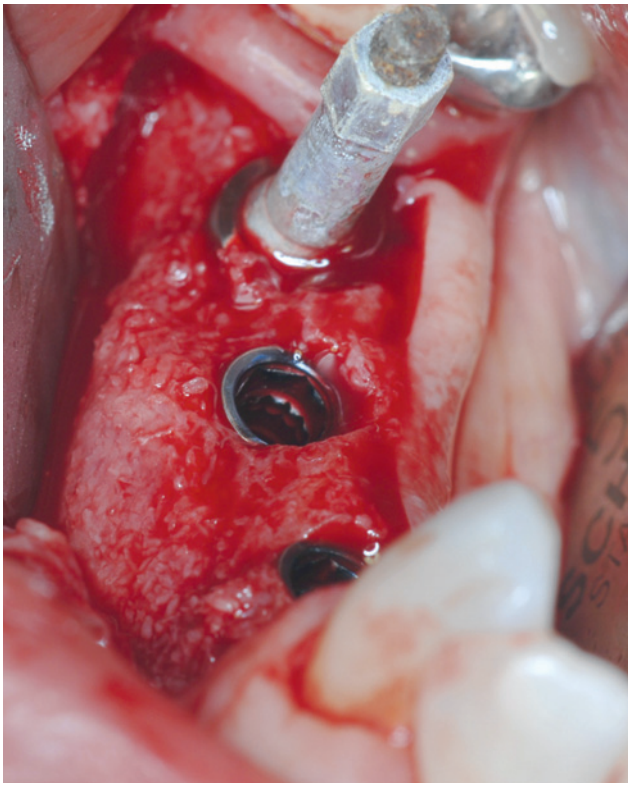


FIGURE 2-15 **E,** Three implants are placed in the appropriate position for the planned prosthesis. The implant stability quotient (ISQ) values, which were measured with the Osstell (Goteborg, Sweden), ranged from 75 to 78. Note the obvious lateral augmentation of the ridge.

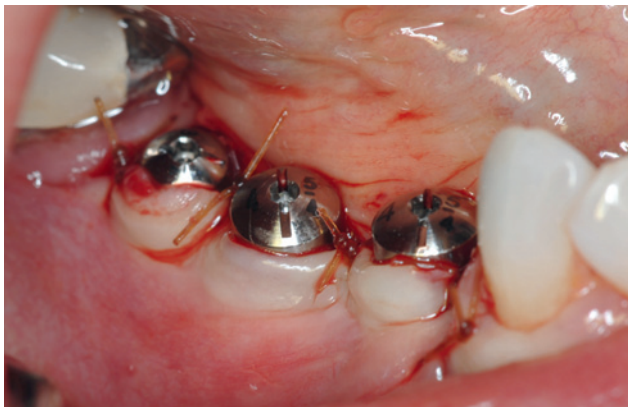
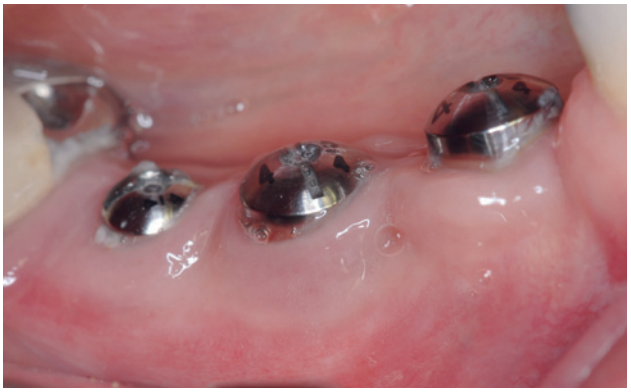


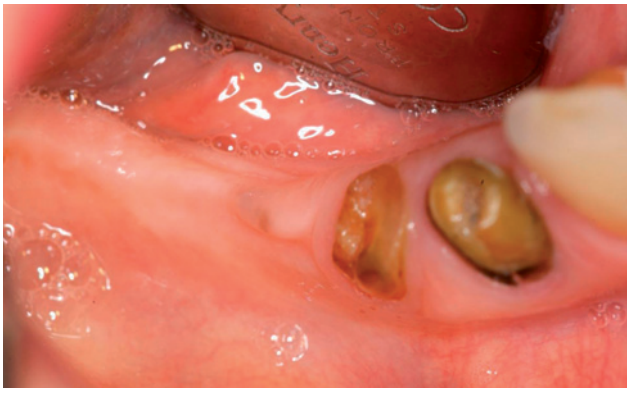
FIGURE 2-15 **F,** Because the ISQ values were greater than 70, healing abutments were placed to allow for a one-stage surgical approach. This patient did not wear a transitional prosthesis and followed dietary instructions to avoid chewing in these healing abutments.



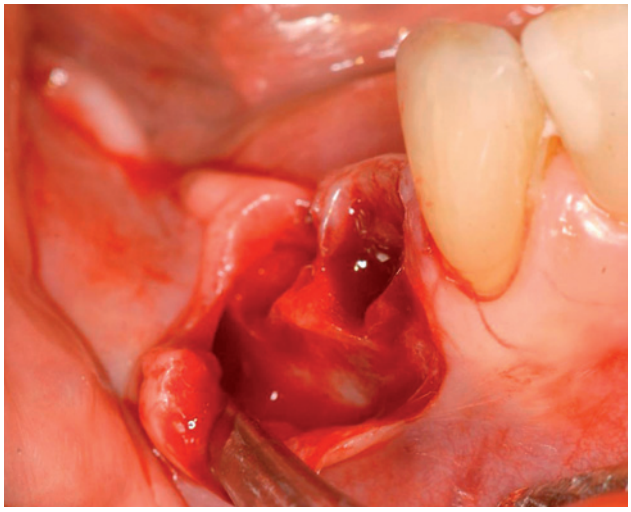
● **FIGURE 2-15 G,** Four months after implant placement, the healing abutments were removed. The ISQ values ranged from 78 to 80, indicating integration of the implants.

Extraction of Anterior Teeth Combined with Posterior Ridge Augmentation. In this case, the patient had been wearing a long-span fixed bridge. The tooth abutments have fractured and need to be removed (Figure 2-16, A-F). In these cases, the clinician often finds a thin ridge in the edentulous region.

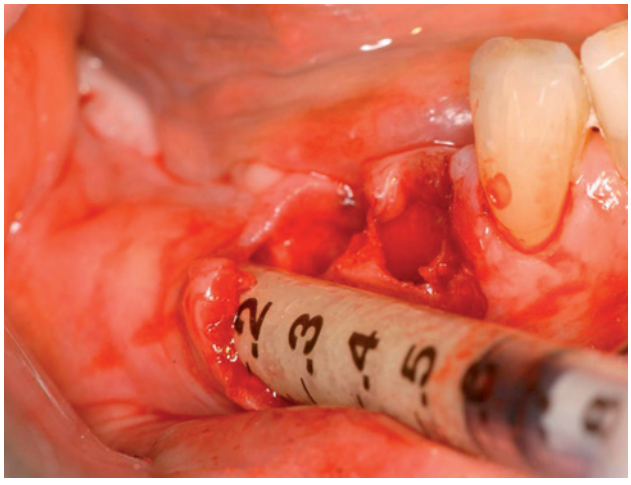
One vertical incision is made anterior to the most anterior tooth to be extracted. The incision is continued into the sulcus of the teeth to be extracted. After reflection of the labial gingiva over the extraction sites only, a subperiosteal tunnel is created from the distal aspect of the extraction site over the lateral aspect of the thin ridge. For posterior edentulous ridges, the dissection is taken to the retromolar pad. When a posterior tooth is to be extracted, the tunnel is taken to this tooth. A sulcular incision is used to gain access to the posterior tooth to be extracted. Often a vertical posterior incision is not necessary. The graft is placed into the extraction sockets after placement of the ridge augmentation graft.



● **FIGURE 2-16 A,** Patient with two fractured premolars that previously had supported a three-unit fixed bridge, with a molar cantilevered from the two premolars. The treatment plan is to extract the two teeth and augment the thin ridge posteriorly to allow placement of three implants.



● **FIGURE 2-16 B,** Vertical incision is made anterior to the first premolar and within the sulcus of the teeth to be extracted. A subperiosteal tunnel is made posterior to the second premolar site. The anterior incision and release of the tissue around the teeth allow sufficient room for the periosteal elevator.



● **FIGURE 2-16 C,** Syringe is placed. Note its posterior location.

Concave Ridge in Single-Tooth Site. A concave ridge is a common finding for a single-tooth site when the tooth was extracted and the socket was not grafted (Figure 2-17, A-E; DVD Figures 2-4, A-E, and 2-5, A-F). The concave ridge creates adequate vertical bone for implant placement but results in horizontal width problems. One treatment

DVD Images 2-4, A-E 2-5, A-F

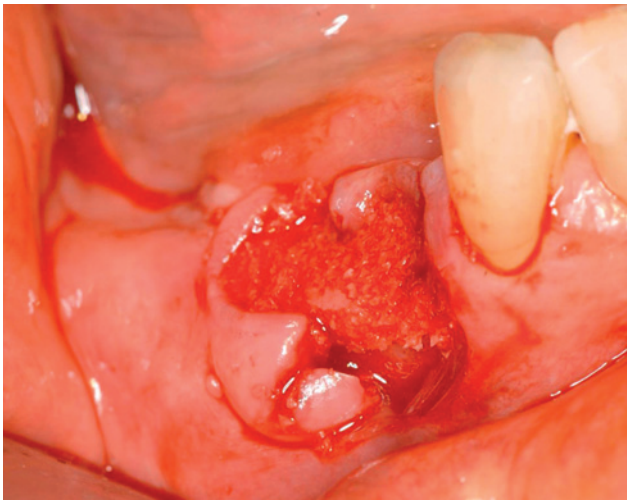


FIGURE 2-16 **D,** Posterior ridge is augmented, and the extracted sites are grafted.

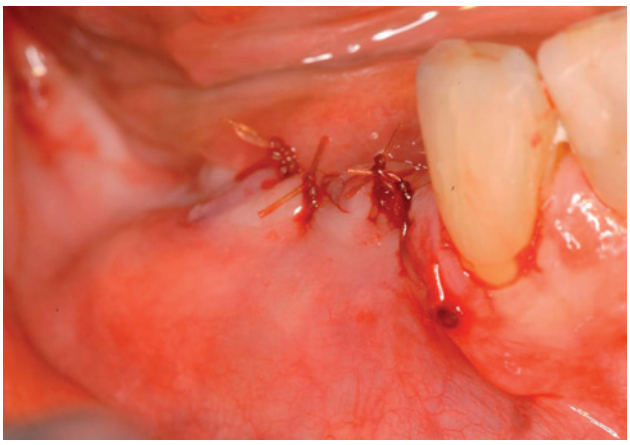


FIGURE 2-16 **E,** Site is closed primarily with resorbable sutures.

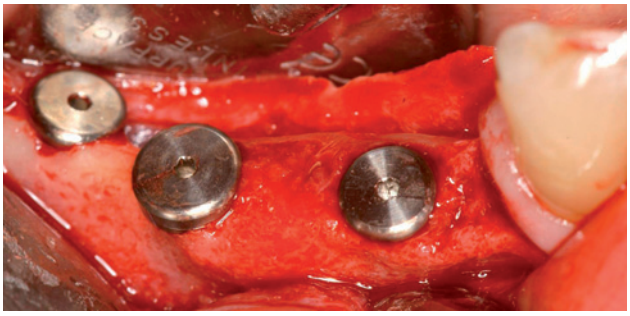


FIGURE 2-16 **F,** After 4 months, three implants are placed. Note the posterior augmentation, which is in the exact location as the syringe in Figure 2-16, C.

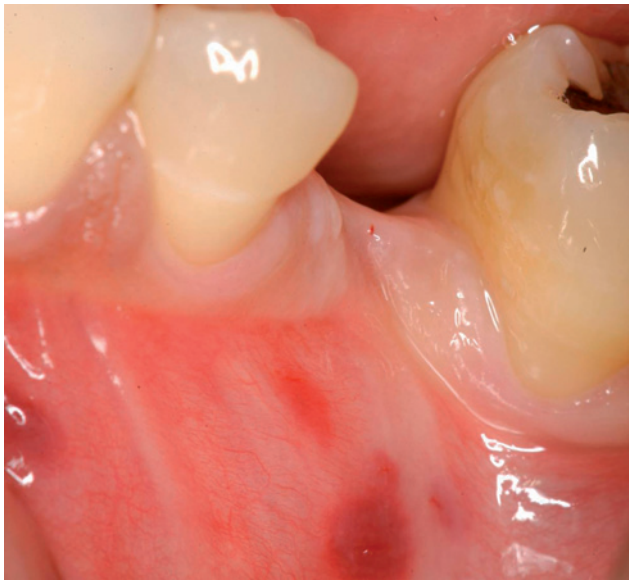


FIGURE 2-17 **A,** Patient whose treatment plan calls for placement of an implant to restore a missing second premolar. The patient had orthodontic therapy to create sufficient space for the implant, but the ridge width was only 2 mm. This view was taken after administration of a local anesthetic.

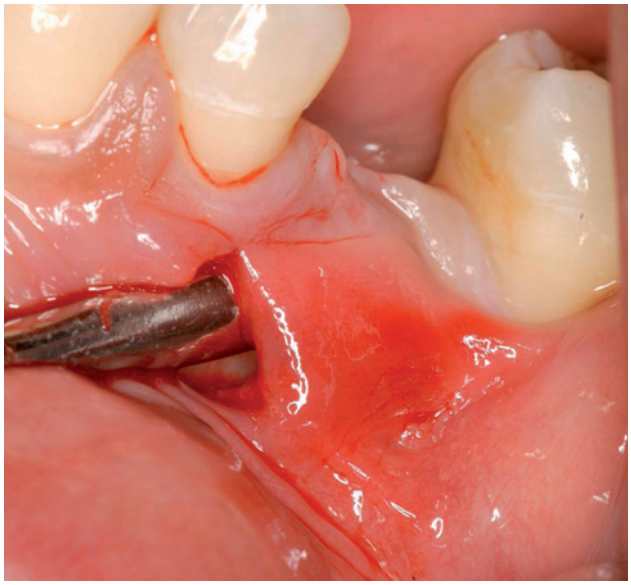


FIGURE 2-17 **B,** Incision was made anterior to the edentulous site, and a subperiosteal tunnel was made over the bone defect. The crestal mucosa was gently elevated to create a smooth transition over the crest of the ridge. The lingual mucosa was not elevated.

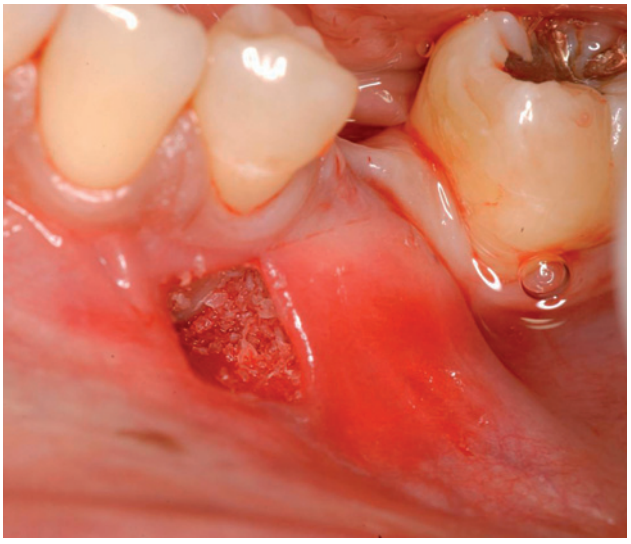


FIGURE 2-17 **C,** Human mineralized bone was placed to augment the horizontal aspect of the ridge.

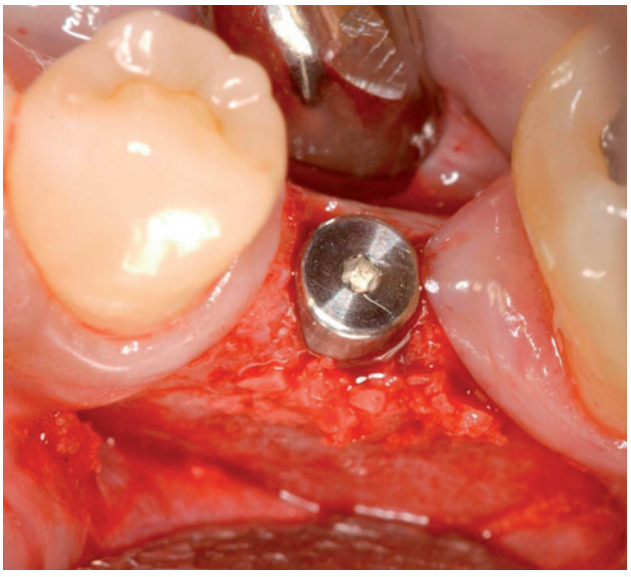


FIGURE 2-17 **E,** Small-diameter implant was placed into the augmented ridge.

option is placement of a small block of bone. Another option is to place a particulate graft either by a tunnel approach or by an open approach, with or without a membrane. The particulate graft method eliminates the morbidity associated with a second bone harvest site. If the particulate graft does not result in satisfactory width, a block graft from the ramus or symphysis still can be used.

A typical thin site is the missing first or second mandibular premolar. This tooth may have been lost secondary to extraction for orthodontic care, or space may have been

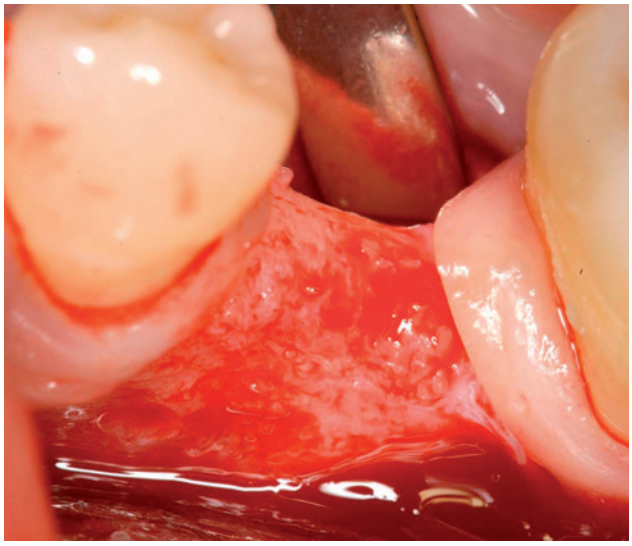


FIGURE 2-17 **D,** After 4 months of healing, the crest was exposed; bone width was sufficient for implant placement.

created for an implant when the permanent tooth was not present. For this thin ridge at the mandibular premolar site, particulate augmentation is a simple procedure. When examining these sites preoperatively, the clinician should note the presence or absence of a widening of the mandible, which creates a base onto which the particulate graft can settle. The clinician should note the width of the alveolus at the adjacent teeth, which most likely represents the final augmentation width that can be attained.

Surgical Technique. A local anesthetic is infiltrated only into the areas of the planned incision and dissection. Care is taken to limit the hydropic dissection to the planned augmentation so as to avoid particle migration. After 10 minutes, most of the fluid from the anesthetic will have dissipated, and a clean dissection can be obtained. An incision is made anterior or posterior to the augmentation site, with care taken to avoid the mental nerve. The incision is made full thickness to expose the bone on the lateral aspect of the mandible. A subperiosteal tunnel is created to allow tension-free tenting of the mucosa over the edentulous site and to achieve a smooth transition at the interface of the defect to the adjacent bone. The crestal tissue must be elevated without trauma to the overlying lingual mucosa. When the dissection is finished, the particulate graft is placed with the small syringe and molded to shape. Resorbable sutures then are placed.

Use of Fibrin Glue to Augment Ridge Width in an Open Approach. Fibrin glue can be used to hold the augmentation material in position. It is used routinely in neurosurgical and general surgical procedures to achieve hemostasis and to hold tissues together through the early healing process. Similar to the process of the well-known clotting cascade, the components of the fibrin glue "kit" activate

when combined to convert fibrinogen to fibrin. The fibrin glue kit used by this author (i.e., Tisseel, Baxter, Deerfield, Illinois) has two components that, when combined, create a rubbery cohesive material that can hold a graft together. Previous reports have indicated excellent success in lateral ridge augmentation and graft containment in sinus grafts.[20,23] In the sinus graft report by Hallman et al.,[23] bovine xenograft was combined with autogenous bone in a 80:20 ratio, and fibrin glue was used to hold the composite graft together in the sinus after membrane elevation. In their study of lateral ridge augmentation, Hellem et al.[20] used xenograft combined with autogenous bone in the same ratio, combined with fibrin glue. They placed the cohesive composite graft directly on cortical bone as an onlay, without a membrane. After 6 to 9 months, the graft had sufficient bone formation and stability for implant placement. Based on these two reports, this author has used a similar approach for large and small defects.

The scientific basis for the use of fibrin glue is as follows: A highly concentrated solution of fibrinogen aprotinin, containing factor XIII, is warmed to 37° F. This solution is added to the graft or composite graft (e.g., allograft and autogenous bone or bovine xenograft plus autogenous bone). After thorough mixing, a solution of thrombin and calcium chloride is added, and coagulation occurs. The presence of factor XIII causes the fibrin to cross-link, which gives the coagulate mass additional strength. To maintain the shape of the graft, slow absorption is required, which the aprotinin provides as an antifibrinolytic agent. Varying the aprotinin concentration affects the resorption of the fibrin glue composite, which may be desired if the patient is known to have low fibrinolytic activity. The fibrin glue kit comes with the solutions necessary to prepare the materials in both vials. It is important to follow the preparation instructions exactly, including cold storage.

A thin ridge in a single- or multiple-tooth area may be easier to augment from an open approach. When a particulate graft is applied with an open approach, containment of the graft in the desired location with minimal migration is critical for success. Lateral ridge augmentation of small defects using membranes or block grafts may provide excellent results, but incision dehiscence can be difficult to manage with graft preservation. The use of fibrin glue to create a coagulated mass of particulate graft material results in ridge augmentation and allows later implant placement.

Surgical Method. For the mandibular premolar or molar region (Figure 2-18, A), a crestal incision is made with sulcular release anteriorly and posteriorly. Vertical incisions often are not necessary but can be used. Keeping the incisions within the sulcus of the adjacent teeth allows for ease of closure and avoids the location of incisions directly over the graft site. The edentulous thin site is infiltrated with a local anesthetic, and a hydropic dissection is performed in the intended graft site. After a satisfactory time for the vasoconstrictive effect of the local anesthetic has elapsed, a crestal incision is made with a 15c blade; the incision is carried anteriorly and posteriorly in the sulcus of the adjacent teeth. The periosteum is incised, and a conservative subperiosteal reflection is completed, exposing the concave bone defect (Figure 2-18, B). The graft material (e.g., mineralized bone allograft or bovine xenograft) is placed in a small bowl. The more viscous solution of the fibrin glue kit is warmed and combined with the graft. Less material is needed than expected, because the coagulative response is very strong. The antifibrinolytic agent forms a barrier that can limit angiogenesis into the graft; therefore, use of less of the fibrin glue product is better than more.

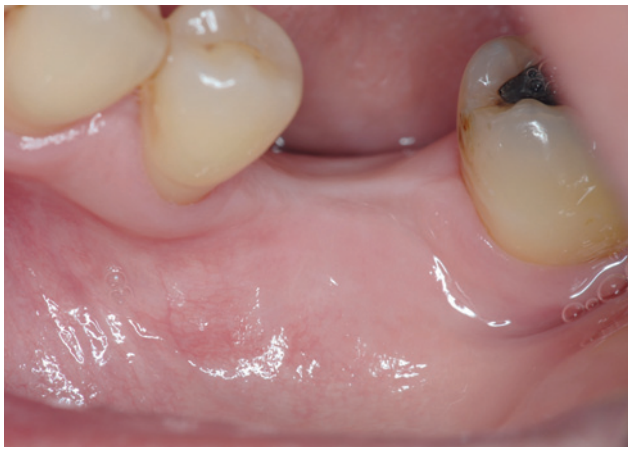


FIGURE 2-18 **A,** Preoperative view of a ridge that is narrow in the buccal dimension at the crest. The ideal implant position is labial to the crestal coronal aspect.

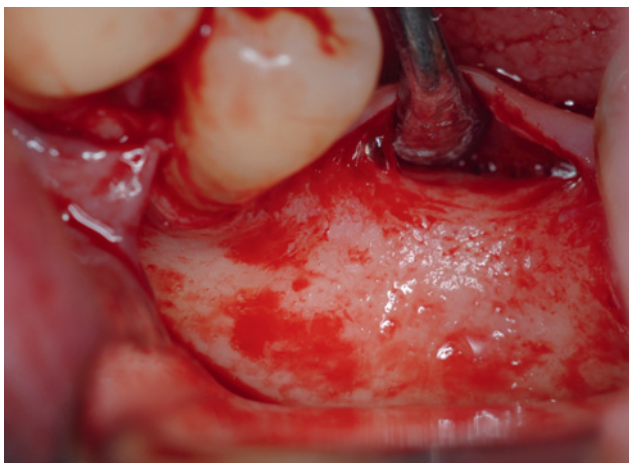
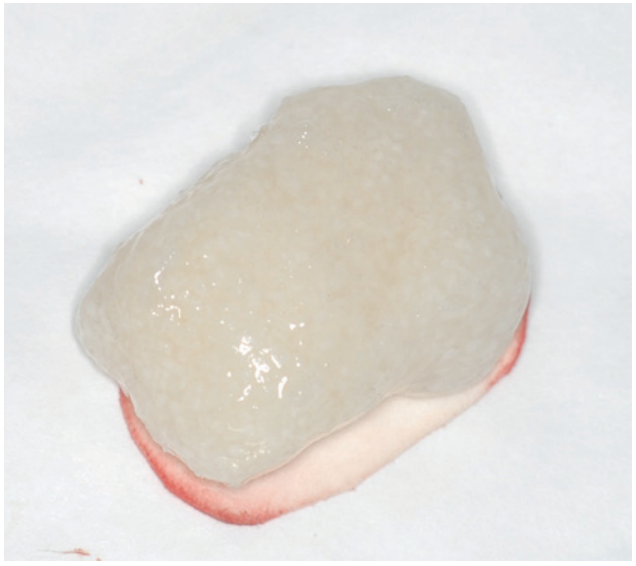


FIGURE 2-18 **B,** Crestal incision is made with a vertical release anterior to the adjacent tooth only in the anterior aspect, combined with a sulcular incision around the posterior tooth. The thin ridge is identified.

● **FIGURE 2-18** **C,** Protein powders in each container are reconstituted and warmed according to the manufacturer's directions.

● **FIGURE 2-18** **D,** Xenograft is mixed with the viscous component of the fibrinogen, and the less viscous calcium chloride and thrombin are then mixed to form a coagulated mass.



● **FIGURE 2-18** **E,** Coagulated mass can be molded into a template with the fingers; this allows accurate positioning with minimal manipulation at the surgical site.

After the fibrinogen components have been mixed with the graft particles, the solution containing the thrombin and calcium chloride is added and mixed. The resultant coagulation response is quite rapid (Figure 2-18, C-E). The graft composite now can be molded and placed directly over the concave bone, resulting in a convex bone ridge profile (Figure 2-18 , F). The incisions are closed with resorbable sutures using a tapered needle. If necessary, the periosteum can be incised prior to graft placement to facilitate a tension-free closure (Figure 2-18, G). A membrane can be used, depending on the clinician's preference.

Postoperative management consists of antibiotic coverage for 7 to 10 days, avoidance of pressure on the ridge, and the application of ice to reduce facial swelling. After 4 months have been allowed for graft consolidation, an implant can be placed (Figure 2-18, H-I).

Single Concave Site in the Anterior Maxilla. A classic case involves the lateral incisor region. The surgical technique is modified to account for the defect's anatomy. Most likely, the crest will be thin, and the ridge will widen as the bone approaches the nasal floor. If the incision is made in the vestibule, secondary scar contracture occurs, and establishing a well-defined subperiosteal tunnel may be difficult. For the incisor region, a crestal incision is made, and a full-thickness subperiosteal tunnel is created. The concave ridge mucosa is transformed to a convex form, and the particulate graft is placed. If necessary, the palatal tissue can be reflected from the crest and a primary closure obtained. In situations involving more than one tooth site, the crestal incision can be combined with a sulcular incision around the adjacent teeth. Vertical incisions are *not* recommended in the esthetic zone.

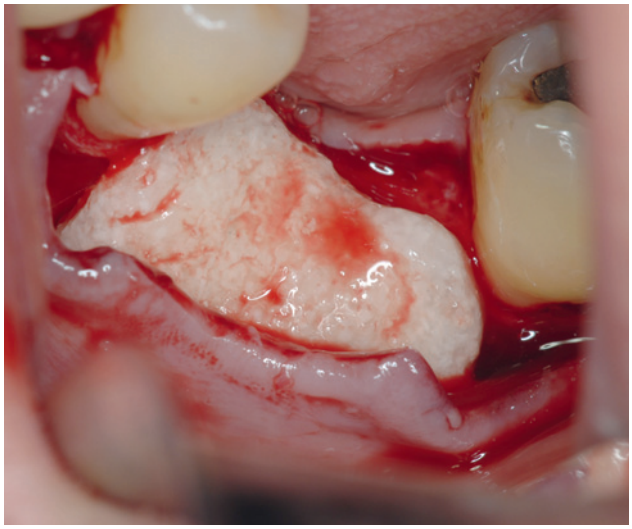


FIGURE 2-18 **F,** Composite is placed over the ridge. Slight overcontouring is recommended, because some settling of the graft occurs to the limits of the periosteal release.

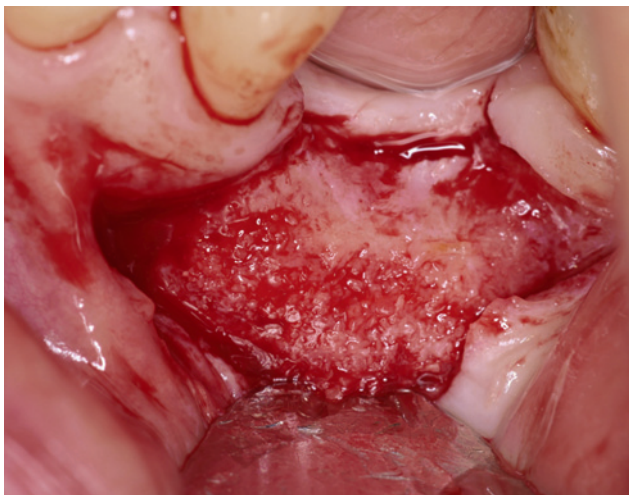


FIGURE 2-18 **H,** Four months after grafting, the area is exposed for implant placement. Sufficient lateral augmentation of the ridge has been achieved to allow ideal implant placement.

Results and Observations. Incisions healed uneventfully in 80% of patients with particulate augmentation of thin ridges, with loss of a small amount of the graft adjacent to the incision when the incision had a small area of breakdown. The breakdown resulted from carrying the incision across the crest, including the lingual mucosa, which did not heal well. Incision breakdown also occurred when the incision was placed too close to the adjacent tooth and not

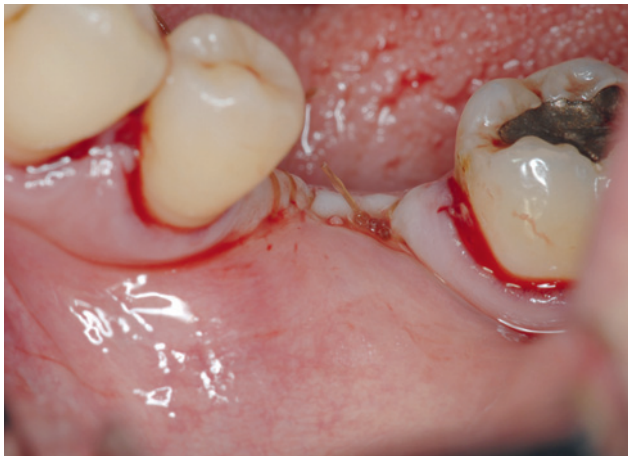


FIGURE 2-18 **G,** Incision is closed primarily and is tension free.

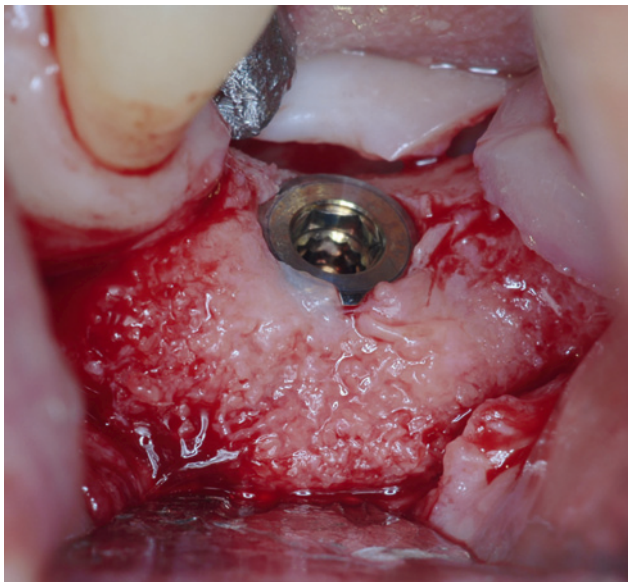


FIGURE 2-18 **I,** Implant is placed in the ideal position.

anterior to the planned augmentation site. The open incisions healed within 7 days by secondary intention.[22]

The augmented ridges usually are firm to palpation within 2 weeks and feel "bone hard" after 3 months. At 3 months, radiographs are taken, and the patient is scheduled for fabrication of the surgical guide stent and implant placement, which is planned 4 months after the augmentation procedure.

At implant placement, the surgeon should have examined the patient to determine the diameter of the implant to be placed. Small-diameter implants may be indicated if resorption results in a ridge 4.5 mm wide. If the ridge

is too narrow because of loss of graft material at the incision site, implants can be placed posterior to the site and a tooth cantilevered, or additional grafting may be performed.

Immediate provisionalization using a CT-generated guide stent

The patient presents with missing posterior mandibular teeth. He requests placement of provisional teeth to fill the spaces, if possible. Two treatment methods were used in this patient. One method involved model-based surgery to prepare a provisional restoration, and the second method involved a CT-generated prosthesis. The model-based surgery was very similar to that presented in a later chapter. This section focuses on the method in which a CT-generated surgical guide is used to fabricate a provisional restoration.

At the time of surgery, the implants were placed with minimal flap reflection, and the provisional restoration was placed with minimal need for modification. The reduction of surgical and prosthetic chair time and procedures resulted in high patient satisfaction because of minimal pain and swelling in the postoperative period.

The decision to use CT guidance to aid implant placement and immediate provisionalization must include balancing of the advantages and disadvantages. When placing implants into bone with adjacent teeth, the surgeon should place the implants accurately within the ridge, parallel, and with sufficient interimplant space for ease of restoration. The implant's surface should be 2 to 3 mm from the adjacent tooth, with its central axis within the intended premolar crown, which is 7 mm wide. The most common error in replacement of a premolar is to place the implant distal to the ideal location; this results in placement of the implant into the embrasure. A typical molar is 9 to 11 mm wide, and implant placement should take this into consideration. The distance from a premolar to the central axis of a molar is thus 5 to 6 mm from the adjacent tooth. Mapping the size of the teeth to be restored facilitates accurate implant placement. It is important to use any technique that increases the accuracy of implant placement so as to avoid malpositioning of the implants. Most surgeons can angle the implants to occlude with the working cusp of the opposite arch, but spacing adjacent to natural teeth may be more prone to error. The angulation of the adjacent tooth's crown, the angulation of the roots, or simply the size of the tooth all must be taken into consideration. If the premolar implant is too far from the adjacent premolar and the molar implant is angled toward the premolar implant, the restorative options become complicated and are not beneficial to the patient.

CT planning and the use of guided surgery with computer-generated stents can eliminate these problems, at the expense of the scan, planning time, and fabrication of the surgical guide stent. The decision whether to pursue CT guidance with immediate provisionalization is a case-specific decision that is made together by the surgeon, the restorative dentist, and the patient.

Case Example. This patient presented with the mandibular left first molar and second premolar missing (Figure 2-19, A-AA). He requested an immediate restoration, if possible, because he did not like the large space left by the missing teeth. To shorten his time in the office, he agreed to the extra expense of using CT scan planning to fabricate the surgical guide and provisional.

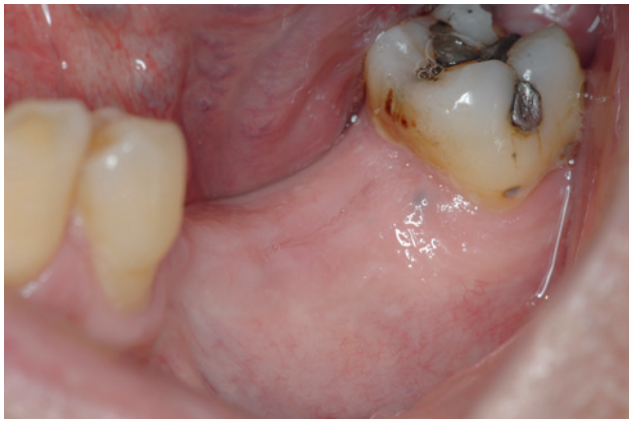


FIGURE 2-19 A, Patient presented without the mandibular left second premolar and first molar. These teeth had been extracted and the sites grafted with mineralized bone approximately 4 months previously.

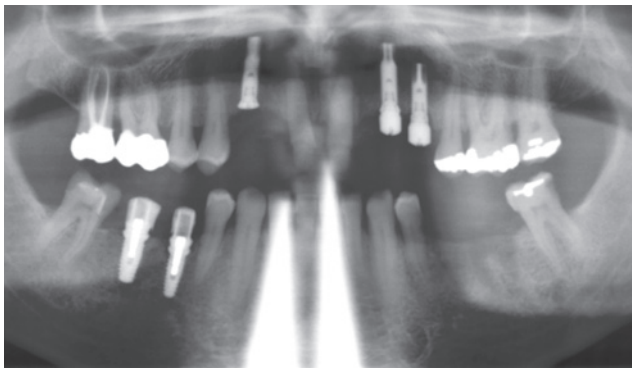


FIGURE 2-19 B, Panoramic radiograph shows the edentulous space and adequate vertical bone height. This radiograph does not show the degree of mineralization in the grafted sites.

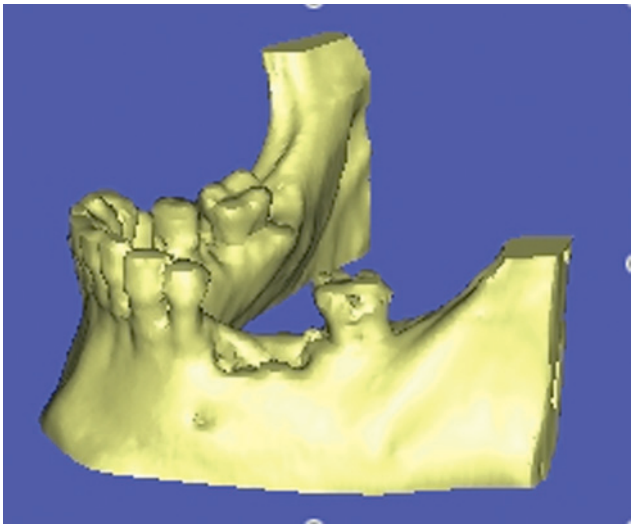


FIGURE 2-19 **C,** CT scan was obtained, and planning software (Materialise, Brussels, Belgium) was used to remove scatter and generate a three-dimensional virtual image of the mandible. Note the adequate labial bone.

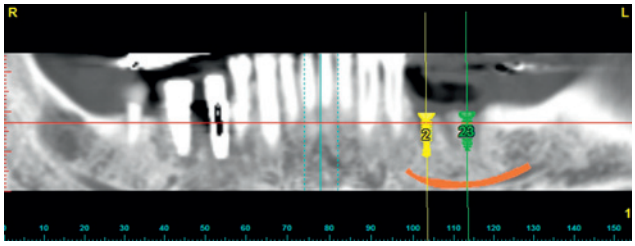


FIGURE 2-19 **E,** Planning software allows for visualization of the inferior alveolar nerve and can outline it in color. This allows the surgeon to choose implant sizes of sufficient length and yet avoid the inferior alveolar nerve.

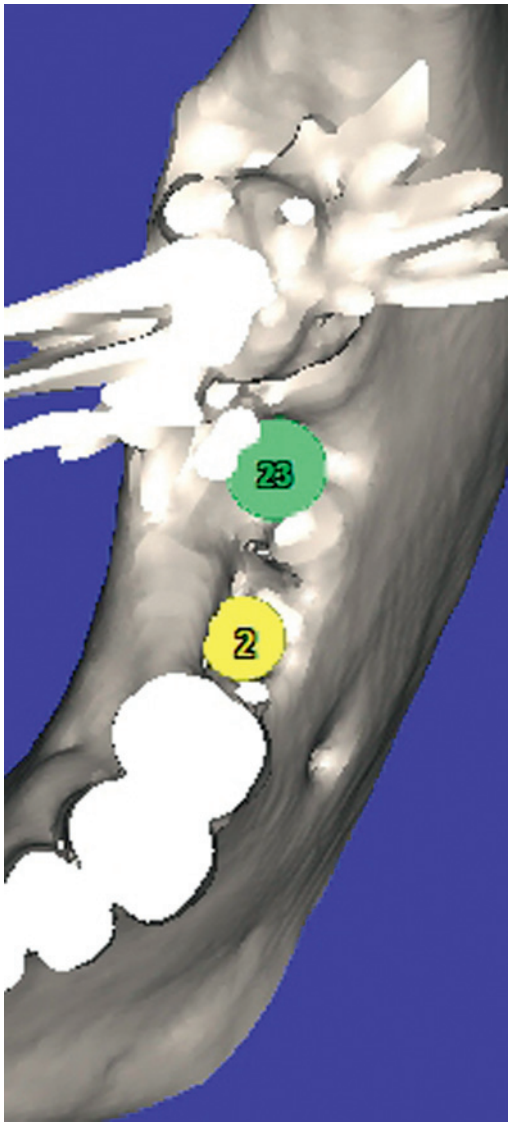
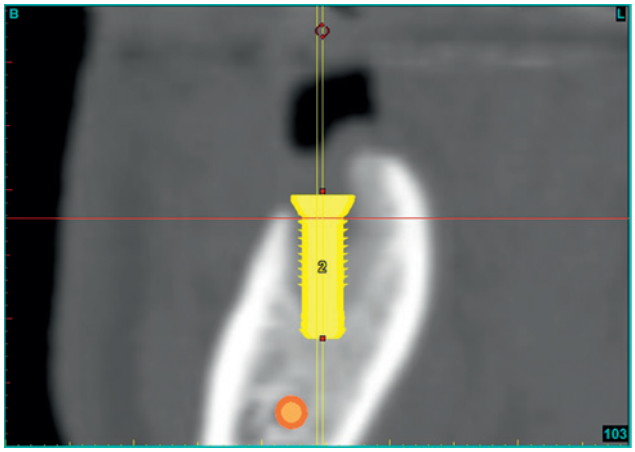


FIGURE 2-19 **D,** Two implants were placed into the edentulous sites using the planning software. In this image, the scatter was not removed before planning. Note that the scatter does not prevent implant positioning, but it makes clear definition more difficult. Removal of scatter is recommended, especially in more complex cases.

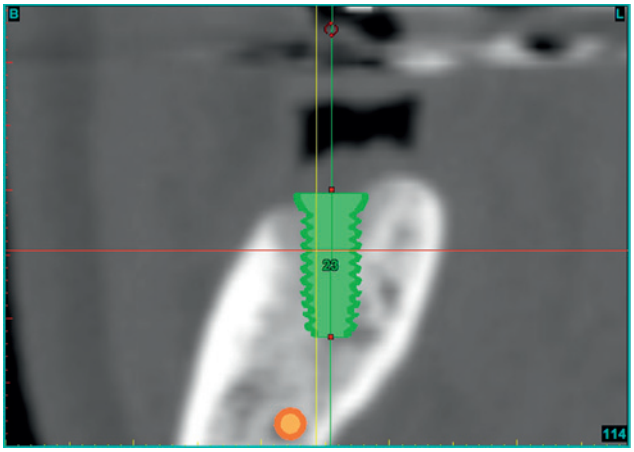
A CT scan was obtained. No radiopaque stent was used, because the implant team decided it was not necessary. The width of the second premolar and first molar was matched to the opposite arch. The central fossa of each tooth was identified on the scan by mapping the size of the intended final restoration. Implants were placed into these locations in the mandible on the planning software. An implant 4 mm in diameter was planned for the second premolar, and an implant platform 5 mm in diameter was planned for the first molar.

Procedure for CT Software Planning. The CT scan was taken with the patient's teeth slightly apart to prevent interdigitation of the maxillary dentition within the mandibular space. The DICOM data set was transferred to a CD. The CD was placed into a laptop computer, on which the scanning software had been opened. The DICOM data set was selected, and the data were imported and converted. The mandibular axial sections were used, but not the maxillary ones, to reduce the computational load on the computer. After the axial sections had been converted, the bone was selected for segmentation and processing. A panoramic curve was selected.

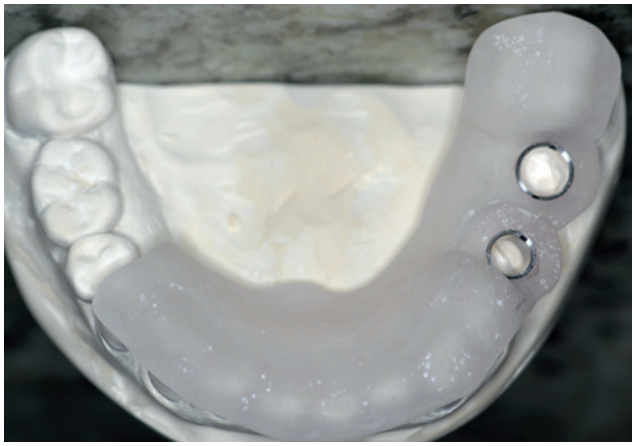
To create a panoramic curve, the axial section is selected slightly below the level of the alveolar crest. A pen is used to mark the curve in the bone of the mandible. If desired, the



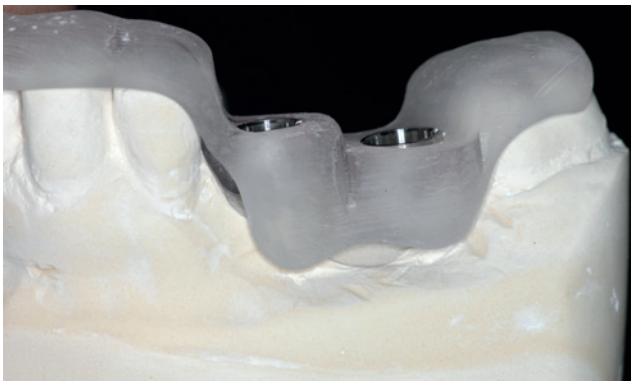
● **FIGURE 2-19 F,** In the second premolar location, an implant is placed that is 4 mm in diameter and 11.5 mm long. Note that the implant avoids the inferior alveolar nerve. It is important to leave at least 2 mm between the virtual implant and the nerve canal.



● **FIGURE 2-19 G,** In the first molar location, an implant that is 5 mm in diameter and 11.5 mm long is placed in the middle of the ridge. The grafted site showed woven bone formation that was less dense than the adjacent cortical bone. When the plan is complete, the surgeon will send it electronically for fabrication of the guide stent.



● **FIGURE 2-19 H,** Guide stent is returned and is tried onto a master cast so that the fit can be examined. The stent should fit tightly and without movement. If the stent rocks on the model, it must be tried in the patient's mouth to confirm accurate fit before the day of surgery. A new scan and guide stent may be needed, although this author has not found that to be common.



● **FIGURE 2-19 I,** Lateral view shows the master cylinders, or tubes, in the stent on the model. The next step is to place analogs in the model to simulate the implant's position after guided surgery.

inferior alveolar nerve can be identified and marked on the panoramic radiograph and the cross sections.

The cross sections then are evaluated. The distance from the distal premolar marking the central fossa of the planned premolar is identified, and an implant 4 mm in diameter is placed. (For this patient, both implants were 11.5 mm long.) An implant 5 mm in diameter is placed in the molar site. The plan is evaluated and approved by the restorative dentist and surgeon. Once the plan has been approved, it is sent electronically to the manufacturer. If the CT-guided stent is intended to be tooth borne, a model of the patient may have to be sent to the manufacturer. However, if a dual-scan technique is used, this is not necessary.

Fabrication of Provisional Prostheses from Surgical Guide Stents. The concept is to place analogs into models that precisely match the surgical placement of the implants in the patient. Tubes in the surgical guide stent guide

FIGURE 2-19 **J,** All guide stent systems have a part that fits into the master cylinder and connects to an implant analog. This allows the surgical guide stent to place the analogs into the model. In this photograph, the analogs of the implants have been connected and oriented correctly through the use of the prosthetic part specifically designed to lock to the master cylinder.

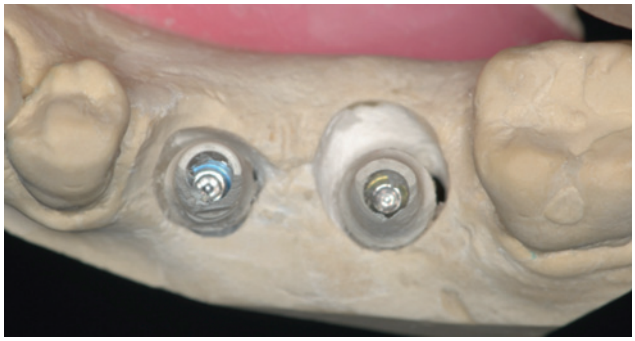


FIGURE 2-19 **K,** Model is marked, and a hole is made to allow seating of the analog into the model. Stone or plaster is used to secure the analog to the master cast.

the surgical placement of the implant. These tubes, called *master cylinders,* have notches that receive parts to lock into the tube and allow analog placement in the model. The CT guide stent is delivered to the treatment team with metal tubes in it. In this patient, the Materialise system

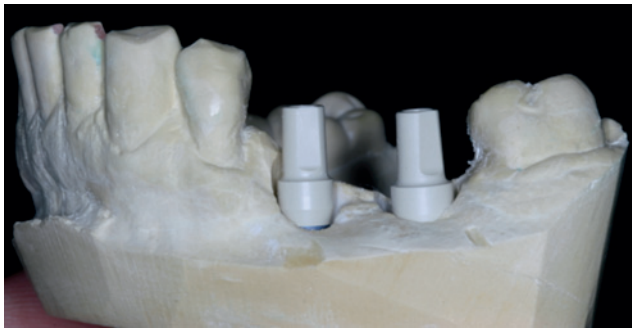


FIGURE 2-19 **L,** Prosthetic abutments are screw retained to the analogs in the master cast.

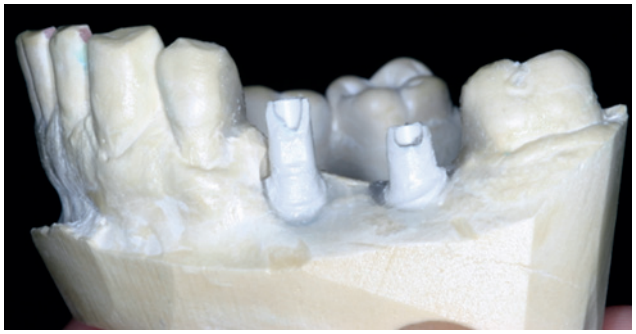


FIGURE 2-19 **M,** Prosthetic abutments are prepared as necessary, resulting in satisfactory interocclusal space and parallel abutments.

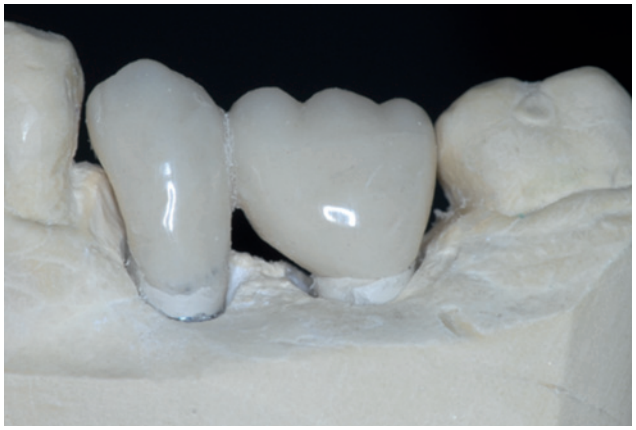


FIGURE 2-19 **N,** Provisional restoration is then fabricated in the laboratory. It is important to polish the margins to enhance gingival health and to clear occlusal contacts to prevent occlusal loading when the teeth come together.

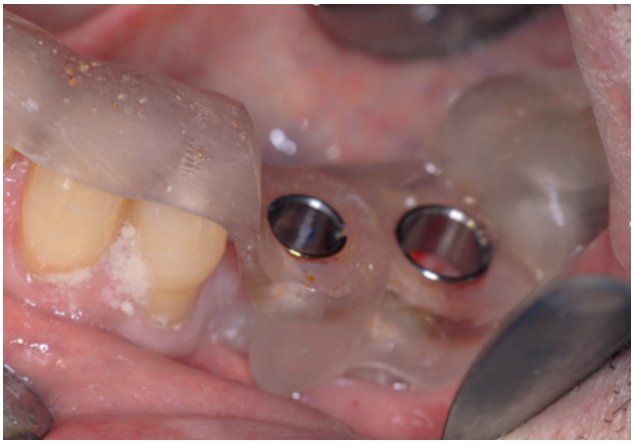


FIGURE 2-19 O, At the time of surgery, a local anesthetic is infiltrated, the surgical guide stent is placed, and the fit is confirmed again. For a posterior mandible with limited KG width, an incision is used with gentle, limited reflection of the KG to preserve it. Use of a tissue punch without gingival reflection removes a significant amount of KG, which may leave the final restoration prone to gingival problems.

FIGURE 2-19 Q, Photograph shows a 2-mm drill that has been placed into the hole of the 2-mm drill sleeve, which has been placed into the master cylinder.

FIGURE 2-19 P, Guided surgical sequence uses sleeves that fit precisely into the master cylinders. Each sleeve has a hole that corresponds to the diameter of the drills. This photograph shows a guide sleeve that has been placed into the master cylinder.

FIGURE 2-19 R, Different sleeve is then placed to allow for the next-sized drill. This drill, which is 2.75 mm in diameter, has been placed into the 2.75-mm sleeve, which is positioned in the master cylinder of the surgical guide stent.

FIGURE 2-19 **S,** Implants that are 5 mm in diameter require a third drill, typically one that is 3.75 mm in diameter. Here, the 3.75-mm-diameter drill is shown inside the appropriate drill sleeve, which has been placed into the master cylinder. In this system, one master cylinder is used in combination with multiple sleeves, each specific for a drill diameter. Note that the precise fit of the drills and sleeves inhibits the flow of irrigation to the depths of the drill site. It is very important to use slow drill speeds (i.e., less than 300 rpm) to avoid burning the bone.

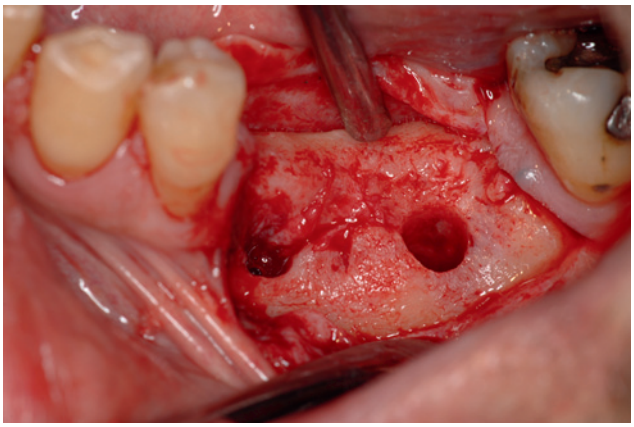


FIGURE 2-19 **T,** After the implant site has been prepared with the drills, the guide stent is removed, and the accurate cation and atraumatic bone preparation are observed.

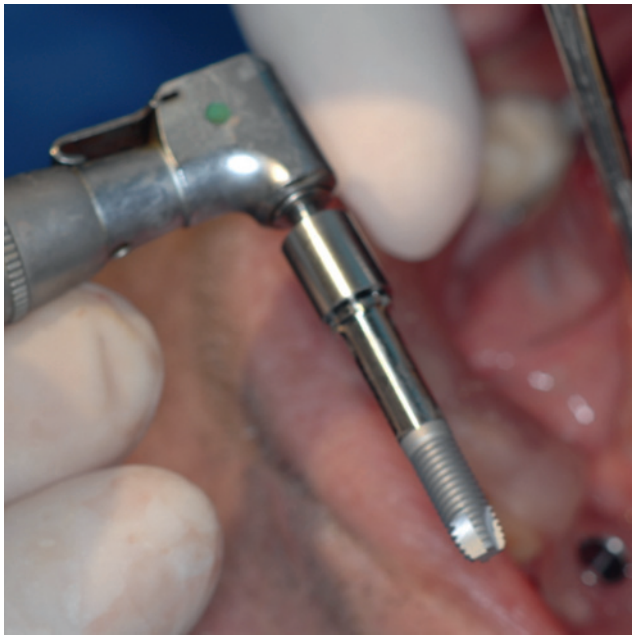


FIGURE 2-19 **U,** Implant mount was chosen, based on the prescription from the manufacturer, to place the implant at the correct depth.

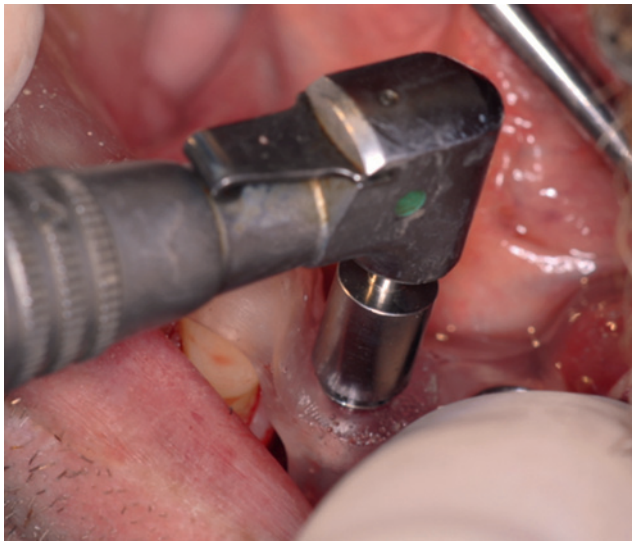
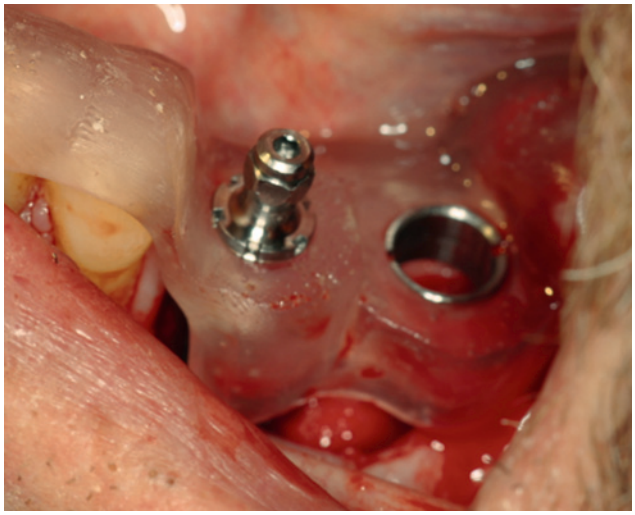
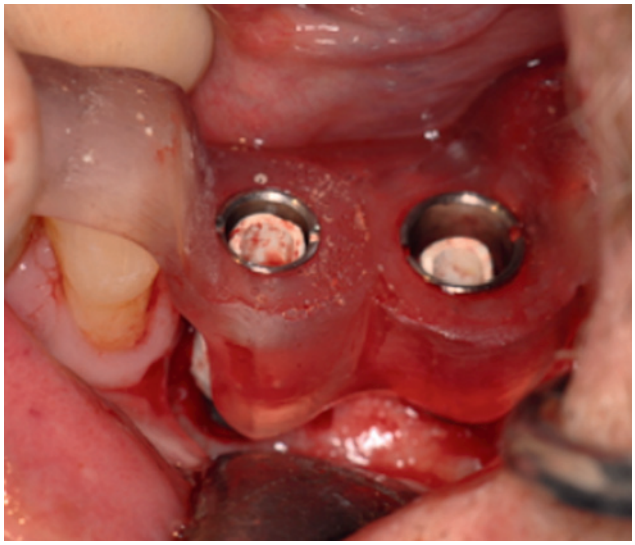


FIGURE 2-19 **V,** Implant is placed into the master tube and secured to the implant site at slow speed.

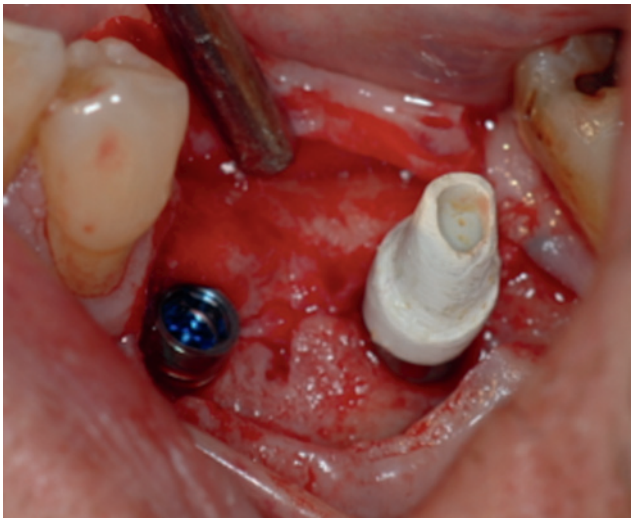


● **FIGURE 2-19 W,** Driver mount shown in proper position, ensuring proper orientation of the implant similar to the rotational position of the analog in the model.

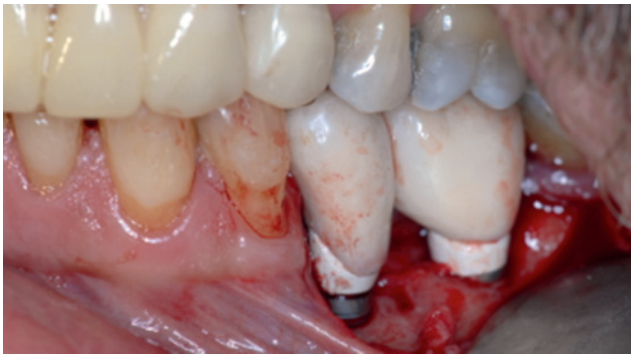


● **FIGURE 2-19 Y,** Both prosthetic abutments have been placed. The accuracy of the system is demonstrated by the precise positioning of the prosthetic abutments in the guide stent.

(Materialise, Brussels, Belgium) was used. The Navigator system (Biomet 3i, Palm Beach Gardens, Florida) was chosen as the guided surgery system. Within the CT-generated guide stent are master cylinders with indentations; the indentations are used to orient the implant and align the internal antirotation feature, which in this implant is an internal hex.



● **FIGURE 2-19 X,** Implant in position with one of the prosthetic abutments secured.



● **FIGURE 2-19 Z,** After the abutment retaining screws were hand-tightened, the provisional prosthesis was placed over the abutments. The position of the prosthesis and the nonocclusal loading criteria were confirmed.

The manufacturer sends a prescription that includes the selection of the specific-length part to match with the planned implant depth. The prosthetic part is chosen, and the implant analog is secured to the part that goes into the tube. The abutment then is positioned and locked to the correct orientation connected to the master cylinder prosthetic connector. The stent is placed over the diagnostic cast, and the analogs' positions are marked. A drill is used to create a hole in the master cast to passively accommodate the analogs, which are connected to the master

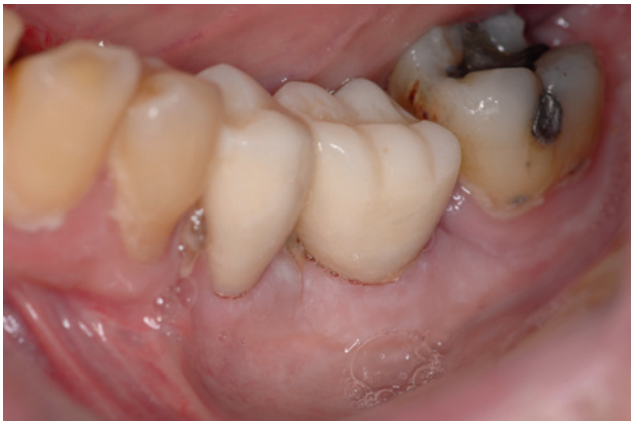


FIGURE 2-19 **AA,** Patient 1 week after surgery. Excellent soft tissue response has been the norm for these patients.

cylinders. The surgical guide stent is placed over the teeth, and the analogs are secured to the cast with stone or plaster. After the stone has set, the prosthetic parts are unscrewed from the surgical guide stent and removed, leaving the analogs within the stone, mimicking the planned positions of the implants.

The provisional restoration is fabricated in the laboratory to cement retention after implant placement. If screw retention is planned, the screw-retained abutments should be picked up in the patient's mouth after implant placement. The provisional restoration should be adjusted to prevent occlusal loading in all jaw movements.

The provisional abutments are placed into the analog. Using the opposing occlusion, the provisional abutments are modified conservatively, leaving as much of the retentive features as possible to allow optimal cement retention of the provisional crown. If desired, a screw-retained abutment can be placed. The abutments are chosen and secured to the implants with screws. They are prepared as necessary to provide occlusal clearance and allow room for the provisional restoration. Preparation of the abutments should maintain parallel walls and leave the surface rough to optimize cement retention.

The provisional crown is then fabricated using conventional dental techniques. These crowns can be polycarbonate shells filled with acrylic or resin, or they can be fabricated from previous diagnostic setups in the laboratory. Either a cemented or screw-retained provisional can be fabricated, depending on the clinician's preference.

In this case scenario, the provisional abutments were the "plastic" posts, which allow cement retention of the provisional crowns. The abutments are prepared to allow for proper morphology of the provisional restorations, which are fabricated in the laboratory. The gingival margins are kept at the level of the gingiva and are not placed subgingivally in the posterior mandible. This allows easy clean-up of the cement after crown placement.

Surgical Procedure. At the time of surgery, the model with the provisional crowns, abutments, and occlusal gold screws must be available. These are kept on the model until separate bowls have been labeled to identify the specific tooth site for the abutments; this prevents the abutments from being placed in the wrong location. Infiltration of a local anesthetic is performed to achieve a small hydropic dissection over the crest. Often a thin bank of KG is present in the posterior mandible; therefore, an incision is made bisecting the gingiva, which allows the KG to be relocated labially and preserved. After the incision has been made, the crestal tissue is reflected to the edge of the crest without further reflection. When CT guidance is used, there is no need to identify the mental foramen. If the ridge is flat, the twist drills are used to start the site preparation. If the ridge is not flat, the countersink drill is used to enter the sloped ridge and make it easier to prepare the site without implant migration as a result of dense bone.

The surgical stent is placed on the teeth. The prescription for drill length is used to choose the first twist drill. The drill sleeve is placed in the stent's master cylinder, and the drill is used to start the drilling sequence. The drill speed is reduced to avoid burning the bone. Because irrigating the drill may be difficult with the stent and drill sleeve in place, external irrigation is used. The drill is taken to depth in both sites. The next-sized drill then is used with the proper drill sleeve, and the implant is placed. The proper implant drill mount is chosen according to the Navigator prescription, which dictates the depth placement of the implant.

To place the drill mount, the clinician opens the implant package, keeping the implant within its tube. The implant driving mount is placed and hand-tightened to secure the mount to the implant with complete seating. The drill then is used at a very slow speed to place the implant through the guide stent into the prepared bone. The drill is removed, and the hand ratchet is used to complete implant seating and align the external grooves of the implant mount to the grooves of the guide stent. This ensures proper orientation of the implant and aligns the internal hex according to the guide stent. The abutments then can be placed in the identical position as on the model.

Seeing the grooves of the master cylinders within the guide stent often can be difficult. A small disc can be used to place a groove in the acrylic, which can be further identified by a marking pen (see Figure 2-19, K).

After the mounts have been oriented properly and completely seated, the wrench is used to hold the implant mounts, and they are unscrewed. They are carefully removed from each implant, and after all have been removed, the stent is

taken out of the mouth. The implant sites are evaluated. If necessary, they can be adjusted by conventional methods, but this is rarely necessary. The provisional abutments that correspond to the implant sites are placed, and the occlusal screws are hand-tightened. These screws must not be torqued above 20 N-Cm. The provisional prosthesis is placed, and if necessary, the internal areas are adjusted for complete seating. These provisionals should not be in occlusion. Occlusal clearance is confirmed. If necessary, the occlusal surface is removed with the aid of thick occlusal paper. No contact with the opposing occlusion should occur in any jaw movement.

The incisions are closed with resorbable suture (e.g., 4-0 chromic) or other suture, depending on the clinician's preference. Postoperative antibiotics are prescribed, and the patient is asked to start an antibacterial mouth rinse 3 days after surgery.

Follow-up visits 1 week after implant and provisional placement should confirm lack of occlusal contact and proper hygiene, as well as conventional observations after implant placement.

Alternatives. The implants can be placed and cover screws used if the provisional restoration is not planned. This author does not place an abutment or manipulate the implants in any way within 8 weeks of initial placement. Thus, if the provisional restoration is not planned, either cover screws or healing abutments are placed and are not removed for at least 8 weeks. If the patient is to wear a removable prosthesis as a temporary, cover screws are preferred to healing abutments to prevent occlusal loading. If a fixed restoration is to be placed over tooth abutments anteriorly and posteriorly, short healing abutments can be placed and the temporary prosthesis modified to prevent loading of the healing abutments.

Use of CT guidance to angle implants and avoid the inferior alveolar nerve

In the posterior mandible, the inferior alveolar nerve may run along the inferior border or in the middle of the cancellous portion of the mandibular body. A cross-sectional image using CT scanning can identify the canal's location. Because of labial bone resorption, the ideal emergence of an implant in the molar location may allow angulation of the implant with the apical portion emerging through the mylohyoid ridge lingual to the inferior alveolar nerve canal. The surgeon can either angulate the implant using landmarks present on the crest or use CT guidance to angle the implant. Angulation of the implant may allow the placement of implants of sufficient length rather than the need to abort implant placement (Figure 2-20, A-D).

Avoidance of the Inferior Alveolar Nerve. CT scanning can identify the inferior alveolar nerve in most cases. When clearly defined, the location of the nerve is easily seen, the distance superior to the nerve can be measured to within 0.5 mm, and the implant length can be predetermined. When the canal is not as distinct, some methods can be useful for helping the clinician identify it.

One such method uses the cross sections that show the mental foramen to identify and then trace the nerve posteriorly. Each cross section from the foramen, moving posteriorly, is evaluated to trace the most likely location of the nerve. The axial and frontal sections also can be used to determine the most likely superior-inferior location of the nerve canal. Changing the gray scale windows can help determine the exact location of the nerve. If necessary, the surgeon can transfer the DICOM files to planning software, and the nerve can be traced using cross sections and the panoramic reconstructions. The use of CT scanning results in high sensitivity for positive location of the canal. Often the panoramic reconstruction makes it difficult to locate the nerve specifically. However, the cross sections can be used to identify the location of the nerve within 0.5 mm (Figure 2-21, A-B).

Vertical augmentation of the posterior mandible: interpositional osteotomy for ridge augmentation

Michael S. Block and Christopher Haggerty

Patients often request fixed dental implant restoration of missing posterior teeth in the mandible (defined here as the region posterior to the mental foramen). This region has obvious limitations for implant placement, including bone deficiency and the presence of the inferior alveolar nerve within the body of the mandible (see Video 2-2).

After teeth have been removed, a continuous resorptive process of the alveolar ridge occurs and is accelerated by denture wear[24]; this is most pronounced during the first 12 months after extraction.[25,26] The continuing resorption of alveolar bone eventually results in less than ideal bone superior to the inferior alveolar nerve, preventing implant placement without augmentation of the alveolar bone height. Augmentation of the bone superior to the inferior alveolar nerve should provide sufficient bone for implant placement and long-term successful restoration of missing teeth with fixed, implant-borne prostheses. All suggested methods should consider patient-related issues, including pain, swelling, sensory nerve disturbances, the incidence of graft failure and resorption, and the functional restoration long term.

Available Techniques: Historical Perspective and Advantages and Limitations

Nerve Repositioning. Repositioning of the inferior alveolar nerve involves exposing the nerve from a lateral approach, releasing it from the canal, and moving it laterally from the cancellous space. This allows implants to be placed to the inferior border of the posterior mandible without

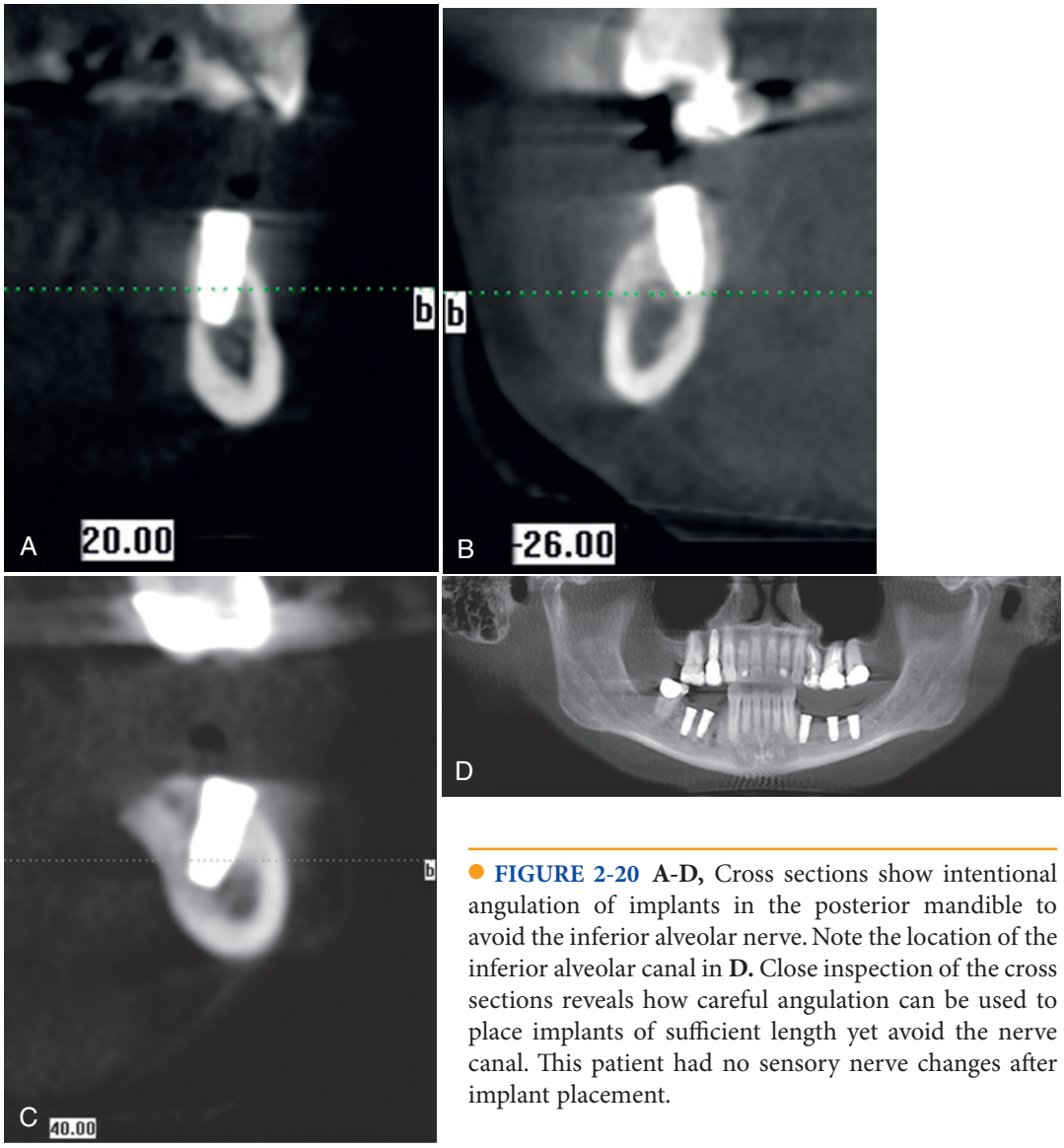


FIGURE 2-20 **A-D,** Cross sections show intentional angulation of implants in the posterior mandible to avoid the inferior alveolar nerve. Note the location of the inferior alveolar canal in **D.** Close inspection of the cross sections reveals how careful angulation can be used to place implants of sufficient length yet avoid the nerve canal. This patient had no sensory nerve changes after implant placement.

directly damaging the nerve, because it has been laterally positioned. Surgical exposure and moving the nerve laterally has obvious disadvantages, including sensory nerve disturbance and an excessive crown-to-root ratio of the prosthesis. The high incidence of these problems has reduced the use of this method.[27-34] Other methods for placing implants into a vertically deficient posterior mandible include the use of short implants or bone augmentation procedures (Table 2-1).

Use of Short Implants. When faced with 5 mm of bone above the inferior alveolar nerve, can we use short implants? What are the options when the patient has 7 to 8 mm of bone height superior to the inferior alveolar nerve? Short implants (5 to 8 mm) are marketed for short vertical bone regions. Mechanical studies using cylindrical implants of different widths and lengths indicated that mechanical pull-out resistance was inversely proportional to the length of an implant, not its diameter.[35,36] With new surface modifications, short implants are placed and splinted together to create a mechanically stable prosthesis. However, long-term functional data are not available; therefore, the decision to use 5- or 6-mm implants is based on case-specific parameters and the patient's understanding of the lack of long-term evidence to support this method.

Data collected using smooth-surfaced, threaded implants indicated that more failures occurred in the posterior mandible with shorter implants.[37] Shorter implants lead to a poor crown-to-root ratio and compromised

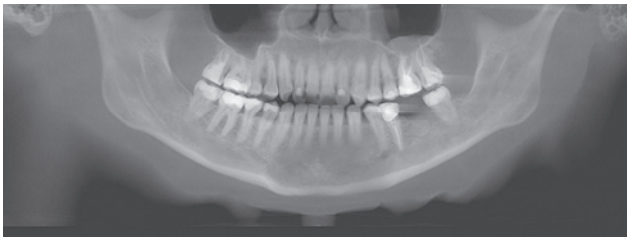


FIGURE 2-21 **A,** Panoramic reconstruction from a cone beam scan; the specific location of the inferior alveolar nerve is difficult to identify.

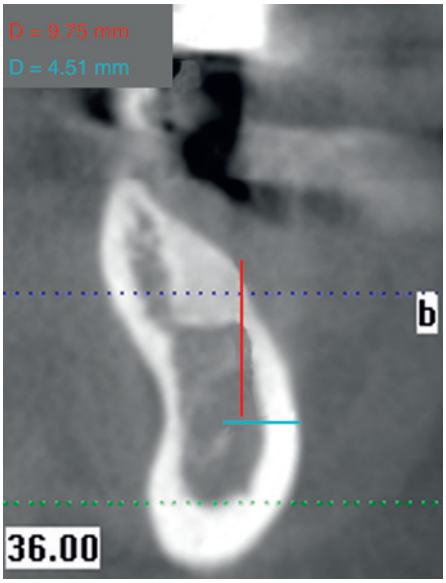


FIGURE 2-21 **B,** Cross section from the same scan as in Figure 2-21, A, definitively shows the canal, and its position can be located to within 0.5 mm.

results of the final prosthesis, depending on the type of prosthesis and the interarch distance.[38] The aforementioned variables frequently lead to use of short implants or the placement of malpositioned endosteal implants.[39] Based on the evidence available for short implant success, the shortest implant length recommended for the posterior mandible traditionally was 10 mm.[39] However, recent improvements in implant design, especially thread specifications, and improvements in implant surface characteristics may be shown to be effective for implants 8 mm or shorter for use in the posterior mandible, after evidence-based clinical series with long-term follow-up have been completed. Angling of short implants using CT-guided surgery may reduce the need for ridge augmentation, and the surgeon can avoid the inferior alveolar nerve by placing the implant lingual to the nerve (see Figure 2-20, A-D).

Onlay Graft Procedures. Bone is grafted onto the superior surface of the residual alveolar cortical bone by gaining access to the cortical bone, placing and securing a bone graft to the region to be augmented, and closing the soft tissue. Various graft materials have been used, including iliac crest cortical and cancellous bone, calvarial bone, symphyseal and ramus bone, and bank bone, including both allografts and xenografts. The grafts include blocks of material, particulate material with membrane coverage, or combinations of the two.

An onlay graft has several advantages: the inferior alveolar nerve can be avoided; the graft is easily placed; and immediate postoperative vertical augmentation can be achieved. However, incision breakdown over the graft may result in reduction of the long-term augmentation, especially when grafts composed predominantly of cortical bone are used.[24,40-43] Grafts composed of corticocancellous blocks of bone from the iliac crest resorb rapidly during the remodeling process; therefore, the implants must be placed in a timely manner, typically between 3 and 4 months after iliac crest block augmentation.

The most common complication with all onlay graft methods is incisional dehiscence and exposure of the graft; when symphyseal or ramus bone blocks are used, this results in loss of the entire block of bone graft. When cancellous iliac crest bone or particulate bone is exposed through incisional dehiscence, a portion of the graft may be viable and produce partial bone augmentation. When the incision breakdown occurs over a particulate graft with membrane coverage, the membrane may require removal and, depending on the status of graft revascularization, a portion of the underlying graft may be retained.

Cordaro et al.[41, 42] placed 18 block grafts, either from the ramus or from the chin, and fixated with small-diameter screws, in 15 patients. After 6 months, the screws were removed, and implants were placed. In the mandible, an average of 2.4 mm of vertical gain was achieved. Only 1.4 mm of the graft remained at the time of implant placement. The onlay grafts lost 41.5% during the first 6 months.

Bell et al.[24] accessed the severely atrophic edentulous mandible via an extraoral approach and placed corticocancellous block grafts from the posterior ileum. Bone was placed along the superior and lateral border of the mandible, including both the anterior and posterior mandible, without stripping the lingual periosteum. The bone grafts were allowed to consolidate for 4 to 6 months, and then implants were placed. Vertical bone height increased 5 to 8 mm in the posterior mandible. After 4 to 6 months, 3 mm of bone had been lost in the posterior mandible (23% loss). Because of the vertical bone resorption in these cases, implants were placed only in the anterior mandible. The rate of bone resorption in the anterior mandible decreased

Posterior Mandibular Vertical Augmentation Using Interpositional Osteotomy

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for posterior mandibular vertical augmentation using interpositional osteotomy, which is performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

In this patient, the left posterior mandible will be augmented vertically, and an interpositional osteotomy method will be used to reposition the alveolar crest superiorly. The bone segment will be stabilized with a small plate and the gap grafted with human mineralized bone.

After infiltration of a local anesthetic, a vestibular incision is made at least 15 mm lateral to the crest. An anterior release incision is made from the interdental papilla at least one tooth anterior to the edentulous site. A 15 scalpel blade is used to develop a mucosa-only dissection from the vestibular incision toward the crest. If necessary, hemostat dissection can be used to identify the mental nerve.

Once the nerve has been identified, an incision is made through the lateral muscle attachments to the bone on the lateral aspect of the mandible. This may need to be accomplished with small incisions and reflection to ensure that the nerve is preserved. Care must be taken to preserve the crestal periosteum; this prevents avascular problems with the superior segment of the bone after it has been separated from the mandible. The periosteum is reflected inferiorly only to expose the mental foramen and the lateral aspect of the bone. A small elevator is used to raise the periosteum where the vertical osteotomies will be performed.

A periosteal elevator is placed to cover and protect the mental nerve. A piezotome with the bone-cutting tip is used to create a horizontal osteotomy first. This osteotomy can be scored and then completed; for this process, the clinician should keep a finger on the lingual aspect to detect the piezotome tip as it perforates the bone and to prevent perforation of the lingual mucosa. The lingual mucosa must not be cut or traumatized or the entire procedure must be aborted because of later avascular necrosis of the repositioned superior segment. The vertical osteotomies are completed, with care taken to preserve the periosteal attachments on the crest. The osteotomies are checked and often need to be completed. The horizontal and vertical osteotomies must be completed and allow for passive separation of the crestal bone from the corpus of the mandible. As clinicians gain experience with the piezotome, they develop the ability to feel the lingual bone cuts without needing to keep a finger on the lingual aspect.

The segment is mobilized gently and elevated to the extent of the lingual soft tissue allowance. If the floor of the mouth is close to the atrophic ridge, the segment often can be raised 7 to 8 mm. If the floor of the mouth is away from the crest, the lingual elevation may be limited to 4 to 5 mm with a rotational movement of the crest to gain more vertical height for the buccal crest.

After the segment has been elevated, a small bone plate is adapted. To limit the profile height of the screw heads, small screws (1.2 mm in diameter) are used on microplates. One plate in the shape of an X or H can be chosen. The superior aspect of the plate may need to be bent so that it lies flat on the crest. The screws are placed into the superior segment first. A drill is used to create a hole in the bone, and then a screw 4 mm long is used to secure the plate to the segment. A periosteal elevator may be used on the inferior aspect of the segment to stabilize it during screw placement. Clamping the segment is unwise, because it is small and may fracture. After placement of the first screw, the plate is turned as necessary to align it further, and the second screw is placed in the superior segment. The segment then is positioned as planned with a gap present.

It is important to palpate the lingual aspect to make sure the lingual bones are aligned and do not create sharp, protruding edges against the lingual mucosa. This must be confirmed before the screws are placed in the corpus of the mandible. The plates are small and do not mold easily. The best course is to have an exact elevation and lingual "smoothness" before the last screws are placed.

The inferior two screws are placed. These typically are 4 mm long and are placed unicortically to avoid the nerve in the marrow space. The gap is confirmed at this time.

The graft material is hydrated and packed into the gap. It is important that the graft be placed full thickness yet not overpacked on the lingual aspect. At each step, care must be taken to prevent trauma to the thin lingual mucosa. Excessive bone graft particles are removed from the site peripheral to the osteotomy site. The incision is closed with 4-0 suture on a tapered needle to prevent trauma to the incision line. The sutures should be placed passively and without excessive tension to prevent ischemia of the wound edge.

TABLE 2-1 Comparison of Procedures for the Posterior Mandible

Procedure	Vertical Augmentation Limit	Primary Advantages	Primary Disadvantages
Nerve repositioning	N/A	Long implants can be used because of ability to engage inferior border; stable bone available for long implant	High neurosensory disturbance Long crown-to-implant ratio for prosthesis
Onlay grafting	7-10 mm	Simple access, ease of fixation; donor sources: mandible, cranium, hip	Incision breakdown results in graft loss; graft resorption significant
Addition of particulate bone with membrane	5-8 mm	Minimal morbidity; small or no donor site	Technically sensitive High rate of incision breakdown for inexperienced clinicians Graft-to-implant interval can be 9 months
Distraction osteogenesis	5-10 mm	Genesis of soft tissue; excellent bone augmentation	Extended interval from start of distraction to implant placement; may require additional grafting Patient morbidity from distraction device
Interpositional osteotomy	4-8 mm	One-stage procedure; allograft can be used; no donor site morbidity	May be technically difficult Height augmentation limited because of soft tissue stretch

considerably after implant placement. In the posterior mandible, where implants were not placed, bone resorption continued at an accelerated rate compared with the anterior bone grafts. In the posterior, non-implant-supported mandible, bone resorption continued at a rate of 11% per year.

Proussaefs et al.[42,43] used intraorally harvested autogenous block grafts for vertical alveolar ridge augmentation. Their results showed a vertical augmentation of 5.75 mm 1 month after surgery and a vertical augmentation of 4.75 mm 4 to 6 months after surgery. Total bone loss during the first 6 months was 17.4%.

According to Pikos,[44] block grafts harvested from intraoral sites can be used to predictably augment the posterior mandible 6 mm. Pikos allows 5 months for graft healing before implant placement and reports 0 to 20% graft resorption provided no flap dehiscence occurs.

Chiapasco et al.[40] treated 17 patients with vertically deficient mandibles either with distraction osteogenesis (DO) or with rigidly fixated autogenous block onlay grafts from the ramus. The DO group showed an average increase in the vertical height of the mandible of 5.3 mm, compared with 4.6 mm for the onlay group. This study showed that DO produced a bone response clinically similar to that achieved with traditional onlay grafting. No difference in bone resorption was seen after placement of implants. Perry et al.[45] also compared DO with onlay grafting. Their results, obtained in a canine model, were similar to those of Chiapasco et al. and showed no significant difference between DO and onlay grafting.

Breakdown of the incision with bone exposure usually results in loss of all or part of an onlay graft. However, late mucosa dehiscence after graft remodeling and revascularization resulted in less bone loss, especially when the bone blocks used had more cancellous bone than cortical bone.[43] Ramus bone and chin bone are composed predominantly of cortical bone, which is replaced slowly and undergoes delayed revascularization; these factors make this type of bone very susceptible to loss when exposed. Cancellous blocks of bone are revascularized early in the healing period, which makes them less prone to total loss when an incision breaks down; however, they are more rapidly resorbed during the remodeling process unless implants are functioning. Cancellous block grafts usually are harvested from the hip. To avoid general anesthesia, the costs of hospitalization, and pain from the donor site, patients often request an alternative.

Particulate bone augmentation with membranes

The use of particulate bone with membrane coverage (guided bone regeneration [GBR]) allows both horizontal and vertical augmentation of the mandible. The membrane is

designed to allow bone to infiltrate the particulate graft mass, rather than connective tissue, with the formation of bone sufficient to support implants and, through implant functional loading, retain the bone that is formed.[46] Three to 6 mm of vertical bone augmentation has been reported.[46,47] A modified technique in which dental implants were left supracrestal as "tent poles," with graft material packed around the implants, resulted in stable bone formation, especially when a titanium-reinforced membrane was used.[46] This method is technically difficult and requires an experienced clinician to attain these results.

A major concern with GBR is the fact that postoperative bone graft resorption is inhibited only as long as the membrane is in place; resorption begins once the membrane has been removed.[48-50] For this reason, numerous authors advocate leaving the membranes in place for 9 months prior to exposure and implant placement[46,47,51] or leaving the membrane in place for up to 12 months.[52]

The main disadvantage of the use of membranes is premature exposure of the membrane through the mucosa and the subsequent infection of the grafted site, which inhibits bone formation.[38,39,52] The percentage of cases in which premature membrane exposure has occurred ranges from 0 to 37.5% (Rasmusson, 0%[48]; Tinti, 13.6%[52]; Artzi, 20%[47]; and Chiapasco, 37.5%[38]).

The use of metallic mesh has been advocated to form and retain a particulate graft for vertical ridge augmentation. Boyne et al.[53] used mesh to form a new maxillary ridge in patients with anterior combination syndrome and in others with an atrophic maxillary ridge. If exposure of the mesh did not occur soon after placement, bone formation was predictable. If the mesh became exposed during the healing process, it had to be removed; depending on the length of time from placement, the result was good or poor bone ridge augmentation. The use of smaller mesh pores and more flexible mesh for posterior mandibular ridge augmentation has shown excellent results, but exposure of the mesh is still a factor that must be considered.[54] As new evidence becomes available, use of a mesh-type material with a combination of graft materials, such as allograft, xenograft, synthetic scaffolds, and growth factors (e.g., bone morphogenetic protein [BMP] and platelet-derived growth factor [PDGF]) may have potential for vertical ridge formation in the future.

Inlay: Interpositional Procedures. Horizontal osteotomy of an edentulous section of the mandible or maxilla, with the creation of a gap between the segments, has a long history in the treatment of edentulous patients. When performed in the posterior mandible superior to the inferior alveolar nerve, excellent stability of the vertical augmentation has been achieved, although the vertical augmentation is limited by the stretch of the soft tissue. DO has been used to increase the height of the ridge, because both soft and hard tissue genesis occurs, reducing the limitations imposed by the soft tissue envelope. The lengthy time needed to achieve distraction of the superior segment and the occasional need for hard tissue grafting prior to implant placement makes this method less attractive to many patients. All of the aforementioned procedures have specific indications and contraindications and have been discussed previously.

History of Interpositional Bone Grafting. Over the past 60 years, numerous methods have been used to reconstruct the posterior edentulous mandible, and all of them have advantages and disadvantages. Clementschitsch[55] pioneered intraoral bone grafting in 1948, using onlay rib grafting for the edentulous mandible.[55]

Autogenous rib grafts were advocated early in the history of vertical ridge augmentation.[56-59] Davis et al.[59] reported 50% or more resorption of autogenous rib grafts. Interpositional grafts then were used in an effort to augment the vertical height of the edentulous mandible without height relapse.

The concept of interpositional, or "sandwich," grafting is based on the theory that bone placed between two pieces of pedicled bone with internal cancellous bone undergoes rapid, complete healing and graft incorporation.[60,61] In 1966, Barros Saint Pasteur proposed the interpositional bone grafting technique.[62] He described a two-stage technique that involved a mandibular horizontal osteotomy from the retromolar pad inferiorly to the inferior alveolar nerve. Three weeks later, the cephalic portion was raised, and either plaster of Paris or a bovine allograft was placed as an interpositional graft.[62-63]

The "sandwich technique" for vertical augmentation of the mandible was proposed by Schettler[65-66] and discussed by Egbert.[64] This involved a horizontal osteotomy of the mandible that left the lingual soft tissue attachments. The cephalic bone was raised, and autogenous grafting material was inserted into the defect, which healed with minimal bone resorption regardless of the interpositional graft material used. At 30 months follow-up, Schettler reported no bone resorption with autogenous bone and a 1 mm decrease in vertical height with bone bank bone. Schettler then revisited his study using a rabbit model.[67] Data showed well-vascularized grafts after 6 weeks. No significant differences were seen histologically between the autogenous and homologous bone grafts. Other studies also demonstrated rapid, complete incorporation when the grafted material was placed between two corticocancellous segments of the mandible.[60,61,68]

A classic osteotomy method for augmenting the vertical height of the anterior and posterior edentulous mandible was introduced by Härle[69,70] and further evaluated and modified by Stoelinga.[71,72] The visor osteotomy involved a parasagittal osteotomy of the mandible from body to body.[69] The lingual plate of bone was raised superiorly,

pedicled to the lingual soft tissue. After 3 years, 36% vertical height relapse was seen, and the average increase in the height of the anterior mandible was 7.8 mm.[70]

The classic sagittal visor osteotomy was modified to include a horizontal osteotomy in the anterior mandible with placement of autogenous bone in the interpositional gap. After 1 year, 20% of the vertical augmentation of the mandible had resorbed.[71,72]

A series was reported in which the inferior alveolar nerve was removed from the canal and a horizontal osteotomy was performed that included the ridge from retromolar pad to retromolar pad; the alveolar bone was raised superiorly and immediately grafted with autogenous corticocancellous bone secured with circummandibular wire fixation.[73] A vestibuloplasty was performed after bone healing, typically 12 to 16 weeks after the osteotomy. After 8.8 months of follow-up, Frost et al.[73] reported graft resorption of 26.1% in the autogenous group. All patients were reported to have some degree of neurosensory disturbance.

Interpositional osteotomies in the alveolar bone heal with rapid vascularization and bone remodeling in the bone gap.[60] After 12 weeks, the interpositional grafts were almost indistinguishable from the surrounding native bone. After 4 weeks, the lacunae of the grafted bone were empty, as expected. Cellular fibrous tissue containing blood vessels was seen in the marrow spaces. Signs of active osteogenesis with minimal bone resorption were found in all specimens. The cranial segment was vital in all animals, and most of the lacunae contained osteocytes. Attachment of the cranial segment to the graft was observed. At 12 weeks, the grafts were fully incorporated into the bone of the mandible. The lacunae of the graft were all empty, although new bone had been deposited on all surfaces of the graft. Little or no resorption had occurred during the first 12 weeks. It was concluded that with interpositional grafts, the osteocytes of the graft do not survive; however, the graft is well tolerated, and new bone quickly forms around the graft. The grafted bone is connected to the surrounding bone by new mineralized tissue. The superiorly repositioned bone segment maintains its vascular supply, demonstrating that the mobilized segment receives adequate circulation from the lingual soft tissue pedicle to maintain its vitality.

The visor osteotomy methods have been abandoned because of the risk of nerve damage and lack of bone retention after grafting.[64,74,75] The high resorption rates seen in these early bone grafting procedures are due to numerous factors. Most of the early visor and sandwich osteotomies received vestibuloplasties. The disruption of the periosteum of the grafted sites resulted in continued resorption of the grafted area.[75] Moloney[75] found that, when a Stoelinga-type "three-piece" osteotomy was performed, less bone resorption occurred if a follow-up vestibuloplasty was not performed. A second reason for the bone loss may be the large area of periosteal separation from the bone and the very large movement of bone (ranging from 10 to 20 mm), which may have gone beyond the effective blood supply to the bone.

These early grafting techniques used wire or suture to fix the segments and grafts. Micromotion of the grafted area disrupts vascular ingrowth and delays and slows the osteogenic capabilities of the grafted area. Bone grafts secured both rigidly and nonrigidly in areas of low motion and high motion showed that the rigidly fixed grafts maintained 56% of their volume after 14 weeks, compared with 46% for non-rigidly-fixed grafts.[76] When grafts were placed into areas of low motion versus areas of high motion and compared, only the high-motion sites showed significantly improved survival for the rigidly fixated group. Rigid fixation exerts its most profound effects during this early phase of healing and should be used to eliminate movement of the graft during the early healing phase.

When performing an interpositional osteotomy and moving the mobilized alveolar bone segment vertically, the clinician must decide on the optimal material for grafting the defect. Cancellous and particulate marrow grafts have shown more rapid vascularization and more osteogenic activity compared with autogenous block grafts.[77-80] Burchardt[77] demonstrated that cancellous grafts tend to repair completely with time, whereas cortical grafts remain a mixture of necrotic and viable bone. Canzona et al.[68] studied the resorption rates in inlay and onlay bone grafting in adult mongrel dogs. They concluded that inlay grafts survive better than onlay grafts. Schettler[67] believed that less bone resorption occurred in interpositional grafts, because the graft is surrounded by bone and periosteum on all sides, which facilitates rapid vascular connection with the surrounding tissues.

Effect of Implants on Bone Graft Resorption. The rate of resorption of the grafted site decreases considerably after implant placement.[24,81] Bell et al.[24] augmented both the anterior and posterior mandible with iliac bone using an extraoral approach. After 6 months, implants were placed in the anterior mandible between the mental foramen; they were not placed in the posterior mandible. Vertical bone graft resorption was found in the posterior non-implant-supported area compared with the anterior implant-supported bone. Breine and Branemark[81] conducted a study on a canine model in which they placed autogenous composite grafts containing integrated titanium implants. They found that implant placement into a grafted area resulted in graft persistence and implant stability, and they concluded that implant placement can slow the resorption process. In their study, after the bone grafts had stabilized, the loss of bone surrounding the implants was less than 0.1 mm per year.[81]

In long bones, removal of load-bearing results in significant bone remodeling, including endosteal, intracortical, and to a lesser extent, periosteal remodeling.[82] Without a load-bearing stimulus, bone mass declines, resulting in disuse osteoporosis. A physiologic, dynamic strain or load is required to prevent a decline in bone mass after tooth extraction.[82]

In 2006, Jensen[83] published a report on interpositional, or sandwich, osteotomies in the posterior edentulous mandible prior to implant placement. Using the sandwich method, Jensen was able to achieve up to 8 mm of vertical augmentation of the posterior mandible. The preoperative bone height was 3 to 7 mm of bone above the inferior alveolar nerve canal. Horizontal osteotomies were created 2 mm above the inferior alveolar nerve canal. The lingual-based flap was stretched superiorly 4 to 8 mm. A miniplate was used for rigid fixation. A cortical wedge of bone from the external oblique ridge and particulate autograft was placed in the interpositional graft site. After 4 months of healing, the miniplates were removed and short implants (8 to 11 mm) were placed. The implants were loaded 3 to 4 months after placement. The average vertical augmentation of the posterior mandible achieved with Jensen's technique was 6 mm. Bone resorption was 0 to 1 mm at a follow-up of 1 to 4 years. Marchetti et al.[84] reported similar results using autogenous cancellous particulate bone as the graft.

Interpositional grafting of the mandible has some limitations. It corrects only vertical defects, not horizontal defects. In addition, the amount of vertical gain that can be achieved with interpositional grafting is anatomically limited. This anatomic limitation is the stretch of the soft tissue attachments to the pedicled, mobilized alveolar segment of bone, which typically can be raised only 5 to 8 mm. Placing undue strain on the lingual soft tissue pedicle by vertically repositioning the mobilized bone may lead to compromised blood flow, incision breakdown, loss of the graft, and/or accelerated graft resorption.

Interpositional grafting is a safe, predictable method of achieving 5 to 8 mm of vertical augmentation in the posterior mandible if the clinician does the following:

- Scrupulously respects the anatomic limitations of the soft tissues
- Avoids excessive periosteal reflection
- Diligently applies the principles of rigid fixation
- Places endosteal implants early in the consolidation phase
- Dynamically loads the endosteal implants
- Uses particulate grafts in the appropriate situations

Case Example. This patient presented with intact anterior mandible dentition in excellent health and bilateral missing posterior teeth (Figure 2-22, A-K). The patient requested fixed restoration of the missing teeth. She has had problems wearing a removable partial denture. Her posterior maxillary teeth were in the proper plane of occlusion without supraeruption. Her posterior interocclusal space was excessive. A cone beam CT scan indicated 5 mm of bone superior to the inferior alveolar nerve bilaterally. Treatment options presented to the patient included a new removable partial denture, extraction of her remaining anterior teeth

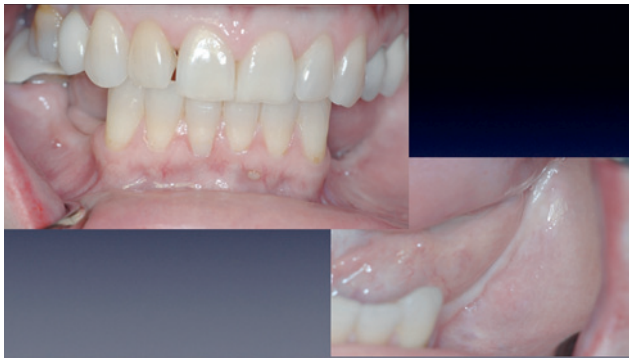


FIGURE 2-22 **A,** Preoperative views show healthy anterior teeth with bilateral posterior edentulism. The patient requested placement of bilateral fixed restorations without having her anterior teeth removed.

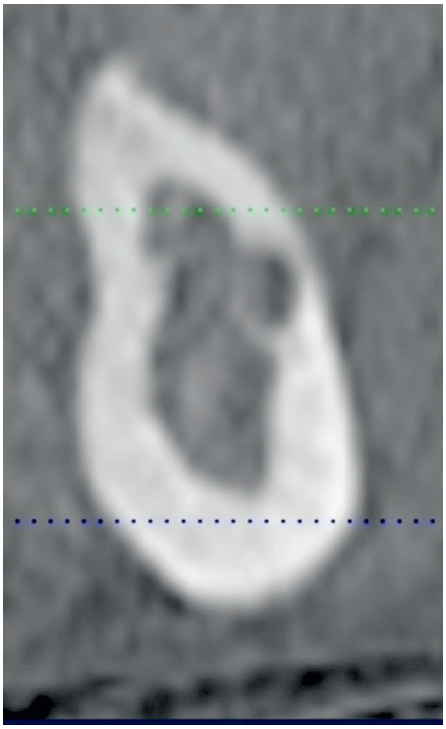


FIGURE 2-22 **B,** Cone beam cross section shows the nerve canal high on the ridge, with 5.5 mm of bone coronal to the canal.

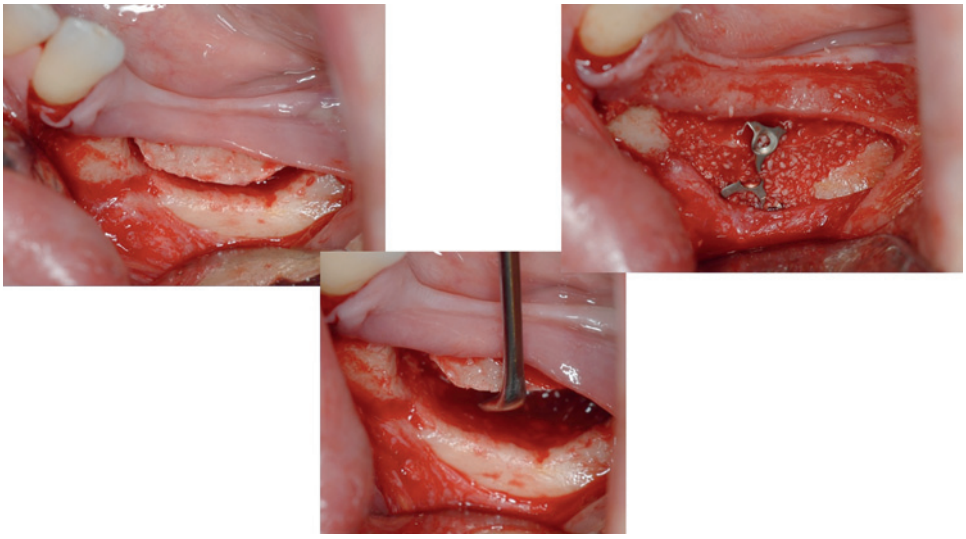


FIGURE 2-22 **C,** Surgery proceeded as follows: A vestibular incision was made with a vertical release one tooth anterior to the edge of the edentulous site. A mucosa-only dissection was performed until the mental foramen was identified. A periosteal incision was made superior to the foramen. The periosteum was reflected inferiorly, with care taken to maintain the attachments on the superior aspect of the crest. In the proposed vertical osteotomy sites, the periosteum was reflected minimally. A piezotome cutting device was used to create an osteotomy through the labial and lingual bone and in the two vertical sites. Completion of the cuts resulted in a mobile superior segment. The superior bone segment was raised carefully, resulting in 5 to 7 mm of bone augmentation. A small plate was used to stabilize the segment. The screws were 1.2 mm in diameter, which kept the screw profile very small. The plate first was secured to the superior segment, then raised to the desired position, and finally secured to the inferior portion of the mandible. Unicortical rather than bicortical screws were used. Care was taken to align the lingual portion of the cortices to prevent sharp bone edges. The interpositional gap was grafted with particles of allograft mineralized bone (350 to 500 μm). After the graft had been carefully placed, the incision was closed with resorbable sutures using tapered needles.

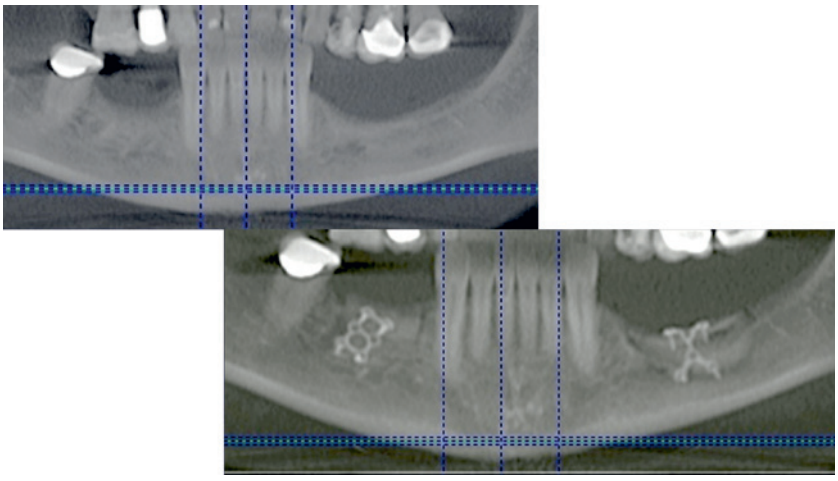


FIGURE 2-22 **D,** Panoramic radiographs show the preoperative and postoperative images.

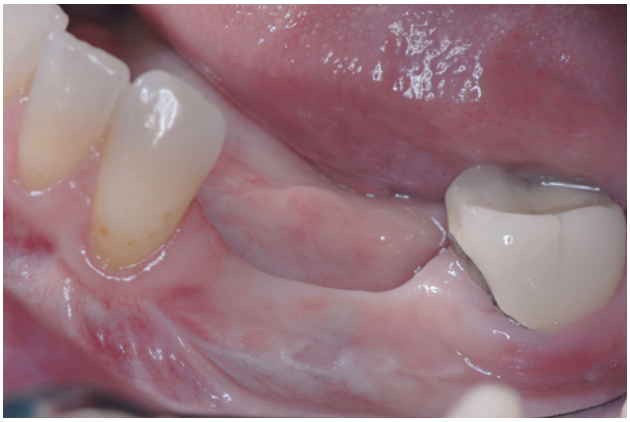


FIGURE 2-22 E, Left side of the posterior mandible 5 months after the interpositional osteotomy.

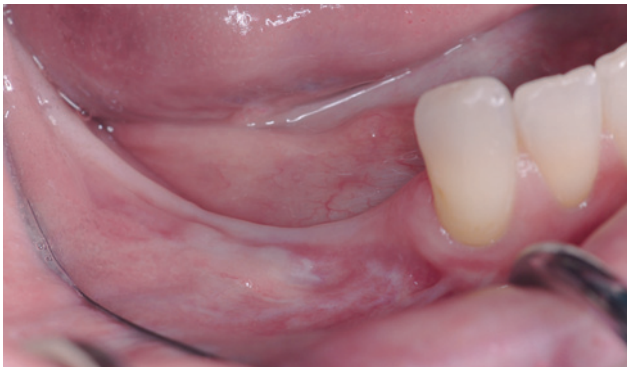


FIGURE 2-22 F, Right side of the posterior mandible 5 months after the interpositional osteotomy.

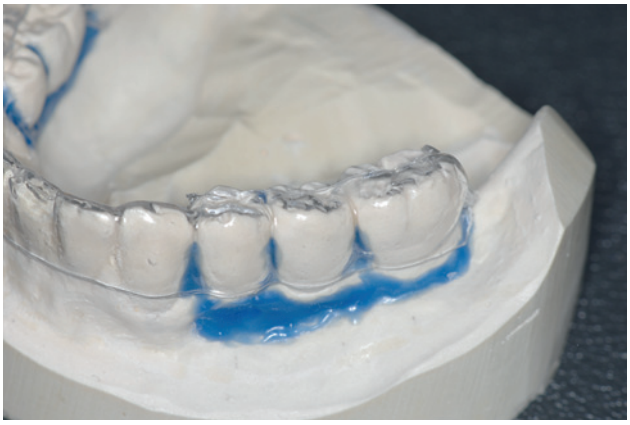


FIGURE 2-22 G, Restorative dentist (Dr. Michael Shannon) made a template based on a diagnostic setup of the planned restoration.

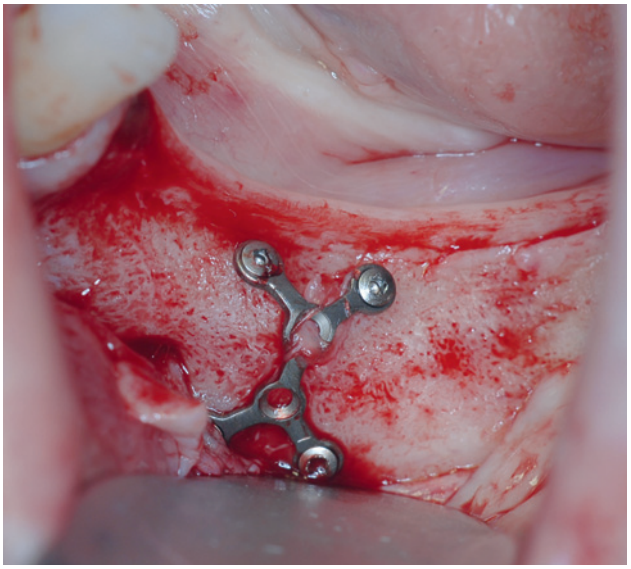


FIGURE 2-22 H, Crestal incision was made, and the periosteum was reflected to expose the plate. Note the excellent bone formation in the gap of the osteotomy. The plate was then removed.

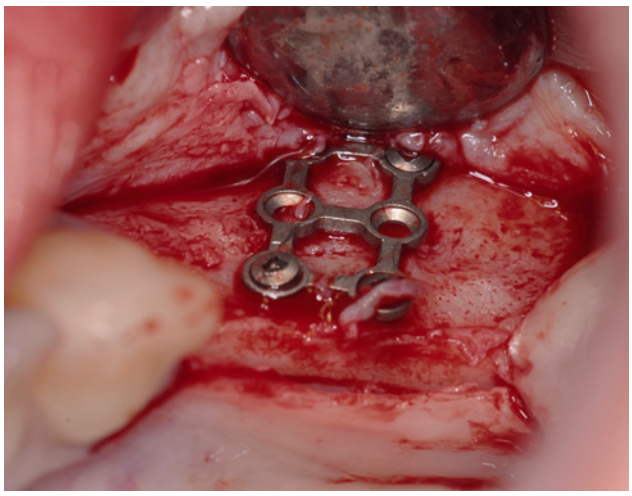


FIGURE 2-22 I, Right-side view. Note the excellent bone formation and intact, newly augmented mandibular ridge.

with placement of five implants for a fixed-hybrid or fixed-removable spark erosion–type prosthesis, or interpositional osteotomies to augment the posterior mandible vertically.

The cone beam cross-sectional images were used to plan the procedure. The patient signed a consent form that had informed her of the risks of sensory nerve damage, failure to achieve vertical dimension, failure of the graft to consolidate, and failure of implants. She then was prepared for surgery.

The patient was sedated for the procedure. A local anesthetic was administered into the vestibule of the left and

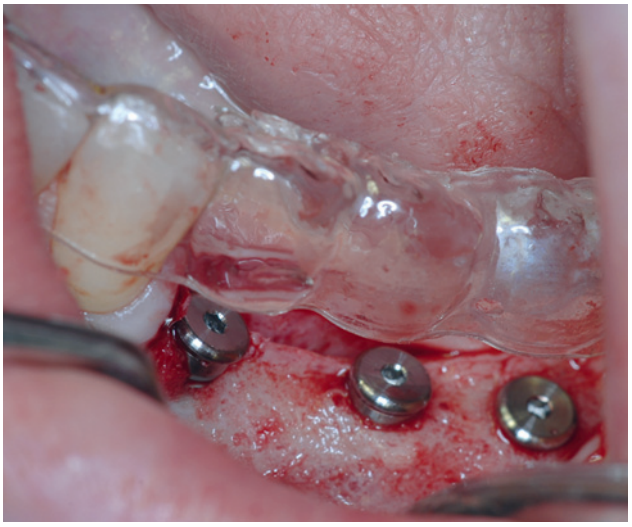


FIGURE 2-22 J, Three implants in position in the left posterior mandible.

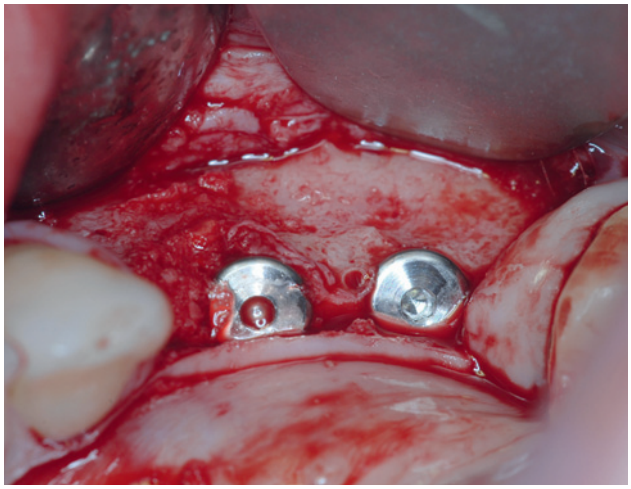


FIGURE 2-22 K, Two implants placed into the right side of the mandible.

right posterior mandible. After a satisfactory time had elapsed for hemostasis, an incision was made into the unattached gingival at least 10 mm lateral to the junction of the attached and unattached gingivae. Anteriorly, the vestibular incision was joined with a vertical incision made to the interdental areas of the teeth anterior to the edentulous site. A full-thickness flap was developed and combined with the dissection made from the lateral vestibular incision. A mucosa-only dissection was performed sharply and bluntly to isolate the nerve branches of the mental nerve. The periosteum was incised above the foramen to prevent damage to the nerve. The periosteum was reflected only inferiorly, which maintained the periosteum to the superior aspect of the ridge. No lingual mucosa was elevated.

A piezotome cutting tip was used to create the horizontal osteotomy above the inferior alveolar nerve canal. The vertical cuts were made with minimal elevation of the periosteum. The osteotomy cuts were made through the lingual cortical bone. Osteotomes were not used so as to prevent shearing of the lingual bone. A finger was placed over the lingual mucosa to feel the piezotome cutting blade exit the bone but not the lingual mucosa. The segment was mobilized passively and elevated to the extent of the soft tissue attachments. (If the floor of the mouth is high, the elevation can be greater than if the floor of the mouth is inferior.) The segment was elevated, and a small bone plate was attached first to the superior mobilized segment of the crest (usually 1.2- or 1.5-mm screws are used for this purpose). After the plate had been secured to the mobilized segment, the segment was elevated and oriented to minimize bone irregularities on the lingual mucosa. The final screws were placed in the inferior mandibular intact bone. The space was grafted with freeze-dried mineralized allograft. After the graft had been placed, the incision was closed without tension.

The patient was placed on a liquid diet and antibiotic therapy. Antibacterial rinses were not started until 3 days after surgery. After 3 months, a new CT scan was taken to confirm bone consolidation, and implants were placed in a routine manner.

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Section

II

Maxilla

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Chapter 3

Surgery of the Edentulous and Partially Edentulous Maxilla

Chapter Outline

Surgery of the Anterior Maxilla

Preoperative Planning and Assessment

Implant-supported therapy for the patient with an edentulous maxilla depends on several treatment planning issues. The following factors determine the treatment of choice:

1. General health of the patient
2. Goals of the patient, such as the need for removal of the palatal portion of the prosthesis, increased stability when chewing, and desire for a fixed prosthesis
3. Esthetic requirements of using acrylic to restore the soft tissue profile of the patient
4. Availability of bone in the anterior and posterior maxilla
5. Financial considerations
6. Consent for bone grafting of deficient sites, including consideration of the morbidity of the harvest site

Treatment planning usually is initiated at the restorative dentist's office. It involves establishing the patient's goals regarding what the patient wants at the completion of implant therapy. Once these goals have been established, the surgeon is consulted, and an assessment of bone availability is performed.

A panoramic radiograph and physical examination often are sufficient to determine whether satisfactory bone bulk is present for the placement of implants into the maxilla. The panoramic radiograph allows an estimate of the amount of vertical bone available in the premolar and molar regions. A good-quality panoramic radiograph can confirm the presence of adequate anterior maxillary bone for the placement of implants at least 10 mm long. Occasionally, a reformatted computed tomography (CT) scan or complex motion tomogram is obtained to confirm the presence of bone before implant placement. If cross-sectional radiography is planned, a radiopaque stent significantly increases the amount of information gathered. The radiopaque material, typically 20% to 30% barium sulfate combined with a clear acrylic, causes the teeth in the patient's prosthesis to become radiopaque in the cross-sectional image. This image provides information concerning the relationship of the bone to the desired teeth.

The amount of bone in the anterior and posterior maxillae should be determined. The *anterior maxilla* consists of the area anterior to the lateral walls of the nose or the anterior border of the sinus. The *posterior maxilla* consists of the regions of the second premolars and molars. The following four conditions are considered:

1. Greater than 10 mm of vertical bone height in the anterior and posterior maxillae
2. Greater than 10 mm of vertical bone height in the anterior maxilla, but less than 10 mm of bone height in the posterior maxilla

3. Less than 10 mm of vertical bone height in the anterior maxilla, with greater than 10 mm of vertical bone height in the posterior maxilla
4. Less than 10 mm of vertical bone height in the anterior and posterior maxillae

A prosthetic plan is completed, with the aid of the restorative dentist, after the amount of bone has been determined. Parel's classification of the edentulous maxilla is useful for conceptualizing the prosthetic plan (Box 3-1).

For the *Class I maxilla,* a fixed, implant-borne restoration can be fabricated, because the patient has adequate alveolar bone to support the soft tissues and is missing only the teeth. Usually greater than 10 mm of bone height is present in both the anterior maxilla and the posterior maxilla. For a fixed crown and bridge restoration, implants need to be placed within the confines of the teeth of the planned restoration. In addition, implant placement should avoid excessive angulation to ensure that the implants can draw as a single unit. Placement should avoid the embrasure regions to promote an esthetic outcome and oral hygiene. Finally, the implants should be placed 3 mm apical to the gingival margin of the planned restoration to allow the restorative dentist to develop a natural emergence of the crowns from the gingiva. A well-made, detailed surgical template is essential for a fixed crown and bridge restoration. The template should have full palatal coverage with anatomic retention at the hamular notches (posterior maxilla), enabling the stent to be placed in a repeatable, stable, and accurate position that allows the surgeon to follow its prescription when placed into the mouth.

If the patient with a *Class I* edentulous maxilla desires a tissue-borne overdenture on four implants because of financial constraints, the overdenture bar must avoid an excessive space-occupying design, because the patient is missing only teeth and not alveolar bone.

The *Class II maxilla* rarely can be managed esthetically with a fixed crown and bridge prosthesis, because this class requires the labial flange of the maxillary prosthesis to support the nasolabial soft tissues. A useful technique for determining the need for acrylic to support the soft tissues is to duplicate the patient's maxillary dentures and remove the labial flange, leaving only the teeth. The resultant soft tissue profile with the modified duplicated maxillary denture can help the implant team and the patient decide on the treatment plan. In addition, a deficiency of alveolar bone necessitates the placement of implants more apical than is ideal, resulting in excessively long teeth, teeth with pink acrylic, a removable lip "plumper," or a type of hybrid prosthesis with space between the prosthesis and implants.

A fixed crown and bridge prosthesis, a fixed-removable (e.g., spark erosion or milled) prosthesis, or a type of removable overdenture prosthesis may be prescribed. The fixed implant-borne and fixed-removable prostheses require at least six (preferably eight) endosseous implants to support a maxillary implant-borne prosthesis adequately. Zygomatic implants are the exception (see later discussion). These traditional fixed or fixed-removable prostheses require posterior maxillary vertical bone height for implants placed in the first molar region. The removable tissue-borne prosthesis requires four implants placed into the anterior maxilla to support a bar, which has retentive vertical stress-breaking attachments. All the edentulous maxillary prostheses usually are fabricated with cross-arch stabilization of the left and right implants.

For patients who smoke or drink alcohol heavily or who have uncontrolled diabetes or other systemic diseases that prevent bone grafting, the surgeon's only option for placing implants is to use the available bone. After a discussion with the restorative dentist, the amount and location of available bone can be determined.

BOX 3-1 Parel's Classification of the Edentulous Maxilla

Class I	Only maxillary teeth are missing, but patient has retained alveolar bone almost to its original level.
Class II	Teeth and some alveolar bone have been lost.
Class III	Teeth and most alveolar bone have been lost to the basal level.

Placement of Four Implants into the Anterior Maxilla

For the patient with adequate anterior vertical bone height and a treatment plan for anterior implants to provide overdenture support, four implants can be placed. Placement of at least four implants is recommended for an implant-supported overdenture in the maxilla, because fewer than four maxillary implants will not predictably resist the forces placed on them (Figure 3-1, A-B, and DVD Figure 3-1, A-F). Two implants are contraindicated to retain a maxillary overdenture.

3-1, A-F

Preoperative radiographs and a physical examination can reveal the height and thickness of the alveolar ridge. Four implants in the anterior maxilla, often combined with vertical stress-broken attachments placed at the distal aspects, are used to support a rigid bar. The anterior maxillary implants should be placed within the confines of the borders of the planned prosthesis and not labial to the borders of the teeth. The implants should be placed to avoid

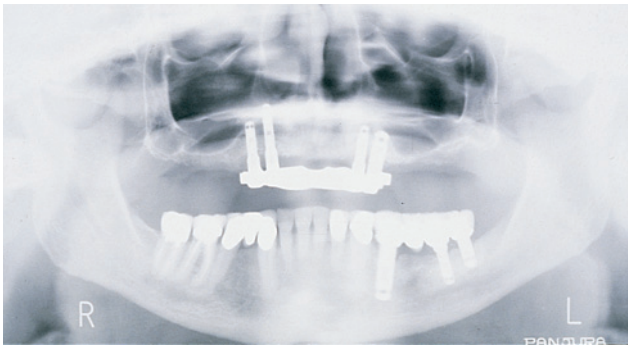


FIGURE 3-1 A, Panoramic radiograph showing the placement of four implants to retain a maxillary prosthesis. Often, sufficient bone is present in the anterior maxilla to allow placement of four implants without bone grafting.

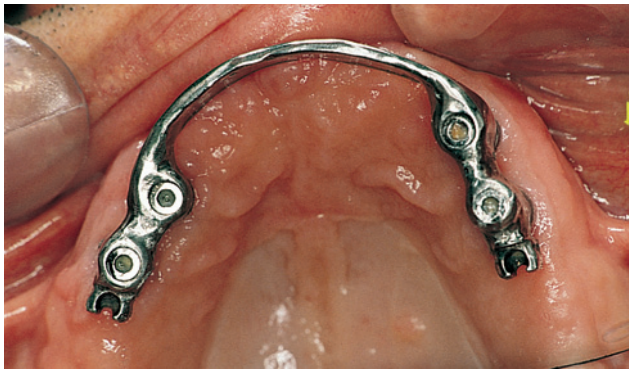


FIGURE 3-1 B, Bar fabricated with ASC52 attachments on its distal aspect. The bar cross-arch stabilizes the maxillary implants and aids mechanical distribution of masticatory forces in this 56-year-old man. (Prosthetics by Dr. Larry McMillen.)

impingement of the teeth in the overdenture and to allow space for fabrication of the bar. Careful attention to the position of the incisal edges of the lower teeth provides important information and prevents conflicts of space between the lower teeth and the palatal portion of the overdenture and the underlying bar.

At surgery, the surgeon should understand the prosthetic plan and recognize the ideal locations of the implants. Often these implants can be placed slightly palatal to the crest to engage more of the palatal bone, providing a thicker width of labial bone (Figure 3-2, A-E). A local anesthetic is infiltrated into the labial and palatal regions of the anterior maxilla. Incisions for implants placed into the anterior maxilla usually are placed over or slightly palatal to the crest. Vestibular incisions are avoided in the anterior maxilla, because they can shorten the vestibule and increase the patient's postoperative discomfort.

The incision is made along the crest, moving labially around the incisive papilla to avoid transecting its contents, and carried to bone through the periosteum. A full-thickness mucoperiosteal flap is raised, with care taken to prevent trauma to the flap. If necessary, vertical release incisions can be made distal to the planned implant locations to help raise the flap superiorly and thus expose the facial aspect of the maxillary bone. An anterior midline release is not used; it would increase postoperative morbidity because of the disturbance in the anterior lip musculature.

A full-thickness palatal reflection is then accomplished. The contents of the incisive canal are preserved and not incised. The palatal reflection should allow visualization of the slope of the vertical palatal bone to ensure that the surgeon can visualize the insertion of the implants without violating either the labial or the palatal cortical bone, thereby keeping the implant body within bone. The visualization also allows determination of the probable need for

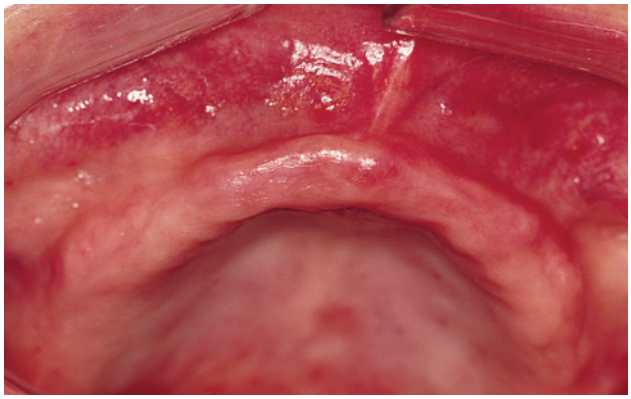


FIGURE 3-2 A, Bone height in this patient is satisfactory for implants in the anterior maxilla, but she does not want posterior implants for a fixed-removable restoration.

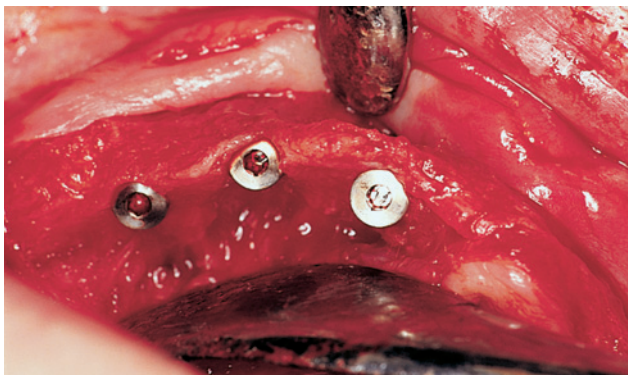


FIGURE 3-2 B, Incision is made slightly palatal to the crest. After subperiosteal reflection, the implants are placed. The slightly palatal location of the implants is shown with maintenance of a thick labial plate, which preserves the labial bone and prevents implant dehiscence.

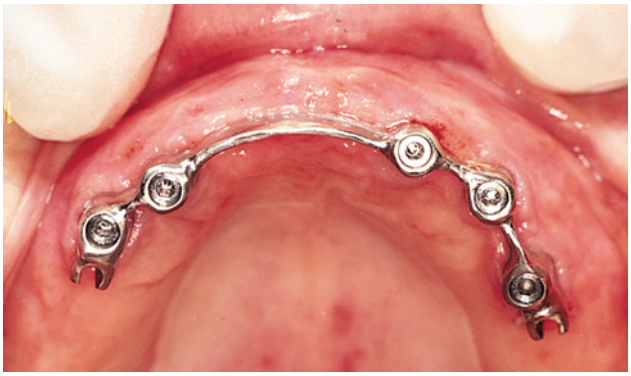


FIGURE 3-2 C, Implants are exposed after 4 months of healing. The bar is made for cross-arch stabilization of the implant-supported, tissue-borne prosthesis. (Prothetics by Dr. Troy Patterson.)

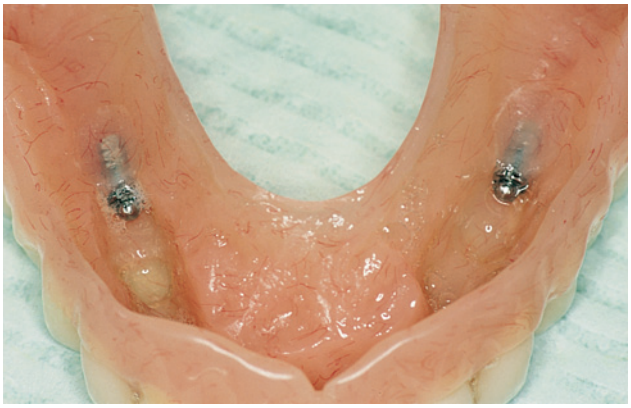


FIGURE 3-2 D, Distal ASC52 vertical stress-breaking attachments are placed within the denture to provide vertical stability.

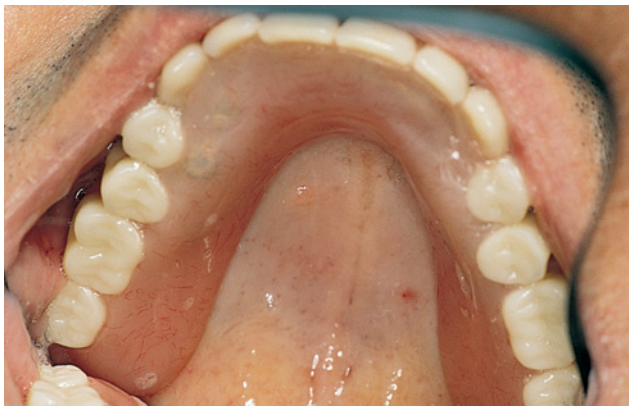


FIGURE 3-2 E, Maxillary prosthesis in place. The palatal portion of the maxillary prosthesis is removed for patient comfort.

osteotomes, either round or flat, to widen the ridge during implant placement.

After the labial and palatal tissues have been reflected, the surgeon should have a good view of the crestal bone thickness and the contours of the palatal and facial cortical bone. The dissection often must be extended superiorly to identify the piriform rim, especially for the more atrophic maxilla. The thickness of bone is confirmed, and the surgical stent is placed. The areas of planned implant placement are examined.

Often the crest of the maxilla is narrow and widens within a few millimeters of the crest. Specific sites may be wider than others, indicating a site that is more ideal for the implant when bone bulk is considered. However, before placing the implant in a site slightly different from that prescribed by the surgical stent, the surgeon should ensure that the prosthetic plan will not be adversely affected.

Because the maxillary crest usually has sharp edges and slopes, the first step is the creation of a depression in the ridge that allows accurate engagement of the drills. The implant sites are scored with either rongeur forceps or a round bur, creating a divot into the bone. The round bur is used to initiate the osteotomy site and to determine the specific location of the implant in the middle of the crest. Accurate placement of this round bur hole is important, because subsequent drills will start in this round hole; changing the position may be difficult once the drilling process has started. If the first drill needs adjustment in position (e.g., the hole is too far labial or palatal), the round bur is used to relocate the hole slightly palatal, labial, distal, or mesial, guided by the need to place the implants into adequate bone and in the correct location. The surgeon must always critically examine the implant sites; the implants must be placed accurately to ensure successful prosthetic treatment.

Subsequent graduating-sized drills initiate and expand the implant site until the final drills are used. If the ridge is excessively narrow, round or flat osteotomes can be used to expand it, or the ridge may require grafting before implant placement. Usually the ridge has sufficient width for placement of the implants. If the ridge width is deficient, the surgeon should consider whether osteotomes can be effective or whether onlay grafting is indicated. If the ridge width is 3 mm, osteotomes can be used to expand it in most cases. However, if the ridge is thin and does not expand as the bone is examined superiorly, the use of osteotomes or ridge splitting in a ridge less than 3 mm is not predictable. For these cases, onlay grafting is indicated and should be discussed with the patient. (See Chapter 4 for examples of onlay grafting of the anterior maxilla with symphyseal bone.)

Implants for overdentures typically are placed with their centers slightly palatal to the crest to avoid dehiscence and

thin bone over the facial aspect of the implants. The incisive canal should be avoided as a site for implant placement. Implants should be placed to prevent dehiscence of the implant within the incisive canal. Specifically, implants for overdentures are placed in the canine and premolar locations, depending on the availability of bone. An implant can be placed in the lateral incisor position if necessary. However, implants placed in the central incisor locations complicate the prosthetic rehabilitation, because the presence of the abutments and bar near the midline may result in excessive palatal bulk in the denture; this outcome may be bothersome to the patient.

If a dehiscence of bone occurs in the midportion of the implant because of concavity of the ridge, particles of dense, nonresorbable hydroxylapatite (HA) are placed to obliterate the defect. Use of a membrane depends on the surgeon's clinical judgment. In general, a membrane is not necessary for small dehiscences.

After the implants and the implant cover screws have been placed into the implant bodies, the incision is closed. Occasionally the periosteum must be released to allow tension-free closure. If no graft has been placed, the type of suture depends on the clinician's preference. If a graft has been placed, nonresorbable sutures are indicated.

The patient's current prosthesis should be left out of the mouth for 7 to 10 days after implant surgery. However, if the patient cannot accept this recommendation, the surgeon or restorative dentist should remove the labial flange to the gingival margin of the denture teeth and relieve the crest region. This extremely relieved maxillary prosthesis then can be glued in with denture adhesive on the palate without adhesive on the incision sites. Patients can wear the modified prosthesis for esthetic reasons, but they must consume a liquid, pureed diet for 2 weeks.

Placement of Eight Implants without a Graft

If the patient's goal is to have a denture that accommodates a palateless prosthesis, enabling the patient to chew all textured foods without the prosthesis, a sufficient number of implants (depending on the tissues for support) is required to resist the forces of mastication. For these patients, six to eight implants for a fixed implant-supported or removable prosthesis is recommended, with an adequate number of implants located posteriorly to support the molars.

The edentulous patient with a Class I maxilla requires only the placement of implants to replace the missing teeth (Figure 3-3, A-G). In most patients with a Class I maxilla, who have lost their teeth with minimal bone loss, the labial bone has an irregular contour. These patients may benefit from augmentation of the labial bone to smooth the bone contour and enhance the final restoration, especially for those with high smile lines (Figure 3-4, A-I).

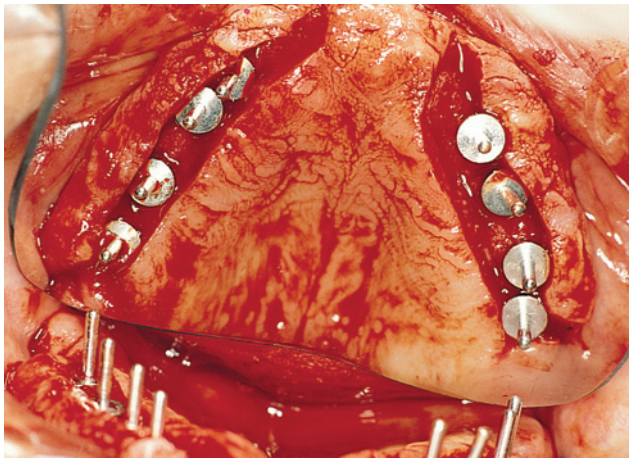


FIGURE 3-3 **A,** Maxillary teeth of this 62-year-old man were removed 6 months before implant surgery. The teeth were removed secondary to caries. His workup indicates that the alveolus has been maintained and that adequate bone is present for a fixed, implant-borne maxillary prosthesis. At surgery, eight implants are placed, with a duplicate denture used as the surgical guide. The incision design avoids the anterior maxilla and incisive canals, and the parallelism of the preparations allows all the implants to draw as a unit.

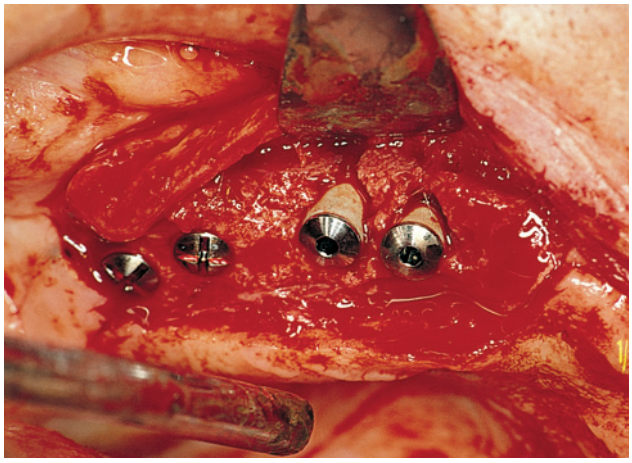


FIGURE 3-3 **B,** Labial bone in the right side is thin, with a portion of the implants exposed. For a fixed restoration, the locations for implant placement depend on the surgical planning; consequently, the implants cannot be placed too far toward the palatal side, necessitating these locations. The implants must be placed directly under the teeth. For a bar-retained prosthesis, additional space is required for the bar; therefore, the implants must be placed more palatally.

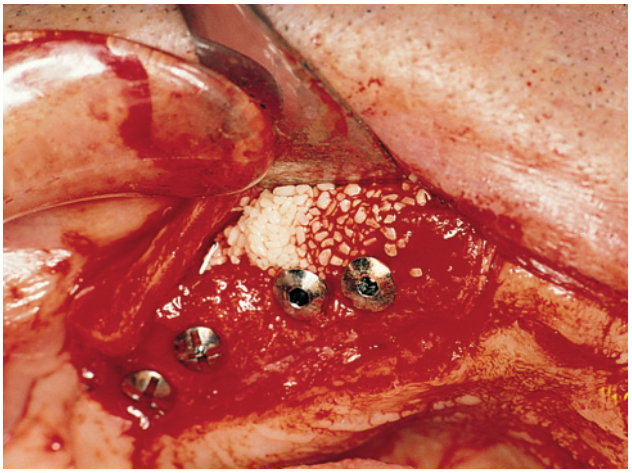


FIGURE 3-3 C, Dense hydroxylapatite (HA) is grafted over the implants. The periosteum is used as a membrane, and the incisions are closed. Bovine bone can also be used.

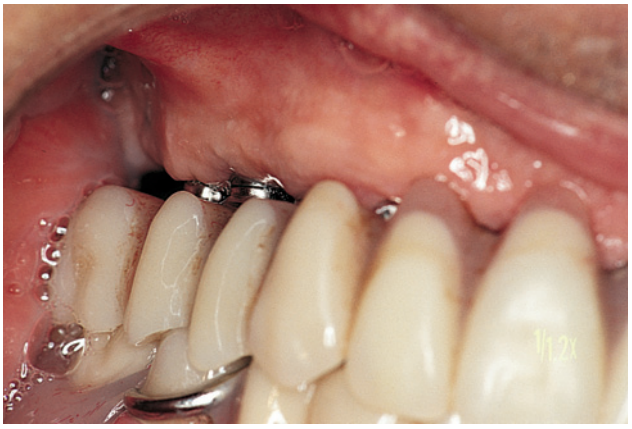


FIGURE 3-3 E, Final restoration is placed. The space created allows for easy maintenance of oral hygiene.

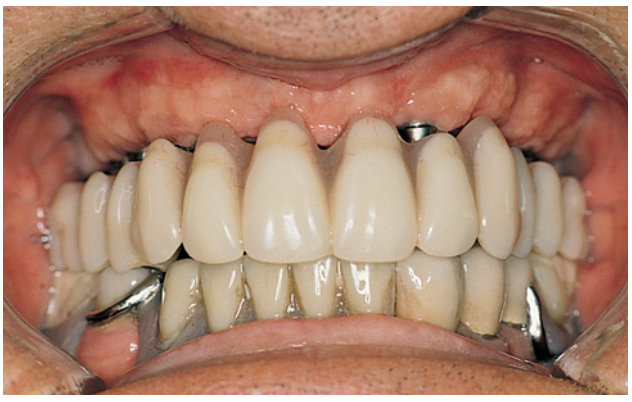


FIGURE 3-3 G, Frontal view demonstrating the occlusion. (Prosthetics by Dr. Troy Patterson.)

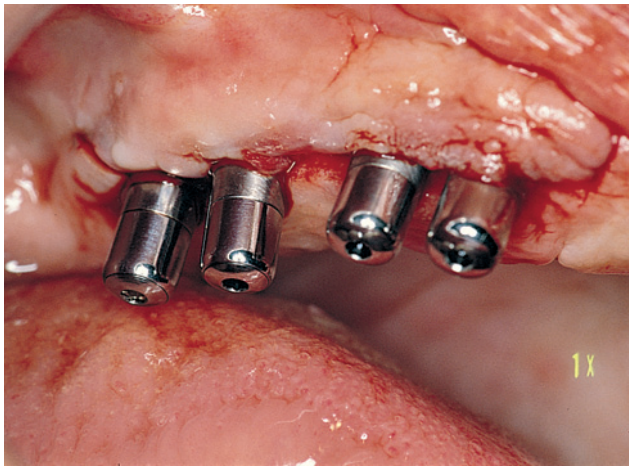


FIGURE 3-3 D, At exposure of the implants, a crestal incision is made, and the flap is reflected. The inner thickness of the flap is thinned with a scalpel, limiting the pocket depth that surrounds the abutments to 3 mm. After 2 weeks, the gingiva around the abutments has healed and is ready for impressions.

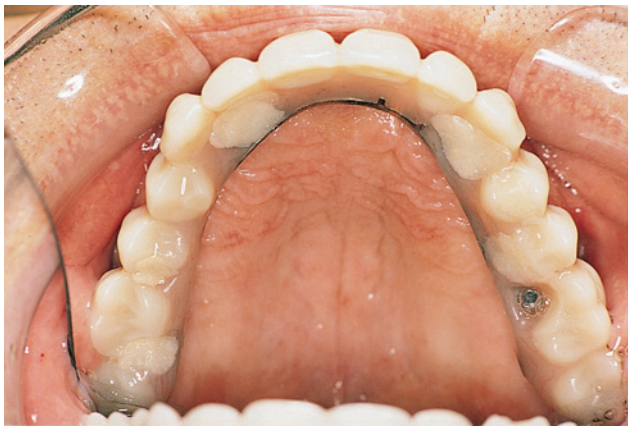


FIGURE 3-3 F, Occlusal view showing the implants positioned within the confines of the teeth as planned.

Patients with a Class II maxilla, who have lost their teeth but have a moderate amount of bone, must have an esthetic evaluation. These patients may require the labial flange of a removable prosthesis to provide nasolabial support. They may have sufficient bone for the placement of implants, but without additional lip support, the result may be compromised (Figure 3-5, A-F). The patient's denture can be duplicated in clear acrylic, and the flange can be completely removed. If the modified denture is placed into the mouth and the lip support is adequate, a fixed restoration can be

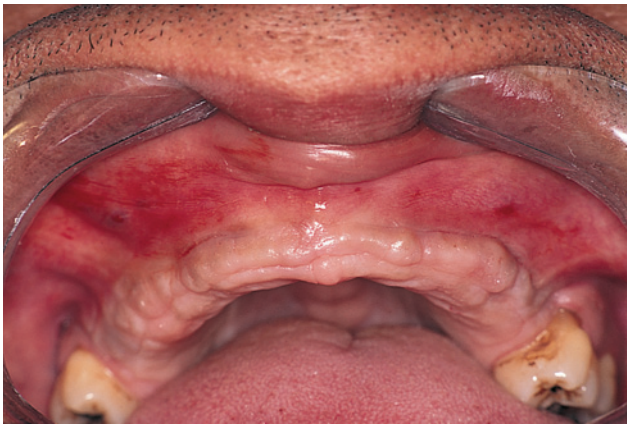


FIGURE 3-4 A, This 49-year-old man desires a fixed maxillary restoration. His presurgical analysis shows that he is missing 2 mm of vertical alveolar bone. His planned restoration can be achieved with implants and a full-arch, porcelain-fused-to-metal prosthesis. Irregularities are noted in the labial ridge contour, which will undergo augmentation during implant surgery. The preoperative panoramic radiograph shows excellent bone height.

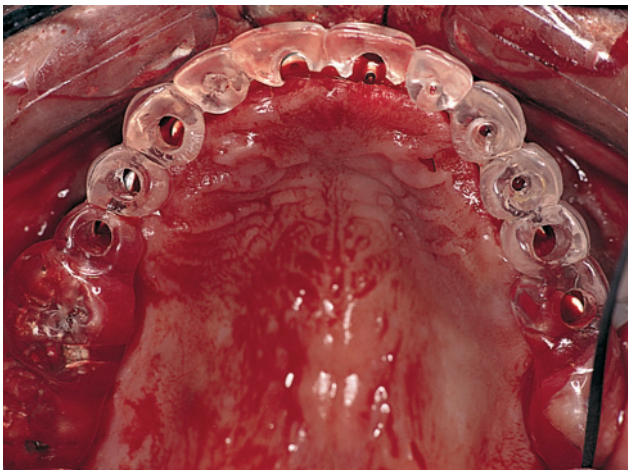


FIGURE 3-4 C, Intraoperative photograph showing the surgical guide in position; the implants are visible through the holes in the guide. The depth to which the implants are countersunk also is guided by the flange of the surgical guide, which accurately shows the position of the gingival margin of the planned restoration.

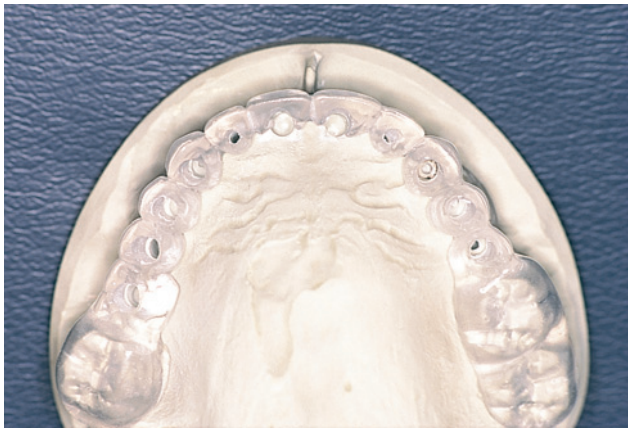


FIGURE 3-4 B, Preoperative workup includes a complete waxup of the planned prosthesis, which is tried in the mouth to confirm esthetics and obtain the patient's approval before surgical placement of the implants. The waxup is converted into acrylic, and a surgical guide is fabricated. Because the second molars are present bilaterally, full-arch coverage is not required. The precise locations of the implants are prescribed by drilling holes through the surgical guide. These holes are 3 mm wide, which coincides with the intermediate drill of the chosen implant system.

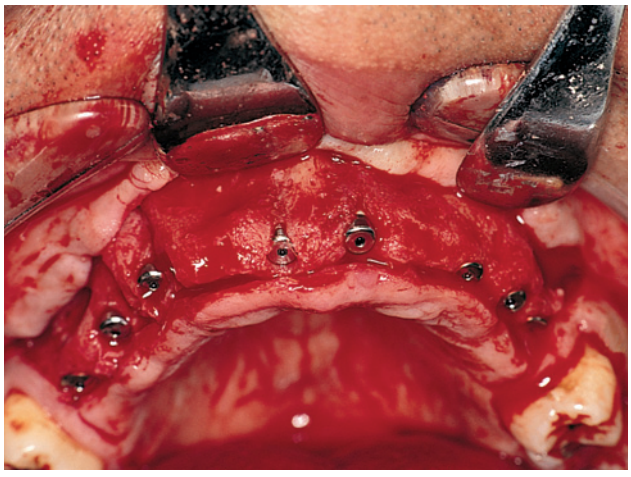


FIGURE 3-4 D, Implants are shown in place. Small areas of irregularity in the alveolus can be seen. Before grafting, the periosteum is released to allow tension-free closure.

used. However, the locations of the implants and the need for removable prosthetics to aid in the maintenance of effective oral hygiene also are important considerations.

Patients with a Class III maxilla, who have lost their teeth and most of the alveolar bone to the basal level, benefit from a fixed-removable restoration (Figure 3-6, A-E).

Preoperative radiographs and a physical examination can reveal the height and thickness of the alveolar ridge. A panoramic radiograph is used as a screening radiograph. If the magnification of the radiograph is known, a good-quality panoramic radiograph may be the only one required for a patient who needs a full-arch implant. If questions

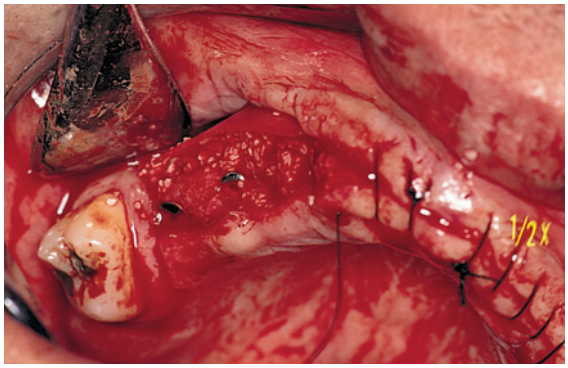


FIGURE 3-4 E, Dense, particulate HA is placed over the irregularities in the ridge. A collagen membrane is placed over the HA to retain it in the desired location. As one side is grafted, the incision is closed with 4-0 silk sutures.

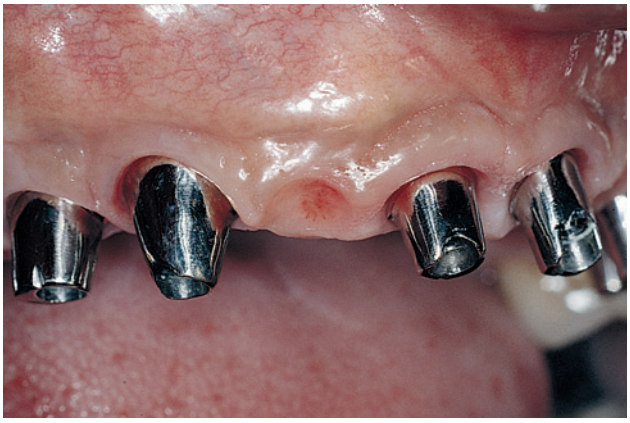


FIGURE 3-4 G, Implant-level transfer and anatomic, custom-made abutments create the subgingival contour of natural teeth. Here the anatomic abutments are shown in place.

concerning bone availability arise, cross-sectional images can be obtained using either CT or complex motion tomography. The CT scans reveal more information than complex motion tomography, especially about the health of the sinus and the thickness of the sinus membrane; in addition, CT is accurate within 0.5 mm.

Eight implants in the anterior and posterior maxillae are used to support a suprastructure for a totally implant-borne restoration, with tissue contact only for speech. If a type of bar structure is planned, the implants should be placed within the confines of the borders of the planned prosthesis, not labial to or outside of the borders of the teeth. The implants should be placed to avoid impinging on the teeth in the overdenture and to allow space for

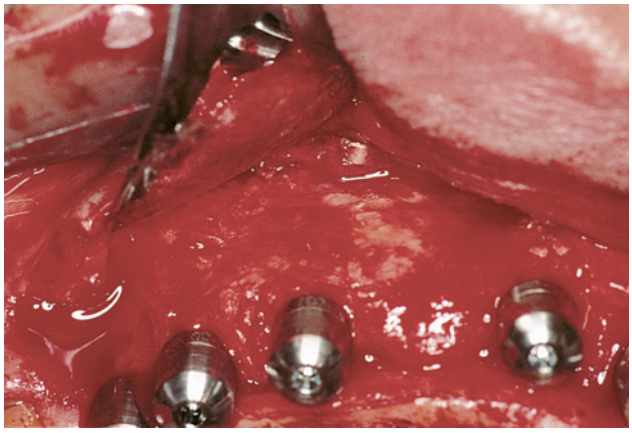


FIGURE 3-4 F, After 5 months, the implants are exposed. A crestal incision is made to transpose keratinized gingiva (KG) to the labial aspect of the healing abutments. The smooth contour of the alveolus is demonstrated. After 3 weeks of healing, the patient is ready for transfer impressions.

fabrication of the bar. The surgical guide stent is made after a complete setup has been performed to allow for accurate planning of placement of the implants in the ideal position for bar fabrication. Careful attention to the position of the incisal edges of the lower teeth provides important information that can prevent conflicts of space between the lower teeth and the palatal portion of the overdenture and the underlying bar. For many of these implant-borne cases, implants are placed from the canine region and extend posteriorly, with a minimal number of implants placed into the incisal region. This pattern of placement makes the design of the anterior portion of the prosthesis easier. However, for patients with shorter vertical bone in the posterior maxilla (e.g., 10 mm), placement of longer implants in the anterior region may be indicated because of the need for mechanical strength for prosthesis loading during chewing.

Incisions for full-arch distribution of implants placed into the maxilla usually are placed slightly palatal to the crest. Vertical release incisions are made posterior to the most distal implant, which typically is in the first or second molar region. Anterior, midline, vertical release incisions usually are not necessary, because they cause increased postoperative discomfort; however, they may be necessary in selected patients. Planning for incision breakdown is recommended; placing the incisions on the crest ensures that the keratinized gingiva (KG) will be labial to the implants. A vestibular incision or an incision made at the junction of the attached and unattached gingivae may

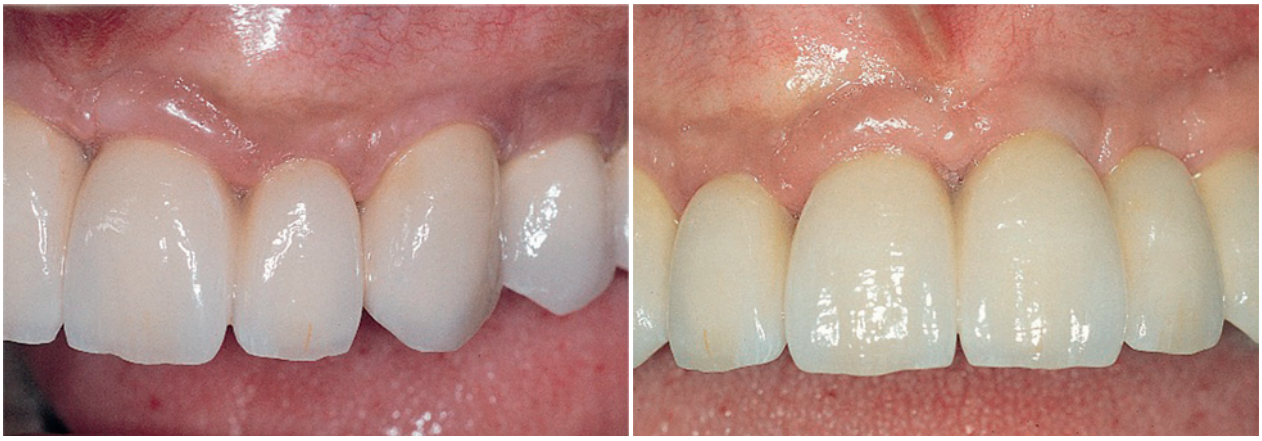


FIGURE 3-4 H-I, Final prosthesis with appropriate gingiva form and papilla. (Prosthetics by Dr. Steven Locasio.)

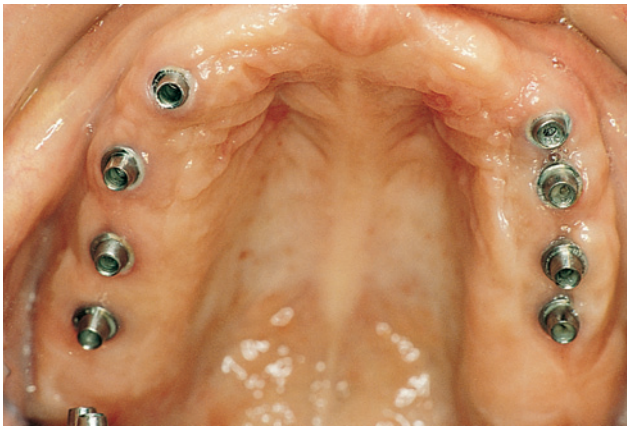


FIGURE 3-5 A, This 45-year-old woman requested a fixed restoration in the maxilla. The preoperative evaluation revealed loss of teeth, as well as loss of some alveolar bone height and horizontal bulk. Eight implants were placed from canine to molar, avoiding the anterior four incisor sites.

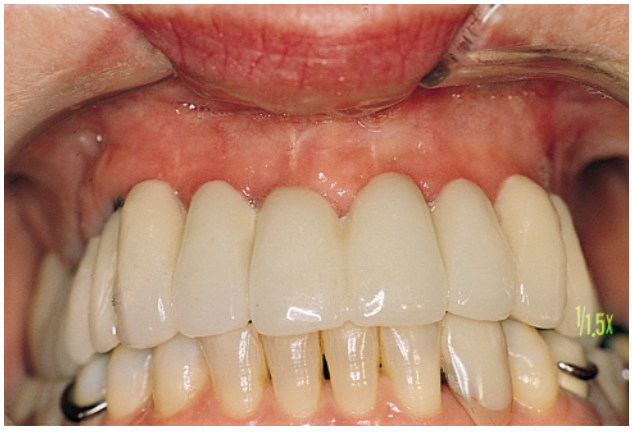


FIGURE 3-5 B, Final implant-borne, porcelain-fused-to-metal restoration. The anterior teeth are ridge lapped for speech and phonetic function.

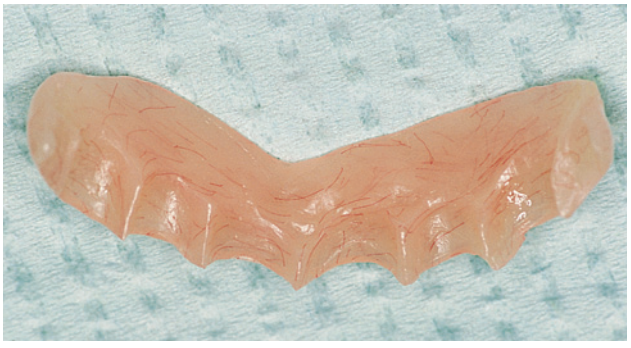


FIGURE 3-5 C, Patient complained of an older-than-desired appearance. An acrylic lip plumper is fabricated and processed to provide lip and paranasal support.

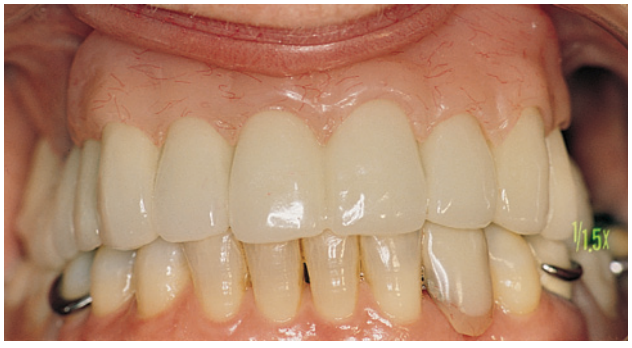


FIGURE 3-5 D, Acrylic lip plumper in place.

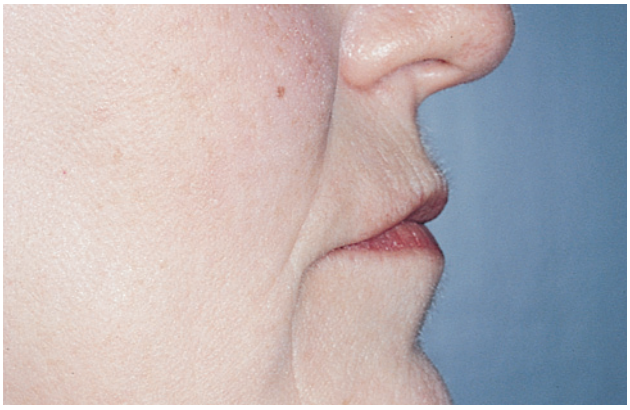


FIGURE 3-5 E, Lateral photograph with lip plumper out shows the lack of nasolabial support.

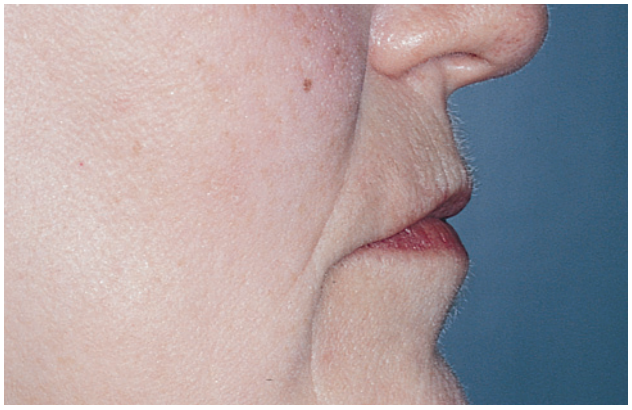


FIGURE 3-5 F, Lateral photograph with lip plumper in place shows a subtle improvement in the patient's appearance. The patient was very satisfied with the result. (Prosthetics by Dr. Larry McMillen.)

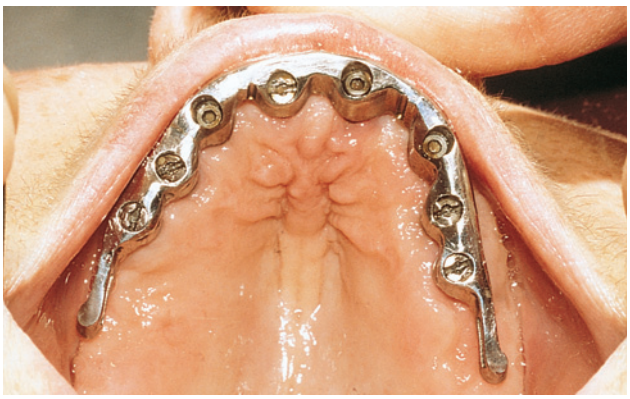


FIGURE 3-6 A, Maxilla showing loss of a significant amount of maxillary horizontal alveolar bulk. For treatment, eight implants are placed in the remaining bone, and a spark erosion prosthesis is fabricated. This fixed-removable type of prosthesis locks onto the bar with small clips. The bar is precision fabricated to mate precisely with the inner metal substructure in the denture.

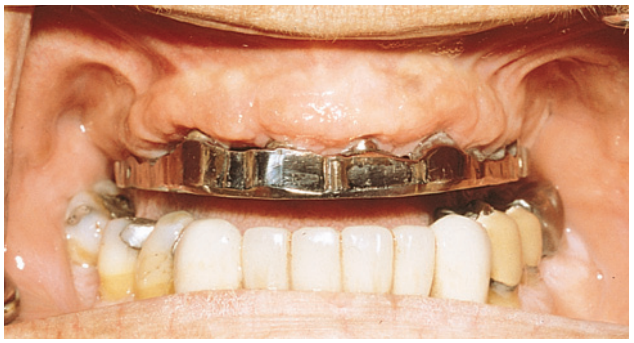


FIGURE 3-6 B, Frontal view showing the Class II skeletal relationship of the maxillary ridge to the mandible.

result in loose gingiva adjacent to the implants if incision breakdown occurs (Figure 3-7, A-H).

For patients who want a fixed crown and bridge restoration, a surgical guide stent must be available to identify the specific locations of the implants. This stent should have full palatal coverage and, if present, intimately adapt to the remaining dentition. For the patient whose treatment plan includes a fixed removable prosthesis (e.g., spark erosion, precision bar–retained overdenture), the implant position is more flexible. The implants should be placed slightly to the palatal aspect to allow sufficient room for the teeth to be placed without encroaching on the framework. However, if the implants are placed too far to the palatal aspect, the bar and denture will have excessive bulk palatally, which will

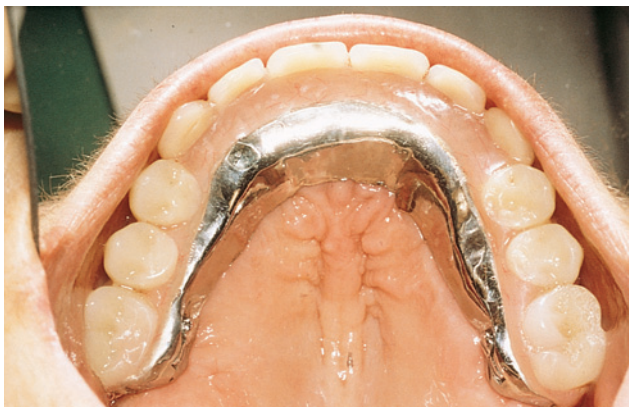


FIGURE 3-6 C, Prosthesis can be made to overcome the skeletal dysmorphism. Note the extent of acrylic and teeth used to provide the proper maxillary soft tissue esthetic support.

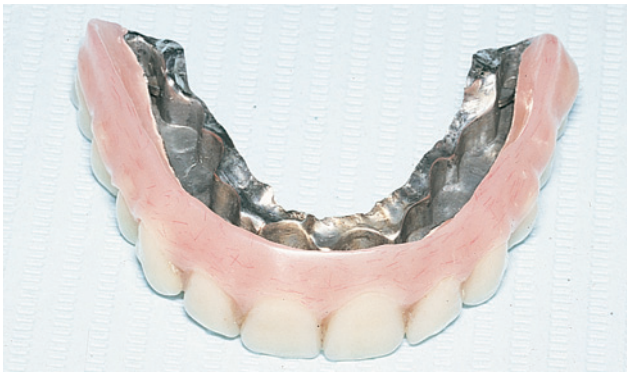


FIGURE 3-6 D, Maxillary prosthesis showing the internal metal substructure.

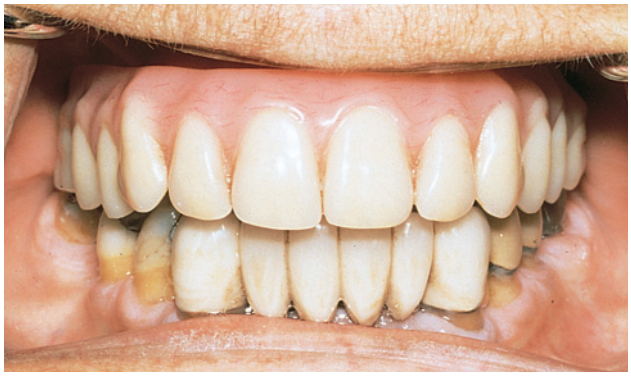


FIGURE 3-6 E, Final occlusal scheme. (Prosthetics by Dr. Israel Finger.)

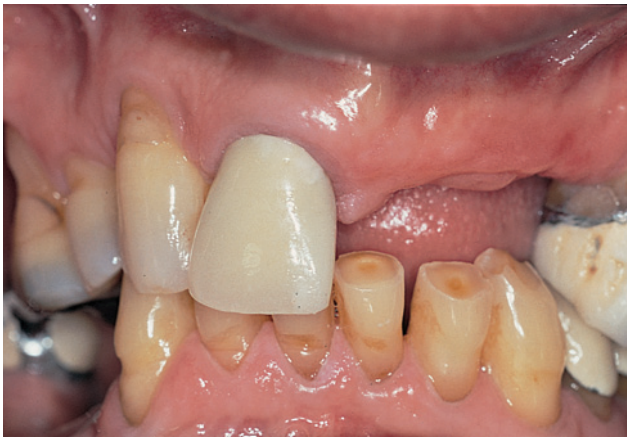


FIGURE 3-7 A, This 60-year-old clarinet player wants maxillary and mandibular prostheses for improved retention. His current periodontally involved teeth are mobile and have exudate on probing. The panoramic radiograph shows excellent bone height from first molar to first molar. The treatment plan includes extraction of the dentition, placement of an immediate denture, and placement of eight implants from first molar to first molar after 8 weeks of extractions. These implants will support a spark erosion fixed-removable prosthesis.

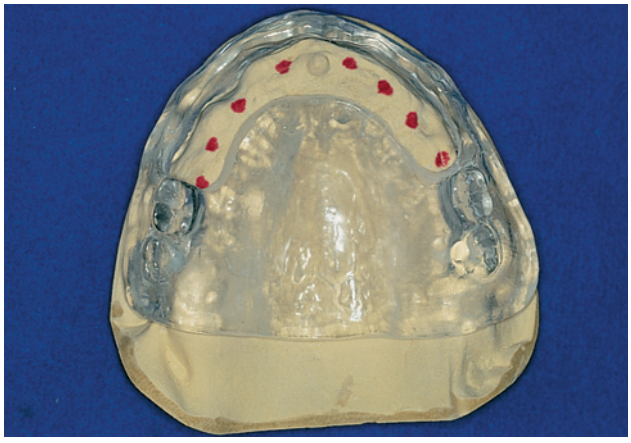


FIGURE 3-7 B, Preoperative prosthetic workup includes setting teeth on appropriate models to achieve the esthetic result. From this setup, a surgical guide is made. The acrylic is trimmed to create a channel, which is the prescribed area for implant placement. The full palatal coverage and posterior retention, which aid stent stability during surgery, are shown.

impair speech and function and impinge on the natural tongue position. A surgical guide stent with a slot can guide the surgeon to the boundaries for implant location.

A local anesthetic is infiltrated into the labial and palatal regions of the maxilla. A crestal incision is made, moving labially around the incisive papilla to avoid transection of its contents. The incision is made through the periosteum to bone. A full-thickness mucoperiosteal flap is raised, with care taken to prevent trauma and avoid perforating the flap. A full-thickness palatal reflection is then accomplished. The contents of the incisive canal are preserved and are not incised.

After the labial and palatal tissues have been reflected, the surgeon should have a view of the crestal bone thickness and the contours of the palatal and facial cortical bone. If necessary, the dissection can be carried superiorly to identify the piriform rim, which is useful for cases that are more atrophic. The bone width is confirmed, and the surgical stent placed. The areas of planned implant placement are identified and marked with a round bur or rongeur forceps.

Often the crest of the maxilla is narrow and widens within a few millimeters of the crest. The implant sites can be

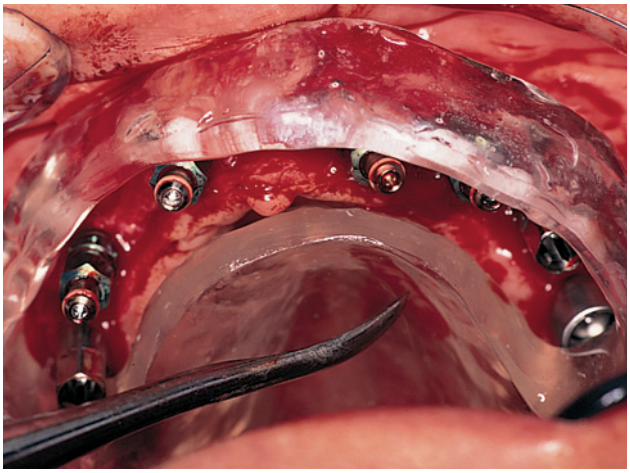


FIGURE 3-7 **C,** Flaps are reflected toward the labial side, and the implants are placed. The implants are shown with the driving mounts. All implants are within the channel of the surgical guide.

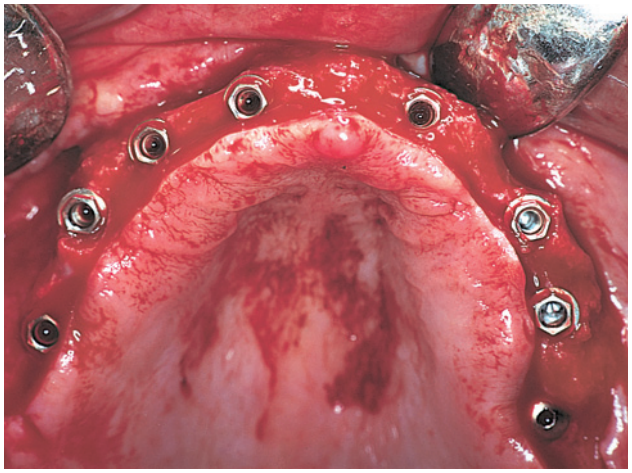


FIGURE 3-7 **D,** Driving mounts are removed. For a spark erosion prosthesis, the implants do not need to be countersunk as deeply as for a fixed crown and bridge prosthesis.

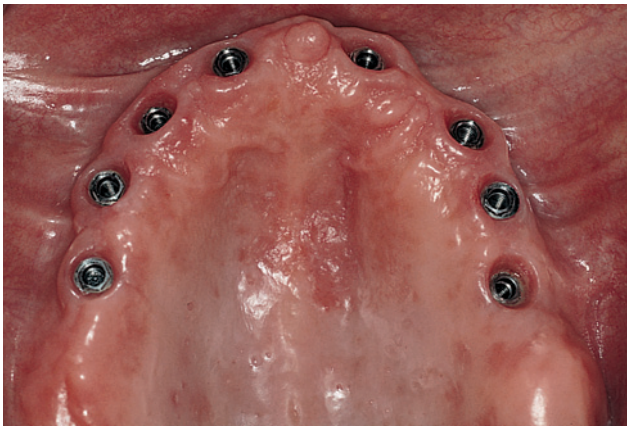


FIGURE 3-7 **E,** After 5 months, the implants are exposed, and the healing abutments are placed. The KG is preserved labial to the healing abutments. After the gingiva has healed, the healing abutments are removed. The mature, healed gingiva is shown.

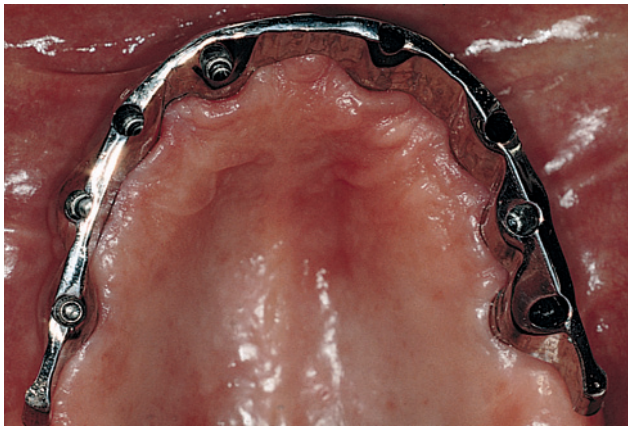


FIGURE 3-7 **F,** Spark erosion bar in place.

scored with rongeur forceps, creating a divot in the bone. A round bur then can be used to begin the osteotomy site. Subsequent graduating-sized drills initiate and enlarge the implant site until the final drills are used. If the ridge is excessively narrow, round or flat osteotomes can be used to expand the ridge, or the ridge may require grafting before implant placement. Usually, the ridge posterior to the canine region is sufficiently wide for the placement of implants.

The implants for fixed removable overdentures typically are placed with their centers slightly palatal to the crest to avoid dehiscence and thin bone over the facial aspect of the implants. The implants can be positioned from second molar to central incisor; however, most restorative dentists prefer to avoid the central incisor and second molar sites. The second molar site can be used in select cases, but the placement of screws, abutments, and transfer copings is difficult. In addition, the bars may need the space of the second molar site for attachments, depending on the prosthetic design of the retentive bar.

If a dehiscence of bone occurs in the midportion of the implant because of concavity of the ridge, particles of dense, nonresorbable HA are placed to obliterate the defect. Use of a membrane depends on the surgeon's

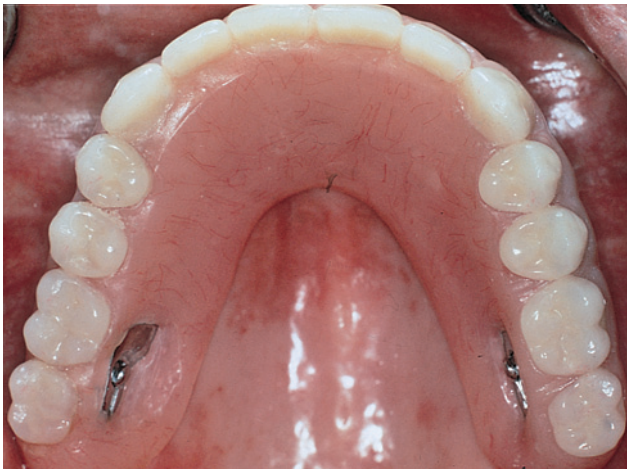


FIGURE 3-7 G, Maxillary prosthesis in place; the retentive clips on the palatal aspect of the prosthesis are shown. (Prosthesis by Dr. Sean McCarthy and Dr. Israel Finger.)

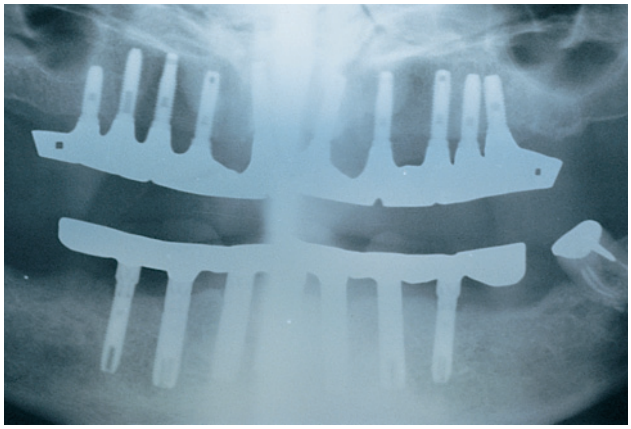


FIGURE 3-7 H, Follow-up panoramic radiograph shows the final bar in place.

clinical judgment. In general, a membrane is not necessary for small dehiscences. When doubt exists, grafting thin bone with HA prevents future problems if the thin labial bone resorbs during function.

All eight implant sites should be prepared sequentially, using the pilot drill, with serial placement of the parallel or guide pins to help align the implants with each other. The surgical guide stent should be used as much as possible to ensure correct positioning of the implants. It is important to place the implants so as to ensure that they can draw as a unit. The surgeon should avoid placing implants on one side to completion and then starting the opposite side of the maxilla, because implant angulation may be difficult to ascertain. As the drill diameters increase, careful attention to preventing bone dehiscence is important. The surgeon may need to move an implant along the ridge mesially and distally or facially and palatally to engage the thickest bone possible. If performed with the aid of a surgical guide stent, these changes will not adversely affect the restoration. However, when implants are placed for a fixed crown and bridge restoration, which is screw retained or cemented, there is less tolerance for small changes. These implants must be placed exactly where prescribed. Overdenture and fixed-removable (e.g., spark erosion) prostheses allow the surgeon more freedom of implant placement.

After the implants and cover screws have been placed into the implant bodies, the incision is closed. Occasionally, the periosteum needs to be released to allow tension-free closure. If no graft has been placed, the type of suture depends on the clinician's preference. If a graft has been placed, nonresorbable sutures are indicated. If the bone ridge has an irregular contour, HA can restore an even contour, which helps establish a smooth, more esthetically pleasing gingiva.

Patients are strongly encouraged to leave maxillary dentures out of the mouth for 7 to 10 days. If this is unacceptable to the patient, the denture is trimmed. The labial flange is shortened to the gingival margin of the teeth in the denture, and the inner aspect of the denture is generously relieved to the horizontal shelf. The patient is advised to wear the denture for social reasons only and to leave it out of the mouth most of the day. The patient should use denture adhesive only on the palatal portion of the denture, avoiding the surgical sites. When patients have been appropriately counseled on the sequelae of trauma to the ridges and the potential loss of implants, they tend to cooperate.

Placement of Implants and Onlay Bone Grafts for Isolated Defects

Patients with isolated bone defects caused by trauma or ablative tumor surgery who have retained a portion of the dentition often seek treatment for these defects. The missing bone results in a functional defect that is not amenable to placement of conventional removable prostheses. For these patients, the history of the problem and accurate treatment planning aid in the choice of a design that likely will include bone grafting and placement of implants to assist in prosthesis retention (Figure 3-8, A-E; [the complete case is presented in DVD Figure 3-2, A-I]). Important information from the patient's history includes smoking habits, radiation therapy, recurrent infection and scar formation, and malnutrition or other systemic factors that can affect wound healing.

3-2, A-I

Treatment planning must include accurate articulation of diagnostic casts, which are used to create a setup of the

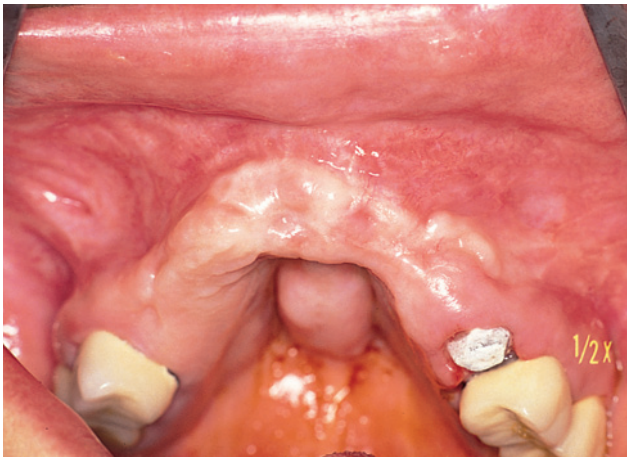


FIGURE 3-8 **A,** This 39-year-old woman lost eight anterior maxillary teeth in an automobile accident when she was 15 years old. When she was 19, she had five endosseous implants placed. Secondary to bone loss, they were removed when she was 39 years old. She requested improved retention of the maxillary prosthesis. The physical examination revealed loss of maxillary height and width and loss of normal maxillary morphologic structure.

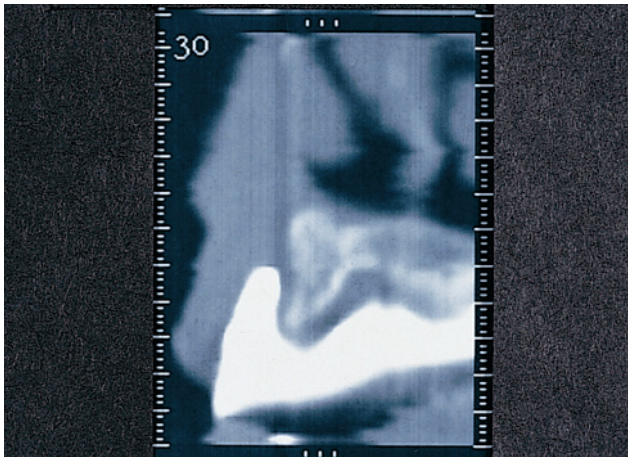


FIGURE 3-8 **B,** Preoperative workup starts with a reproduction of the patient's esthetic removable partial denture, with the labial flange and teeth impregnated with 30% barium sulfate. A computed tomography (CT) scan with the radiopaque stent in place is reformatted to allow visualization of the size of bone graft needed to aid reconstruction of the missing bone.

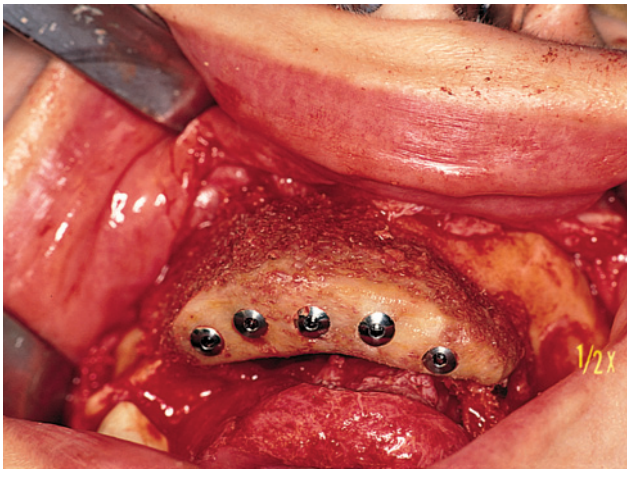


FIGURE 3-8 **C,** Based on the CT scan and the patient's desire to have a palateless prosthesis, the treatment plan includes onlay grafting with posterior ilium, combined with the placement of five endosseous implants. The incision is made in the vestibule to allow for tension-free closure at the conclusion of surgery. A corticocancellous graft is obtained and trimmed to sit firmly and without rocking on the residual ridge. Five HA-coated, threaded implants are placed to stabilize the position of the graft.

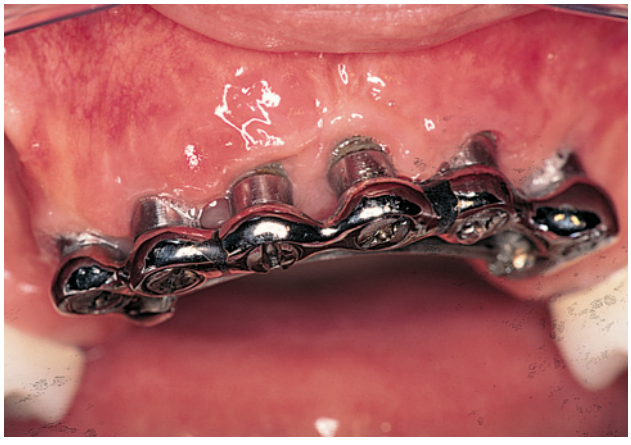


FIGURE 3-8 **D,** Overdenture is made using a bar-clip design.

ideal restoration. This setup can be tried in the patient's mouth for the individual's approval of its esthetic characteristics and function. The setup is used to fabricate radiopaque stents for CT scanning and as the surgical guide stent for graft and implant placement. Based on diagnostic imaging of the available bone, a treatment plan with alternatives can be formulated and presented to the patient. Preoperative planning is crucial to these complex cases. If the treatment planning has been performed meticulously, the grafts will be placed in a position that allows for ideal implant positioning and thus a predictable prosthetic reconstruction.

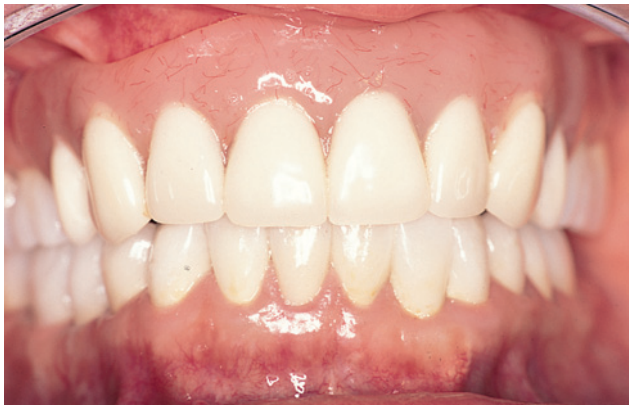


FIGURE 3-8 **E,** Final prosthesis in place. The prosthesis has minimal palatal coverage. (Prosthetics by Dr. Roger Vitter.)

Some patients who have had ablative tumor surgery or extensive trauma with resultant bone loss want a fixed restoration. However, the requirements for a fixed crown and bridge–type restoration include sufficient available bone and healthy, normal-appearing gingivae. Often the reconstruction of the anatomy does not lend itself to a good esthetic restoration based on a crown and bridge prosthesis; an implant-borne, fixed-removable restoration frequently results in a more esthetic restoration.

Before surgery, the treatment plan often includes a corticocancellous graft harvested from either the posterior or the anterior iliac crest, depending on the patient's and the clinician's choice. At surgery, the maxilla is anesthetized and the incision marked. Either a crestal or a vestibular incision can be used, depending on the amount of scar tissue and the surgeon's approach. If a crestal incision is used, vertical release distal to the graft site is necessary, with extensive undermining of the lip. A vestibular incision can be used to reach the crest, followed by subperiosteal release and reflection. The vestibular incision is easier to close under a large bone graft.

The recipient site is exposed after careful reflection of a subperiosteal flap, with care taken to prevent trauma to the soft tissues. Bone wax can be used to simulate the size and shape of the bone graft needed to reconstruct the alveolar defect. Use of a surgical guide stent allows for accurate approximation of the required size of the bone graft to ensure that the graft is appropriate for the ideal placement of implants. The dimensions of the bone wax pattern are used to guide the surgeon in harvesting the necessary amount of corticocancellous bone.

The corticocancellous bone graft is harvested from the iliac crest and contoured to mortise to the underlying bone, then secured with screws to the intact maxilla. When the iliac graft is contoured, rather than removing the marrow from the graft, the surgeon can squeeze or compress the marrow to conform to the morphologic structure of the recipient site. The cortex can be trimmed to prevent sharp edges; however, the surgeon should conserve as much of the cancellous portion of the graft as possible.

In selected cases, threaded implants can be used to stabilize the graft, with a minimum of half the implant engaging intact maxilla to allow for secure stabilization of the graft. Harvesting cancellous bone separately is not usually necessary, because the bone block should be sufficient to restore the defect completely. Using membranes to cover the graft is not indicated or recommended; the use of membranes over solid blocks of bone has not been scientifically validated. If the onlay graft consists of a mixture of small blocks of bone and particulate bone material, membranes should be used to facilitate guided-tissue regeneration.

Augmentation of the Anterior Maxilla Using Particulate Graft Material Combined with Fibrin Glue and Resorbable Membrane

The patient presented with a thin anterior ridge secondary to loss of teeth and bone from trauma. These patients often have sufficient vertical height but have lost most of the width of the alveolus. They require restoration of width sufficient for esthetic implant positioning and restoration of the esthetic ridge profile.

The patient had lost three anterior maxillary teeth. Diagnostic models showed that orthodontic treatment was indicated to realign the teeth that had been moved during healing of the patient's complex alveolar fractures. After orthodontic realignment of the teeth, the extent of the necessary horizontal ridge augmentation was defined (Figure 3-9, A-K). The treatment plan called for horizontal ridge augmentation and, after graft healing, the placement of implants for a three-unit, implant-borne restoration.

At the time of surgery, the arch wire was removed. A crestal incision was combined with sulcular incisions three

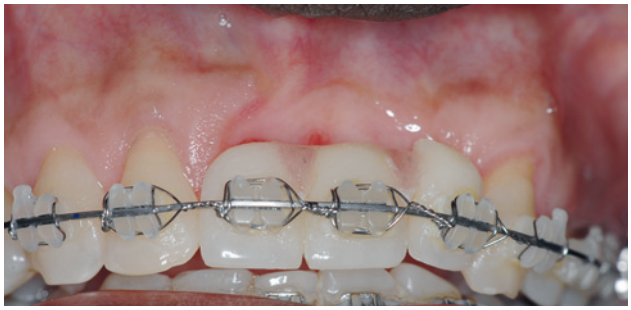
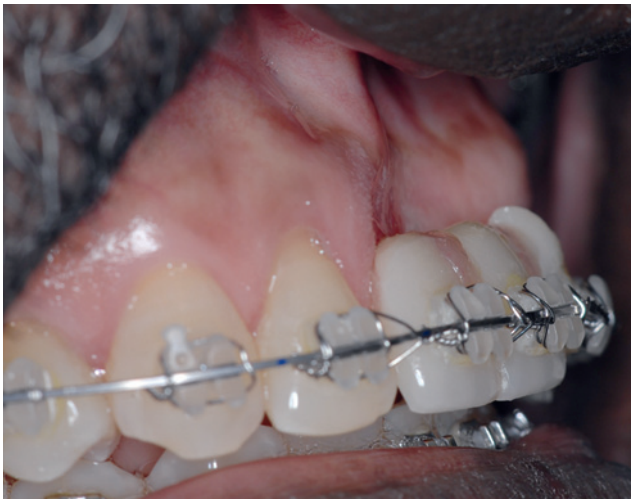
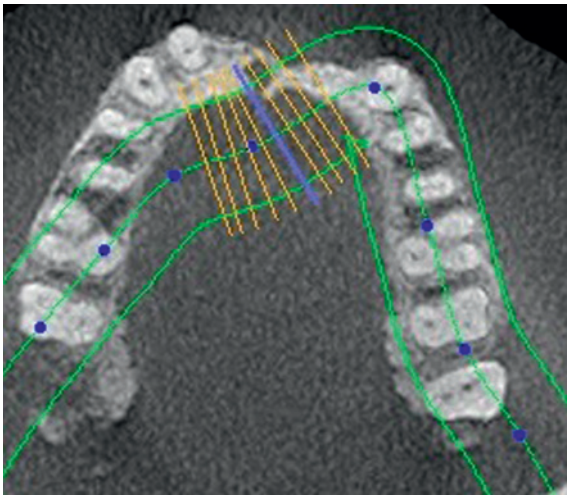


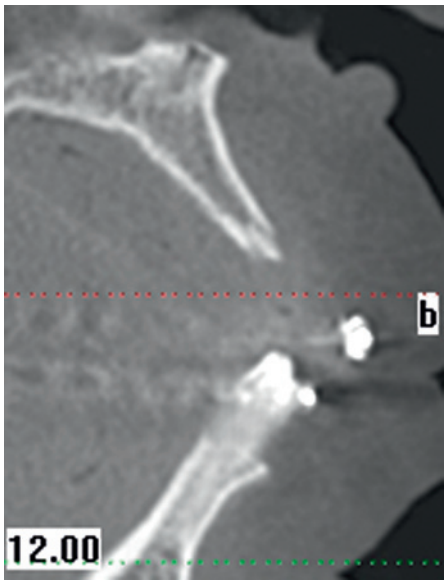
FIGURE 3-9 **A,** Preoperative view showing an obvious horizontal ridge deficiency. The teeth on the orthodontic wires are in an acceptable esthetic position.



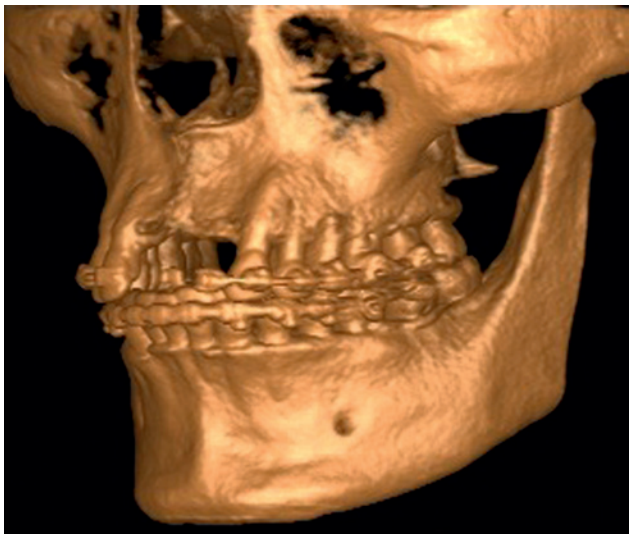
● **FIGURE 3-9 B,** Lateral view clearly showing the large deformity. The deformity requires at least 6 mm of ridge augmentation to achieve sufficient osseous structure for implant placement in the correct positions, as well as restoration of the ridge contour.



● **FIGURE 3-9 C,** Pregrafting axial section showing the anterior ridge defect.



● **FIGURE 3-9 D,** Cross section through the left central incisor site showing a thin, concave ridge form with adequate vertical height.



● **FIGURE 3-9 E,** Three-dimensional reconstruction uses cone beam software to demonstrate the extent of the deficiency. The surgeon must correct the horizontal deficiency to achieve sufficient bone for an implant 13 mm long.

teeth distal to the edentulous site. A full-thickness flap was elevated from the alveolus and teeth without tearing the facial gingiva. The subperiosteal release was extended to the piriform rim without damaging the nasal mucosa.

Bovine bone xenograft (Endobon, Biomet 3i, Palm Beach Gardens, Florida) was used for this augmentation. Fibrin glue (Tisseel, Baxter, Deerfield, Illinois) was combined with the xenograft to form a composite, which was placed over the defect. Because scar tissue was present at the level of the nose, care was taken to avoid excessive pressure by tapering the augmentation in this region. The graft was placed 17 mm apical to the crest. This man had a

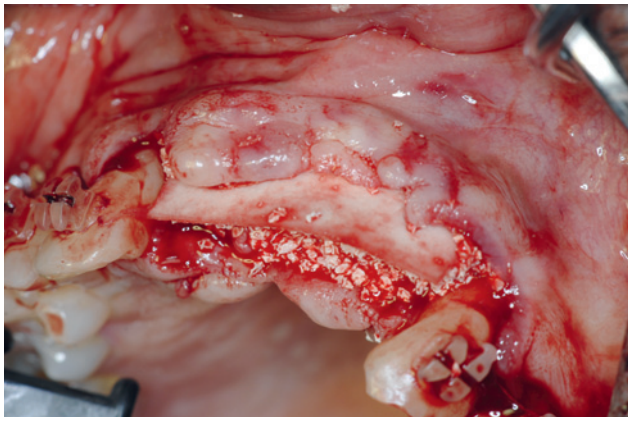


FIGURE 3-9 **F,** At the time of surgery, a crestal incision is made with sulcular incisions. A full-thickness envelope flap is raised without vertical releasing incisions. The flap is reflected to the nasal floor. The periosteum is released to allow tension-free closure. Bovine xenograft (Endobon, Biomet 3i) is combined with fibrin glue and molded to the bone defects. Because of the large defect and extensive periosteal release, a collagen membrane with a 6-month resorption rate (Osseoguard, Biomet 3i) is placed between the mucosa and the graft.

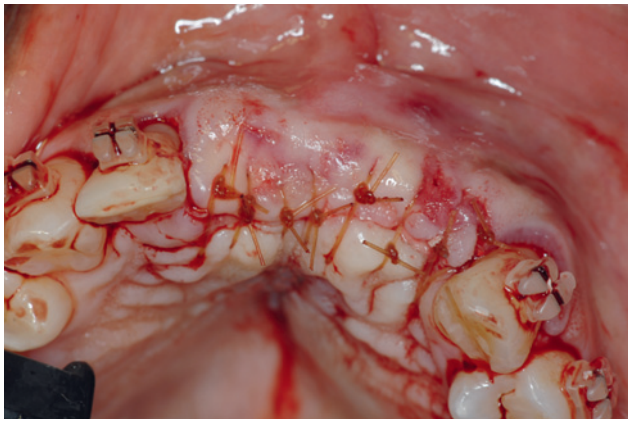


FIGURE 3-9 **G,** Incision is closed with 4-0 chromic suture and limited tension on the incision. A tapered needle is used to prevent gingival tears.

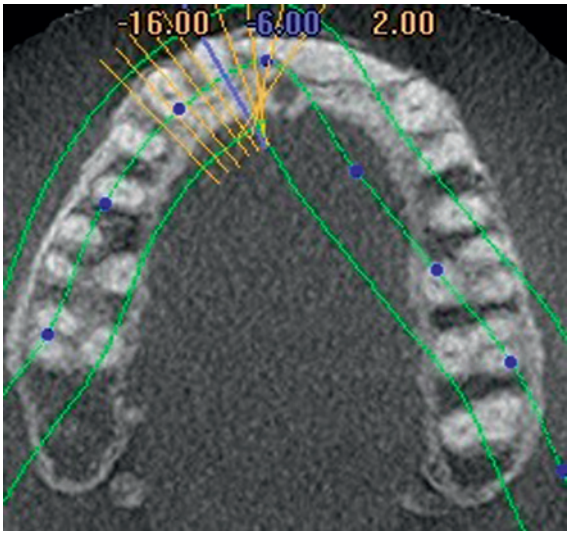


FIGURE 3-9 **H,** Axial section taken 4 months after grafting shows restoration of ridge form.

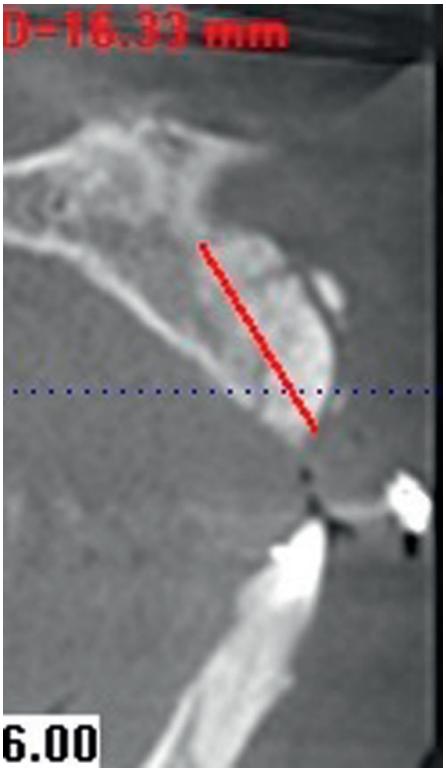


FIGURE 3-9 **I,** Cone beam cross section shows graft presence sufficient for an implant 15 mm long. The soft tissue near the nasal region was resistant to reflection, which accounts for the lack of graft in this region.

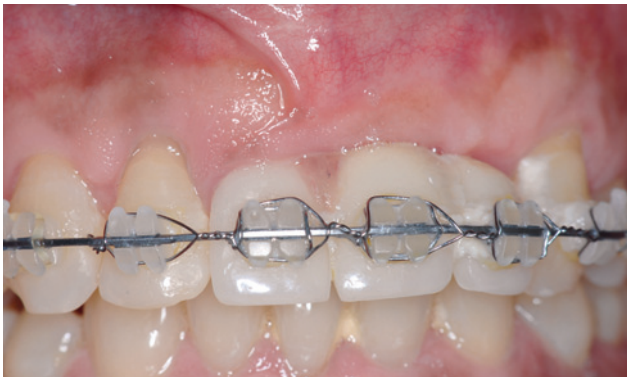


FIGURE 3-9 J, Postgrafting appearance of the ridge shows sufficient ridge form for the proposed esthetic restoration.

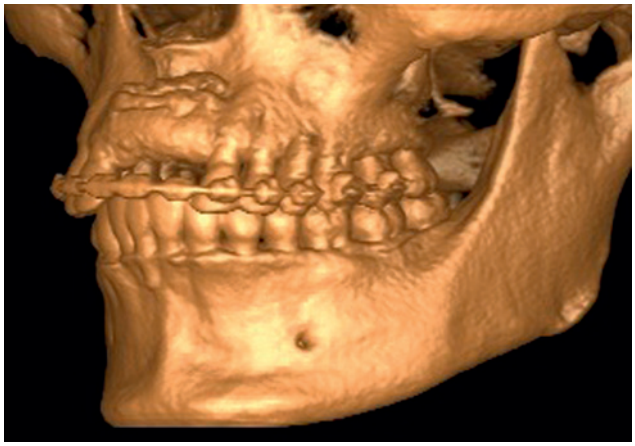


FIGURE 3-9 K, Three-dimensional reconstruction showing restoration of the deficient ridge using the combination xenograft and fibrin glue method of grafting.

significant distance from the crest to the floor of his nose. After the composite was placed over the concave defects and molded with the fingers, a collagen membrane was placed. The collagen membrane chosen (Osseoguard, Biomet 3i) has a half-life of barrier character of 6 months. Because of the extensive periosteal release, the flap was closed without tension. The arch wire then was replaced, with care taken to shorten the pontics to prevent pressure on the ridge. Swelling occurs after this procedure, therefore judicious reduction of the apical portion of the pontics at the time of surgery is very important.

Postoperative instruction included a liquid diet and rinses using diluted mouthwash. Chlorhexidine was avoided for 10 days after the augmentation because of its fibrocyte toxicity. Antibiotics were prescribed for 2 weeks with staphylococci coverage. Sutures were removed after 2 weeks if they were still present.

Four months after the procedure, imaging was performed to confirm the augmentation. The orthodontic appliances were removed, and the final diagnostic setup was performed before implant placement.

Simultaneous Sinus Augmentation and Anterior Maxillary Horizontal Ridge Augmentation

Patients often present with partial maxillary dentition that has a poor prognosis yet supports a fixed prosthesis (Figure 3-10, A-P). (See Video 3-1.) This patient desired a fixed prosthesis during the treatment phase, which required sinus grafting and horizontal ridge augmentation before implant placement. The sequencing of the treatment should take into consideration a patient's strong emotional need to avoid having to wear a provisional removable prosthesis.

The phasing of the treatment began with the restorative dentist removing the patient's current fixed prosthesis, stabilizing the teeth, and fabricating a diagnostic new prosthesis, which could be removed when surgical procedures were necessary. The first phase of treatment was the sinus augmentation and horizontal ridge augmentation. After 6 months were allowed for bone consolidation, the fixed provisional prosthesis was removed, implants were placed, and the provisional prosthesis was replaced. After the implants had integrated, a new fixed provisional prosthesis was made on the implants, the remaining teeth were removed, and additional implants were placed. After the second set of implants had integrated, the final restoration was made.

Surgical technique

At the time of graft surgery, the patient's full-arch fixed provisional was removed. The area was prepared with povidone-iodine (Betadine). A local anesthetic was infiltrated to the maxilla. An incision was made on the crest with a 15c blade in the edentulous regions and around the teeth in the sulcus. A full-thickness flap was elevated, and care was taken to prevent tears and to remain subperiosteal in the entire flap. Posterior vertical releases were necessary to achieve elevation for the sinus window. Bilateral sinus windows were created, and the bone from the procedure was trapped and collected in a sieve in the suction line. The sinus membranes were carefully elevated. No obvious perforations were seen on the right side, but on the left side, a small perforation had occurred in the anterior-superior region of the window. The surrounding membrane was elevated to limit the perforation. A small piece of collagen membrane (Osseoguard, Biomet 3i) was used to cover the perforation.

After the membranes had been elevated, the bone from the sieve was combined with 6 ml of bovine particulate material (Endobon, Biomet 3i). Then, 0.5 ml of fibrin glue

Horizontal Ridge Augmentation Using Particulate Graft with a Membrane

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for horizontal ridge augmentation using particulate graft with a membrane, which is performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient is undergoing horizontal ridge augmentation simultaneously with bilateral sinus augmentation. The video portion is specific for the augmentation of the concave anterior maxilla. A crestal incision has been made with sulcular extension around the remaining teeth, extending posteriorly for the sinus graft. The video starts with the bone exposed from elevation of the full-thickness subperiosteal envelope flap up to the level of the piriform rim, avoiding perforation of the nasal mucosa.

After flap elevation, the periosteum must be released to allow a tension-free closure after the augmentation. A small pickups is used to hold the edge of the flap gently, and a scissors then is used to incise only the periosteum. A scalpel also can be used for this procedure. Care is taken to incise only the periosteum and to avoid muscle dissection.

This author uses a long-lasting, slow-resorbing collagen membrane (Osseoguard, Biomet 3i, Palm Beach Gardens, Florida) to help hold the graft material in position and to delay soft tissue infiltration into the graft. The collagen membrane is rehydrated and trimmed to fit passively into the site. This author elevates the palatal periosteum slightly to tuck the membrane under it. However, the membrane should fit passively to prevent extrusion during the healing period.

The graft material then is placed. In this case, bovine graft material (Endobon, Biomet 3i) is combined with a low percentage of fibrin glue (Tisseel, Baxter, Deerfield, Illinois) and compacted directly against the bone under the collagen membrane. The graft material is placed carefully to augment the full vertical height of the alveolar bone or that portion most critical for later implant placement.

A small amount of graft material is placed and then compacted with gauze; then, additional material is placed until the desired augmentation width has been achieved. The incision is closed free of tension. A running suture is used, with passive alignment of the wound edges and without excessive tightness of the margin, to avoid ischemia of the incision line. After one site has been sutured, the same procedure is performed in the opposite arch.

In this case, lateral ridge augmentation is desired in the areas over the premolars sites; therefore, additional graft material is placed directly on the ridge. The low dose of fibrin glue adds cohesive handling properties but does not create a barrier to revascularization, which can occur with higher concentrations of fibrin glue.

The incision is closed using gentle techniques and tension-free adaptation. In this patient, after closure had been completed, the full-arch provisional restoration was recemented.

(Tisseel, Baxter) was added to form a cohesive graft. The graft was placed under the sinus membranes to achieve 13 mm of vertical bone height in the posterior maxilla. After the grafts had been placed in the sinus sites bilaterally, the periosteum was released so that a tension-free closure could be performed after the ridge augmentation had been placed.

The technique for periosteal release is simple and contributes to the eventual success of this and other onlay grafting procedures. A small pickup is used to elevate the flap, exposing the periosteum on its undersurface. Scissors or a scalpel then is used to cut only the periosteum. If the muscle is dissected, additional bleeding will occur, and the patient will have significantly more swelling and ecchymosis postoperatively; in addition, muscle activity may be interrupted. The periosteum is released, and the flap should be advanced with minimal effort. If bleeding occurs, arterial bleeders can be cauterized or tied; for generalized oozing, gauze can be placed for several minutes to apply pressure. This procedure should be performed prior to graft placement to prevent blood from mixing with the augmentation particles and displacing them.

A collagen membrane is trimmed to fit passively over the lateral aspect of the maxilla. This author does not tuck the membrane under the palatal periosteum; rather, it fits up to the crest to provide support and to minimize graft movement. The graft composite is placed directly over the bone, under the collagen membrane. If the graft is placed before the membrane, accurate placement of the membrane over the graft and under the periosteum often is difficult and messy. The graft material must be

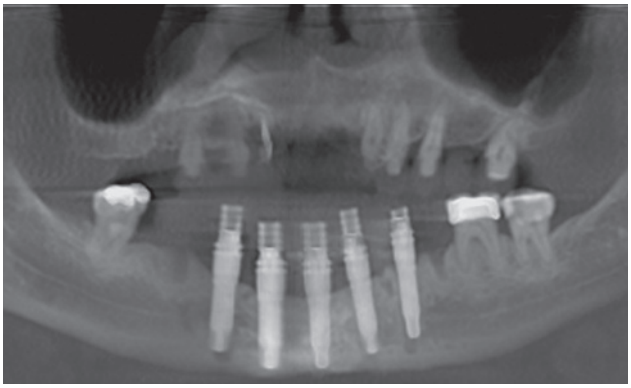


FIGURE 3-10 A, Preoperative panoramic radiograph showing previously placed mandibular implants for a fixed provisional prosthesis. The remaining maxillary teeth are short and have a very poor prognosis. Note the limited bone in the posterior maxilla. The treatment plan for this patient calls for at least eight maxillary implants to be placed from the canine posteriorly.

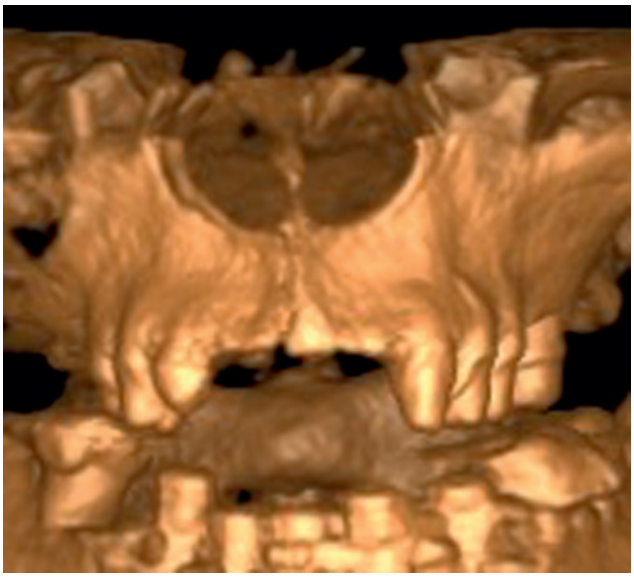


FIGURE 3-10 C, Cone beam three-dimensional view clearly shows the concave defects in the anterior maxilla and over the apical regions of the remaining teeth.

packed up to the desired apical dimension, anticipating later implant placement dimensions (which in this patient was 13 mm in length). The graft is placed and packed, and blood is removed with gauze. Additional graft material is placed until the desired augmentation has been achieved.

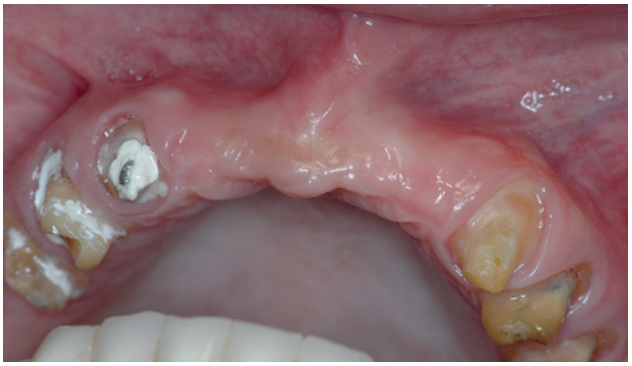


FIGURE 3-10 B, Provisional prosthesis has been removed; note the thin concave region of the anterior maxilla, including the areas over the remaining teeth.

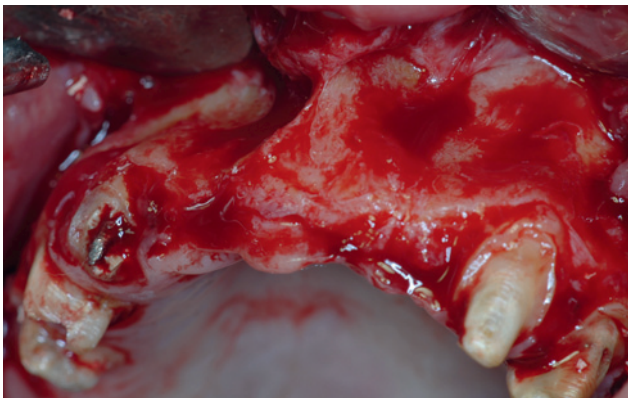


FIGURE 3-10 D, Crestal incision made anteriorly was combined with sulcular incisions around the remaining teeth, on the crest posteriorly, with vertical release incisions only in the posterior maxilla. A full-thickness flap was raised to expose the maxilla. Note the concavity on the maxilla, similar to that seen in the three-dimensional view. The periosteum was released to allow-tension free closure after augmentation. This author prefers to do this before placing the augmentation, because bleeding may disturb graft placement.

After the graft has been placed on one side, the incisions are closed to stabilize the site further and to prevent displacement of the graft. The graft then is placed under the collagen membrane on the left side. Lateral bone augmentation is achieved by placing the graft directly over the bone and covering it with periosteum and the sinus window. The incisions are closed using a tapered needle. The provisional prosthesis is adjusted to prevent pressure on the ridge and is recemented.

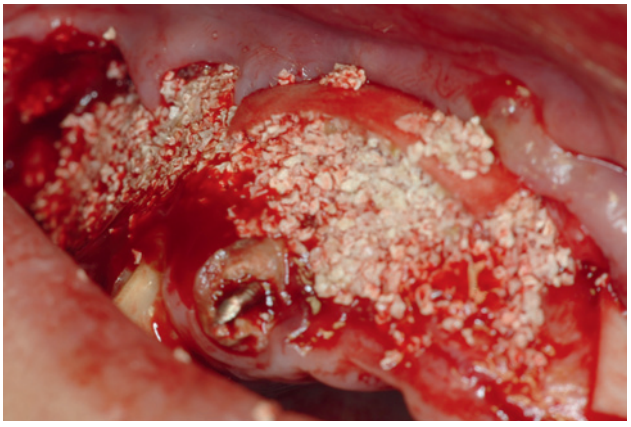


FIGURE 3-10 **E,** Collagen membrane (Osseoguard, Biomet 3i) was placed over the ridge and carefully elevated from the ridge. Bovine particulate graft material (Endobon, Biomet 3i) was combined with bone harvested from the sinus window preparation. The composite mixture then was combined with fibrin glue (Tisseel, Baxter) to create a cohesive graft, which was placed directly on the bone under the collagen membrane. The graft was placed to cover the apical portions of the ridge and the crestal region.

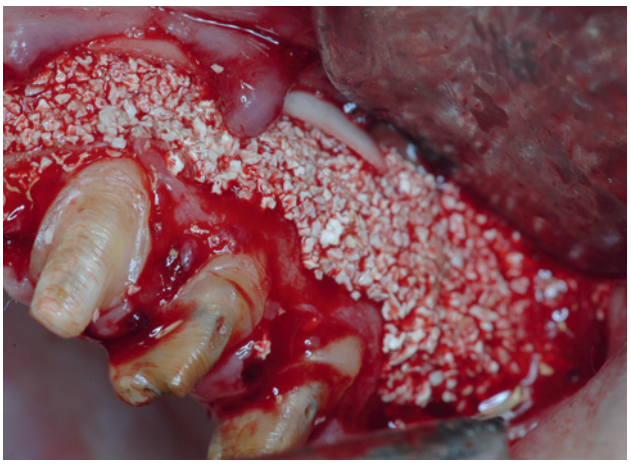


FIGURE 3-10 **G,** On both sides, the lateral aspect of the maxilla was augmented to ensure that implants could be placed in the optimal position after bone formation had matured. The graft handles easily with the aid of the fibrin glue.

Placement of Eight Implants with Sinus Grafts

Some patients have insufficient vertical bone for the placement of implants in the maxilla posterior to the canines; however, the treatment plan can include an implant-borne restoration combined with sinus grafting. The sinus grafts can be performed as one surgery, after which implants are placed 6 to 12 months later; or the sinus graft can be performed and the implants placed at the same time. If the sinus graft is performed before implant placement, the surgeon should verify that bone has formed within the graft. This may require a CT scan of the graft site.

This author and colleagues perform sinus grafting with immediate placement of implants. Currently, the recommended sinus graft material is autogenous bone, harvested from the jaws, tibia, or iliac crest. If necessary, the autogenous bone volume can be augmented with demineralized bone in a ratio not to exceed 1:1. HA-coated implants are used for immediate placement into sinus grafts.

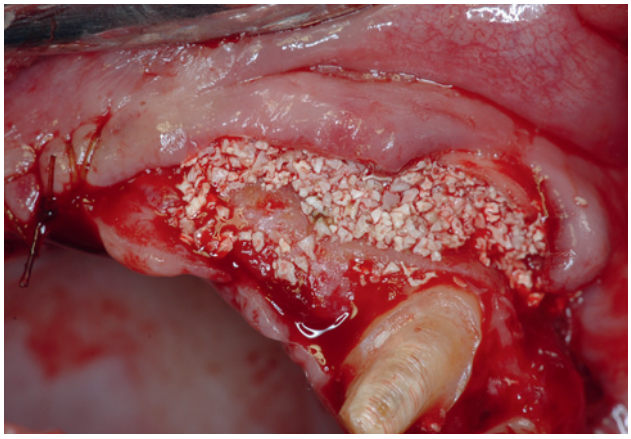


FIGURE 3-10 **F,** After the right side of the maxilla was completed, with the sinus graft and onlay graft reaching the augmentation's planned dimensions, the incision was closed on that side. The graft composite then was placed on the left side under the membrane and directly on bone.

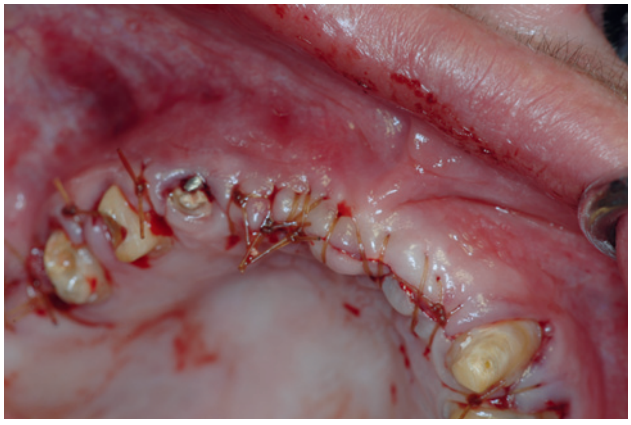
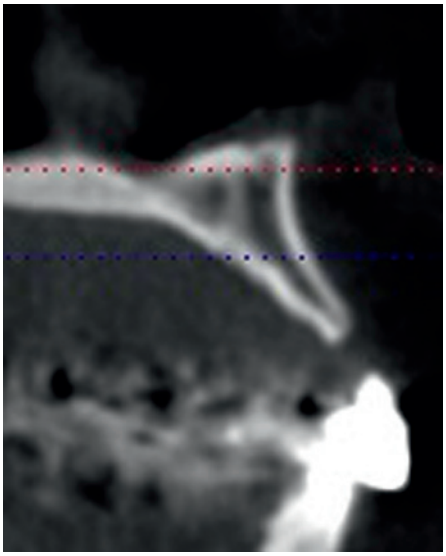
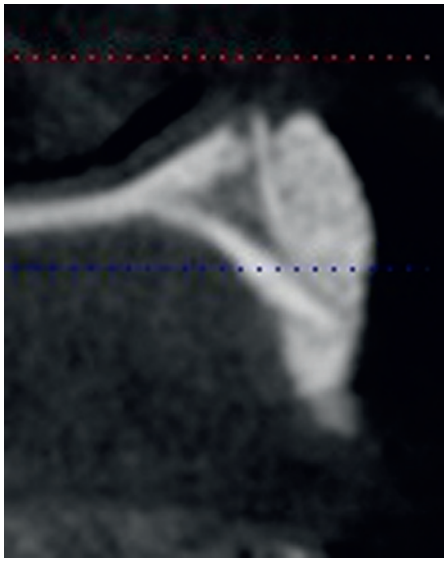


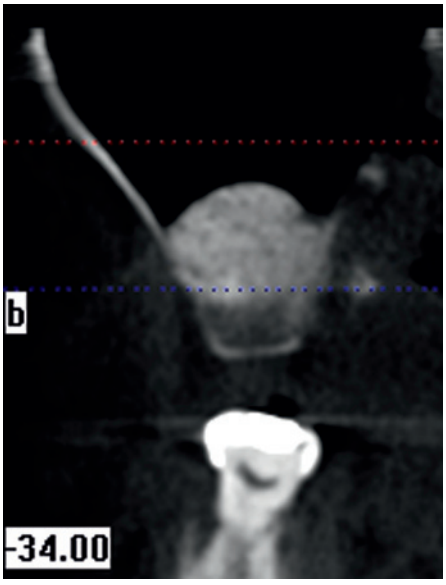
FIGURE 3-10 **H,** Incisions are closed tension-free with a tapered needle with 4-0 chromic suture.



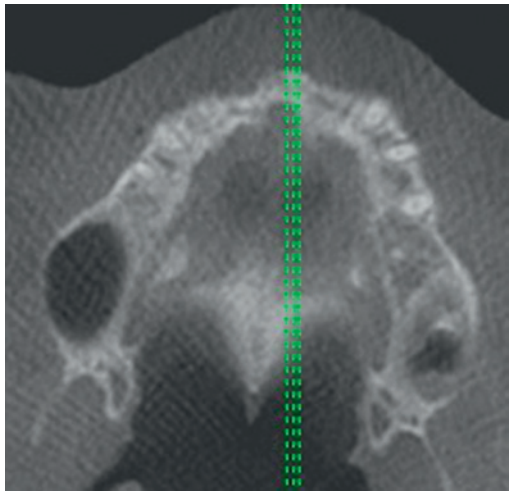
● **FIGURE 3-10 I,** Pregrafting cross section of the anterior ridge.



● **FIGURE 3-10 J,** Postgrafting cross section shows the extent of the horizontal augmentation.



● **FIGURE 3-10 K,** Postgrafting cross section shows the right posterior maxillary sinus augmentation.



● **FIGURE 3-10 L,** Preoperative axial view of the maxilla at the level of the crest shows anterior atrophy in the horizontal dimension.

The surgical procedure requires an accurate understanding of the planned restoration, and a surgical guide stent should be used. The choice of general anesthesia with nasal endotracheal intubation, intravenous sedation, or a local anesthetic alone is made after the planned procedure and the patient's tolerance levels have been considered. A local anesthetic with a vasoconstrictor is infiltrated into the labial and palatal tissues, and additional local anesthetic is administered to perform a hydropic dissection. After a satisfactory plane of anesthesia has been reached, the sinus graft dissection and elevation of the membrane are performed (see Chapter 4). The surgical stent is used to initiate and complete the preparation of the implant sites. After the sites have been prepared, the graft is harvested and placed in the medial aspects of the sinus, the implants are placed, and the graft is located

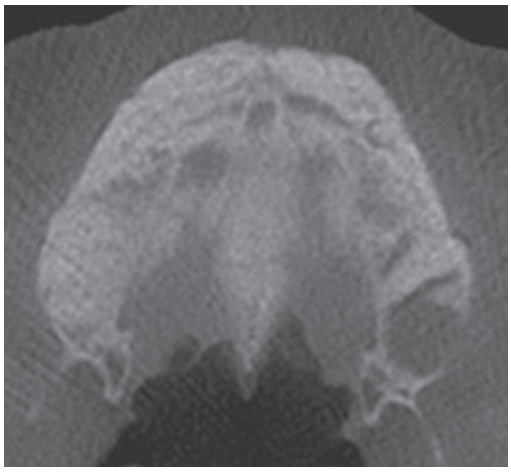


FIGURE 3-10 **M,** Postaugmentation axial view showing the extent of the augmentation.

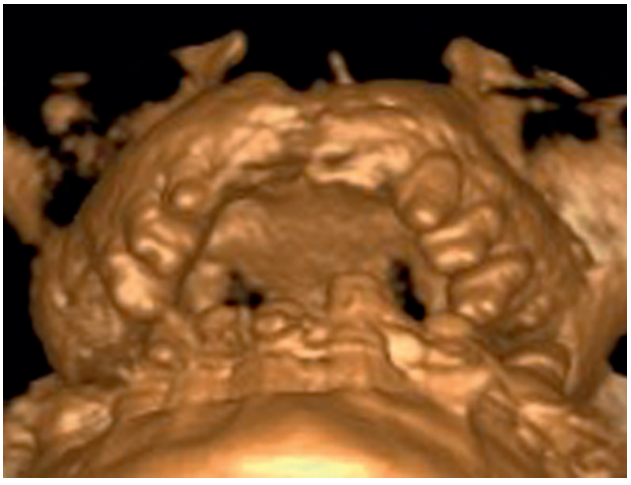


FIGURE 3-10 **O,** Occlusal view of the three-dimensional reconstruction shows adequate ridge width for implant placement.

over the facial aspects of the implants. The incision then is relieved to allow tension-free closure. Nonresorbable sutures are used.

Exposure of Implants in the Edentulous Maxilla

After an appropriate amount of time has been allowed for implant healing, the patient returns for exposure of the implants and placement of temporary healing abutments (DVD Figure 3-3, A-C). After administration of a local anesthetic, an incision is made bisecting the KG to

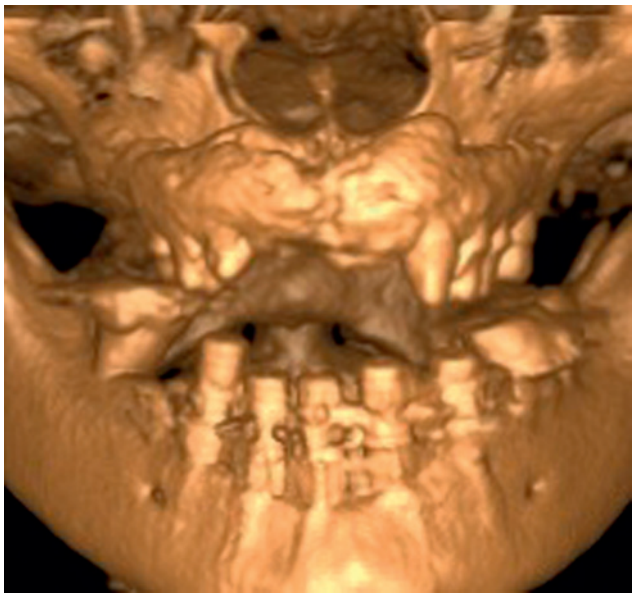


FIGURE 3-10 **N,** Three-dimensional reconstruction from the postoperative cone beam scan clearly shows the augmentation. Note the ease with which exceptional ridge form was achieved with minimal surgical trauma.

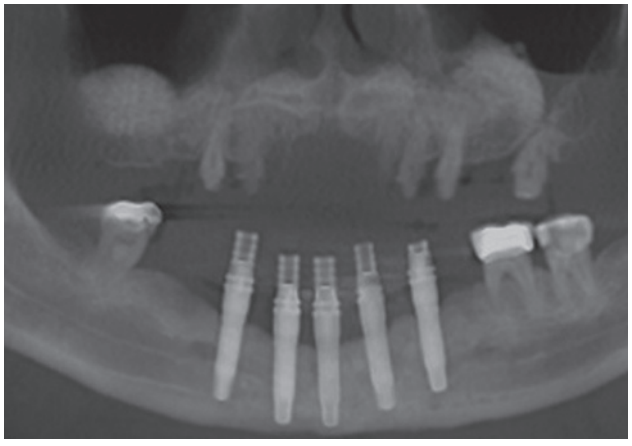


FIGURE 3-10 **P,** Postgrafting panoramic image shows the graft placement.

transpose it labial to the implant abutments. The mucosal flap is reflected full thickness, including periosteum, to allow direct visualization of the implant. The cover screws are removed, the top of the implant is gently cleansed of soft tissue, the inside of the implant is irrigated with sterile solution, and the temporary healing abutment is placed. The gingival flap may be excessively thick and may need to be thinned. The inside thickness of tissue is removed with

DVD Images 3-3, A-C

a scalpel to thin the flap, which is reduced as necessary. The incision is closed around the healing abutments. The denture is relieved and relined to stent the mucosa to the alveolus.

Surgery for the Posterior Maxilla

Single-Premolar or Single-Molar Restorations

Diagnosis and treatment planning indicate whether sufficient space and bone are available for implant placement. Periapical radiographs are necessary for single-tooth restorations to confirm that the roots of the adjacent teeth do not impinge on the space that will be used by the implant. If root angulation is a problem, preoperative orthodontics must be performed before implant placement, or a fixed bridge can be made rather than placement of an implant.

The periodontal status of the adjacent teeth must be controlled, and the teeth must show no evidence of recent active periodontal disease. If the patient's oral hygiene is marginal in the remaining dentition, cross-contamination can occur from the teeth to the implant, resulting in failure of the implant secondary to infection during the early phases of healing. Important information about the patient's dental history and ability to maintain the teeth can be gained from a consultation with the patient's dentist.

If the patient's teeth otherwise are healthy, radiographs are taken at the consultation visit. The surgeon should consult with the restorative dentist to confirm the treatment plan and the type of implant to be used. The procedure is discussed with the patient, and the patient reviews a consent form and receives answers to all questions. Financial policy is discussed, with a complete understanding of the patient's responsibilities.

At the surgical visit, a local anesthetic is administered. The incision is made slightly palatal to the crest, with vertical release incisions flaring into the vestibule to keep the base of the flap wider than the crestal incision width (Figure 3-11, A-E). Full-thickness, subperiosteal labial and palatal flaps are reflected to expose the crest and allow visualization of the vertical cortices of bone. The implant should be placed with its axis parallel to the occlusal forces, and the emergence of the implant should be angled to meet the buccal cusps of the mandibular teeth. A surgical guide stent can be used; however, if the neighboring dentition is in good repair and the mandibular dentition is well aligned, the fossae of the teeth can be used to direct implant placement.

A round bur is used to mark the planned implant location. The graduating-sized drilling sequence is used, and the implant is placed. If extremely soft maxillary bone is felt, osteotomes may be used to compact the bone in the

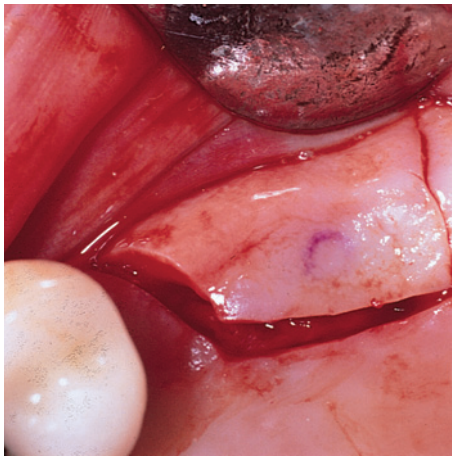


FIGURE 3-11 **A,** Preoperative assessment reveals 12 mm of vertical bone available for an implant-supported restoration in this 65-year-old woman. Diagnostic models are made. The planned restoration is established in wax, and an acrylic surgical guide is fabricated. A hole 3 mm in diameter is prepared in the exact location the prosthodontist prescribed for implant placement. The occlusal height is reduced to allow drill engagement in the bone. At surgery, a marking stick is used to identify the location of the implant on the gingival mucosa. After administration of a local anesthetic, an incision is made slightly palatal to the crest, with vertical release incisions flaring toward the base of the flap. The planned implant location and its relationship to the incisions are shown.

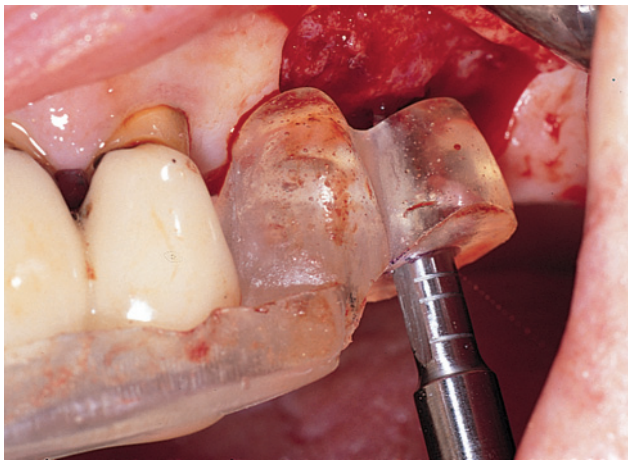


FIGURE 3-11 **B,** Drills are used through the acrylic stent. The drill can be observed engaging bone in the prescribed location for accurate implant placement.

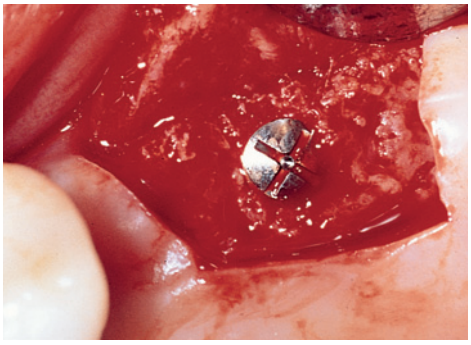


FIGURE 3-11 **C,** Implant is placed at the prescribed vertical position in the bone site.

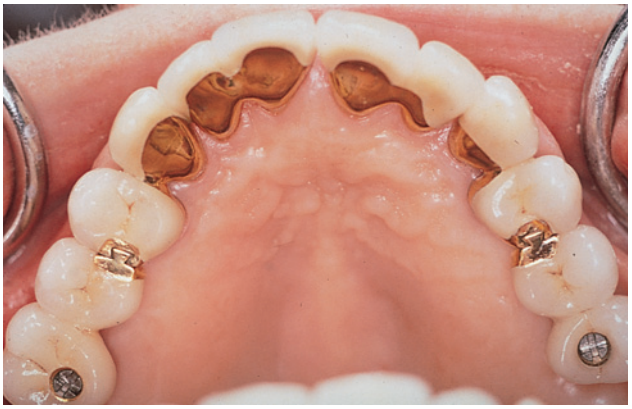


FIGURE 3-11 **E,** Final restoration is screw retained to the implants with the fixed partial denture nonrigidly attached to the natural teeth. A precision attachment is used. (Prosthetics by Dr. Gerald Chiche.)

implant site, although minimal scientific information validates the assumption that compaction of bone with osteotomes helps the integration rate. If encountered in the labial bone, dehiscences are treated in a manner similar to that discussed previously for anterior maxillary implants. After the implant has been placed, the periosteum is released as necessary, and the incision is closed (Figure 3-12).

After the appropriate healing period, which depends on the quality of the bone and the type of implant used, the implants are exposed. At the time of implant exposure, the KG is bisected so that it can be placed and transposed to the labial aspect of the implant as necessary. The KG is reflected, the cover screw is removed, and a temporary healing abutment is placed. After 2 weeks or longer for gingival healing, the depth of the sulcus is measured, and the restorative dentist places the abutment of the appropriate length. Comfort caps, which cover the sharp edges of the abutments, can be used until a provisional or permanent prosthesis can be delivered (DVD Figure 3-4, A-D).

DVD Images 3-4, A-D

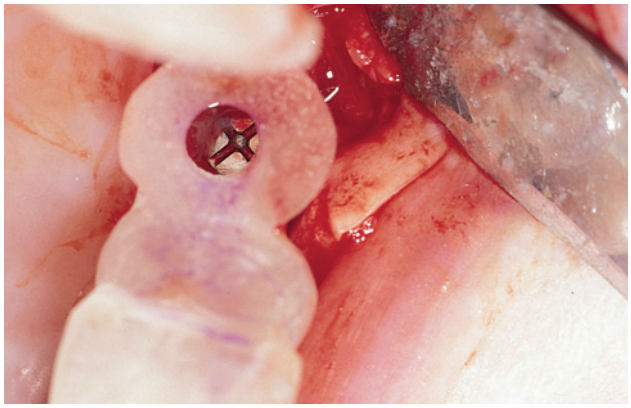


FIGURE 3-11 **D,** This type of surgical guide results in accurate placement of the implant.

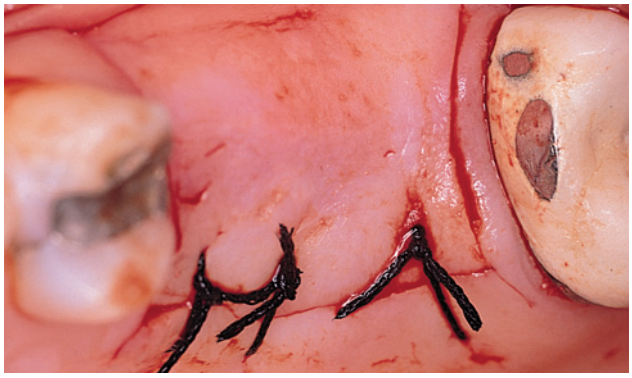


FIGURE 3-12 Incision made slightly palatal to the crest can be closed with two sutures, resulting in an atraumatic surgical procedure and minimal postoperative morbidity for the patient.

Multiple-Teeth Implant-Borne Restorations

The preoperative treatment planning for multiple teeth is similar to that for the single-tooth restoration. However, a surgical guide stent is necessary, because fewer landmarks are available to guide the surgeon for ideal placement of the implants in relation to embrasure spaces and angulation to the buccal working cusps. These restorations typically involve the distal teeth; therefore, assessment of the availability of bone in relation to the sinus is critical. If 10 mm of bone is not available, sinus augmentation is indicated. If two long implants can be placed without the need for a sinus graft, along with sinus elevation of a third site using osteotomes, 8 mm of bone for the third implant is acceptable. However, the use of osteotomes to elevate

the sinus floor greater than 2 mm is a procedure that does not have abundant scientific validation; therefore, the patient must be informed of the potential for risks and failure. When in doubt, a sinus elevation is performed (see Chapter 4).

Patients may have sufficient vertical bone but may be deficient in the width projection of the bone, which is common after extraction of the maxillary teeth. These extractions, which are performed for a variety of reasons, allow facial bone resorption, leaving the palatal bone intact but the alveolus thin and deficient. Placing the implant in the ideal position may result in facial bone dehiscence. For a thin ridge in the posterior maxilla with sufficient bone height, the surgical options are (1) particulate bone grafting with membrane coverage, (2) solid onlay grafts harvested from the symphysis or ramus, and (3) ridge expansion using osteotomes or osteotomies (see Chapter 6).

CT guidance: treatment planning sequence

General Principles. The dental implant team must plan a patient's treatment prior to actual therapy. When treatment involves fixed or removable restorations in the maxilla, the treatment sequence is the same for all patients, regardless of whether two, four, or all of the teeth are missing. The patient presents with goals and anticipation of a final result. After all pathologic conditions have been resolved or removed, including caries and nonrestorable teeth, an implant treatment plan can be initiated.

Each patient has case-specific needs; however, the general sequence of planning is as follows:

1. Development of the restorative final treatment plan. This includes fabrication of an esthetic provisional restoration, such as a new denture, that establishes the form, function, and esthetic aspects of the goal.
2. CT imaging to determine the available bone and soft tissue needs, and the use of CT planning software to refine the plan. A stent is made of clear acrylic or a radiopaque material to depict the plan. CT imaging is performed with the radiographic guide stent of the final plan in the patient's mouth. The CT scan then is evaluated in cross sections on the imaging software. The DICOM data are processed by the CT planning software to generate axial, panoramic, cross-sectional, and three-dimensional images, which can then be used to generate a patient-specific plan.
3. Phasing of procedures, which can include elimination of previously undiagnosed problems, such as sinusitis, bone grafting to establish the bone dimensions required by the final restoration, determination of the length and width of implants, determination of the angulation required to achieve the restoration, and preoperative model-based preparation using a CT-generated surgical guide stent.

CT-guided surgery: complications associated with scanning, processing, surgery, and prosthetics

CT can be used to image a patient with or without radiographic stents to plan implant reconstructive surgery. These three-dimensional images in DICOM format are entered into a computer, and planning software is used to virtually plan implant placement and restorations, create rapid prototype surgical guide stents, and subsequently fabricate provisional or final restorations before implant placement surgery. As this process becomes more widely available, the indications for using parts or all of it are being defined, and complications are being collated. Factors that contribute to the accuracy or inaccuracy of the CT planning and CT-guided surgery process include diagnostics, radiographic stent fabrication, scanning error, planning error, and the surgical and prosthetic technical aspects of orchestrating the process in the patient[1] (Table 3-1). The following sections present specific examples of complications that can occur in each stage of the process. The clinician must account for the cumulative error that may be involved in all the steps leading up to surgery.

Complications During the Workup Phase: Template Fabrication

Complication: Planning Errors Resulting from Use of Nonideal Prosthetic Setup. If a radiographic stent is made on an existing prosthesis that is not ideal with regard to tooth position, the planning that follows will be inaccurate. Use of a nonideal plan jeopardizes the positioning of implants; implants may be placed in embrasures, may exit the labial surface of teeth, or may be positioned palatal or lingual to the ideal implant angulation for the restoration. The solution is fabrication of a provisional restoration, such as a removable prosthesis or a mockup of the ideal restorative plan. The mockup can be fabricated in clear or radiopaque acrylic so that the clinician understands the requirements of the implant restoration with regard to the position, size, and number of implants and can confirm the final restorative plan. The ideal tooth setup then is used to develop and present a comprehensive restorative plan, which can be presented to the patient.

Complication: Vertical Malposition of the Implant. Placement of the implant in the ideal vertical location is very important. When CT guidance is used to plot the placement of an anterior implant, the virtual implant should be placed approximately 3 mm apical to the planned facial gingival margin. Therefore, the planned restoration used to fabricate the radiographic stent must include the ideal facial gingival margin. If the margin of the radiographic stent is more apical than ideal, the virtual implant

TABLE 3-1 Complications with Computed Tomography and Their Solutions

Complication	Solution
The ideal setup is not used during the CT scan.	The setup should be a duplicate of the diagnostic waxup *or* the existing denture, which includes the planned incisal edge and gingival margin.[8]
Poor adaptation of the duplicated denture to the tissue, causing malposition of the radiographic prosthesis or air space between the intaglio surface of the prosthesis and the mucosa, and resulting in fabrication of an inaccurate guide stent.	The duplicated denture can be relined in acrylic (not a soft liner), and a bite registration can be used during the scan and during placement of the stent.[8]
Lack of occlusal support, causing poor orientation when the stent is placed in the mouth.	Occlusal stops can be left in the surgical guide stent. Bite registration must be used in this situation, with coverage of the posterior teeth.[8]
Patient not properly oriented when the scan is taken.	If an outside facility is used, the clinician must be present at the scanning session, especially if the stability of the duplicated denture is questionable. Provide written instructions to the technician (e.g., orient scan parallel to occlusal plane and separate occlusal surfaces to prevent overlapping of teeth).[8,24]
Patient movement during the scan.	Cone beam scanners have chin cups and forehead straps to help ensure stability. The importance of keeping still during the scan should be conveyed to the patient.
Extensive dental restoration artifact that obscures axial images.	Some scatter can be eliminated with the software applications; however, if the dual-scan technique is used, radiopaque markers should not be placed in the occlusal plane so that scatter artifact does not obscure the markers.
Overlapping of the maxillary and mandibular teeth, obscuring the position of the teeth.	An occlusal bite registration is used with the teeth separated.
Inadequate mixing of radiopaque material in the radiographic scanning prosthesis.	Mix the barium sulfate with the monomer before mixing with the polymer. The barium sulfate powder should be pulverized before mixing.
Placement of wrong master cylinders into the stent.	The guide stent must match the implant system, and the clinician should check the guide stent before the day of surgery.
Fixation screw tubes placed in the guide stent are smaller than ordered.	The surgical stent must be checked before the day of surgery.
Failure to seat fixation pins before pouring the master cast.	A removable prosthesis should be considered as a backup, if possible.
Implant dehiscence with thin ridges.	The ridge should be reduced with a reduction stent either before or after implant placement. If this is done after implant placement and the ridge is less than 7 mm, the pilot holes are placed with the stent in position, and the stent is then removed to allow checking for precision.[6,15,16]
Implants placed too superficially.	The planned gingival margin must be transferred to the guide stent. If the clinician is unsure of this, the implants are checked at the end of the case and hand-tightened as needed.[8]
Lack of integration from burning or heating of the bone.	The operator should use slow drill speeds, clean drills frequently, use new drills, use self-irrigating drills, and use irrigation ports if available.[2,5,20]

may be placed too deeply. If the margin on the radiographic stent is coronal to the ideal, the implant will be placed superficially. If the vertical malposition of the virtual implant is transferred to the guide stent and, ultimately, to the patient, an ideal crown emergence from the gingiva will be difficult to achieve.

Complication: Shrinkage of Acrylic During Denture Duplication. In most cases, a new denture is fabricated to establish the functional and esthetic needs of the patient before scanning is performed for guide stent fabrication. This denture is used to guide fabrication of the final prosthesis.[2,3] Accurate laboratory methods ensure the

accuracy of the duplicate prosthesis and an accurate fit in the mouth. Shrinkage of acrylic during the duplication process adds error when a slightly shrunken, duplicated denture is used to position implants precisely. Shrinkage artifact can add 0.3 mm of error to the case.[4] If the intaglio surface of the prosthesis does not match the soft tissue, inaccuracies occur, and the result is a poorly fitting surgical guide stent. The surgical guide stent is only as accurate as the accuracy of the radiographic stent, whether a single or dual-scan method is used. The surgical guide stent should fit and should be retained as well as a new denture. A small rotational misfit results in the placement of implants outside the cortical plates.

Complications During CT Imaging of the Patient. CT scanning results in radiation exposure for the patient. Therefore, it is important to limit CT scans to those critical for patient treatment. Use of a cone beam scanner with small windows reduces the patient's radiation exposure. Often one scan is obtained on the screening visit so that the clinician can view available bone and rule out concomitant pathology. Use of a CT scan for implant planning should include a stent, which can be used to align the planned implants with the planned restoration. If multiple scans are taken without a prosthetic plan in the patient's mouth, the patient may be exposed to unnecessary radiation. For this reason, the restorative plan should be in place early in the radiographic planning process.

Complication: Poor Adaptation of Duplicated Denture to Soft Tissue. CT-guided surgery is based on accuracy, which includes an accurate scan of the planned prosthesis in relation to the soft tissue and bone. The radiographic prosthesis must fit intimately with the mucosa of the edentulous jaw. The prosthesis also must fit to the jaw without rotational mobility. When scanned in the mouth, the prosthesis may require a bite registration so that the radiographic-duplicated denture can be positioned properly to the jaw. After the prosthesis has been scanned, the cross sections are examined to confirm that no air spaces are present between the intaglio surface of the duplicated denture and the mucosa. If an air space is present, the surgical guide stent will not fit securely and reproducibly to the edentulous jaw, which results in additional inaccuracy of implant placement.

Complication: Lack of Occlusal Support, Causing Poor Orientation of the Stent in the Mouth—the Need for an Accurate Bite Registration. To better ensure that the surgical guide stent is accurately positioned to the jaw, occlusal stops can be left in the surgical guide stent and a bite registration added to achieve the proper orientation. The bite registration should include the posterior occlusion so that the posterior portion of the guide stent is seated properly. If the posterior portion of the guide stent is not in the ideal vertical position, the anterior implants will not be accurately positioned as planned.

This problem can be illustrated by an example. The denture of an edentulous patient is duplicated for scanning. The denture fits well but has small rotation movement because of small areas of misfit or mobile soft tissue. The scan is taken with the mouth open to prevent overlapping of the mandibular dentition with the stent. The surgical guide stent is then fabricated. At surgery, the stent is placed in the mouth and secured with the patient in occlusion. However, because no bite registration is used, either for scanning or during surgical placement of the implants, rotational movement of the guide stent creates 2 mm of lateral implant malposition, and the implant is placed outside the cortical bone. This error should not occur if the patient is scanned with a bite registration that also fits the surgical guide stent or that is used to accurately create a bite registration based on proper cast mounting.

Complication: Improper Patient Orientation During the Scan. CT planning software programs have specific scanning parameters that the radiologist must follow for proper processing of the DICOM data. The scan must follow the specific guidelines, which include scan thickness and increments, and the DICOM files must be placed on a separate compact disc (CD).

With hospital-based scanners, the CT scans are taken with the patient in the supine position. If the CT scan is taken at a separate radiologic facility, a technician who is unaware of the guidelines for this type of imaging may scan part of the jaw, missing the inferior border of the mandible, or may cut the scan short of the incisive edges of the teeth. The technician should be instructed to include in the prescan image all the necessary parts of the jaws. The most common errors are elimination of the inferior border of the mandible, elimination of parts of the incisive edges of the teeth, and use of the wrong occlusal plane to orient the gantry angle. The clinician may need to be present at the scanning session to ensure that the scan is performed properly. Scanning only the region necessary for evaluation, rather than the entire head, reduces the patient's exposure to radiation. This is an important consideration with hospital-based spiral CT (SCT) scanners, because these scanners subject the patient to much greater radiation exposure than do cone beam scanners.

The gantry angle of the scanner should be parallel to the occlusal plane of the arch to be planned. The technician may not be familiar with dental terminology and thus the necessary orientation. Correct occlusal positioning of the radiographic stent during scanning is important to prevent errors when the planning software is used. Technicians may not be familiar with the use of bite registration material or may want to scan the patient in occlusion or with the jaws separated to prevent interference from overlapping teeth. Therefore, when a hospital or an outpatient medical imaging center is used, the clinician may need to be present to prevent these common errors of communication.

Outcomes are less predictable when maxillary scans are taken parallel to the palatal plane instead of the teeth, and mandibular scans are taken parallel to the inferior border instead of the occlusal plane of the teeth. Planning inaccuracy and difficulty determining small anatomic details limit the usefulness of these scans.[5]

With cone beam scanners, the patient's head usually is parallel to the floor, and the patient is in the sitting position. The patient's head should be aligned so as to prevent tilting or rotational errors, which lead to difficulty in accurate implant planning. If a dual scan technique is used, the plate holding the clear acrylic appliance should be radiolucent. If a radiolucent spacer is used between the flat stent platform and the acrylic scanning prosthesis, the spacer should not include materials such as corrugated cardboard or tape with metallic particles, because these will impair the images.

Complication: Patient Movement During the Scan. If the patient moves during the scan, the images will not be sharp, and they will be inaccurate. All cone beam scanners have methods for assessing patient movement when the scan is processed. It is important to follow the manufacturer's recommendations concerning the use of chin cups, forehead straps, and verbal instruction during the scanning to limit patient movement.[6] This problem can occur with SCT scanners in the hospital setting, but the use of head straps tends to limit patient movement. If the scan is blurred, all the subsequent steps in the planning process will be compromised.

Complication: Axial Images Obscured by Extensive Dental Restoration Artifact. Metallic artifact of dental restorations may lead to geometric distortion of the image and invalid data acquisition.[7] In some patients, dental restorations can be removed before scanning. However, in many cases this is not practical, although it may be possible in a partially edentulous patient, and it provides the clearest image. CT planning software can eliminate the axial cuts with extensive scatter, or it can use software applications to remove scatter for clearer planning. Scatter complicates planning because it impairs visibility, and this, in turn, makes fabrication of a guide stent more difficult. As the clarity of the images declines, accuracy may diminish, resulting in poorly planned implant placement and eventual compromise of the restoration.

Complication: Fiduciary Markers Placed in Axial Planes, Including Teeth Restorations. For dual-scan stents that include radiopaque markers to align the stent with the patient, a common error made in a partially edentulous patient is placing the radiopaque markers (e.g., gutta percha or radiopaque composite resin) in the occlusal plane rather than apical to the occlusal plane. In a patient with metallic restorations, scatter in the axial planes must not interfere with the markers in the stent. When the dual scan method is used to scan a clear acrylic radiographic stent in the mouth and by itself, the CT planning software looks for the markers (typically 8 points) to allow superimposition of the separately scanned radiographic guide stent over the scan of the patient with the stent in the mouth. If the computer cannot recognize the marks, this step in the planning process will not be successful. The markers then will have to be replaced and the patient rescanned, which increases the patient's radiation exposure.

Complication: Position of Teeth Obscured by Overlapping of Maxillary and Mandibular Teeth. If the patient's teeth are in occlusion, the cusps and incisal edges will overlap. When this is captured on the CT axial slices, the CT software user may find it difficult to determine the exact position of the incisal edge of the planned restoration, which will affect virtual implant positioning. Often the axis of the implant should emerge within 1 mm of the incisor edge or within a fossa of a tooth. To ensure the most accurate transfer of restorative planning to the surgical outcome, an occlusal record should be used during the CT scan to separate the teeth and prevent overlapping of the incisor edges. If the teeth do not overlap, the planned incisal edge can be visualized during the planning phase.[8] Often one member of the treatment team needs to be at the radiologic facility to confirm proper imaging.

Complication: Inadequate Mixing of Radiopaque Material in the Radiographic Scanning Prosthesis. When a radiopaque material is used for the single-scan method, it must be homogenous and uniform in appearance and must not create scatter. One such material is barium sulfate, which is commonly used for gastrointestinal imaging. It is provided as a powder to be dissolved in water. When used for CT imaging, it is mixed with acrylic powder and monomer to form a radiopaque stent. If the barium sulfate is combined with the acrylic powder in a 10% to 20% ratio, it must be thoroughly mixed to ensure that the powder dissolves completely. If mixed too quickly, the barium sulfate will not have dissolved, and small concentrated areas will be surrounded by clear areas. This results in less accurate planning and less accurate rapid prototyping of the surgical guide stent. The best course is to dissolve the barium sulfate powder in the monomer and then add the remaining acrylic powder. In addition, a coffee grinder can be used to reduce the barium sulfate to a finer powder. The concentration of barium sulfate should not exceed 20%, a proportion that prevents scatter from excess barium sulfate in duplicated dentures.

The advantage of acrylic impregnated with barium sulfate is that this mixture produces a solid radiographic planning stent that does not deform. Other materials that can be used for smaller, single-scan stents include radiopaque resins or composites (Protemp, 3M EPSE, St. Paul, Minnesota; Integrity, Dentsply/Caulk, Milford, Delaware);

temporary cements (IRM, Dentsply/Caulk); and even endodontic filler materials (gutta percha; Cavit G, 3M ESPE), which may retain their form within a vacuform but not by themselves as the prosthesis.

Accuracy of CT Images, Planning Software, Guide Stent Fabrication, and Surgical and Prosthetic Procedures. A reasonable question is whether cone beam imaging is more accurate than spiral CT (SCT) imaging. An ex vivo study evaluated and compared the accuracy of cone beam CT and SCT in five cadaver mandibles (n = 66).[9] A statistically significant difference was seen between the two, with a mean measurement error of 0.22 mm (± 0.15) and 0.36 mm (± 0.24), respectively (Table 3-2). The error ranged from 0.01 to 0.65 mm with cone beam CT and 0 to 1.11 mm with SCT. The clinical significance of the error difference, which has a large range, is not clear.

Another question might be, are distances measured digitally on the computer monitor different from actual measurements? A study involving this comparison did not demonstrate a statistically significant difference between hand-measured distances and those measured on the cone beam CT monitor.[7] Although these differences were not significant, they ranged from 0.0 to 0.3 mm and 0.05 to 0.6 mm in horizontal and vertical dimensions, respectively.[10] Another study evaluated the differences between horizontal and vertical measurements of two-dimensional, reformatted, 1.5-mm axial CT images and hand-measured linear distances.[7] Based on 2664 measurements on 37 human jaw specimens, the differences were 0.29 mm (± 0.32) for the horizontal measurements and 0.65 mm (± 0.43) for the vertical measurements.

The tolerance of guide stent tubes is another factor. Fabrication of the rapid prototype stent from the CT plan has been reported to have a tolerance accuracy of 0.1 to 0.2 mm to the CT scan images.[11] Within the guide stent are metal tubes that guide the drills used to prepare the implant site. These tubes may have different heights and widths, depending on the manufacturer. For example, most tubes are 5 mm in height and 0.2 mm larger in diameter than the drill sleeve diameter. In one study, this resulted in up to 5 degrees of angulation error.[2]

The accuracy of actual implant placement compared with the virtual implant plan also has been studied. Ex vivo and in vitro studies have reported deviation at the implant neck

TABLE 3-2 Methods and Reported Accuracy

Procedure	Clinically Reported Accuracy
Cone beam computed tomography (n = 66)	0.01 to 0.65 mm, average of 0.22 mm ± 0.15 ($p < .0001$)[9]
Spiral computed tomography (n = 66)	0 to 1.11 mm, average of 0.36 mm ± 0.24 ($p < .0001$)[9]
Fabrication of rapid prototype stent	Up to 0.2 mm[2]
Linear difference of planned and actual implant placement at neck of implant in general (n = 110, n = 94, n = 21)	1.1 (± 0.7) to 1.45 (± 1.42) mm[6,15,16]
Linear difference of planned and actual implant placement at apex of implant in general (n = 110, n = 94, n = 21)	1.41 (± 0.9) to 2.99 (± 1.77) mm[6,15,16]
Angular difference of planned and actual implant in general (n = 110, n = 94, n = 21)	4.1 ± 2.3 to 7.35 ± 2.67 degrees[6,15,16]
Difference of planned and actual implant neck of tooth-supported template (n = 94)	0.87 ± 0.4 mm[15]
Difference of planned and actual implant apex of tooth-supported template (n = 94)	0.95 ± 0.6 mm[15]
Difference of planned and actual implant neck of bone-supported template (n = 94)	1.28 ± 0.9 mm[15]
Difference of planned and actual implant apex of bone-supported template (n = 94)	1.57 ± 0.9 mm[15]
Difference of planned and actual implant neck of mucosa-supported template (n = 94)	1.06 ± 0.6 mm[15]
Difference of planned and actual implant apex of mucosa-supported template (n = 94)	1.6 ± 1 mm[15]
Difference of planned and actual implant angulation of tooth-supported template (n = 94)	2.91 ± 1.3 degrees[15]
Difference of planned and actual implant angulation of bone-supported template (n = 94)	4.63 ± 2.6 degrees[15]
Difference of planned and actual implant angulation of mucosa-supported template (n = 94)	4.51 ± 2.1 degrees[15]

ranging from 0.3 to 1.2 mm from the planned position.[11-14] In vivo studies demonstrated differences in the planned and actual positions of the implant: at the neck, 1.11 mm (± 0.7) to 1.45 mm (± 1.42); at the apex, 1.41 mm (± 0.9) to 2.99 mm (± 1.77); and angular deviation, 4.1 degrees (± 2.3) to 7.35 degrees (± 2.67)[6,15] (see Table 3-2).

The linear and angular deviation of the planned and the actual implant neck and apex position have been compared in tooth-, bone-, and mucosa-borne surgical guides. In one study, 110 implants were placed into 30 subjects.[16] The average differences in distance between the planned and the actual locations at the implant neck and apex were 0.87 mm (± 0.4) and 0.95 mm (± 0.6) for the tooth-borne surgical guides; 1.28 mm (± 0.9) and 1.57 mm (± 0.90) for the bone-borne guides; and 1.06 mm (± 0.6) and 1.6 mm (± 1) for the mucosa-borne guides (see Table 3-2). The tooth-borne guide stent was superior to the bone- and mucosa-borne guide stents in linear differences at the apex of the planned and actual positions ($p < 0.01$). No statistically significant differences were found in the linear measurements at the implant neck for any of the three guides types. The mean angular differences were reported as 2.91 degrees (± 1.3), 4.63 degrees (± 2.6), and 4.51 degrees (± 2.1) for the tooth-, bone-, and mucosa-borne surgical guides, respectively (see Table 3-2). The implants placed with the tooth-borne surgical guide showed significantly less angular deviation than the bone- or mucosa-borne guides ($p < 0.02$).

No significant differences have been found between the linear and angular deviations of implants placed in the maxilla and those placed in the mandible. In one study, for 48 implants placed in the maxilla, the angular deviation, the linear deviation at the neck, and the linear deviation at the apex were 5.31 degrees (± 0.36), 1.04 mm (± 0.56), and 1.57 mm (± 0.97), respectively.[6] For the 46 implants placed in the mandible, the angular deviation, the linear deviation at the neck, and the linear deviation at the apex were 4.44 degrees (± 0.31), 1.42 mm (± 1.05), and 1.44 mm (± 1.03), respectively.

Another study evaluated the success rate in 29 individuals of 179 implants that were placed in the maxilla and the mandible with CT guidance and immediately loaded.[16] The overall survival rate was 89%; the success rate in the maxilla was 92%, and the success rate in the mandible was 83%. Implant losses in three of the 29 patients resulted in loss of the suprastructure. In 26 of 31 jaws, the suprastructure remained stable during the 44 months of the study, and success rates of 90% in the maxilla and 70% in the mandible were seen.

Manufacturing Error

Complication: Wrong Master Cylinders Placed into Stent. When the clinician plans the case, a specific implant is chosen, and the surgical guide stent system must match the implant. Implant manufacturers have developed guided surgery kits with specific parts that match their implants. Obviously, the guide stent manufacturer needs this information so that the wrong tubes are not placed in the guide stent. The clinician must check the surgical guide stent before the day of surgery to make sure the correct tubes have been placed by the manufacturer. The clinician also must use the correct implant library during implant planning, or the wrong tubes will be placed by the manufacturer as a result of clinician error.

Complication: Fixation Screw Tubes Smaller than Ordered. The surgical guide system chosen by the clinician includes a fixation tube of a specific internal diameter to match a fixation screw or pin. These fixation screws or pins help stabilize the guide stent when the implants are placed, preventing movement of the stent during surgery. When the virtual surgical plan is created, the stent fixation tubes are placed to engage the alveolar bone, and their diameter must be defined. If the fixation tubes are smaller than the available fixation screws, the surgical guide stent cannot be secured. Especially in edentulous patients and in cases involving a multiunit implant, an unstable guide stent increases surgical inaccuracy.

Complication: Improper Positioning or Inadequate Seating of the Guide Pins During Master Cast Fabrication. Guide sleeves in the computer-assisted manufacture (CAM) surgical template duplicate the platform position and level of the implant replica, or analog. The laboratory technician must seat the fixation pins appropriately before pouring the master model. Failure to do so can result in less than ideal positioning of the surgical template, the implants, and in turn, the provisional prosthesis if it is prefabricated by the laboratory.[17]

Surgical Complications

Complication: Unstable Surgical Guide. Implant placement using CT-generated, guided surgery begins with accurate placement of the surgical guide. If the surgical guide stent rotates slightly, the location of the implant is moved from its virtual planned location, and part of the implant will not be within bone. As the implant is driven into the bone, using the guide stent, the flush fitting of the driver mounts will meet with the master tubes of the guide stent, without the surgeon realizing that the implant is not completely within bone. If the implant has a large dehiscence yet part is within bone, the resistance to rotational movement when abutments or cover screws are placed may be sufficient to obscure the inaccurate placement. Radiofrequency testing of implant stability immediately after removal of the guide stent can reveal poor implant stability from lack of bone contact. In such cases, implant failure occurs sometime during the healing or restorative process.

The surgical guide stent should not be handheld to position it, rather than securing it with fixation screws or pins, in the proper occlusion with complete mucosa seating.

In the edentulous patient, the clinician should always use fixation screws when placing implants using CT guidance. The surgical guide stent can be held with the anterior region well adapted to the mucosa, but slight rotation will move the posterior implants from their ideal position, which can result with implants placed through the buccal bone or under palatal mucosa. This will occur in areas that have relatively thin ridges where accuracy is critical to avoid implant placement problems.

Should the clinician use a CT-guided surgery system that uses multiple templates or guide stents with gradually enlarging holes, requiring taking the stent in and out during the surgery? If the guide stents are absolutely accurate in their manufacturing and placement, for example in a tooth-borne case, then accuracy can be achieved. However, as the complexity of the case increases, especially in the edentulous patient, the use of multiple stents may lead to operator-induced error and thus less accurate implant placement.[18]

Complication: Inadequate Interocclusal Space for Implant Placement. For implant placement in the molar locations, especially the second molar site, adequate interocclusal space must be available.[19] Space can be restricted by the surgical guide stent's metal tubes, which vary in height, depending on the CT guide system chosen by the clinician. Additional space limitations occur because of the height of the drill sleeve and handle; the length of the drills (which typically are longer than conventional because of the need to compensate for the height of the tubes within the guide stent); and the length of the implant driver mount, which also must compensate for the height of the tubes in the guide stent. If the stent is tooth borne, it may be removed, the drills and sleeves placed into the stent, and the stent then replaced over the teeth. However, each time the stent is removed and replaced, error may increase. Implants to be placed in second molar locations may need to be started by a shorter drill and then finished with the surgical guide stent removed from the mouth.

Complication: Implant Placed but not Completely Surrounded by Bone. In deciding whether to use CT guidance to place implants with a surgical guide stent, the clinician should measure the width of the available bone. A relatively narrow ridge has minimal room for error. If the implant site is slightly off as a result of intrinsic inaccuracy of the system, the implant may be placed outside the cortical plate of bone, with implant dehiscence.

When alveolar bone width and height are excellent, minimal significant differences in implant results are seen between the flapless and open approaches with CT-guided surgery.[15] However, because of the intrinsic cumulative error associated with all phases of CT-generated, CT-guided surgery, flapless surgery may not be the best option for a thin ridge. If the alveolar ridge is less than 7 mm, an open approach may be the most appropriate method.[1,18] Placement of an implant 4 mm in diameter into a ridge 7 mm wide results in 1.5 mm of bone thickness if the implant is perfectly positioned. If the error in the process is 1.5 mm, the surgeon should consider exposure of the ridge during the implant placement process. This exposure can be limited and still allow direct visual confirmation of implant placement, which helps prevent complications.

A thin ridge is commonly seen in the edentulous mandible. The ridge may be narrow at the crest and widen inferiorly. The surgeon may elect to reduce the ridge during surgery and use a surgical guide stent planned on a reduced ridge, or the surgeon may elect to place a bone-anchored stent, drill through the thin ridge, and then flatten the ridge after placing the implant. In a thin ridge, the surgeon should visually examine the first pilot drill holes in the bone on the ridge to ensure that the preparation is centered in the ridge and not labial or lingual. Understanding the limitations of the CT-guided system enables the clinician to avoid technical problems.

Complication: Implants Placed More Superficially than Planned—Need for Countersinking. The drill guide is used to prepare the implant sites and place the implants. The implant depth is determined by the surgical planning and use of the prescribed parts. If the surgical guide stent is inaccurate, implants may be placed too superficially. After the implants have been placed and the driver mounts have been removed from the implants, the surgical guide stent is removed. The surgeon should verify proper implant depth. If the implants are placed too superficially, they should be hand-tightened to the proper depth, with care taken not to strip the threads within soft bone. If necessary, the implants can be removed and the site deepened for proper implant positioning.

Complication: Lack of Integration from Burning or Heating of Bone. The drills used to prepare the implant site fit into a small hole within a sleeve, which fits intimately with the master cylinder, which is closely adapted to the mucosa of the jaw. External irrigation may not reach the cutting surface of the drills used in CT-guided preparation. Therefore, the surgeon must prevent overheating of the bone by using slow drill speeds and new drills. Excessive drill speed generates heat. Dull drills also generate heat. Although open surgical procedures have been shown to have greater morbidity, they may allow prevention of overheating of the bone during the drilling process.[20] Slow-speed drilling, self-irrigating drills, and irrigation ports in the template may be useful, although these are not available in all cases or systems.[2,5] Atraumatic surgery is critical for implant integration to bone, which must occur for a successful restoration.

Delivery of the Prosthesis. A provisional or the final prosthesis can be fabricated using the CT guide process. The

accuracy of the fit of the prosthetic parts to the implants varies from case to case. The clinician should assume an error of at least a 0.5 mm, with an occasional error of implant position of 1.5 mm. The provisional prosthesis may need to be adjusted after placement of the implants. Both CT-guided surgery and traditional open surgical approaches have appropriate loading parameters. Excessive loading of provisional prostheses should be avoided.

Postoperative Complications. Precise planning and flapless execution have been shown to reduce surgical morbidity. The implant survival rate for CT-guided, flapless surgery has been reported as 89% to 92%. Failures have been attributed to lack of initial stability of the implants, decreased ability to irrigate during the osteotomy, and overloading of the prosthesis with conditions such as heavy occlusal contacts or bruxism. Several factors have been suggested as favorable conditions for immediate loading; these include a bone density unit reading greater than 500; an implant stability quotient (ISQ; or radiofrequency index) greater than 65; and implant insertional torque greater than 35 N-Cm.[5,21] Patients are strongly encouraged to avoid chewing textured food to limit occlusal loading during the first 2 months after immediate provisionalization. Immediate provisionalization should be used cautiously in patients who have opposing natural teeth with poor occlusal schemes or who have parafunctional habits (Table 3-3).

Discussion. CT-guided surgery is promoted as a means of placing implants and provisional restorations with minimal morbidity for the patient because of great accuracy from the CT scan, software applications, and rapid prototyping of the surgical guide stents. However, as with every technique, the actual limitations become clear as the experience of the clinician increases. The evidence set forth previously shows that CT-guided implant surgery has an inherent level of error, which is based mostly on human contribution.[6,15,16] Complications and offered solutions have been described in a sequential fashion as they might occur during the steps of CT-guided implant surgery. It must be emphasized that errors in this process can be cumulative and, if not identified early, can lead to undesirable results.

The first step, which usually is the diagnostic setup, should be accomplished so as to minimize error. Communication with the restorative dentist should confirm the planned gingival and incisal margins, because the initial diagnostic setup, or "CT denture," is the foundation for the guide stent. The guide stent's ability to transfer the CT-guided treatment plan allows the surgeon to place implants in the ideal location with predictability. Not only should the guide stent represent the final position of the teeth and gingiva, it also should fit well, with resistance to mobility, with the teeth separated, and should be capable of being placed repeatedly in this location. Relining of the prosthesis, occlusal stops, and a bite registration index for use with the scan and placement of the stent have been reported to help minimize these problems. The stent usually is replicated in a 10% to 20% mixture of pulverized barium sulfate and acrylic. An uneven mixture of the barium sulfate, insufficient barium sulfate, or excess barium sulfate can affect the image quality displayed for treatment planning and ultimately the fabrication of the guide stent.

The error of cone beam CT scans has been estimated to be as much as 0.6 mm. This is very important when the placement of virtual implants and the proximity of anatomic structures are considered. Helical CT scanners

TABLE 3-3 Recommended Solutions for Clinical Problems

Clinical Scenario	Recommendation
Bone width is narrow.	Use a crestal incision with minimal reflection to directly visualize implant insertion and prevent bone perforation.[6,15,16,18]
Edentulous maxilla opposing Class III ridge relationships and natural dentition.	Place implants without immediate provisionalization because of occlusal forces.
Single-tooth site with high esthetic demands with narrow ridge.	Expose the bone and use guided surgery combined with connective tissue grafting.
Mandibular dentition to be removed with immediate implant placement and immediate provisionalization.	Plan on flap, bone reduction, and use of a bone-anchored guide stent, with understanding of potential need to adjust implant placement in areas of thin bone because of 1.5-mm error.
Low Hounsfield density: <500 Implant stability quotient (ISQ) <60 Torque >35 N-Cm	Do not immediately load.[21]
Patient is a bruxer.	Do not immediately load.[21]

have been shown to have similar or slightly greater ranges of error than cone beam scanners.[9,22] Although the reported average differences of error for cone beam CT and SCT were 0.22 (± 0.15) and 0.36 (± 0.24), respectively, and were significant, the clinical relevance is nearly negligible.[9] The prudent course is to round up to a magnitude of at least 1 mm for treatment planning around important anatomic structures. If the scan is done at a separate facility, the clinician should be present for the first scan or two and/or should write explicit orders for the scanning protocol.

The surgical template, which is fabricated from the scan, has approximately 5 degrees of angulation error built into the metallic guide tubes, which should be considered when implants are placed close to teeth with curved or dilacerated roots.[2] The typical accuracy of the rapid prototype process is within 0.1 to 0.2 mm.[11] However minimal this may seem, these discrepancies are additive.

As for the type of stent to choose (i.e., tooth borne, tissue borne, or bone borne), the data clearly point in the direction of the tooth-borne application. However, this is not always a possibility. The bone-borne stent has shown no statistically significant advantage for implant position over the tissue-borne stent; however, the tissue-borne stent is less invasive, and less morbidity is transferred to the patient.[6,23] With a thin ridge (i.e., less than 7 mm of ridge width), the bone-borne stent may be the stent of choice, necessitated by anatomy and the near 1.5 mm of error seen with flapless, CT-guided surgery.[1,6,15,16]

The surgeon is responsible for checking the treatment plan sent to the manufacturer. The surgeon must make sure the correct implants are chosen from the library and that they correspond with the desired prosthetic plan. The surgeon also must communicate with the laboratory and recheck materials sent from the laboratory before the day of surgery.

During surgical placement of the implants, the surgeon must ensure correct placement of the surgical stent. Use of an occlusal registration index is critical in the edentulous patient and in patients with a multiunit restoration. The stent is fixed with screws or pins, and the surgeon should try to avoid moving the stent into and out of the mouth unless necessary (e.g., patients with thin ridges). If the tube is placed in the most ideal position and fixated in that position, the clinician can expect as much as 5 degrees of angulation error because of the size of the master cylinder; studies have reported an average 4 to 7 degrees of error.[6,15,16] Linear differences at the implant neck are reported in the range of 1 to 1.5 mm.[6,15,16] These linear differences have been shown to be less in tooth-borne stent applications, possibly because of the repeatable and reliable tooth position as a point of reference. The larger error seen in some of these studies likely is a combination of the CT scan, the rapid prototyping process, and human error. Human error is seen with treatment planning, placement of the stent in the oral cavity, and moving the stent into and out of the mouth.[1,6,15,16]

In addition to the inaccuracies inherent in CT-guided surgery, difficulties with interocclusal space often prove to be a challenge to surgeons. The thickness of the guide stent in the posterior oral cavity can sometimes prevent conventional use of the stent and force surgeons to be creative. Use of shorter drills and removing the stent in tooth-borne situations are two suggestions that may help.

As with any implant surgery, atraumatic placement is critical to implant success. Overheating during drilling has been reported because of the lack of space for irrigation. New drills should be used, bone debris should be cleaned out frequently, and slightly slower speeds should be used during drilling. Some systems have irrigation ports and self-irrigating drills.[20]

When a prosthesis is to be delivered on the day of surgery, challenges to fit the prosthesis may be expected because of error within the entire system. An interim hybrid can be relieved and luted for implants placed in a more mesial or distal location than planned; implants placed too palatally or facially present a bigger challenge and may require removal. Initial implant stability is essential before immediate loading of these fixtures. The same rules apply as with conventionally placed, immediately loaded implants. Guidelines have been published to aid the practitioner in the decision-making process.[21] Occlusal adjustments are necessary to prevent unfavorable loading on the implants. Excessive adjustments should be avoided and may be the result of inadequate depth of placement. This may be seen more with alveolar ridge leveling in edentulous cases, in which inadequate reduction of the ridges or part of the ridge before implant placement is a factor.

Stent fabrication for CT planning

Computerized planning of implant cases requires a representation of the planned restoration. Either a single- or a dual-scan technique is used (Figure 3-13, A-L). The single-scan technique uses a radiographic prosthesis that is radiopaque. The scan is taken with the stent in the patient's mouth. The dual-scan technique uses a clear acrylic stent with at least eight small radiopaque markers placed in the flanges of the stent. One scan is obtained with the clear acrylic stent in the patient's mouth; the second scan is taken of the stent by itself in the same orientation as with the stent in the mouth. The planning software uses the small markers to superimpose the images for planning. Both techniques work well and are used by clinicians, depending on the specific software chosen. Examples of these stents are provided in numerous locations in this text.

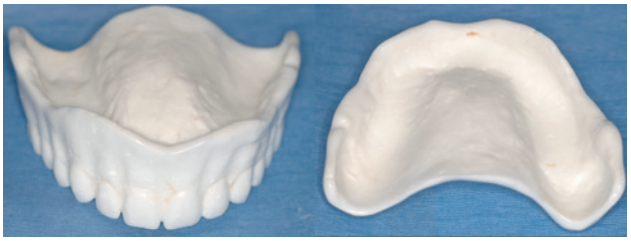


FIGURE 3-13 A, New denture was fabricated to meet the exact functional and esthetic needs of the patient. The denture is duplicated in 20% barium sulfate acrylic for use in a one-scan method.

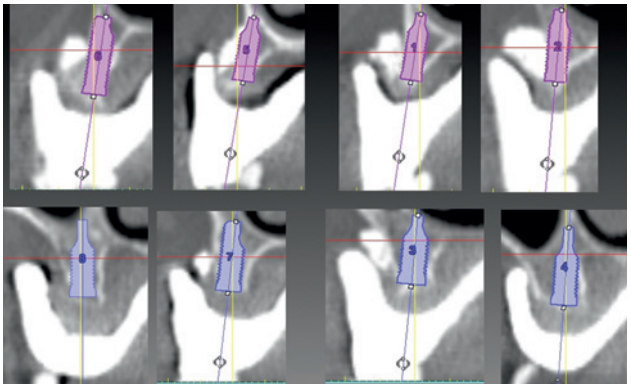


FIGURE 3-13 C, DICOM data are entered into a computer, and planning software is used to align the virtual implants. The cross sections are used to orient the implants so that they emerge as needed for the prosthetic planned restoration.

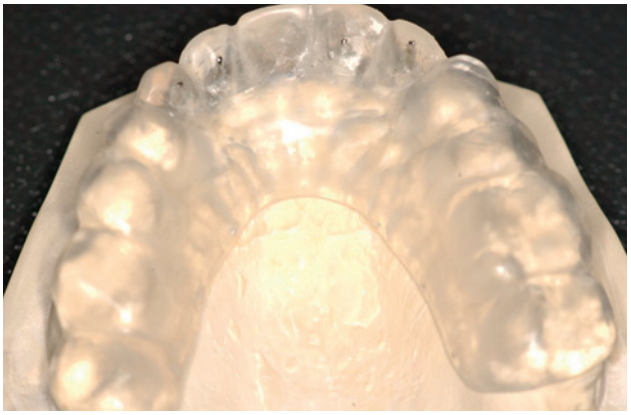


FIGURE 3-13 E, Example of a clear acrylic stent used in a dual-scan method. The proposed anterior teeth are in clear acrylic, and small markers are placed in the palatal aspect of the prosthesis apical to the restorations. The markers must be placed to prevent scatter in axial sections.

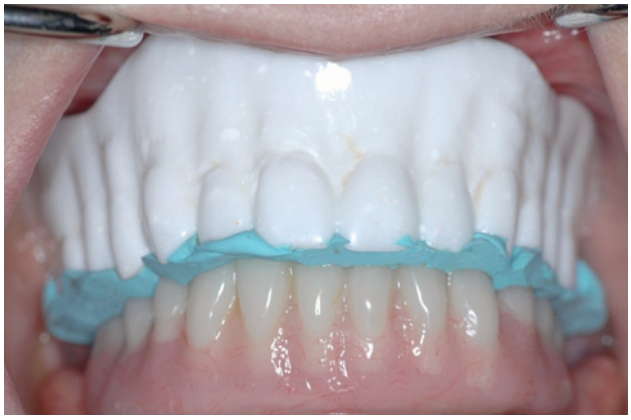


FIGURE 3-13 B, Duplicated denture must be scanned in the patient's mouth with a bite registration to ensure proper placement in the mouth and to prevent movement during the scan.

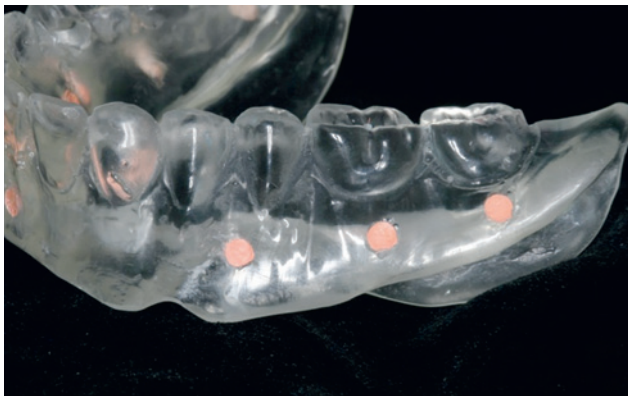


FIGURE 3-13 D, If a dual-scan method is chosen, the patient's new denture is duplicated in clear acrylic, and radiopaque markers (here, gutta percha) are placed in the flanges on the labial and palatal aspect. The denture is scanned in the patient's mouth and by itself. CT planning software converts these images so that they can be used for planning.

Case examples

CT-Guided Replacement of the Maxillary Right Two Premolars and Canine. The patient was an active, 59-year-old man. The treatment plan called for implants to replace his maxillary right canine and two premolars. Because he wanted to have the implants placed and avoid downtime from swelling, CT-guided surgery was chosen.

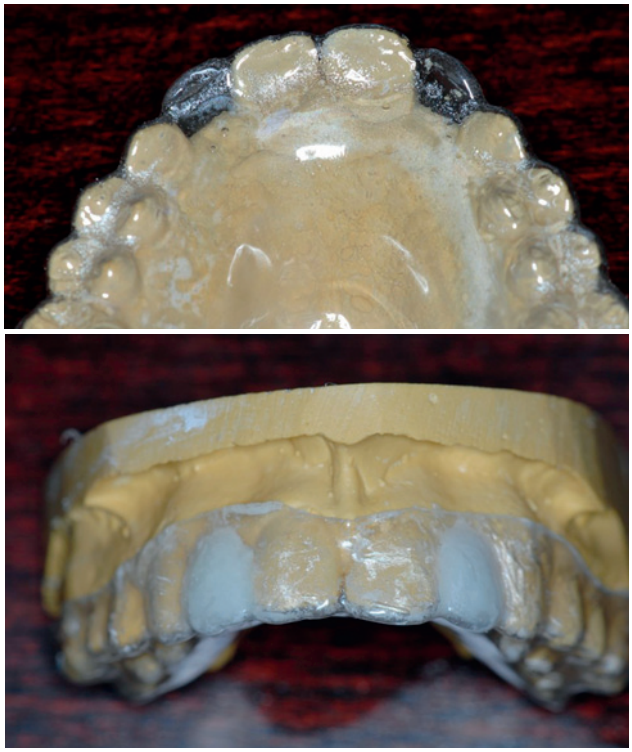


FIGURE 3-13 **F-G,** For patients missing the lateral incisors, an impression can be taken with and without the provisional flipper device. A vacuum form is made over the cast with the flipper, and the teeth voids are filled with acrylic impregnated with barium sulfate. The patient is then scanned.

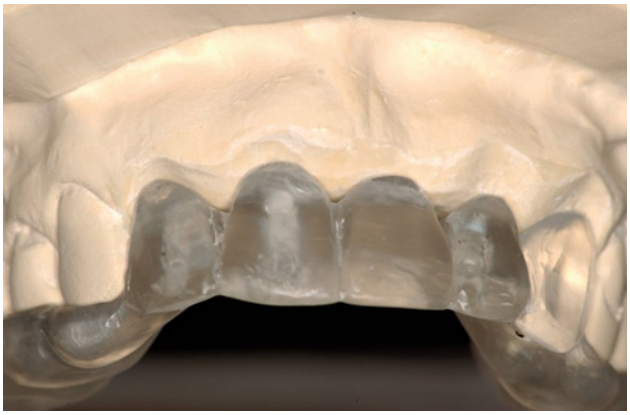


FIGURE 3-13 **H,** Frontal view of a patient who requires replacement of the anterior teeth. This stent is not well made because of the lack of a labial or palatal flange in acrylic. No markers can be placed without interference with dental restorations.

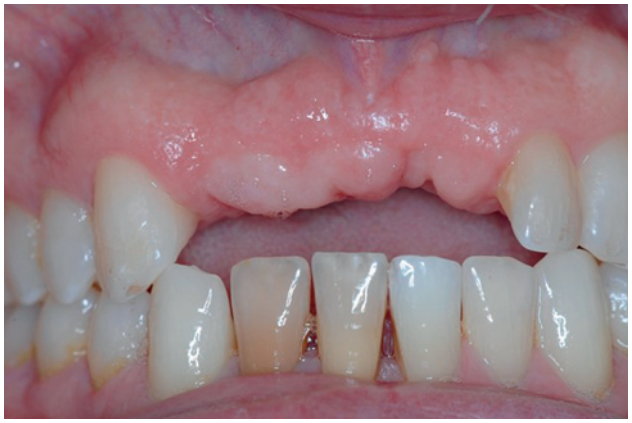


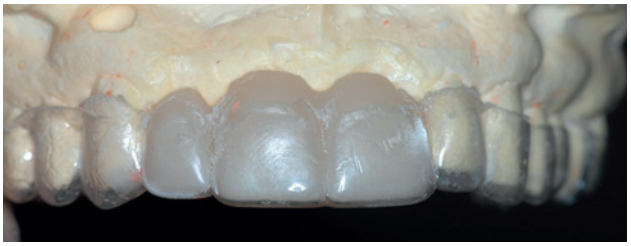
FIGURE 3-13 **I,** This patient requires implants for replacement of three anterior teeth.

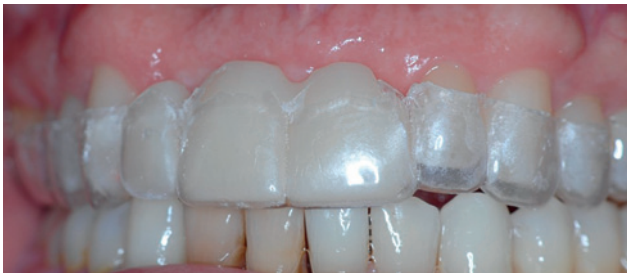
Preliminary work by his restorative dentist (Dr. Ace Jovanoski) resulted in the placement of a provisional restoration; this was converted into a radiopaque provisional made of acrylic combined with 20% barium sulfate by volume (Figure 3-14, A). The radiopaque provisional was placed, and a CT scan was taken with a SCT scanner using the radiographic parameters recommended by the manufacturer of the CT planning software. The DICOM data were loaded into a personal computer, and virtual implants were placed on the cross sections (Figure 3-14, B).

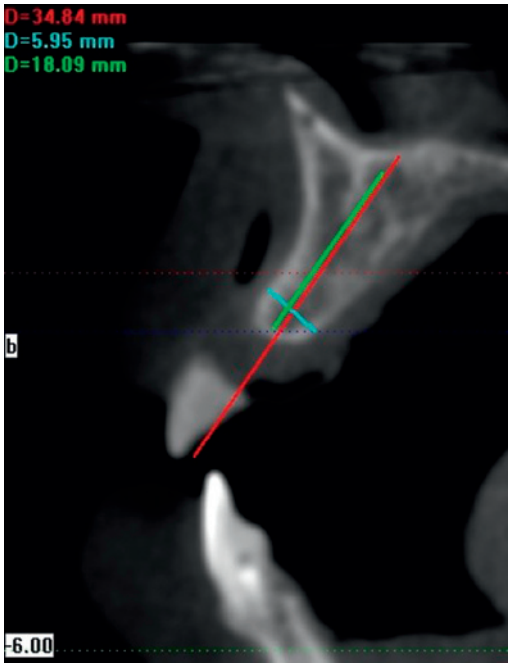
After the CT plan had been approved by both the surgeon and the restorative dentist, it was sent to the manufacturer for rapid prototyping of the surgical guide stent. A model of the patient's maxillary teeth without the provisional in place was mailed to the stent manufacturer. The CT guide stent was made to fit onto the teeth and preparations. The stent was tried into the patient's mouth before surgery to ensure the correct fit. While the guide stent was being made, the patient wore his provisional (Figure 3-14, C).

On the day of implant surgery, a local anesthetic was infiltrated, including the implant sites and the prepared teeth. The provisional prosthesis was removed (Figure 3-14, D). The guide stent was placed, and the perfect fit, without mobility, was again confirmed (Figure 3-14, E-F).

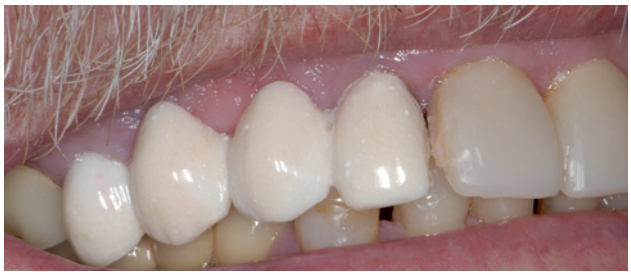
The drilling sequence followed the protocol for the system chosen (Navigator, Biomet 3i). The tissue punch was used, and the gingiva was removed. The countersink drill was used to initiate preparation of the implant site. Graduating-sized drills were used according to the lengths prescribed, and the drill sleeves were used to provide absolute control of angulation and depth. (Although not necessary in this case, the sites can be tapped to form threads if dense cortical bone is engaged.) The implant



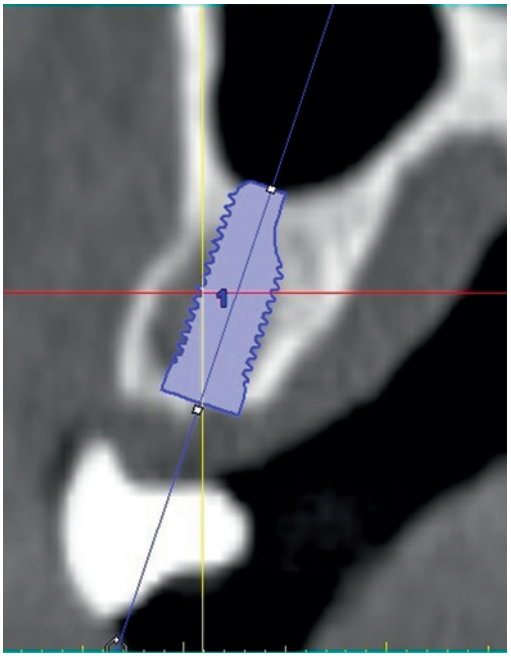




● **FIGURE 3-13** **J-L,** Esthetic tooth setup is approved by the patient. The setup on a model is duplicated in stone. A vacuum form is made and filled with radiopaque composite resin. The resin is trimmed to the exact dimensions and shape of the planned restoration. This device is placed in the patient's mouth, and a cone beam scan is obtained. Planning thus can make use of the knowledge of the exact position of the planned crown.



● **FIGURE 3-14** **A,** The patient's temporary bridge can be used to obtain an excellent scan for planning. The provisional is duplicated in a radiopaque material (e.g., resin or acrylic impregnated with barium sulfate) and placed in the patient's mouth. The scan is loaded into a computer for planning and virtual implant placement. A surgical guide stent then can be fabricated.



● **FIGURE 3-14** **B,** DICOM data were loaded into a computer, and virtual implants were placed to align with the planned restoration. The plan then was sent electronically to the manufacturer (Materialise, Brussels, Belgium), along with an accurate model of the patient's maxilla with the tooth preparations. The manufacturer fabricated a surgical guide stent as a tooth-borne device.

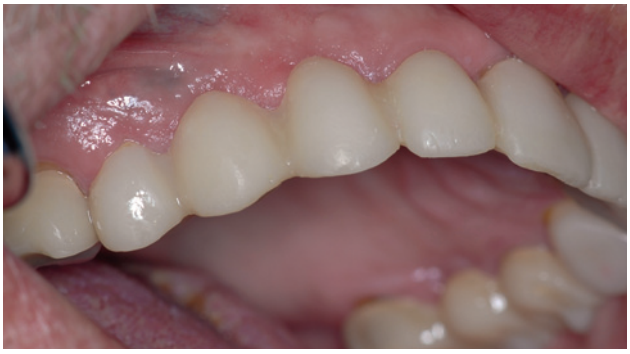


FIGURE 3-14 C, On the day of surgery, a temporary bridge is in place. It is removed and will be recemented after the implants have been placed.

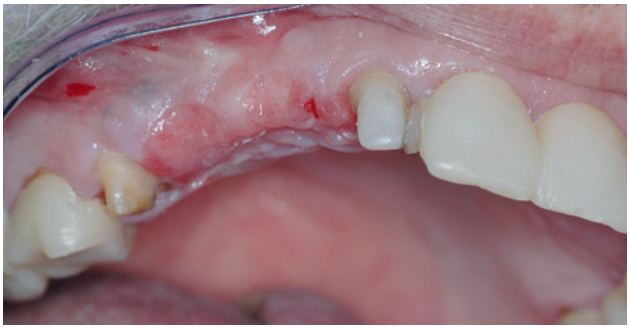


FIGURE 3-14 D, Provisional fixed bridge is removed to expose the preparations on the adjacent teeth. The surgical guide stent was fabricated from a model of these preparations and from CT planning. Note the gingival irritation, caused by contact of the intaglio surface of the provisional with the gingiva on the crest. This space should be relieved before surgical placement of the implants.

driver mount of the appropriate length was connected to the implant, which was placed using a slow speed. A hand wrench was used for final positioning. The driver mounts then were removed from the guide stent, and cover screws were placed. The provisional restoration was recemented. After integration had been achieved, the healing abutments were placed, and a final restoration was fabricated (Figure 3-14, G-O).

CT-Guided Surgery in the Edentulous Maxilla. Several reasons support the use of CT-guided surgery for the placement of implants in the edentulous maxilla.

1. *Implants can be placed in the ideal position based on preoperative planning.* The implants are placed very close

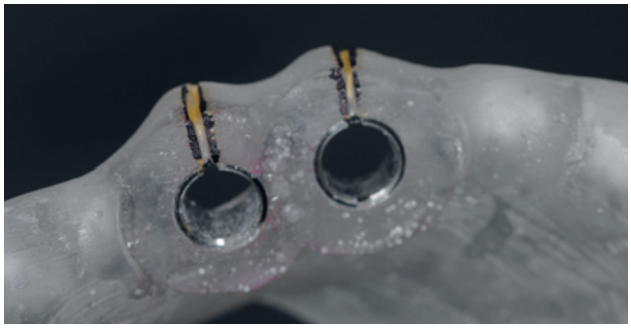


FIGURE 3-14 E, Master tubes in the surgical guide stent have small grooves for aligning the implants into the planned orientation. To identify these grooves, a small disc is used to create a groove in the acrylic of the guide stent, and a marking pen is used to mark the grooves.

FIGURE 3-14 F, Surgical guide stent is placed over the teeth. The surgeon must have absolute confidence in the position of the stent. It should fit without any movement, and full-arch tooth coverage is recommended.

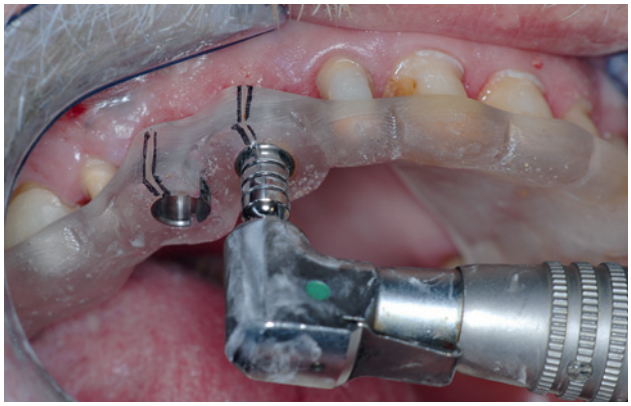


FIGURE 3-14 G, Drilling sequence begins with a tissue punch. The stent can be removed, and the gingival circles from the punch also are removed. The next drill is used to initiate the osteotomy into the ridge. This drill has a very sharp tip that can begin the osteotomy sequence in crestal bone, which is not flat.

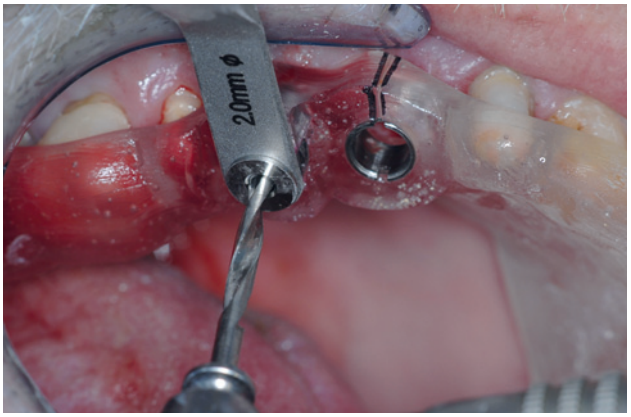


FIGURE 3-14 H, Drill sleeve for the first drill is placed into the master tube. It should fit flush with the surface of the master tube. This sleeve is size specific for the drill. The prescription sent by the manufacturer of the guide stent records the drill length required for each site. The first drill is used at slower speeds than are conventionally used because of the lack of irrigation within the site. The next series of drill sizes follows until the final-sized drill is used. The manufacturer's recommendation for the drill sequence should be followed.

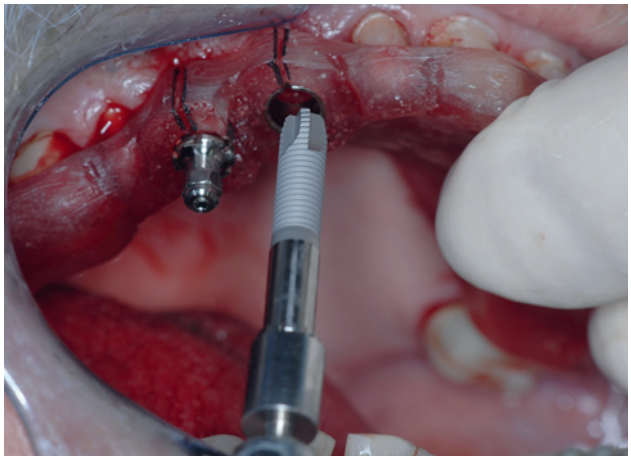


FIGURE 3-14 I, Drill mount (the length of which is prescribed by the manufacturer) is mounted to the implant without touching the implant's surface. The implant then is placed into the site and slowly secured. A hand wrench is used for final adjustment of the orientation and to achieve a flush seating with the master tube. It is important to avoid overtorquing, which will disengage the threads of the implant.

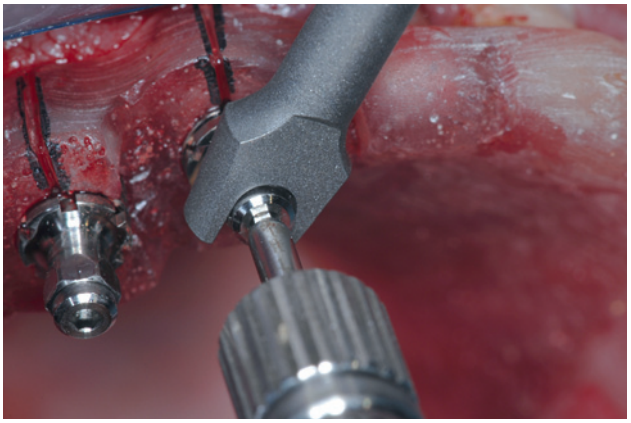


FIGURE 3-14 J, After the implants have been placed, the hex drive is used to release the driver mounts, which are removed individually.

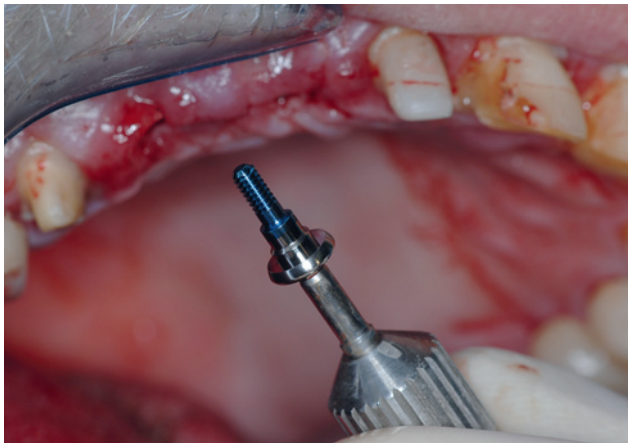


FIGURE 3-14 K, Stent is removed, and the sites are irrigated. Additional soft tissue or hard tissue manipulation can be performed as needed. For this case, the cover screws are placed into the implants.

to the ideal locations as determined by fabrication of a radiographic duplicate of the planned restoration. The initial procedure performed by the restorative dentist determines the exact location of the teeth. This often requires fabrication of a new denture. The new denture, with its approved form, function, and esthetics, is duplicated for scanning. The duplicated denture is used to direct implant placement, with the type of final prosthesis taken into consideration. For example, if the final prosthesis is to be a fixed crown and bridge, the implants must be placed so as to avoid embrasures and 3 mm from the planned gingival restoration. If the final prosthesis is to be the fixed-removable type with a bar, the implants must be placed with sufficient space for fabrication of the

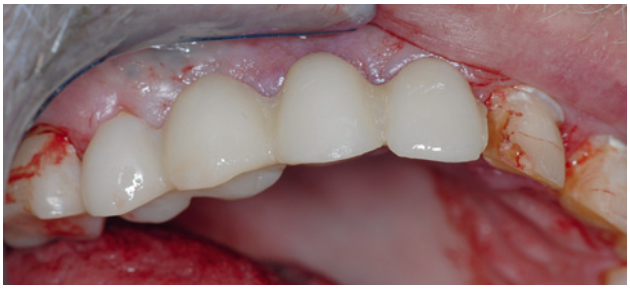


FIGURE 3-14 L, A temporary bridge is recemented.

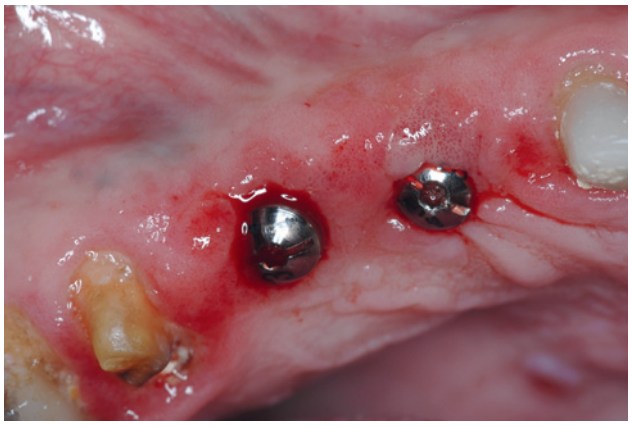


FIGURE 3-14 M, Four months later, the bridge is removed and the healing abutments are placed. Note the gingival irritation caused by contact of the bridge with the gingiva.

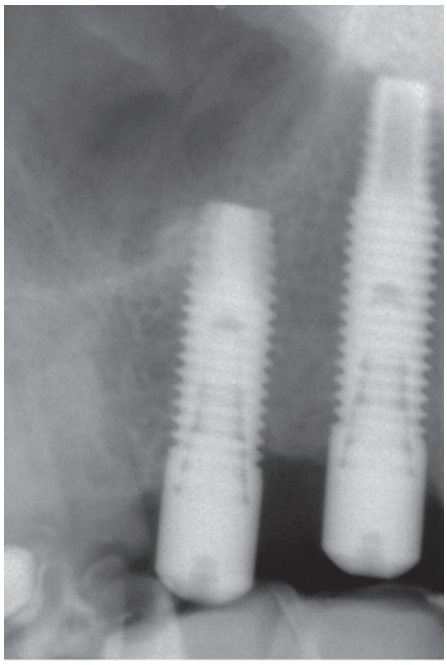


FIGURE 3-14 N, Periapical radiographs show excellent bone and implant integration.

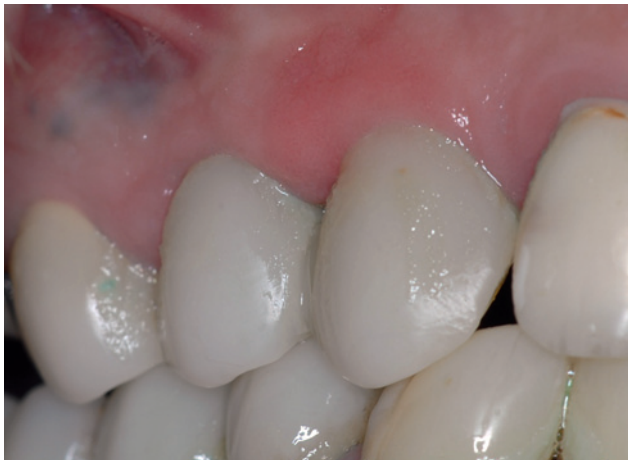


FIGURE 3-14 O, Final temporary in place over the implants. (Prosthetics by Dr. Ace Jovanoski.)

bar and prosthesis, which includes a metallic intaglio surface that interdigitates with the milled bar. If the planned prosthesis is a hybrid denture, the implants must be placed with consideration given to the space necessary for cleaning the fixed prosthesis, which can be removed by the dentist but not by the patient.

2. *Implants can be placed without the creation of flaps.* If tissue need not be raised to allow direct visualization of the bone and its adjacent structures, the patient has less swelling, bruising, and pain. If bone is not reflected, the result is believed to be less disruption of the blood supply to the bone and thus less crestal bone resorption. However, this has not been clearly proved in clinical trials.
3. *Provisionalization can be done immediately after implant placement.* CT planning software enables the surgeon and restorative dentist to position implants virtually in relation to the planned restoration. The surgical guide stent can be used to pour a model, which then can be used to fabricate a restoration or prepare a restoration for chairside modification and attachment to implants. The CT plan also can be used to generate a model of the bone, with or without mucosal equivalent, for placement of implant analogs.

A case example (Figure 3-15, A-C) is provided to demonstrate one method of making a provisional that is placed immediately after placement of maxillary implants. The

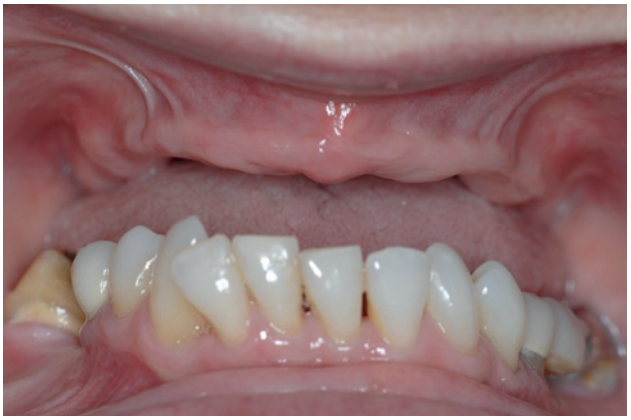


FIGURE 3-15 A, Frontal view of a patient who wants the palate portion of her maxillary prosthesis removed and who also wants to be able to chew a normal-textured diet. Her mandibular dentition is not ideally aligned but will not be changed.

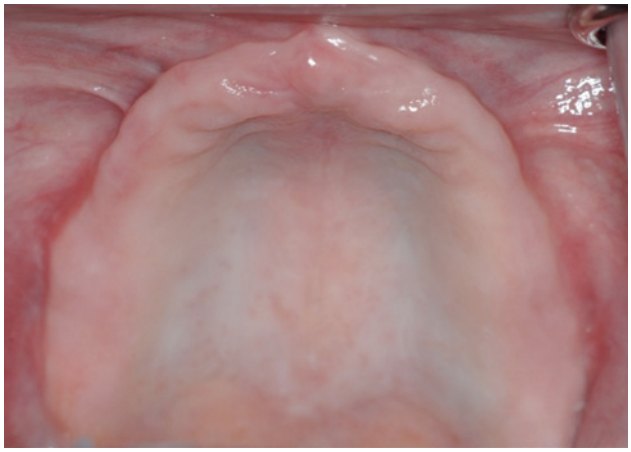


FIGURE 3-15 B, Maxillary occlusal view showing adequate ridge form for a prosthesis.

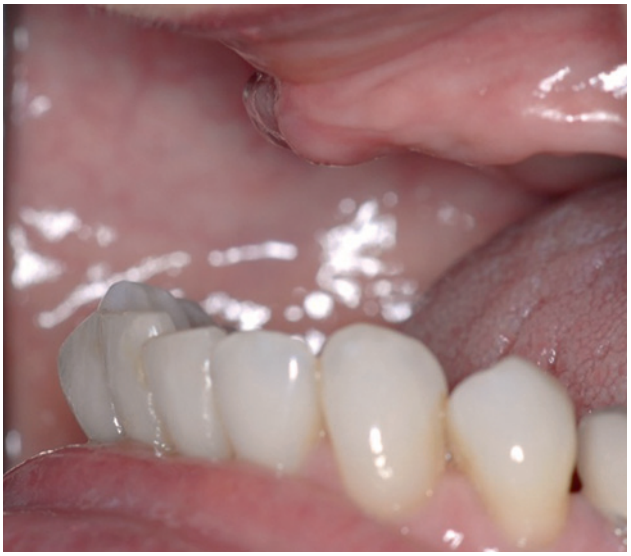


FIGURE 3-15 C, Note the Class III ridge relationship and the 8-mm discrepancy between the mandibular incisors and the maxillary anterior crest.

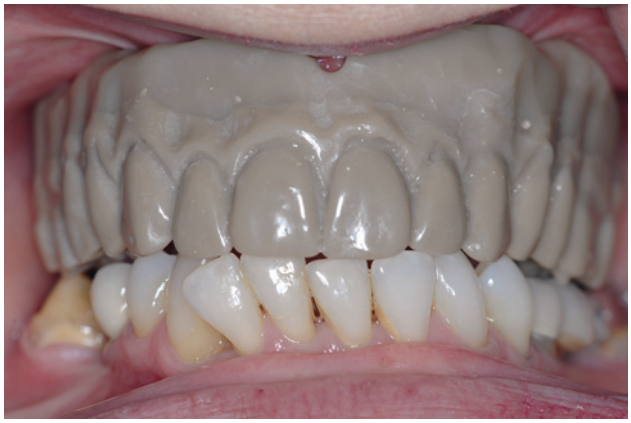


FIGURE 3-15 D, New esthetic denture is fabricated and duplicated in acrylic impregnated with 20% barium sulfate. Occlusion is verified prior to scanning.

prosthesis can be cemented onto abutments that have been prepared on models with laboratory-processed, cemented provisionals. The prosthesis can be screw retained in the fashion of a hybrid prosthesis.

Step-by-Step Method for Immediate Provisionalization of the Edentulous Maxilla. The maxillary denture is confirmed to satisfy the requirements of form, function, and esthetics. If necessary, a new denture is fabricated to establish the precise requirements for ideal treatment for the patient. Use of an old denture that is not perfect is not acceptable. The new or ideal denture is duplicated by laboratory standard methods to preserve accurate intaglio surface anatomy. If a dual-scan method is chosen, the denture is duplicated in clear acrylic with radiopaque markers in the labial and palatal flanges. If a single-scan method is chosen, the denture is duplicated in acrylic impregnated with 10% to 20% barium sulfate (Figure 3-15, D-E). It is critical that the entire denture be duplicated accurately to ensure that it has the same excellent fit and positional

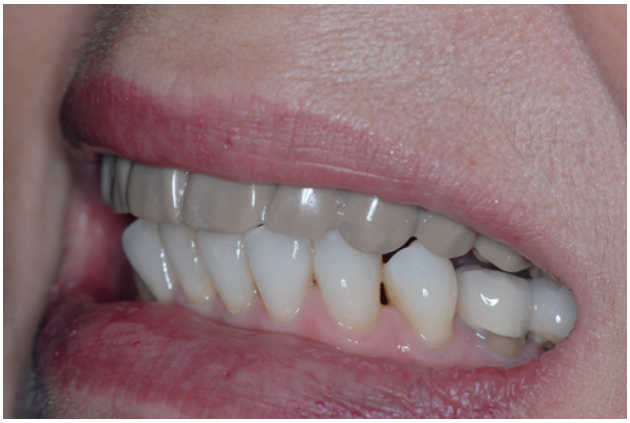


FIGURE 3-15 **E,** Lateral view shows adequate lip support and an adequate overbite and overjet of the planned prosthetics.

stability as the denture recently fabricated for the patient. The procedure then continues as follows:

1. The duplicated denture is placed into the patient's mouth; if the denture is not perfectly stable, an occlusal bite registration is used to stabilize it in position. This same registration is used to position the guide stent, because occlusal stops will be retained in the surgical guide stent.
2. The scan is taken with either the registration or cotton rolls in the mouth (Figure 3-15, F). Keeping the opposing occlusion out of the axial cut of the incisive edge of the denture is helpful, because this eliminates the problem of having the maxillary and mandibular teeth together in the same axial plane.
3. After the scan has been taken, the DICOM data are placed on a CD to be used for planning software.
4. The CD is inserted into a computer that contains the planning software. The data are uploaded and converted for planning. The teeth are split from the three-dimensional model, and the cross sections are used to place the implants (Figures 3-15, G-I).
5. In the patient in Figure 3-15, the implants are placed from the canine posteriorly to allow the restorative dentist maximum freedom to ridge lap and provide lip support in the incisor region. The implants are placed palatal to the incisor edges and sufficiently deep to allow space for the bar. The plan calls for a precision-milled locking bar and a fixed-removable prosthesis. This device was chosen to provide sufficient flange support of the nasolabial region. Without the flange in the anterior region, the patient's nasolabial support was deficient, and she did not achieve the youthful appearance she wanted with the flange of the maxillary prosthesis. After final virtual placement of the implants, the plan was reviewed by all members of the implant team and then electronically uploaded to the manufacturer for fabrication of the surgical guide stent.

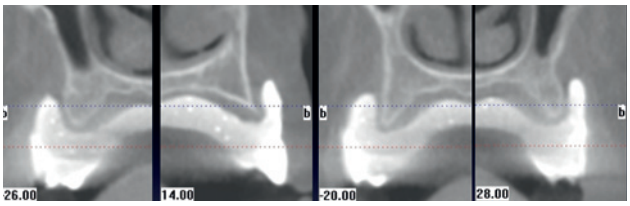


FIGURE 3-15 **F,** Cone beam scan was taken using a 10 × 4 voxel format. The cross sections show the bone under the radiographic stent. The stent fit well and had no obvious voids of air between the intaglio surface of the stent and the maxillary gingiva.

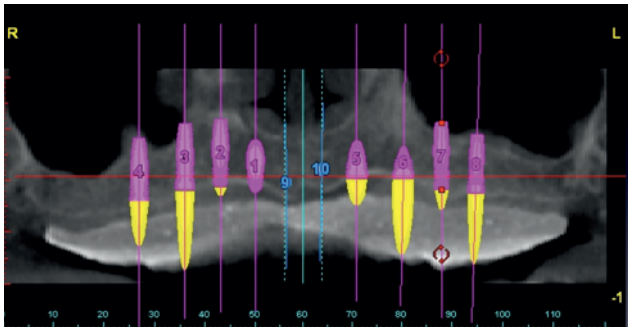


FIGURE 3-15 **G,** DICOM data from the cone beam scan were loaded into the planning software (Simplant 12.0 Pro, Materialise, Brussels, Belgium). Virtual panoramic image shows virtual implants in place. Eight implants were planned, to emerge from the canine posteriorly.

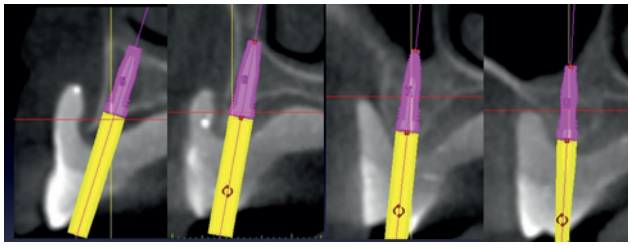
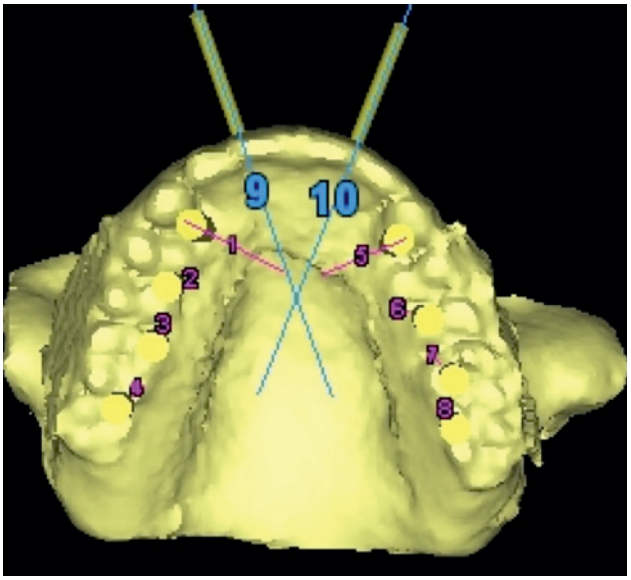
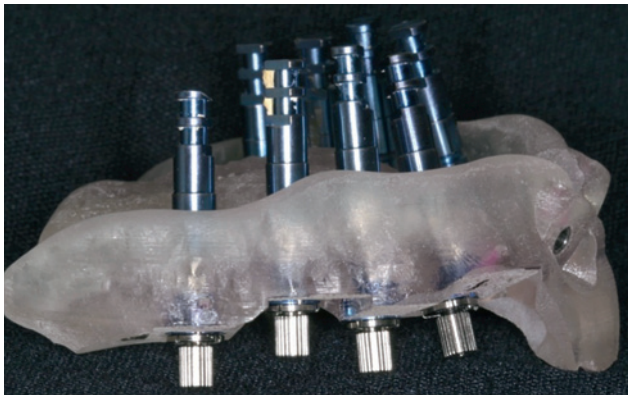


FIGURE 3-15 **H,** Four cross sections from the planning software show the planned implants in the bone, with the emergence axis slightly palatal to the incisive edges of the duplicated stent.



● **FIGURE 3-15** **I,** Occlusal view of the three-dimensional representation of the planned implant positions and the two fixation pins. Note that the implants emerge from the canine posteriorly, leaving the anterior maxilla without implants; this arrangement allows the greatest flexibility for the prosthetics. The implants at the canine sites are planned to allow for either a fixed or fixed-removable prosthesis, although a fixed-removable prosthesis was planned.

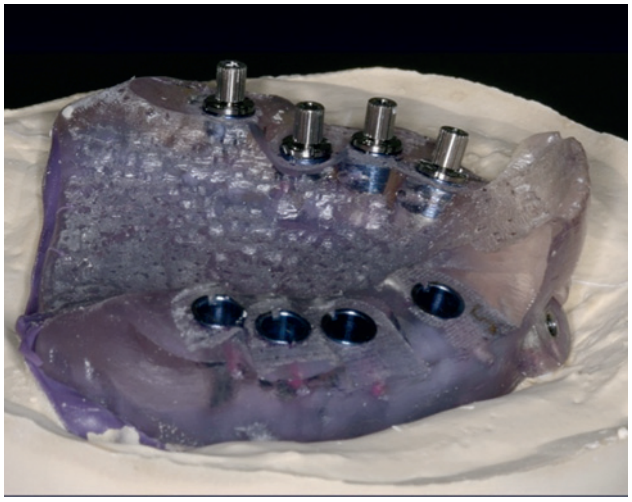
● **FIGURE 3-15** **J,** Plan was electronically uploaded, and a tissue-borne guide stent was fabricated with eight master tubes. Occlusal stops were left on the surgical guide stent.



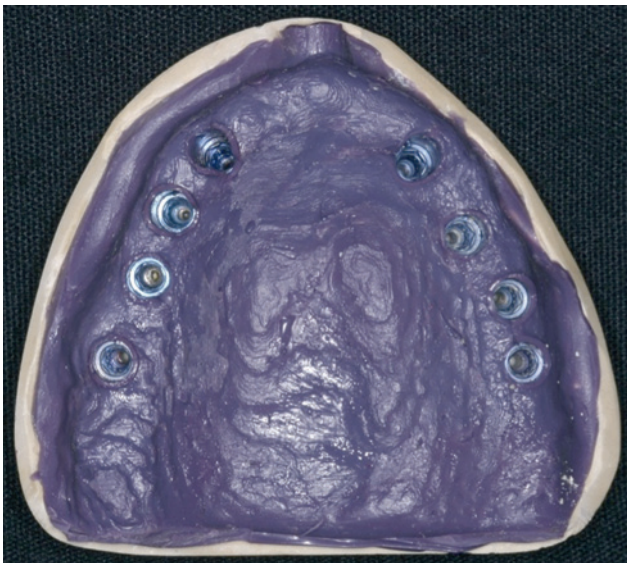
● **FIGURE 3-15** **K,** Prior to surgery, implant analogs were attached to the master tubes with prosthetic connecting parts. Each was carefully placed and engaged the grooves of the master tubes.

6. The surgical guide stent (Figure 3-15, J) was used to fabricate a model with implant analogs in the positions planned for the implants.
   a. The prosthetic components to be attached to the implant analogs were connected to the master cylinders (Figure 3-15, K).
   b. The intaglio surface of the model was poured in soft impression material to create a resilient surface, to which the patient's denture could be attached. After the resilient material had set, the model was based with stone (Figures 3-15, L-N).
   c. The shouldered immediate occlusal load abutments were placed into the implant analogs in the model (Figures 3-15, O). The gingival height was 4 mm, which allowed a supragingival margin for the temporary cylinders to the abutments.
7. The temporary cylinders were placed on the shouldered abutments and secured with the laboratory screw (Figure 3-15, P). The gold screw is used only when the temporary cylinders are placed on the abutments in the patient, not in the laboratory. The maxillary denture was placed over the temporary cylinders on the abutments, and the locations of the temporary cylinders were marked on the intaglio surface of the denture. Holes were drilled through the maxillary denture for all the temporary cylinders (Figure 3-15, Q). The maxillary denture with the holes drilled is placed over the model. The height of the temporary cylinders is marked for adjustment. The denture is removed from the model and the heights of the temporary cylinders are adjusted to be flush with the denture (Figure 3-15, R).
8. At surgery, the surgeon had the denture with the holes drilled and the model with the temporary cylinders on the abutments. It is important to maintain the position of the modified temporary cylinders on the model to

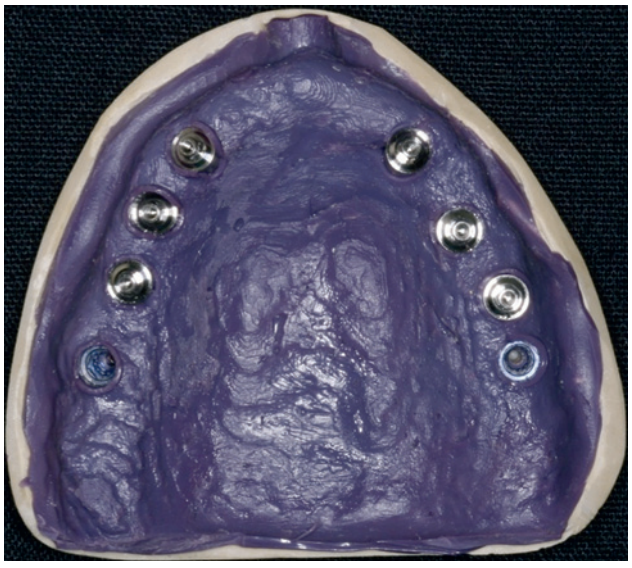
● **FIGURE 3-15** **L,** Resilient material used for impressions (Impregum, 3M EPSE) is poured into the intaglio surface of the stent to form a mucosa equivalent on the model. This allows the patient's denture to fit onto the model. Stone is not flexible; therefore, a stone model does not allow the denture to be placed onto the model for the next step in the procedure.



● **FIGURE 3-15** **M,** After the resilient layer has set, the model is poured with a stone base.



● **FIGURE 3-15** **N,** Prosthetic parts are removed, revealing the surface of the maxilla with the implant analogs in position. From this model, the abutments and the temporary cylinders can be placed and the provisionalization completed.



● **FIGURE 3-15** **O,** Immediate occlusal load (IOL) abutments are placed into the analogs. These are placed on the implants after the implants have been placed in the patient.

avoid mixing them up. After the implants have been placed, the assistants must maintain control of the temporary cylinders to help the surgeon place them according to their preparation.

9. The surgery was performed, and the implants were placed.

Surgical Procedure in Detail. A local anesthetic is administered to the maxilla, with care taken to prevent excessive swelling of the tissues over the ridge. Injections are given to anesthetize the floor of the nose. The mouth and soft tissues on the skin are prepared with povidone-iodine (Betadine), and a sterile drape is placed.

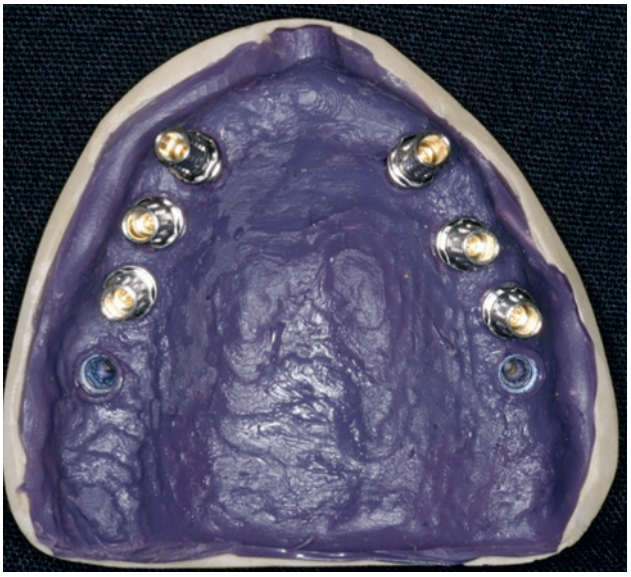


FIGURE 3-15 P, Temporary cylinders are placed onto the IOL abutments and secured with screws.

FIGURE 3-15 R, Temporary cylinders are shortened to match the acrylic of the denture.

The surgical guide stent is sterilized in cold solutions. It is placed into the mouth, and the tissue punch is used to remove the gingiva in the implant sites. The stent is then removed. This author uses a laser (Biolase MD, Biolase, Irvine, California) to sculpt the periphery of the tissue punch sites and to control bleeding. Small rongeur forceps then are used to remove the gingival plugs. The gingival tissue is removed before the guide stent is fixed to the jaw to facilitate tissue removal prior to bone preparation. After the guide stent has been secured to the maxilla with screws or pins, removing this tissue becomes very difficult.

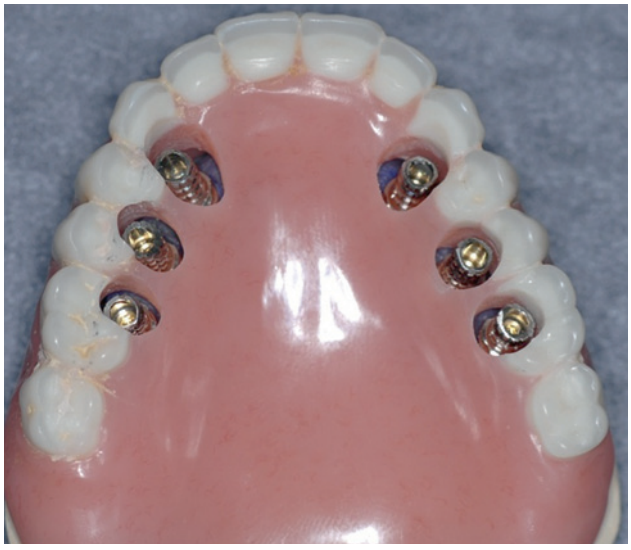


FIGURE 3-15 Q, Denture is placed on the model, and the sites of the temporary cylinders are marked. Holes are created in the denture to allow passive seating of the denture onto the model over the temporary cylinders. Performing this step in the laboratory reduces chair time immediately after implant placement.

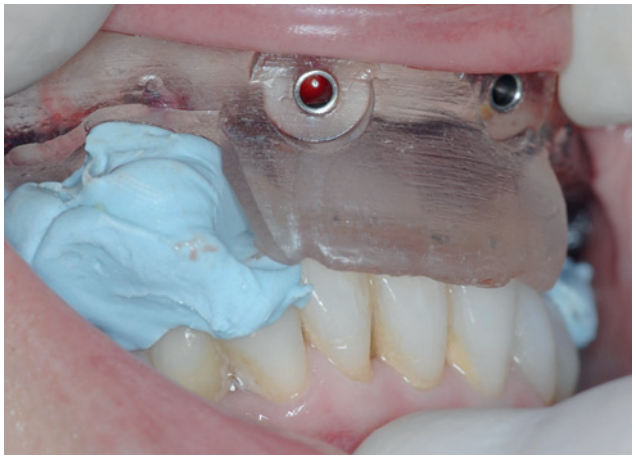


FIGURE 3-15 S, At the time of surgery, an occlusal registration is used to accurately position the surgical guide stent in the mouth before the stent is secured to the maxilla with screws. It is important to completely seat the posterior aspect of the stent.

The surgical guide stent is placed into the mouth, and an occlusal index is used to ensure that the stent is in the correct position (Figure 3-15, S). With the patient in occlusion, the fixation screws or pins are placed to secure the stent. Two or three fixation screw or pins are used

to secure the guide stent in an edentulous patient. The patient's mouth is opened, and the occlusal indexes are removed.

Pressure is put on the palatal aspect of the guide stent to prevent malpositioning of the anterior implants from posterior stent movement. One implant site is prepared on one side of the mouth, typically in a premolar location. For the Navigator system (Biomet 3i), a countersink drill is used to initiate preparation of the implant site through the master cylinders without a drill sleeve. For the rest of the drills, and for the Nobel Guide system (Nobel Biocare, Yorba Linda, California), the initial drill is a small-diameter twist drill that is used with the correct-diameter drill sleeve placed into the master cylinders. The consecutively sized drills are used to increase the diameter of the implant site gradually. After the final drill diameter has been used (e.g., the 3-mm drill for a 4-mm implant), the implant is brought to the surgical field. The implant driver mount of the appropriate length is placed onto the implant. The implant is placed into the prepared site at a speed of less than 20 rpm. The implant mount is brought to the surface of the master cylinder. Care must be taken not to strip the threads of the implant in the bone by overtorquing. Use of the hand ratchet for final seating of the implant in the master cylinder in the bone prevents stripping of the implant from the threads.

A second implant site is prepared on the opposite side. After two implants have been placed, combined with the anterior fixation screws or pins, the maxillary guide stent is quite stable. The remaining implants are placed sequentially, alternating right and left sides, until all the implants have been placed.

The drills for preparation of the implant site fit very closely into the drill sleeves. The drill sleeves fit very closely into the master cylinders of the guide stent. The guide stent fits very closely to the gingiva on the ridge. Therefore, the surgeon must assume that minimal irrigation reaches the cutting surface of the drill. Consequently, slow speeds (i.e., less than 300 rpm) should be used to prepare the implant sites. If the crestal bone is sloped or if the implant is to be placed along the edge or slightly into the cortical labial or palatal lingual bone, use of a thread-former may prevent a small deviation in the final orientation of the implant; the threads in the bone prevent the implant from moving away from the cortical bone, because the implant follows the path of least resistance.

After the implants have been placed, the final depth and orientation are checked, and hand ratchets are used as necessary to tighten the implants into the ideal position. Tightening is recommended rather than counterclockwise rotation, which may reduce the stability of the implant. The implant mounts are removed one by one, rather than all together, because of the internal connection and small draw discrepancies. The fixation screws or pins then are removed, and the guide stent is removed from the mouth.

The implants sites are examined carefully. Proper implant depth must be verified. If necessary, the implant can be driven deeper or removed and the site prepared carefully. The soft tissue over the implant site can be trimmed or sculpted with scalpels or a water-cooled laser (Biolase MD). After the soft tissue has been cleaned, the abutments can be placed. If no provisional restoration is to be placed, the cover screw can be placed rather than the abutments.

With immediate provisionalization, the shouldered abutments are placed with the aid of the torque driver and seated at 20 N-Cm. This ensures that the abutments will not loosen when the prosthetic portion of the procedure is performed. After all the abutments have been placed, a long-acting anesthetic solution is infiltrated to provide patient comfort over the next few hours, when the provisional restoration is placed.

Prosthetic Procedure. The prosthetic procedure involves securing the temporary cylinders to the maxillary denture, adding resin to the denture around the temporary cylinders, smoothing the surfaces of the denture, and removing all flanges and the palatal portion, resulting in an implant-borne prosthesis.

The temporary abutments are placed onto the shouldered abutments in the same location and orientation as on the model (Figure 3-15, T-U). The gold screws are placed with hand pressure only. The occlusal holes of the screws are covered with cotton to prevent acrylic from falling into the holes. The denture is tried in place, and the occlusion is checked and adjusted as necessary. The denture should have sufficient stops and stability based on the palate and shelves of the alveolar ridges. Once the occlusion and clearances

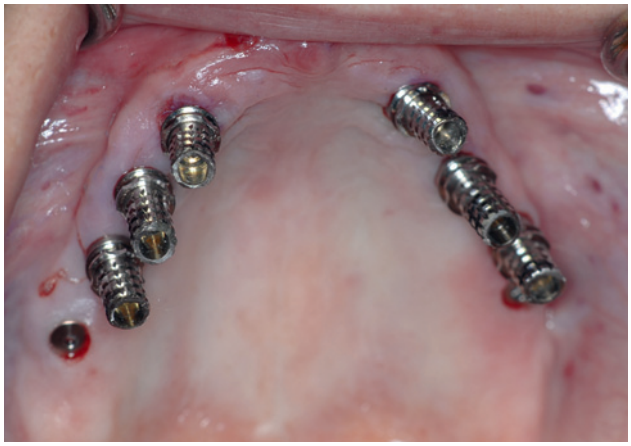


FIGURE 3-15 T, Implants and abutments have been placed, and the shortened temporary cylinders have been secured to the abutments with screws.

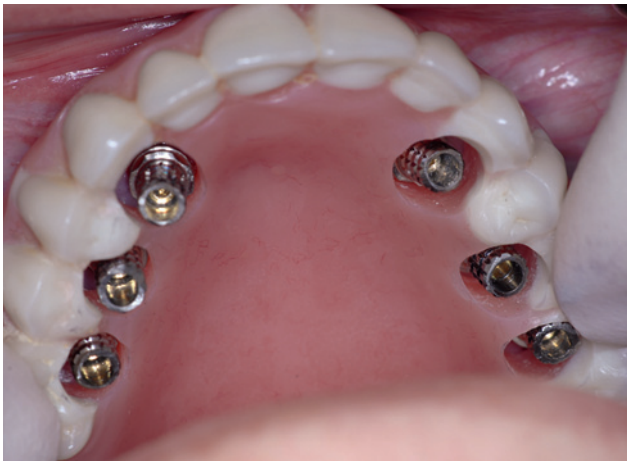


FIGURE 3-15 U, Prosthesis is tried in place to confirm passive seating and balanced occlusion. Acrylic will be placed between the temporary cylinders and the denture, and a syringe will be used to lute them together.

have been confirmed, the lateral flanges are removed with a bur in the laboratory. The denture is placed back over the temporary cylinders. The temporary cylinders should be in view from the lateral aspect of the denture, because the labial flange has been partly removed. A syringe filled with denture resin is used to apply the resin to the temporary cylinders, luting them to the denture. After the denture resin has set, the screws are removed and the prosthesis is removed with the temporary cylinders in the denture.

In the laboratory, more acrylic is added to complete the luting of the temporary cylinders to the denture. The resin is allowed to set and is then smoothed. The palate is removed from the prosthesis (Figure 3-15, V). The labial flange also is removed. The resultant provisional prosthesis is smoothed to prevent food collection and appears as a "high and dry," implant-supported, hybrid prosthesis without tissue contact. As necessary, the labial flange can be kept in place as long as no implants are covered and the patient has easy access for hygiene purposes.

The prosthesis is tried in place and secured with screws. As necessary, additional flange is removed until the patient is able to clean with superfloss or proxy brushes. The occlusion is checked and adjusted to keep it light anteriorly and balanced from canine to molar. The screws are hand-tightened, and the access holes are covered with cotton and a light-cured temporary material (Figure 3-15, W-AA).

Postoperative medications include antibiotics and pain medication as necessary. Patients have minimal discomfort, facial swelling, and less bruising than with full-flap access. The diet is restricted to a very soft or liquid diet for the entire time until the implants have integrated, especially when natural teeth constitute the patient's opposing

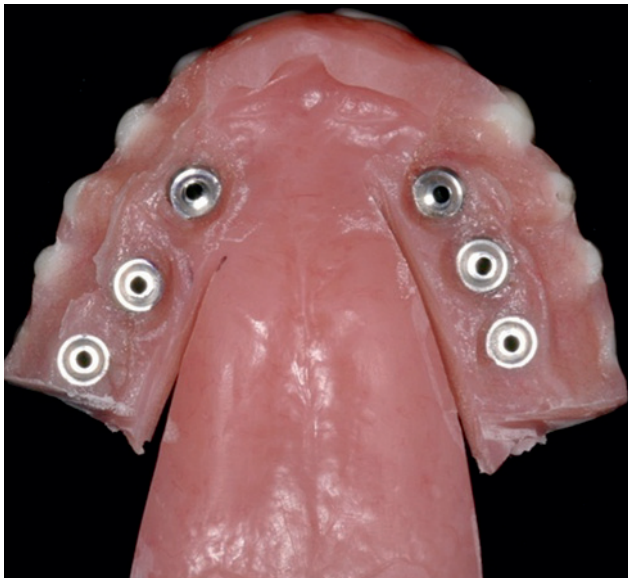


FIGURE 3-15 V, After the denture resin has set, the screws securing the temporary cylinders of the IOL abutments are removed, and the prosthesis with the luted temporary cylinders is taken to the laboratory. In the laboratory the palate and flanges are removed, and the result is an implant-borne prosthesis.

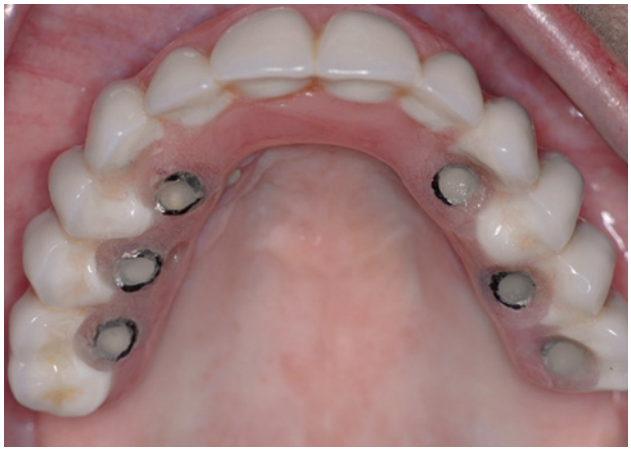


FIGURE 3-15 W, After the prosthesis has been trimmed and fitted in place, and the occlusion has been confirmed and adjusted as necessary, screws are used to secure the prosthesis, through the temporary cylinders, to the IOL abutments. Light-cured temporary material is used to cover the screw holes.

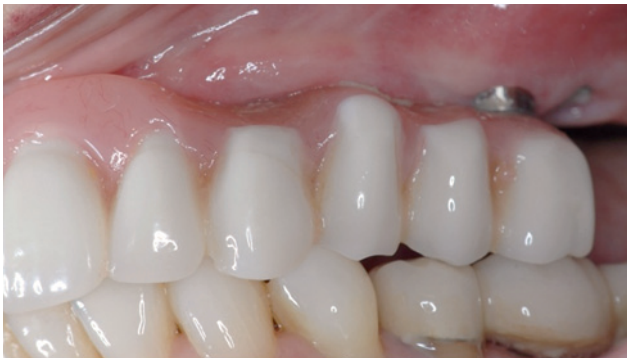


FIGURE 3-15 X, Lateral view showing the implants and the extent of removal of the lateral flange to allow patient hygiene.

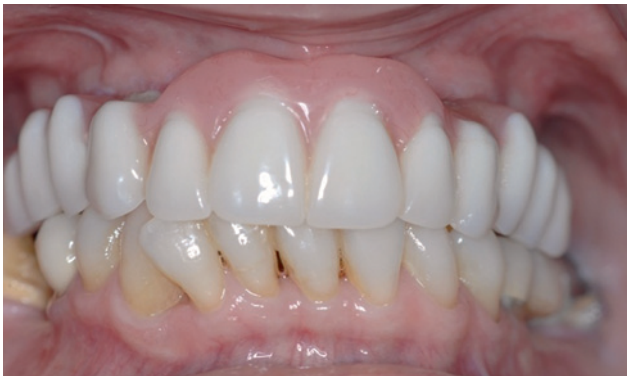


FIGURE 3-15 Y, Anterior view of the completed prosthesis. The anterior flange was left in place to provide nasolabial support. The implants were not placed in the anterior incisor locations, anticipating this need.

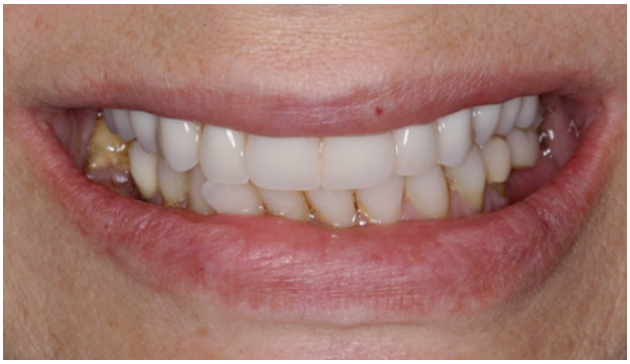


FIGURE 3-15 Z, Anterior view with smile showing immediate esthetic result. (Prosthetics by Dr. Yosvany Vento and Dr. Paulino Castellon.)

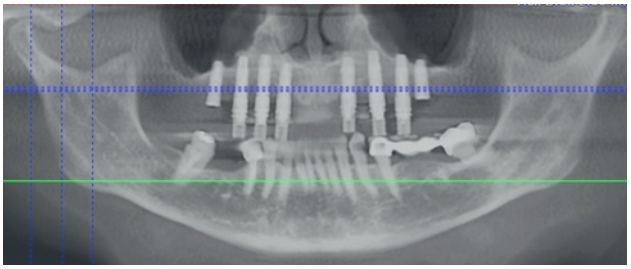


FIGURE 3-15 AA, Immediate postoperative radiograph showing implants in position.

occlusion. Conservative chewing is recommended. Hygiene instructions are given, but most patients do not clean well in the first week and need encouragement and often assistance in cleaning at the first-week visit, 7 days after surgery.

CT-guided surgery in the edentulous maxilla without immediate provisionalization

Immediate loading of maxillary prostheses is advantageous for the patient when successful. However, if the patient loses an implant because of occlusal trauma or other factors, the transition back to a removable prosthesis may not be well received. Immediate loading is not recommended for patients with a fixed dentition in the opposing arch, which may not have ideal vertical height or occlusal planes, or for patients with any parafunctional habits. However, CT-guided surgery allows implant placement in accurate locations in preparation for the final prosthesis. A procedure involving no or minimal tissue reflection certainly reduces patient morbidity. The following case example illustrates this point.

Case example

Ten years ago, the patient underwent sinus augmentation with bone morphogenetic protein (BMP). Two implants were placed into the posterior augmentations in the right and left maxilla. The anterior dentition had a Class III relationship to the mandibular natural teeth. The entire anterior dentition deteriorated over time and required removal as a result of caries. The teeth were removed, the extraction sites were grafted with mineralized particulate bone, and a transitional denture was made to fit over the healing abutments of the posterior implants. The patient desired a fixed prosthesis. A new maxillary prosthesis was required to establish esthetic and functional guidelines for the final prosthesis. The flange was removed from a setup (Figure 3-16, A), which showed a lack of nasal support and demonstrated the proclination of teeth to overlap the lower teeth. Based on

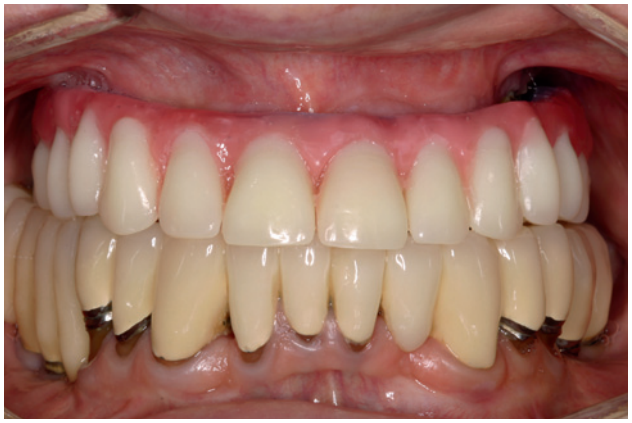


FIGURE 3-16 **A,** In this patient, posterior implants were placed in a sinus augmentation performed with bone morphogenetic protein (BMP). These four posterior implants have been successful; however, the remaining maxillary dentition from premolar to premolar has been removed secondary to caries. The patient now desires an implant-supported maxillary prosthesis. A new denture setup was fabricated, and the labial flange was removed to allow evaluation of nasolabial support. For this patient, a precision-milled, locking bar–type prosthesis was chosen because of the proclination of the proposed tooth setup and because an acrylic flange is needed for soft tissue support and facial esthetics.

this diagnostic information, a fixed-removable, implant-supported prosthesis was recommended to and accepted by the patient. The new denture was duplicated in acrylic impregnated with barium sulfate, and a scan was obtained.

The cross sections of the maxilla showed satisfactory bone for implant placement without the need for bone grafting; this was important, because the prosthetic plan involved a fixed-removable prosthesis (Figure 3-16, B-C). The DICOM data from the scan were used to place virtual implants. When planning for a precision bar–type prosthesis, it is best to avoid excessive bar bulk under the anterior maxilla. If implants are placed in the central incisor position, the bar may be more bulky in the anterior region. For this reason, implants were placed in the lateral incisor sites, the canine site, and one premolar site (Figure 3-16, D-E). Fixation pins were placed to engage the anterior bone. Even when a removable prosthesis is planned, implants should be placed under the teeth, if possible, avoiding embrasures and allowing for prosthetic alternatives if the plan changes after the implants have been placed. It is important to allow sufficient space from the implants for bar fabrication, a sufficient volume of acrylic, and the teeth. If the space becomes limited, the thin acrylic may result in constant fracture of the teeth from the base of the prosthesis,

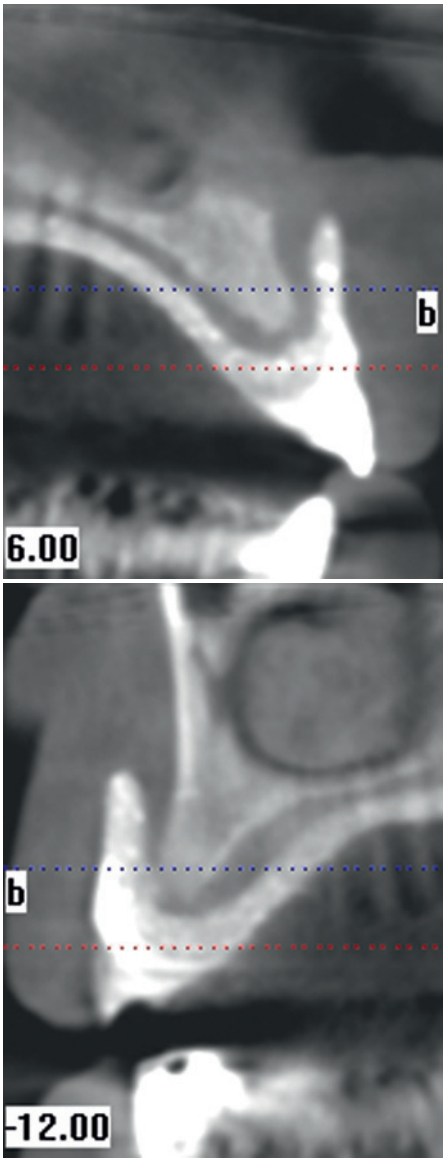


FIGURE 3-16 **B-C,** Approved denture setup was converted into a denture, and a duplicate was made using acrylic impregnated with 20% barium sulfate. A cone beam scan was taken with the prosthesis in place. These cross sections show the bone under the setup. Adequate bone is present for implant placement. The DICOM data were then used for further planning and fabrication of a guide stent.

which is more prone to happen when the teeth are protrusive and occluding against a natural fixed dentition. The implants chosen to be placed on the virtual plan should be chosen from an implant library for the implant system to be used. The implants' diameter, length, platform, and shape should be identical to those planned for actual use. The specific diameter of the fixation pins or screws also may need to be identified.

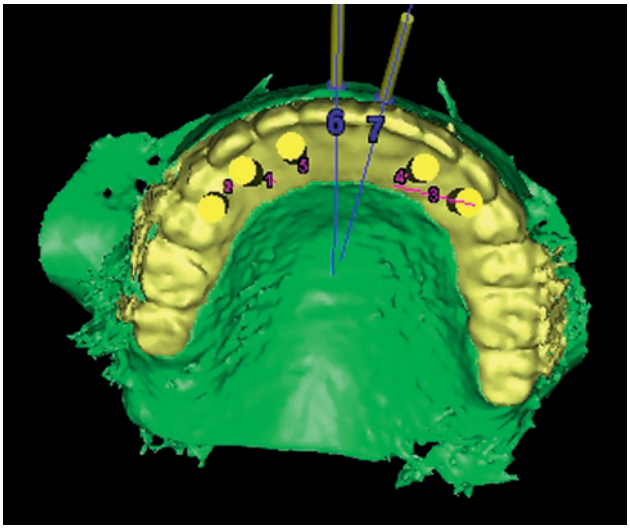


FIGURE 3-16 **D,** Implants were placed in the lateral incisor positions moving posteriorly to avoid implant placement in the central incisor region. This results in less bulk from the final precision bar in the anterior palatal region. Note that the implants are palatal to the incisor edges but under the teeth and not in the embrasures, to allow for a fixed alternative if the prosthetic plans change.

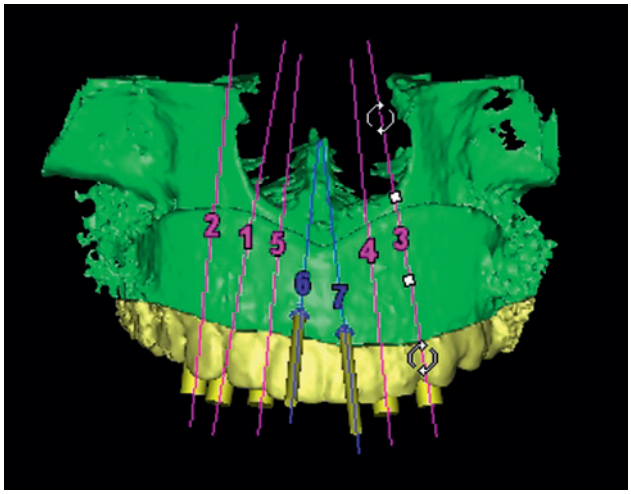


FIGURE 3-16 **E,** Placement and angulation of the five proposed implants and the fixation screws.

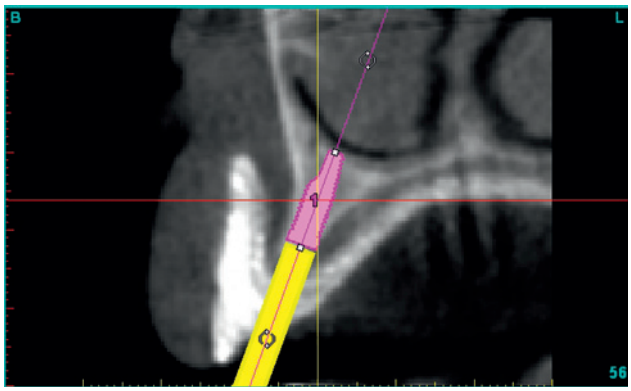


FIGURE 3-16 **F,** Cross section of one site showing virtual placement of the implant, which bisects the facial and palatal bone, engages the floor of the nose, and emerges palatal to the incisive edge of the proposed prosthesis.

The cross-sectional images from the CT planning software (Figure 3-16, F) can be used to measure the space from the implant to the intaglio surface of the prosthesis. In this cross-sectional image for this patient, the distance from the implant platform to the incisive edge of the tooth was more than 15 mm, which is adequate for prosthesis fabrication.

The members of the restorative team conferred and approved the planned implant placement. The software then was used to generate a virtual guide stent. The plan was transmitted to the manufacturer electronically for fabrication of the guide stent. Each manufacturer has specific steps for this part of the process.

Surgical Procedure. Before surgery, the guide stent should be inspected to make sure that (1) no interferences are present in and around the tubes, (2) sufficient clearance is available for the drill sleeves, and (3) the guide stent fits without movement in the patient's mouth. Consent forms must be signed before the day of surgery. The implants required for the surgery must be in stock. The patient is asked to use an antibacterial rinse for 3 to 4 days before surgery to lower the bacterial count in the mouth.

The use of sedation depends on the clinician's and patient's preference. The procedure is atraumatic; therefore, the experience generally is well accepted. The guide stent is soaked in a Betadine solution, and the face and mouth are prepared with Betadine. A local anesthetic is infiltrated in the maxilla, with care taken to prevent excessive swelling of the tissues under the guide stent. Additional time may be needed to allow tissue swelling from the local anesthetic to resolve. The stent is placed, and the tissue punch drills are used to facilitate removal of the gingiva over the implant sites. In thin ridges, a small flap can be elevated. The guide stent is removed. This author uses a Biolase MD water-cooled laser for final tissue removal. After the gingival circular punched tissue has been removed, the surgical stent is placed in the mouth.

The patient must bite into the stent to put pressure on the tissues (Figure 3-16, G). The posterior aspect of the stent must be seated and may require additional pressure by the assistants. Proper seating of the posterior aspect of the guide stent prevents malpositioning of the anterior

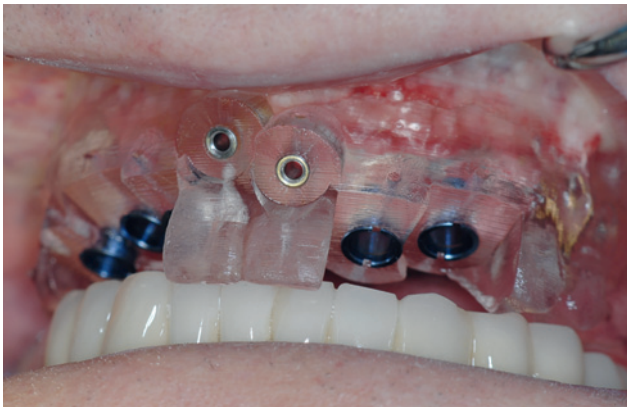


FIGURE 3-16 G, Occlusal stops were retained in the guide stent to allow for accurate placement. If necessary, an occlusal index can be used and is recommended if any question exists regarding the fit.

implants. The fixation pins or screws are placed. One implant site then is prepared. Care is taken to use very slow drill speeds, because the irrigation fluid has limited access to the cutting surfaces of the drills inside the drill sleeves, which in turn have tight tolerances to the tubes in the guide stent. In locations with closed approximation of the implant to the cortical bone, a thread-former may be used to prevent movement of the implant from its desired position. Small variances of implant position are tolerated when a delayed approach to loading is used, but the implants still must be placed within the confines of the bone. The first implant is placed with the driver mount flush with the master cylinder tube. Excessive torque is not recommended, because it may strip the implants' threads within the bone. The second implant is placed in the opposite quadrant, and the rest of the implants then are placed (Figure 3-16, H).

The implant drivers are removed one by one, and then the fixation screws or pins are removed. Finally, the guide stent is removed from the mouth. It can be replaced to observe the implant placement through the tubes of the guide stent (Figure 3-16, I). The implant sites are cleaned of soft tissue remnants. This author uses the laser for this purpose. Cover screws then are placed. If necessary, the bone profiler can be used to seat the cover screws completely (Figure 3-16, J). The denture can be relined if necessary. Postoperative scans are used to confirm the implants' position (Figure 3-16, K-M). The tissues may cover the implant sites within a short time (Figure 3-16, N).

Case examples

The following two cases illustrate the use of different CT-generated guide stents for the placement of maxillary implants. Each case involves a specific problem, which

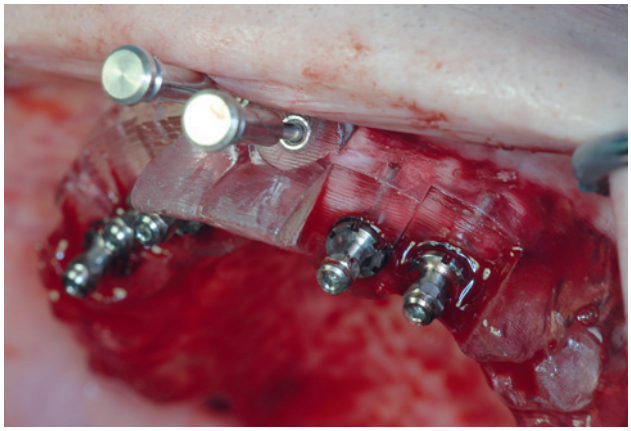


FIGURE 3-16 H, Implants have been placed. The fixation pins are present, and all of the driver mounts are in place. At this point, the implanat mounts are removed individually, the pins are removed, and the guide stent is removed.

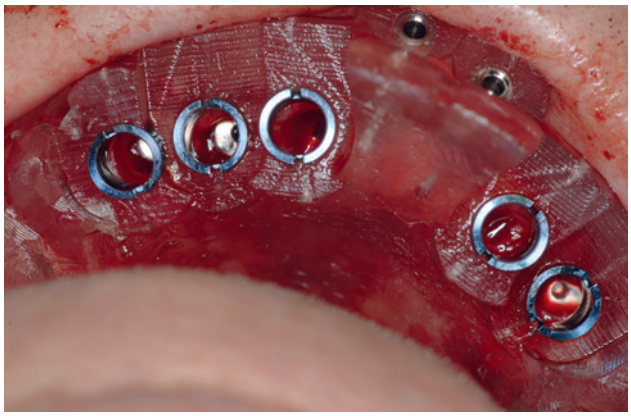


FIGURE 3-16 I, Accurate placement of the implant, as seen through the tubes of the guide stent.

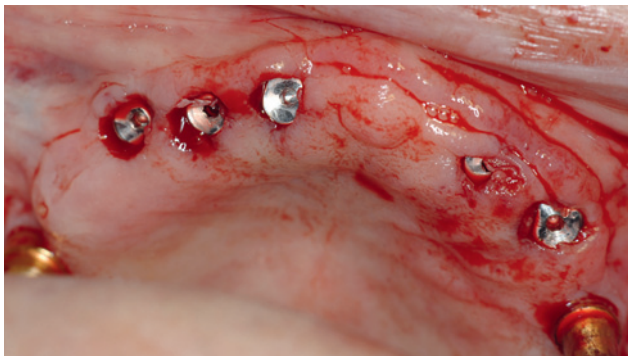


FIGURE 3-16 J, Soft tissue is irrigated, and the cover screws are placed. A soft liner has been placed in the patient's denture.

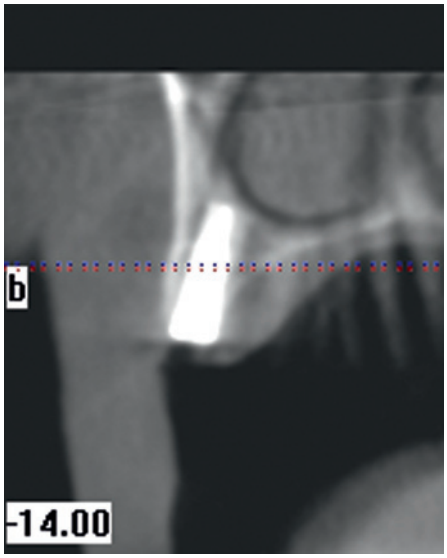


FIGURE 3-16 K, Postoperative scan showing accurate placement of the implant as planned.

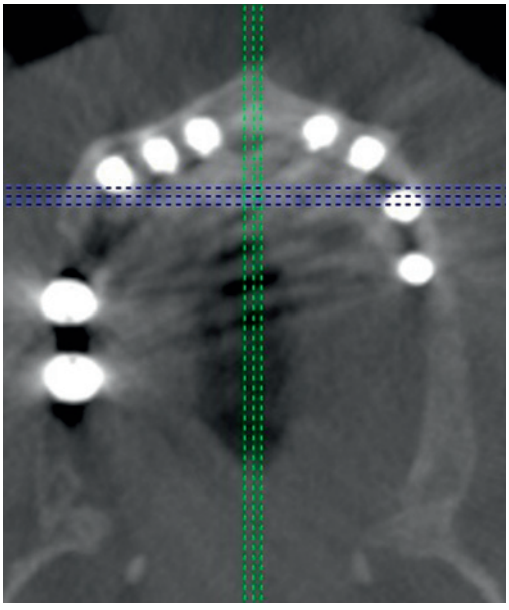


FIGURE 3-16 L, Axial views from a cone beam scan can be used to confirm symmetric positioning of the implants within the confines of the labial and palatal bone.

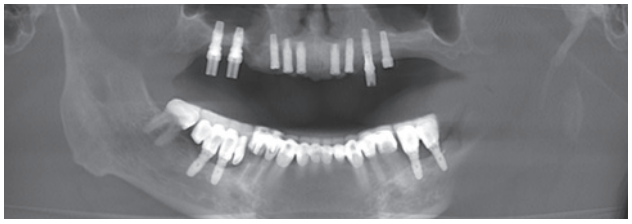


FIGURE 3-16 M, Panoramic view shows the postoperative result.

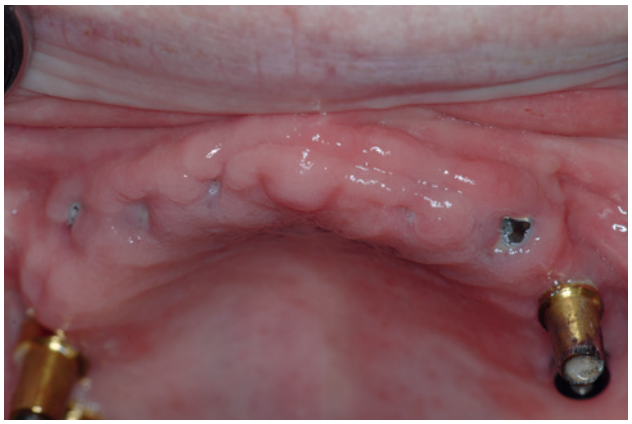


FIGURE 3-16 N, Two weeks after surgery, the implant sites appear healthy and are partially covered with soft tissue.

was addressed. The figure legends describe the cases in detail.

Immediate Loading Using a Final Prosthesis after Sinus Augmentation with Bone Morphogenetic Protein. After forming bone in the sinus, a new, ideal, esthetic denture is made with patient approval. A duplicate is scanned, and using CT planning software (NobelGuide, Nobel Biocare, Goteborg, Sweden) implants are placed as virtual surgery. A surgical guide is made from the computer plan. The guide is then used to create a new master cast with implant analogs. The final hybrid restoration is made and placed at the time of implant placement (Figure 3-17, A-Q).

Use of CT Planning to Place Angled Implants. Angling implants to follow the lateral nasal wall allows longer implant length and places the posterior implant platform near the first molar location. This allows increased stability of the bar due to increase anterior-posterior "spread" of the implants. The implants are angled on CT planning software and a guide stent fabricated the implants are placed either flapless or with minimal flap elevation, minimizing patient morbidity (Figure 3-18, A-H).

CT-Guided Maxillary Surgery

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for CT-guided maxillary surgery, which is performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

The treatment plan for this patient calls for placement of five implants in the premolar, canine, and lateral incisor sites using CT guidance. A local anesthetic has been infiltrated without excessive ballooning of the mucosa, because the surgical guide stent will sit on the mucosa.

The guide stent is placed on the maxilla, and the tissue punch drill is used to create gingivectomies in the planned implant sites. This drill is used at a low speed and is pressed to the level of the bone.

The stent is removed from the mouth. A water-cooled laser (Biolase MD, Biolase, Irvine, California) is used to finish the soft tissue cuts, because the bone crest often is not level, and the tissue punch drills cut the tissue only to the first contact with the crest. The laser completes the gingivectomy and also provides hemostasis. The tissue is removed from the planned sites with small-tipped rongeur forceps.

The surgical guide stent then is replaced in the mouth. In this case, occlusal stops were retained in the guide stent to the opposing occlusion. With the patient biting into the stent, and after confirmation of the seating of the stent posteriorly, drills 1.5 mm in diameter are used through the fixation screw tubes to fix the stent to the maxilla. In this case, two pins were used rather than screws. Blanching of the underlying soft tissues should be observed in contrast to lack of tissue contact.

The patient's mouth is opened, and the first drill is used. In this system (Navigator, Biomet 3i, Palm Beach Gardens, Florida), a counterbore drill is used to open the ridge for the subsequent drills. This drill intimately fits the master cylinders and can cut a hole in the bone in the predetermined axis even when the crest is uneven.

After the counterbore drill has been used in all sites, the first implant site is prepared. Pressure should be placed on the palatal portion of the guide stent to maintain proper posterior seating of the stent; here, this is accomplished with suction. A 2-mm drill sleeve is chosen, and the appropriate-length drill that is 2 mm in diameter is used to depth. The drill speed should not exceed 300 rpm, because irrigation does not reach the depths of the drill. After the 2-mm-diameter drill, the next-sized drill diameter is used until preparation of the site is complete. A drill mount of specific length is used to guide the implant into place at the correct predetermined depth. The mount is positioned flush with the master cylinder's surface. A second implant then is placed, following a similar sequence on the opposite arch. After the second implant has been placed, the remaining sites are prepared.

In areas of thin ridges of dense cortical bone, a thread-former can be used to prepare threads in the cortical bone. This prevents the implant from tipping because of the implant's tendency to follow the path of least resistance.

After the final implants have been positioned, the final rotational position and depth are accomplished with a hand ratchet. The implant mounts are removed one by one, the pins are removed, and the guide stent is removed from the mouth.

The sites are inspected. In this case, the radiofrequency "smart pegs" were placed to obtain an immediate placement implant stability quotient (ISQ) value for each implant. A laser can be used to trim excess tissue tags, and the cover screws are placed. The denture is relieved if necessary.

Particulate bone grafting with membrane coverage

The use of particulate autogenous bone with alloplast (HA) to cover facial dehiscence after the placement of two implants is demonstrated in a patient with a thin posterior maxillary ridge (Figure 3-19, A-G). The implants are placed with the aid of a surgical guide stent. The apical third of the implant is completely covered with bone. Bone is harvested from the tuberosity and from the burs used to prepare the implant sites. The bone is mixed with an equal volume of HA and placed over the implants. A nonresorbable membrane is secured to the implants with the implants' cover screws and is secured apically with small screws. After 5 months of healing, the implants are exposed and the membrane is removed, showing a well-healed, firm graft.

Solid onlay grafts harvested from the symphysis or ramus

The use of symphyseal bone to augment a thin maxillary ridge is demonstrated in a patient who has lost implants but has sufficient vertical bone (DVD Figure 3-5, A-H).

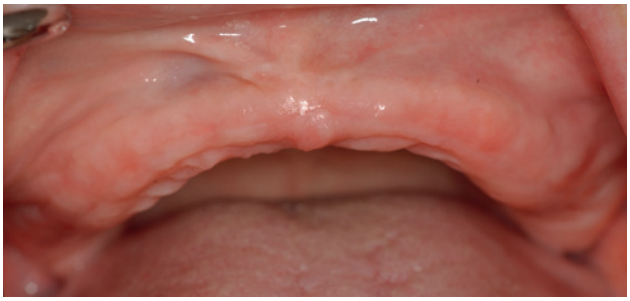


FIGURE 3-17 **A,** This patient has a good ridge form but desires a fixed prosthesis with minimal coverage of the palate.

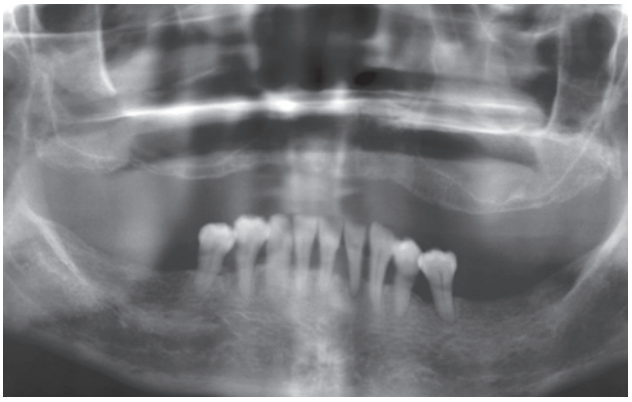


FIGURE 3-17 **B,** Preoperative panoramic radiograph shows a large sinus antrum with lack of bone height in the canine regions.

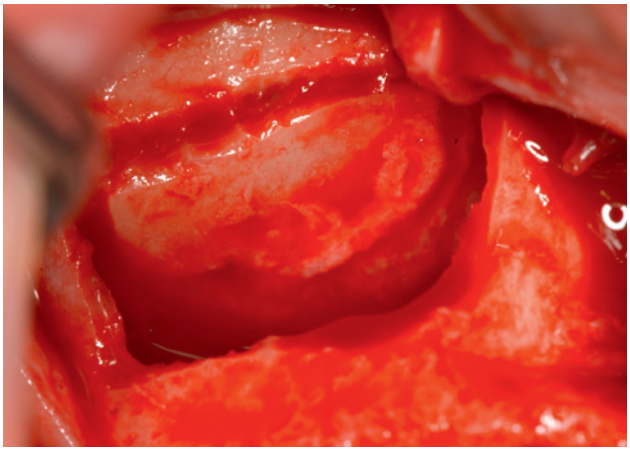


FIGURE 3-17 **C,** Bilateral sinus augmentations were performed using BMP (InFuse, Medtronics, Boston, Massachusetts) in each of the sinuses, with grafting of the middle and anterior portions. A conventional lateral sinus window was created, and the membrane was elevated. The BMP was reconstituted and placed onto a collagen carrier. After 15 minutes had elapsed to allow the BMP to connect with the collagen, the collagen was cut into strips.

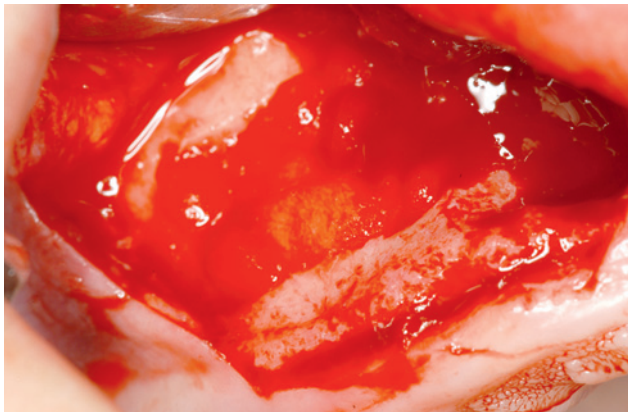
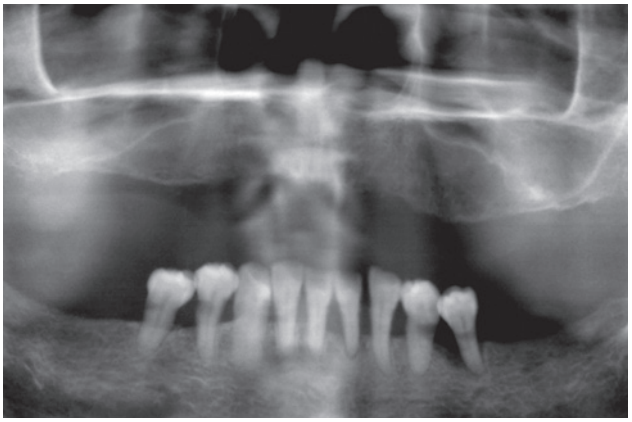


FIGURE 3-17 **D,** BMP-collagen strips have absorbed blood and turned red. This has been related anecdotally to a very positive prognosis for bone formation.

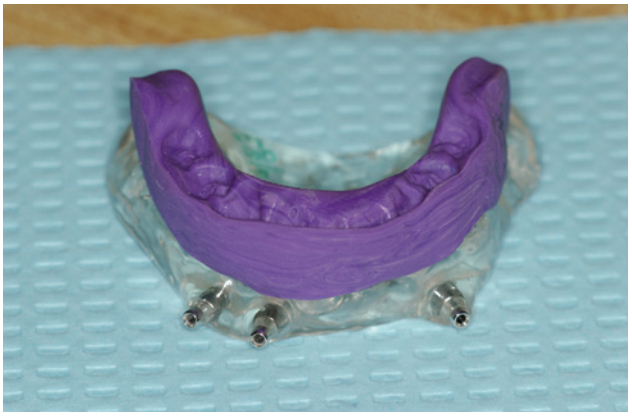
The ridge is only 3 mm wide and therefore cannot support implants, even with guided tissue regeneration. The incision is made crestally, with anterior and posterior vertical release. A surgical guide stent is placed, and bone wax is used to delineate the graft size before bone is harvested from the chin. The chin is approached through a vestibular incision; the graft is outlined with a small, fissure-shaped drill and then harvested. The graft is contoured to match the wax pattern and secured in position with screws. After healing for 4 months, the graft is exposed. The retaining screws are removed, and the implants are placed.

Angled implants as an alternative to sinus grafting

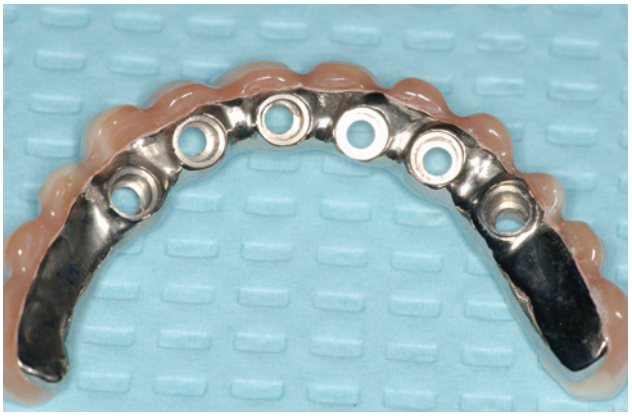
Alternatives to bone grafting techniques for prosthetic restoration of the edentulous maxilla include zygomatic implants and, more recently, angled implants, which do not require the grafting procedures some patients may be reluctant to undergo. Although zygomatic implants require more extensive surgical training, the placement of angled implants requires minimal special training other than traditional implant placement methods. For this report, the term *angled implants* refers to implants placed at angles often 30 degrees greater or more than traditional vertical or axially directed implants.



● **FIGURE 3-17** **E,** Six months after the procedure, a BMP-grafted sinus shows excellent bone formation.

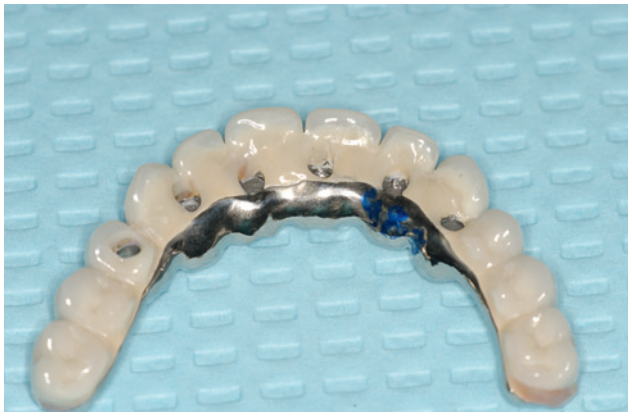


● **FIGURE 3-17** **G,** From the mounting of the denture to the mandibular dentition, a bite registration was fabricated so that the maxillary guide stent could be positioned accurately.



● **FIGURE 3-17** **I,** Intaglio surface of the final prosthesis. Note the smooth metal surface, which is very hygienic.

● **FIGURE 3-17** **F,** Patient's esthetic new denture was duplicated in clear acrylic, and a dual-scan method was used to obtain information for CT planning. The DICOM data were entered into a computer, and implants were positioned for fabrication of a final, screw-retained, hybrid-style prosthesis. The surgical guide stent was fabricated based on the virtual plan. Note the use of three fixation pins and the complete palatal coverage of the guide stent.



● **FIGURE 3-17** **H,** CT planning software is used to fabricate the final prosthesis. The framework is milled titanium. The retaining screw channels can be kept small because of the precision of the workup.

The theoretical success of angled implants is based on the following principles[25]:

1. The use of longer implants allows more implant surface–bone contact.
2. Anchorage of one or more cortices allows immediate implant stabilization.
3. Prosthetic rehabilitation can be directed more posteriorly, allowing a more even load distribution throughout the arch.

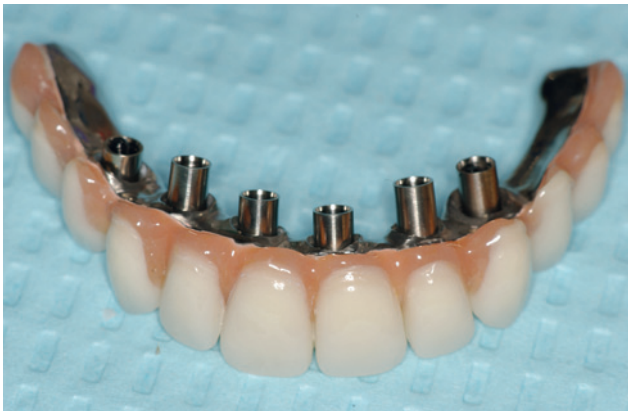


FIGURE 3-17 J, During implant placement surgery, the abutments are placed into the prosthesis. When the retaining screws are placed through the prosthesis and abutments and are tightened, the prosthesis is secured.

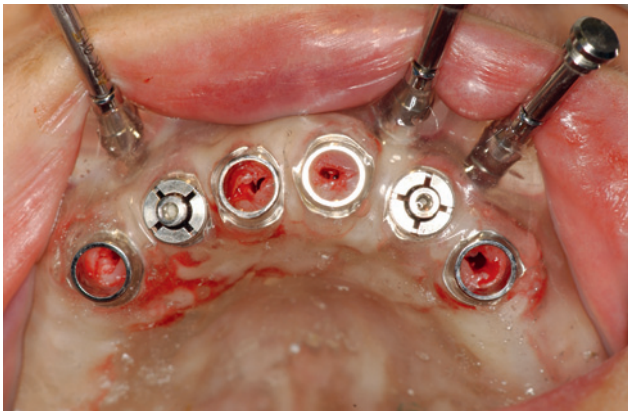


FIGURE 3-17 K, At surgery, the three pins are placed with the patient in occlusion. One implant is placed on a quadrant site, and a second implant then is placed on the opposite quadrant. At this point, the stent is very stabile.

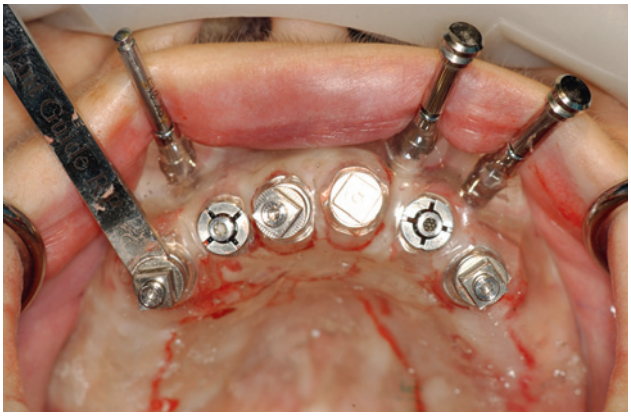


FIGURE 3-17 L, All the implant driver mounts are in place just before they and the guide stent are removed.

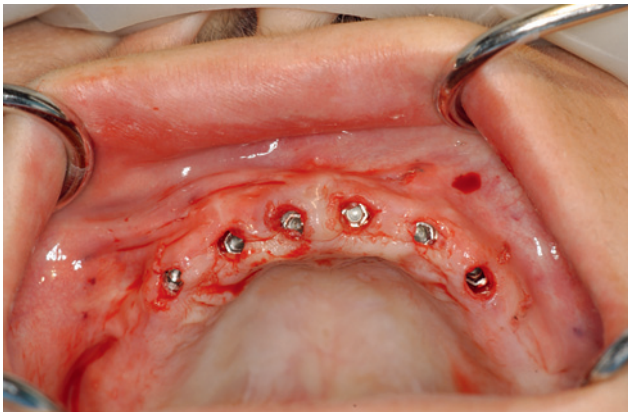


FIGURE 3-17 M, After removal of the guide stent, the sites are irrigated and cleaned.

The use of tilted implants eliminates the potential complications associated with morbidity of graft donor sites, as well as complications directly related to sinus surgery. In Table 3-4, papers that have reported on the use of angled implants for maxillary reconstruction are critically reviewed and summarized.[26-33] The information includes the number of patients, number of implants, time of loading, number of implants lost, reason for implant loss, overall survival rate of angled versus axial implants, prosthetic success, and length of follow-up.

Review of the literature on angled implants

Nonaxial loading of implants previously was thought to inhibit adequate osseointegration. ten Bruggenkate et al. described angled implants with tissue-supported overdentures[34] and fixed restorations[35] in the partially edentulous posterior maxilla. Celletti et al.[36] confirmed that nonaxially loaded implants achieved integration and were functionally successful after 1 year of loading, with no adverse effect on the surrounding bone or soft tissue.

In 1999, Mattsson et al.[31] described a surgical technique for restoring the severely resorbed edentulous maxilla with a fixed restoration without grafting of the alveolus or maxillary sinus. This study included 15 patients who received four to six implants, all angled, for a total of 86 implants. The surgical technique involved raising a mucoperiosteal flap and exposing the anterior lateral wall of the maxillary sinus and the nasal piriform aperture. A fenestration was made in the anterior sinus to locate the lateral nasal wall. Bilaterally, posterior implants were placed at an angle parallel to the

TABLE 3-4 Summary of Angled Implant References

Reference Number	No. of Patients	Total No. of Implants	No. of Angled Implants	Time to Loading	No. of Implants Lost	Smokers	Reason for Implant Loss	Overall Implant Survival	Prosthesis Success	Length of Follow-Up
26	44	166	82	Immediate provisional Final: 12 mo	Angled = 2 Straight = 0	16	Bruxism	Angled = 97.5% Straight = 100%	100%	1 yr
27	32	128	64	Immediate provisional Final: 6-12 mo	Angled = 3 Straight = 0	N/A	Bruxism = 2 Mobility = 1	Angled = 95.3% Straight = 100%	100%	1 yr
28	18	60	27	Provisional within 3 days	Angled = 1 Straight = 1	N/A	Fracture of provisional, causing micromotion	Angled = 96.3% Straight = 97%	100%	1-4 yr
29	25	101	42	6-8 mo	Angled = 0 Straight = 2	6	Mobility	Angled = 100% Straight = 95%	100%	21-87 mo
30	41	246	82	Provisional within 2 days	Angled = 2 Straight = 3	N/A	Mobility = 4 Mobility and pain = 1	Angled = 97.1% Straight = 97.9%	100%	1-5 yr
31	15	86	86	6 mo	Angled = 1	N/A	Mobility	Angled = 98.8%	100%	36-54 mo
32	22	75	42	2 wk = 2 patients 4-6 mo = 20 patients	Angled = 3 preload Angled = 1 1-yr postload Straight = 0	N/A	Preload ▯ mobility Postload ▯ ill-fitting prosthesis	Angled = 92.8% Straight = 100%	100%	1-10 yr
32	22	138	40	6 mo	Angled = 1 Straight = 6	N/A	N/A	Angled = 97.5% Straight = 93.8%	100%	1-5 years
33	19	103	103	6 mo	Angled = 3	6	Preload ▯ mobility	Angled = 97%	100%	8-12 years

From Block MS, Haggerty CJ, Fisher GR: Nongrafting implant options for restoration of the edentulous maxilla, *J Oral Maxillofac Surg* 67:872-881, 2009.
N/A, Not applicable.

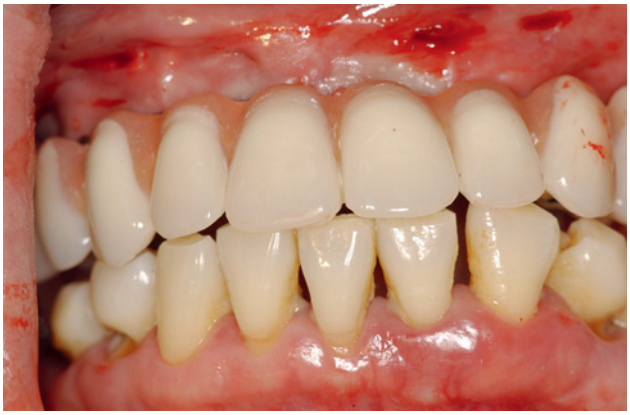


FIGURE 3-17 **N,** Final, definitive prosthesis is secured to the implants, and the screws are tightened. The occlusion is adjusted as necessary. The patient is given hygiene instructions and asked to consume a liquid diet or to chew a very soft diet.

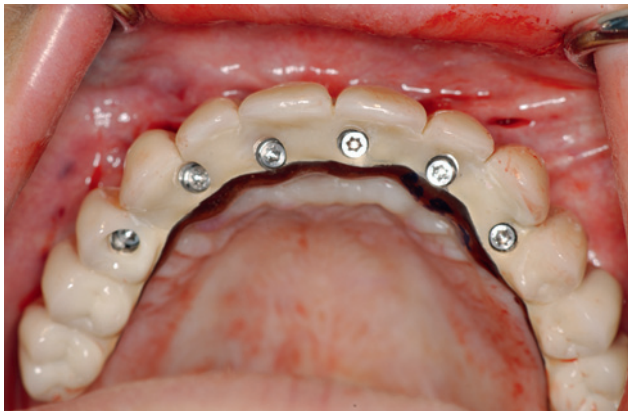


FIGURE 3-17 **O,** Screws of the final prosthesis are shown in an ideal location. They are covered with light-cured resin.

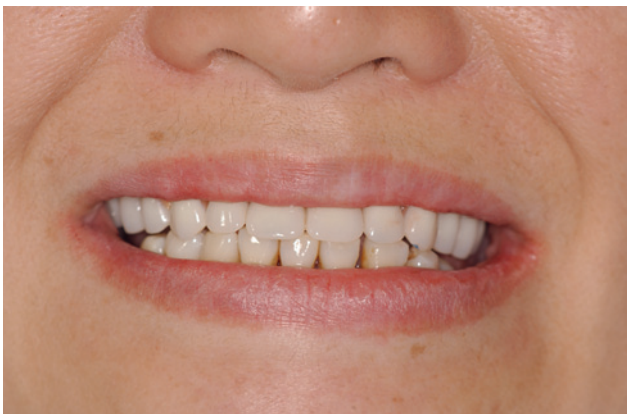


FIGURE 3-17 **P,** Esthetics is confirmed.

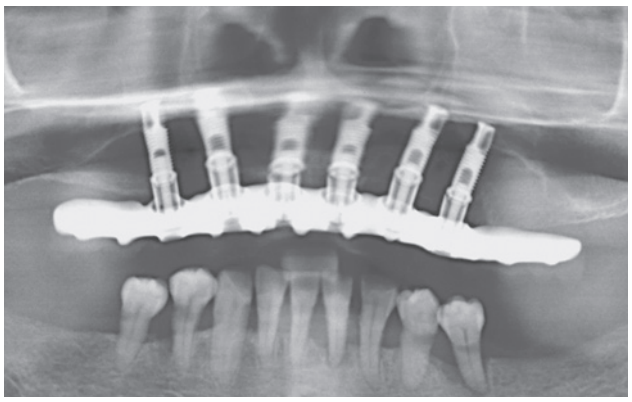


FIGURE 3-17 **Q,** Postoperative panoramic radiograph shows accurate placement of the implants. All abutments have been seated. (Prosthetics by Dr. Paulino Castellon).

anterior wall of the sinus. Additional axial implants were placed into the anterior maxilla in a vertical orientation compared with the posterior implants. One or two implants then were placed more mesially at an angle to engage the nasal spine or cortical bone of the nasal cavity. The patients were not allowed to wear their removable prosthesis for 2 weeks. The implants were uncovered 6 months after placement, and all patients were restored with a fixed restoration. The patients were followed for 36 to 54 months. One implant was lost at the time of exposure because of poor osseointegration. The overall survival rate of the implants was 98.8%, and the prosthetic success rate was 100%. In this preliminary study, the authors concluded that angled implants could be a cost-effective alternative to traditional bone grafting techniques for restoring the completely edentulous maxilla.

Krekmanov[25, 32] reported on angled implants in the mandible and maxilla. For this review, only the maxillary implants were included. The researcher's objective was to modify the traditional method of implant placement in the posterior jaws and still provide distal support for fixed prostheses to avoid cantilevering and grafting. Twenty-two patients received 138 implants; 40 of the implants were placed at an angle. This study used an open technique with a sinus fenestration to locate either the anterior or posterior wall of the maxillary sinus. The most posterior implants were placed along either the anterior or posterior sinus wall at approximately 30 to 35 degrees of angulation. A two-stage protocol was used, with implant exposure 6 months after placement. The implants were loaded 1 day to 3 weeks after placement of abutments. Implant bone level measurements were taken

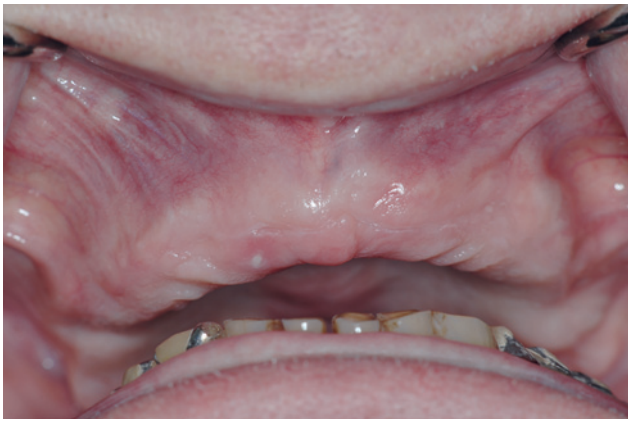


FIGURE 3-18 A, This patient desires a fixed prosthesis and removal of the palatal portion of the denture. He has adequate ridge form for implants. The vertical height of the maxilla is satisfactory.

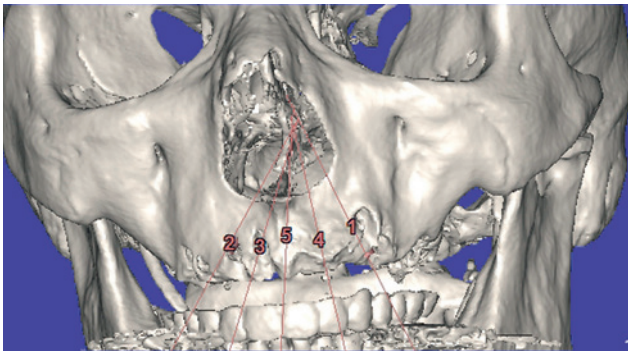


FIGURE 3-18 C, Patient's denture was duplicated with barium sulfate–impregnated teeth only. Because the flange was left in clear acrylic, the manufacturer was sent a master model of the maxilla for fabrication of a guide stent. A CT scan was obtained, and CT planning software was used to plan the case. Five implants were positioned in the maxilla, with the distal implants engaging bone medial to the lateral nasal wall (seen here in a three-dimensional reconstruction).

at follow-up, ranging from 1 to 5 years after loading. Implants were classified as successful if they remained stable and had less than 2 mm of bone loss after loading. Implants were classified as surviving if they remained stable and had more that 2 mm of bone loss after loading. One angled implant and six axial implants were lost. All the failed implants were lost after loading. The angled implants had an overall success rate of 95.7% and an overall survival rate of 97.5%; the axial implants had an overall success rate of 92.5% and an overall survival rate of 93.8%. The overall prosthetic success rate was 100%. Complications included early

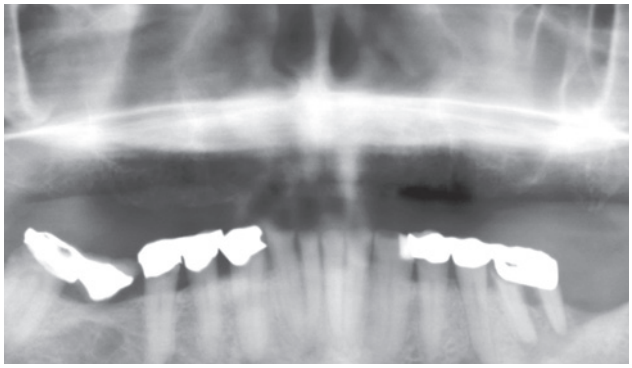


FIGURE 3-18 B, Preoperative panoramic radiograph shows anterior bone but a lack of posterior bone. Because this patient has a long-standing history of smoking (which he has stopped within the past 3 months) and because of his tendency for sinus problems, the treatment plan called for angled implants without sinus grafting.

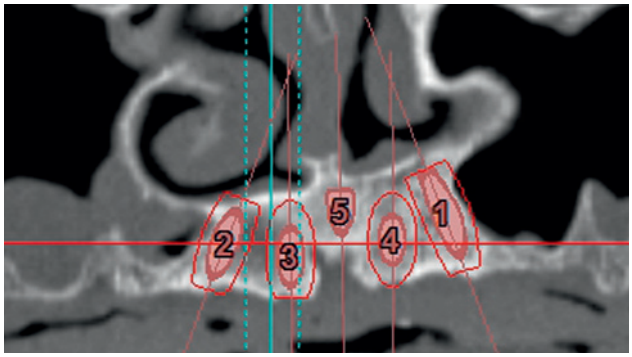


FIGURE 3-18 D, Panoramic image of the virtual plan shows implant placement and engagement of the lateral nasal wall bone by the distal implants.

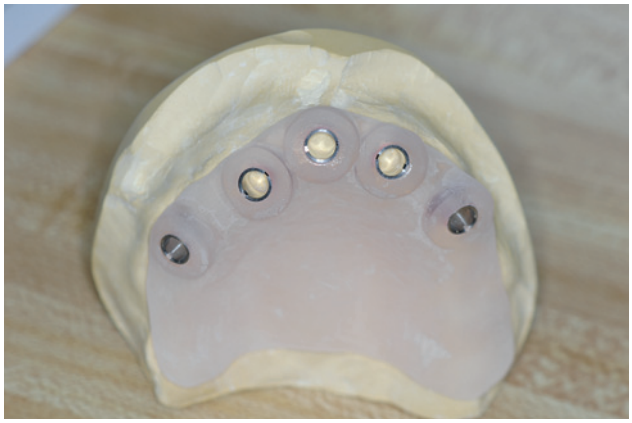
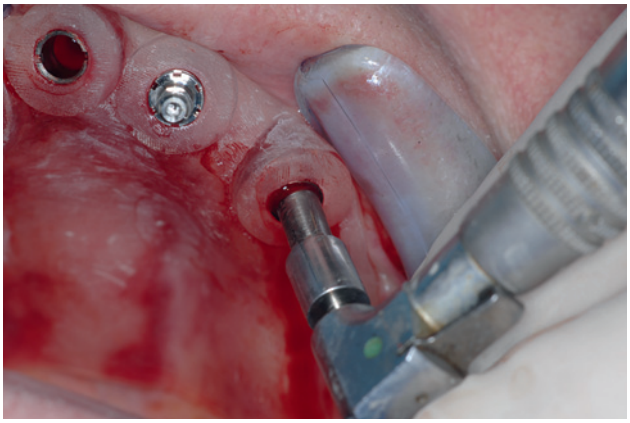
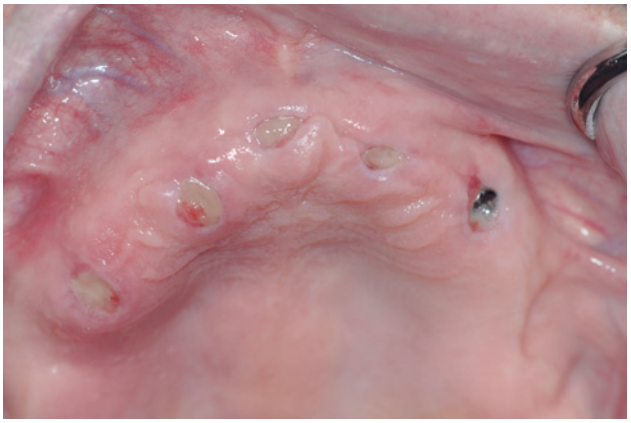


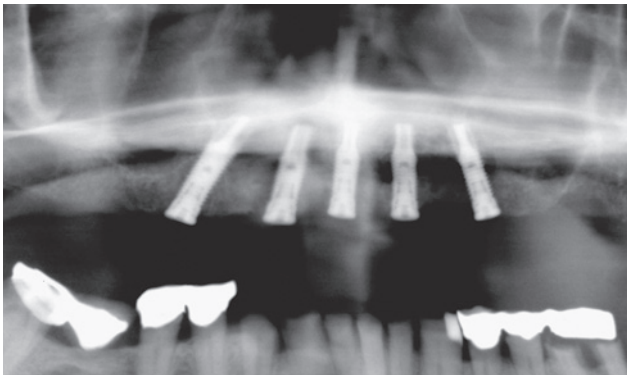
FIGURE 3-18 E, Surgical guide stent was fabricated. Because of the patient's excellent ridge form, no fixation screws were used. The stent fit intimately with the maxilla without movement. Note the angulation of the distal tubes.



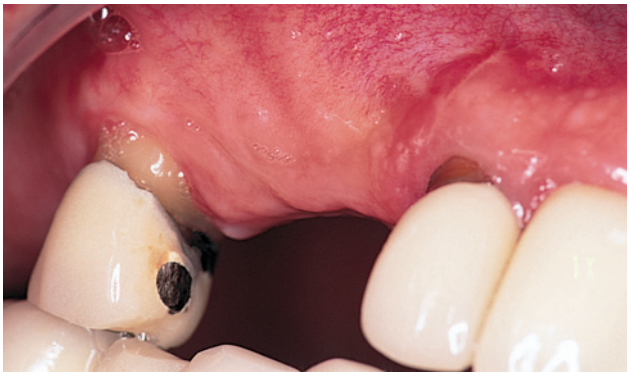
● **FIGURE 3-18** **F,** Distal implants were placed after the three anterior implants were in place. Note the angulation of the implant.



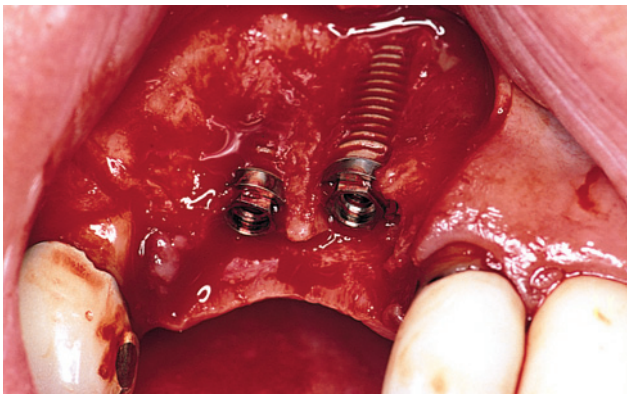
● **FIGURE 3-18** **G,** One week after implant placement, the sites appear to be healing nicely.



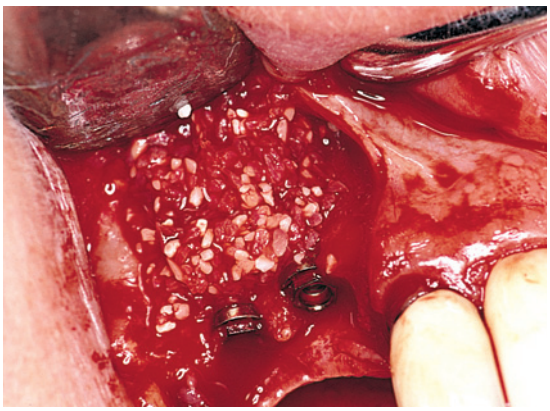
● **FIGURE 3-18** **H,** Postoperative panoramic radiograph shows placement of the implants. The prosthesis then was fabricated.



● **FIGURE 3-19** **A,** This patient desires an implant-borne restoration without attachment to the adjacent natural teeth. Upon palpation, the ridge is found to be thin and to have adequate vertical height for the placement of two implants.



● **FIGURE 3-19** **B,** Two implants are placed in the thin posterior maxillary ridge with the aid of a surgical guide stent. The apical third of the implant is completely covered with bone. Facial dehiscences are present on both implants.



● **FIGURE 3-19** **C,** Bone is harvested from the tuberosity, and burs are used to prepare the implant sites. The bone is mixed with an equal volume of HA and placed over the implants.

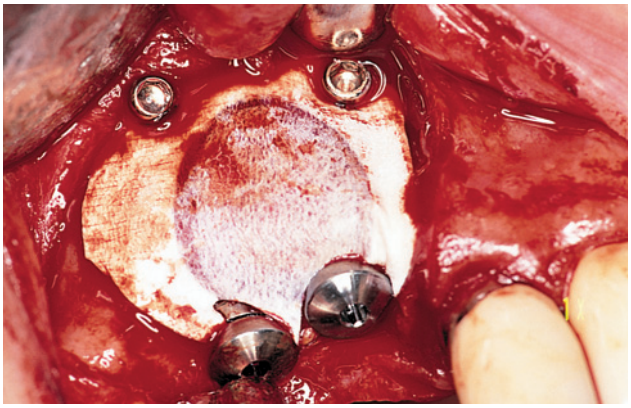


FIGURE 3-19 **D,** Nonresorbable membrane is secured to the implant with the cover screws and secured apically with small screws.

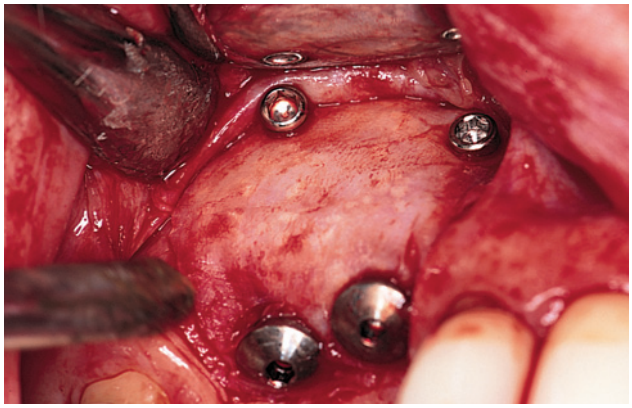


FIGURE 3-19 **E,** After 5 months of healing, the implants and membrane are exposed.

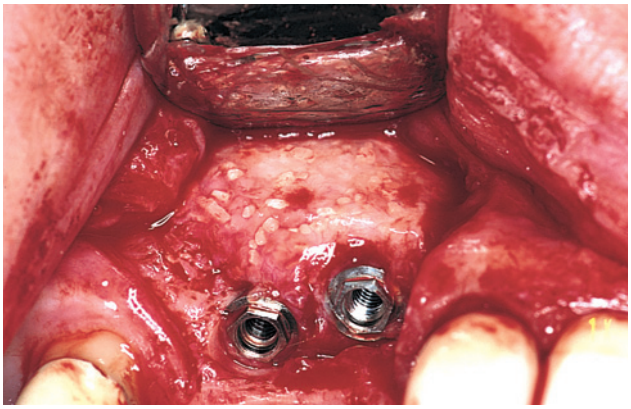


FIGURE 3-19 **F,** Membrane is removed, exposing a well-healed, firm graft.

incision dehiscence and less accessibility of the tilted implants. The authors concluded that the use of tilted implants for the treatment of edentulous arches with posterior resorption eliminated the need for advanced techniques and presented a good alternative to these techniques.

Angled implants have been used to engage both the piriform region and the posterior maxilla. Krekmanov[32] reported on 22 patients who received a total of 75 implants, 42 of them angled. Two patients were loaded within 2 weeks. The remaining patients were loaded after 4 to 6 months, with abutment placement as a second-stage procedure. Three angled implants were lost prior to loading, and one angled implant was lost after loading. No axial implants were lost. Follow-up ranged from 1 to 10 years. The overall survival rates were 92.8% for the angled

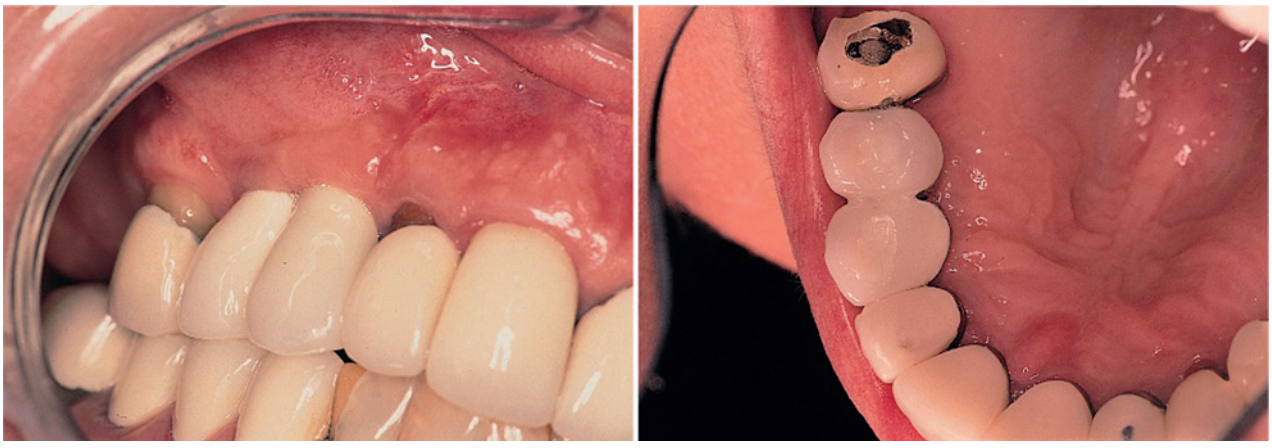


FIGURE 3-19 **G,** Completed restoration after more than 7 years of successful follow-up. (Prosthetics by Dr. Chuck Boudreaux.)

implants and 100% for the straight implants. The overall prosthetic success rate was 100%. Krekmanov postulated that survival of the angled implants was linked directly to cortical bone contact.

Aparicio et al.[29] used straight and angled implants as a treatment option to sinus grafting in patients with partially edentulous posterior maxillae. They reported on 25 patients with 101 implants, with 42 implants placed at an angle. Six patients were smokers. The angled implants were placed in the tuberosity/pterygoid area, palate, mesial sinus wall, and nasal pyriform area. The implants were allowed to osseointegrate for 6 to 8 months and then were uncovered and loaded with fixed restorations. The patients were followed for 21 to 87 months. The implants were evaluated clinically, radiographically, and with the Periotest. Success and survival rates were determined as per Albrektsson et al.[37] Two of the axial implants failed before loading. None of the angled implants failed. Three of the axial and two of the angled implants were classified as surviving but not successful. The axial implants had a success rate of 95%, and the angled implants had a success rate of 95.2%. Based on this study, the authors concluded that partial edentulism in the posterior maxilla, with insufficient bone for traditional implant placement, could be restored with a combination of axial and angled implants and that angled implants were a viable alternative to sinus grafting.

Immediate loading of angled implants combined with axially directed implants also has been studied. Calandriello[28] reported on 18 patients who received a total of 60 implants, of which 27 were angled. Immediate loading was performed with a screw-retained prosthesis on the same day or within 3 days. One each of the axial and angled implants failed; the overall survival rates were 97% for the axial implants and 96.3% for the angled implants. The implants failed because of fractured provisionals, which allegedly caused micromotion and prevented osseointegration. The overall survival rate for the implants was 96.7%, and the prosthetic success rate was 100%.

In 2005, Malo et al.[27] evaluated an immediate function protocol for complete maxillary arch reconstruction with a fixed restoration supported by four implants. The report included 32 patients who received 128 implants. Each patient received two angled and two axial implants, for a total of 64 axial and 64 angled implants. An open surgical technique was used in this study. Each of the posterior implants was placed tangential to the anterior sinus wall at an angle of 30 to 35 degrees. Two anterior implants were placed axially mesial to the posterior implants. The implants were placed at a torque of 40 N-Cm. A provisional fixed acrylic restoration was delivered within 3 hours after implant placement. The first 22 patients also received 51 rescue implants. These implants were not immediately loaded and were used in case of implant failure or were included in the final prosthesis. The patients without rescue implants received their final prosthesis at 6 months after implant placement. The patients who received rescue implants received their final prosthesis 12 months after initial implant placement. Follow-up examinations were performed 6 months and 1 year after implant placement. Clinical and radiographic examinations were performed. The implants were classified as surviving according to routine implant evaluation methods. Three angled implants failed. None of the axial implants failed. Two of the angled implants failed because of heavy bruxism, and one failed because of poor osseointegration and mobility. The survival rates were 100% for the straight implants and 95.3% for the angled implants. The overall survival rate was 97.6%, and the prosthetic success was 100%. Marginal bone loss was 0.9 mm on average, and no difference was seen between the axial and angled implants. These authors concluded that immediate loading with two angled and two axial implants to restore the edentulous maxilla is a viable treatment alternative to sinus grafting.

In 2006, Malo et al.[26] confirmed their earlier results. In this study, 16 of the 44 patients were smokers. Most of the prostheses were supported by four implants. A total of 166 implants were placed; 82 of the implants were placed at an angle along the anterior maxillary sinus wall using an open sinus technique. The implants were immediately loaded with provisional acrylic prostheses on the day of surgery. The final fixed restoration was delivered 12 months after implant placement. The patients were followed for 1 year. Two implants failed, both angled implants. Both failures were replaced with implants that survived and were included in the final prostheses. The survival rate was 100% for the straight implants and 97.5% for the angled implants; the overall survival rate was 98.7%. The prosthetic success rate was 100%. No difference was seen between the angled and the axially directed implants regarding marginal bone loss during the observation period.

Using the prosthetic protocol of Mattsson et al.,[31] Rosén and Gynther[33] confirmed positive results with smokers. In their study, six patients were smokers. The patients were followed clinically and radiographically for 8 to 12 years. A total of three implants in two patients were lost during the follow-up period, for an overall survival rate of 97%. The other patients all had their implants restored with fixed prostheses. The overall prosthetic success rate was 90%. Complications included mucositis with sinusitis, speech problems, and esthetic problems with the restoration. This long-term follow-up provided evidence that the use of angled implants in patients with severely atrophic posterior maxillae was a viable and evidence-based option to bone grafting.

Tiziano et al.[38] evaluated the treatment outcomes for immediate-loaded maxillary, full-arch fixed restorations

with the use of axial and angled implants and compared the clinical success rates of axial and angled implants in partially edentulous patients. The patients were evaluated at 1 month, 3 months, 6 months, 1 year, and then yearly up to 5 years. Three of 164 axial implants failed, for a survival rate of 97.9%. Two of 82 angled implants failed, for a survival rate of 97.1%. The prosthetic success rate was 100%. No difference was seen in marginal bone loss in the two groups at 1 year after placement.

When the clinical data from the references are summed, angled implants have an overall success rate of 96.5%, and straight implants have a success rate of 97%. The literature appears to support the use of angled implants combined with axial (straight) implants for implant-supported implant prostheses.

Advantages of using angled implants for implant-supported prosthetic rehabilitation

The data to date strongly suggest that the use of angled implants for the reconstruction of partially and/or completely edentulous atrophic maxillae, with or without axially loaded implants, presents an excellent treatment alternative to conventional sinus bone grafting. Previously it was thought that nonaxially loaded implants would fail because of unfavorable forces applied to the implant and surrounding bone. However, the work of Celletti et al.[36] and others has disproved this theory, especially when multiple implants are used to distribute the load.

Angled implants appear to be successful because of several factors described in multiple studies. Longer implants can be used, which provide more surface area for osseointegration. The longer implants engage more than one cortical plate, which allows for excellent initial implant stability. Angled implants also provide more posterior support, which eliminates the need for distal cantilevers and allows for more widespread load distribution throughout the arch. Angled implants also eliminate the need for sinus grafting and the possible need for a donor site, along with donor site complications and morbidity. Although all the surgical protocols reviewed here used an open surgical technique with sinus openings, advances in CT-guided technology may eliminate the need for the open surgical technique completely. In addition, although traditional grafting techniques are an excellent treatment option, the use of angled implants provides the clinician with a viable alternative to traditional techniques for patients with limited resources or those who may not be amenable to sinus procedures.

Angled implants can be placed in the office setting with minimal patient morbidity (Figure 3-20, A-F). The use of CT-guided surgery may allow the placement of angled implants without the need for incisions or flaps, further reducing patient morbidity compared with grafting options.

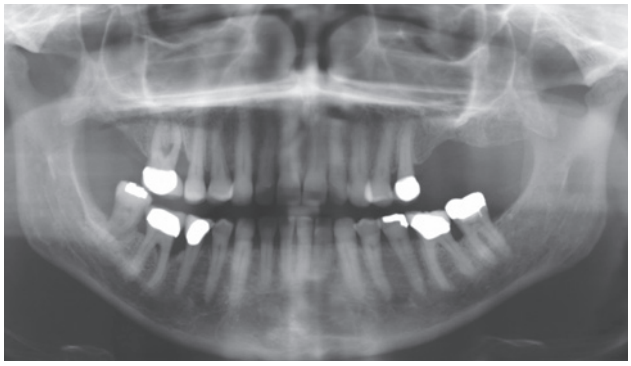


FIGURE 3-20 A, Preoperative panoramic radiograph showing missing maxillary left molars. Patient desired replacement of the first and second molar without sinus grafting.

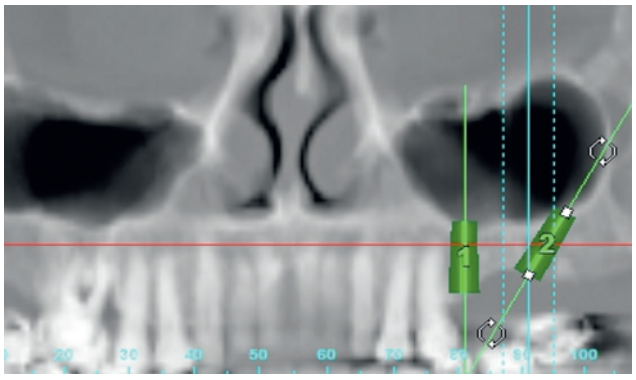


FIGURE 3-20 B, CT scan was obtained, and CT planning software was used to perform virtual implant placement surgery. This panoramic reconstructed image shows the plan to angle the posterior implant into bone, avoiding the sinus. The patient and restorative dentist (Dr. Charles Boudreaux) agreed to the plan.

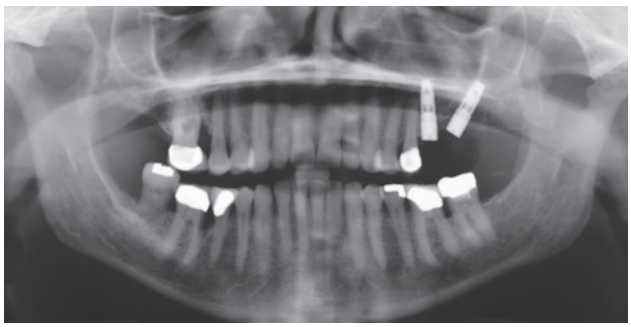


FIGURE 3-20 C, Panoramic radiograph shows the implants in place, at the time of exposure, with placement of the healing abutments.

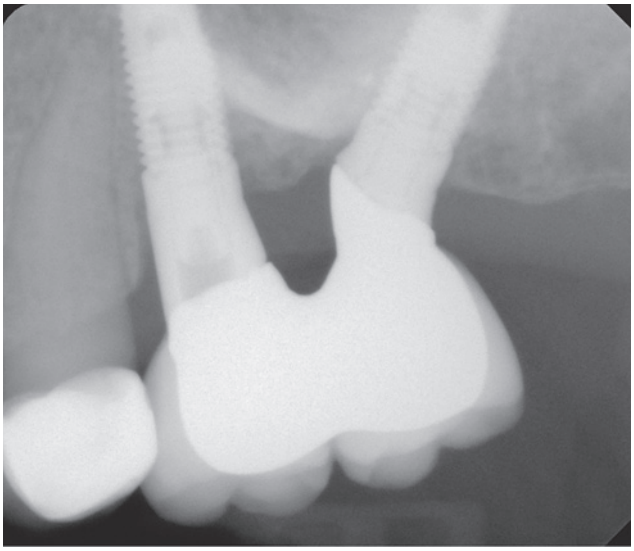


FIGURE 3-20 **D,** Custom abutments were used to correct for the posterior implant's angulation, with the final prosthesis cemented to the abutments.

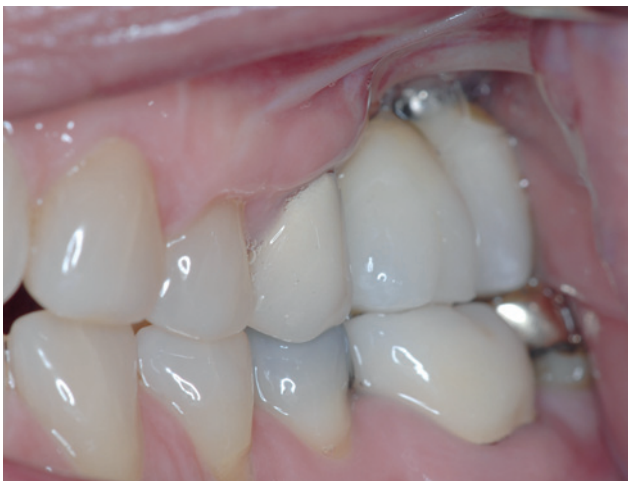


FIGURE 3-20 **F,** Final prosthesis. (Prosthetics by Dr. Charles Boudreaux.)

Disadvantages of using angled implants for implant-supported prosthetic rehabilitation

The placement of angled implants along with two axially directed implants in the anterior maxilla requires long implants and proper prosthetic coordination. The clinical evidence in the literature seems convincing that the forces placed on these four implants, with cross-arch stabilization, can result in adequate function. The follow-up period is shorter than with zygomatic implants. Continued follow-up at 5 and 10 years will confirm the early results reported in this discussion.

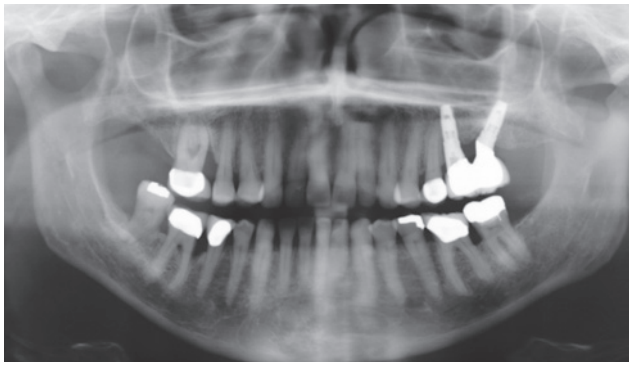


FIGURE 3-20 **E,** Panoramic radiograph taken 2 years after restoration shows excellent crestal bone preservation around the implants.

Reconstruction of Severe Anterior Maxillary Defects Using Distraction Osteogenesis, Bone Grafts, and Implants

Trauma to the anterior maxilla varies in severity from minor injuries of the soft and hard tissues to more complex injuries involving severe loss of soft and hard tissues.[39] Often, maxillary anterior teeth have been avulsed and are unsalvageable. Severe avulsive injuries to the anterior maxilla present a great challenge because of the loss of both hard and soft tissue.

Mild avulsive injuries can be considered a defect of up to 3 mm; a *moderate* defect may measure up to 6 mm. A hard and soft tissue defect greater than 6 mm should be considered a *severe* avulsive injury. Mild to moderate defects generally involve less of a soft tissue problem than do severe defects. In severe defects, secondary bone grafting often is necessary after distraction, whereas in mild to moderate defects, less need exists for secondary grafting.

For reconstruction of the missing tissues and teeth in a severe anterior maxillary defect, treatment must include the genesis of new tissue. For implant-retained restorations, the quality and quantity of both hard and soft tissue must be adequate, or the final restoration will be compromised.[40] Augmentation of defects of the anterior maxillary alveolar ridge with autogenous bone grafts is well documented.[41] Procedures that reconstruct vertical and horizontal bone include onlay grafts, interpositional bone grafts placed after a LeFort I downfracture or a sagittal split of the alveolus, and guided bone regeneration.[42-45] After severe avulsive trauma, the healed soft tissue often is deficient and scarred next to the underlying atrophic remaining maxilla. Adequate, tension-free closure must be performed to prevent incisional breakdown over a large onlay bone graft[46];

therefore, when confronted with scarred, deficient soft tissue after avulsive trauma, the surgeon must find a method to reconstruct the quantity and restore the quality of the soft tissue.

Lack of soft tissue is the primary reason the surgeon uses *distraction osteogenesis* (DO) to reconstruct severe defects. After trauma, scar formation on the ridge and the loss of soft tissue from the avulsion injury limit the surgeon's ability to elevate tissue and achieve a tension-free closure over a bone graft. Slow movement of the bone promotes neogenesis of the soft tissue, which secondarily allows for bone graft coverage.

With the loss of large amounts of anterior maxillary alveolus and soft tissue, DO offers a way to regain bone and soft tissue. The principle of DO is well established in endochondral bones.[47-49] DO has been applied to the maxilla[50-52] and the mandible.[53,54] Small to medium-sized segments of the alveolar process have been distracted successfully.[55-62] Classic DO involved atraumatic sectioning of bone, application of an expandable device, an interval between sectioning of the bone and initiation of bone movement, and slow movement of the bones at a rate not to exceed 1 mm in at least two steps (0.5 mm) daily. After the desired movement of the bone has been achieved, the device is left in place during bone formation in the gap created by the distraction.

Extraoral distraction devices are anchored by transcutaneous pins, which are used to transport and stabilize the skeletal fragments. Extraoral devices are not used for the maxillary alveolar area because of scar formation. *Intraoral* distraction devices are used in most cases of maxillary alveolar DO. Internal distraction devices may be divided into intraosseous and extraosseous types. Both types provide vertical movement but are limited in the horizontal movement of the transported segment. *Intraosseous* distractors may not be appropriate in areas of proposed implant sites because of less control over implant placement, and loss of the distractor means loss of an implant site. *Extraosseous* distractors are limited by the need for space above or below the transported segment. In addition, epithelialization occurs along the device and leads to loss of attached tissue.

General Surgical Principles

The patient who presents with missing anterior teeth receives the same evaluation, regardless of the severity of bone and soft tissue loss. Diagnostic models are made, with a setup of the planned restoration (Figure 3-21, A-C). The defect can be easily seen with the esthetic setup made in tooth-colored material. Radiopaque barium sulfate can be incorporated into the setup if a CT scan will be used. A routine panoramic radiograph is obtained (Figure 3-21, D).

With a severely compromised anterior maxilla, the process follows these steps:

1. Diagnostic setup and imaging are performed to diagnose the extent of bone loss.
2. A distraction device is placed to increase the vertical dimension of bone and soft tissue.
3. Seven days after placement of the distraction device, the alveolus is distracted 0.5 mm twice a day, for a total of 1 mm daily, for 15 days. During distraction, the removable device requires adjustment of the flanges and teeth to clear the way for the alveolus.

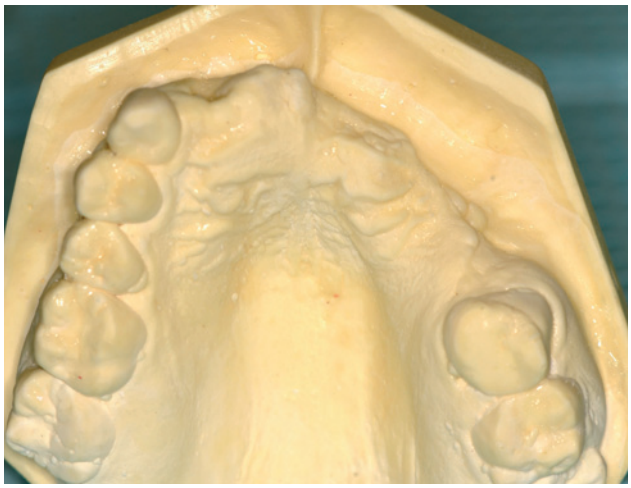


FIGURE 3-21 **A,** Occlusal view of maxilla showing significant deficiency of the maxillary alveolus.

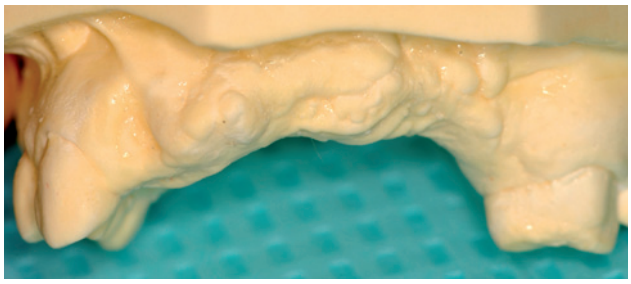


FIGURE 3-21 **B,** Frontal view showing 12 mm of vertical bone defect.

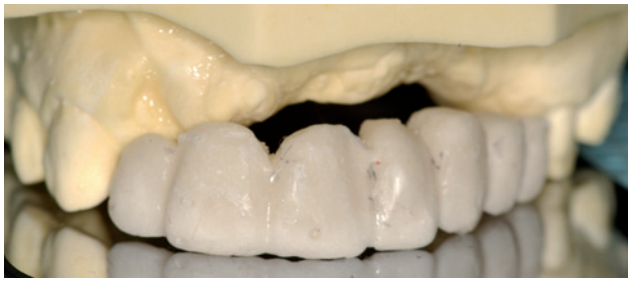


FIGURE 3-21 **C,** Planned setup showing the vertical bone deficiency.

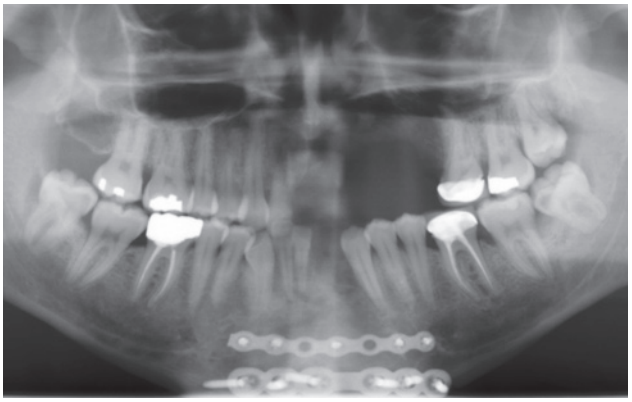


FIGURE 3-21 **D,** Panoramic radiograph of the maxilla before distraction. Note the presence of bone in the lateral incisor area; however, but a significant deficiency is present on the left anterior maxilla.

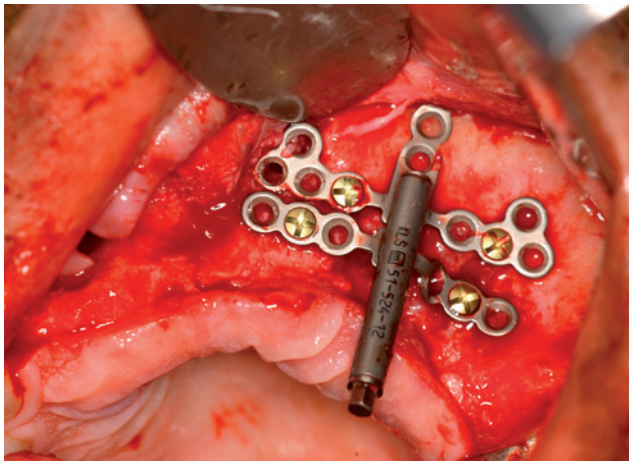


FIGURE 3-21 **E,** Crestal incision is combined with distal vertical release, and a distraction device is adapted to the remaining alveolus. Four screws are placed, and the osteotomy is made except for the region of the screws.

4. After 6 to 8 weeks to allow for bone formation, the distraction device is removed and a bone graft is placed to achieve the appropriate horizontal ridge form. A template is used to guide the placement of the bone graft.
5. After 4 months, implants are placed with the use of a surgical guide stent.
6. After the implants have integrated, they are exposed. A temporary fixed prosthesis is placed. When the prosthesis is satisfactory to the patient and dentist, a final prosthesis is designed and placed.

Case Report

The following case report illustrates the technique just described.

Preoperative workup

A 22-year-old man sustained a major avulsive injury of the hard and soft tissue in the anterior maxilla (see Figure 3-21, A-D). Eight weeks were allowed for initial healing. A setup of the planned restoration was made and tried-in for patient approval of the planned esthetics (see Figure 3-21, C). It was determined that at least 12 mm of bone and soft tissue would be needed for proper esthetics.

Placement of the distraction device

A sulcular incision was made two teeth distal to the defect bilaterally. Broad-based releasing incisions were made vertically. A crestal incision was made across the defect. A full-thickness mucoperiosteal flap was raised to expose the anterior maxilla. A palatal flap was minimally reflected. A 12-mm alveolar distractor (KLS Martin, Jacksonville, Florida) was adapted to the defect (Figure 3-21, E). Four screws were then placed into the four corners of the device to stabilize it.

The osteotomies were initiated with the distractor in place. The distractor then was removed, and the osteotomies were completed. The palatal mucosa was not cut, because the surgeon placed a finger on the palate to sense when the oscillating saw emerged through the palatal bone. The vertical osteotomies were slightly tapered and made 2 mm mesial to the canine roots bordering the defect. This allowed the transport segment to draw vertically without interference. A spatula osteotome was used to ensure that all osteotomies were complete. The distractor was placed in its original position and secured with screws (Figure 3-21, F).

A test distraction of 4 mm was performed to ensure passive movement of the distracted segment. The segment then was returned to its original position. The periosteal side of the flap was scored with a 15 blade to ensure passive closure over the distractor. The flap was closed with 4-0 chromic suture in an interrupted pattern (Figure 3-21, G).

A hole was made in the patient's removable partial denture to allow emergence of the distractor's arm. This transitional device also maintained the vector of the distractor and prevented it from moving palatally (Figure 3-21, H-I).

The patient was placed on a liquid diet for 2 weeks, then a soft diet for the remainder of the distraction. After a latent period of 7 days (the time of initial healing), the distractor was activated at a rate of 1 mm per day (0.5 mm twice daily) for 12 consecutive days. As the alveolus moved inferiorly, the labial flange of the transitional denture had

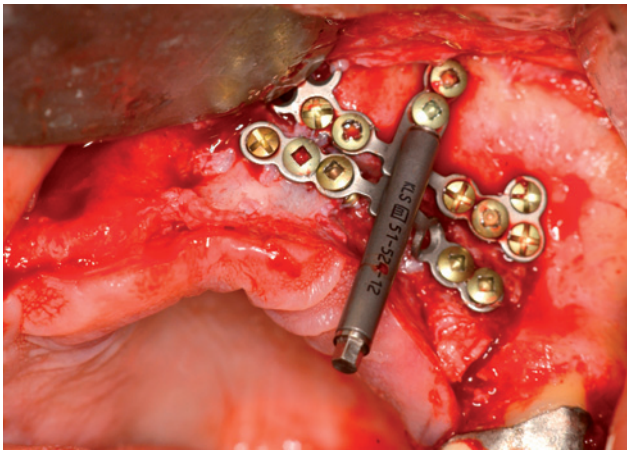


FIGURE 3-21 **F,** Screws are removed, and the osteotomy is completed, with care taken to prevent trauma to the palatal mucosa. The device is replaced, and additional screws are placed.

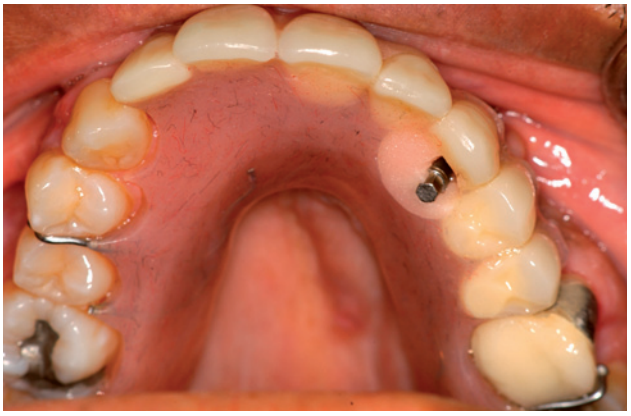


FIGURE 3-21 **H,** Hole has been drilled through the transitional removable partial denture (RPD) to allow the arm to be kept in the proper vertical vector.

to be removed to make room for the transported segment (Figure 3-21, J). A portion of the teeth on the partial denture eventually was removed. After 12 days the distraction was stopped, and the bone was allowed to consolidate (Figure 3-21, K).

Removal of the distractor and harvesting of the bone graft

After 8 weeks, the alveolar form appeared well healed, and the next stage of the treatment was initiated (Figure 3-21, L). A vacuum form of the planned restoration was made to serve as a template for bone graft positioning.

FIGURE 3-21 **G,** After release of the periosteum, the incision is closed without tension.

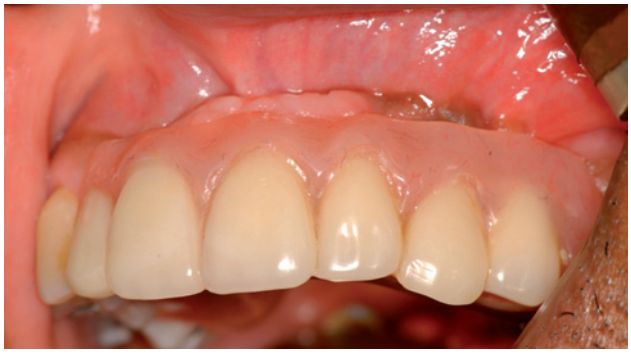


FIGURE 3-21 **I,** RPD is placed; the flange is expected to need trimming as the distraction proceeds.

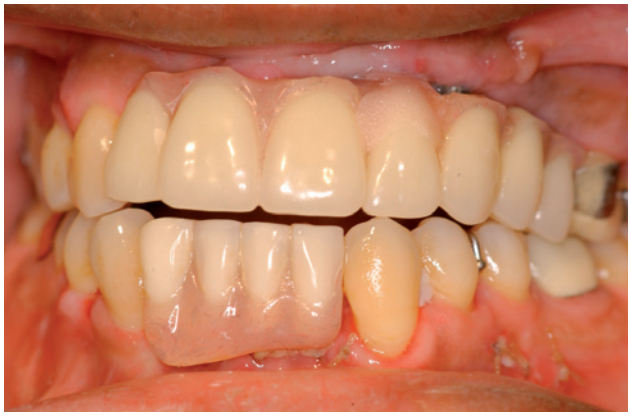


FIGURE 3-21 **J,** Distraction is accomplished at the rate of 1 mm per day, in increments of 0.5 mm made twice daily. The alveolus moves inferiorly, requiring removal of the flange every 2 to 3 days. A portion of the teeth eventually will be removed.

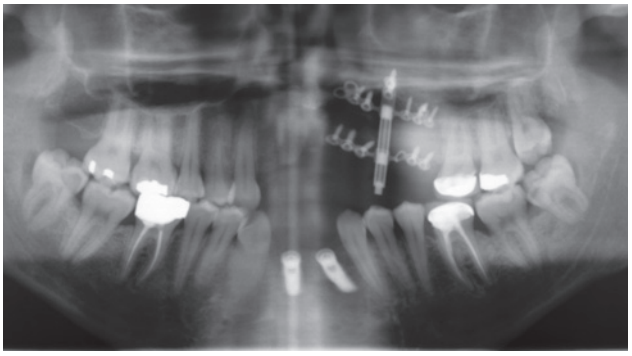


FIGURE 3-21 **K,** Panoramic radiograph showing the distraction of the alveolus.

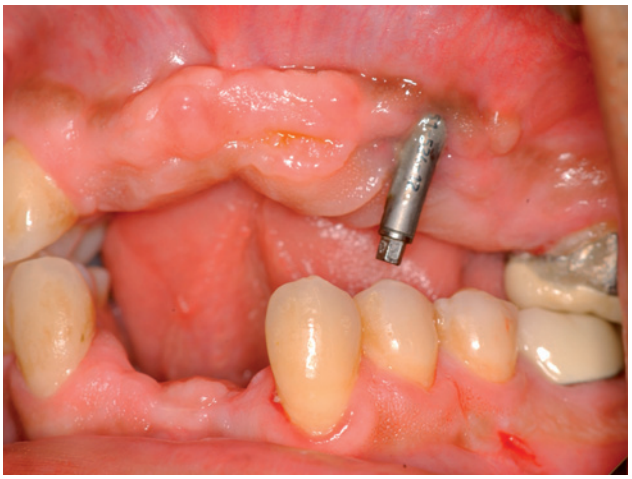


FIGURE 3-21 **L,** Alveolar vertical dimension has been restored by the distraction.

A crestal incision was made, and the soft tissue was elevated from the distractor, exposing its distracted position (Figure 3-21, M). The distraction device was removed, and the bone was evaluated (Figure 3-21, N). Bone had formed across the distraction gap but was deficient horizontally, as expected. The template was placed, and wax was used to form a template for the bone grafts (Figure 3-21, O). Corticocancellous blocks were harvested from the iliac crest and secured over the alveolus, as guided by the template (Figure 3-21, P-Q). The periosteum was relieved to allow tension-free closure (Figure 3-21, R).

Placement of the implant

Four months were allowed for bone graft consolidation, and then a new surgical template was made to guide the placement of the implants (Figure 3-21, S-T). A crestal incision was combined with vertical release incisions, and the bone graft was exposed (Figure 3-21, U). The screws

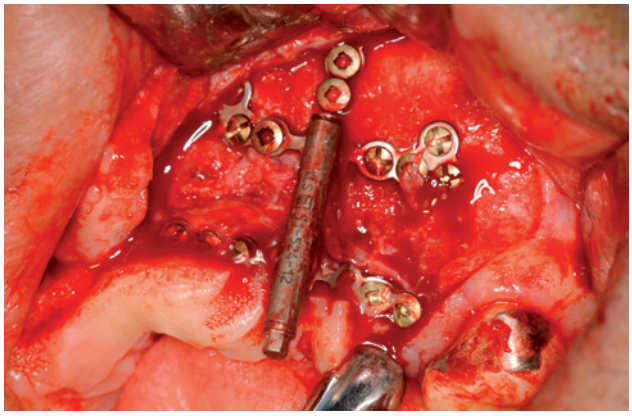


FIGURE 3-21 **M,** After 8 weeks, the distraction device is removed by exposure through crestal and vertical release incisions. The vertical incisions are made two teeth distal to the defect.

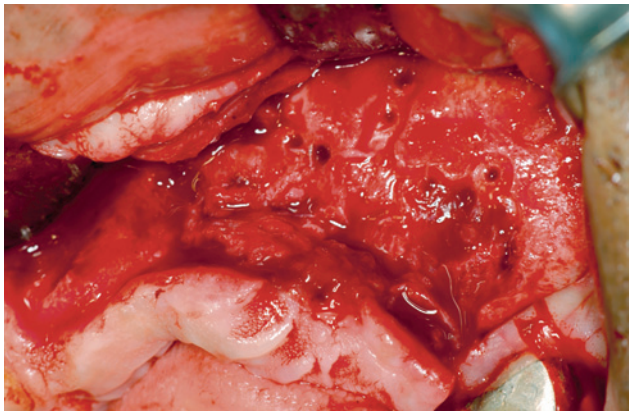


FIGURE 3-21 **N,** Distraction device is removed. Bone has formed palatally, but horizontal deficiency is present, as expected.

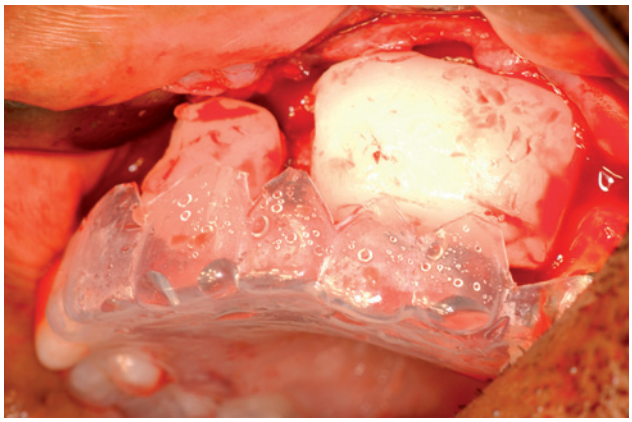


FIGURE 3-21 **O,** Bone wax is adapted to the ridge to form templates for carving the bone grafts. Note that a template is used to ensure that the grafts are placed in the proper position, with the final prosthesis in mind.

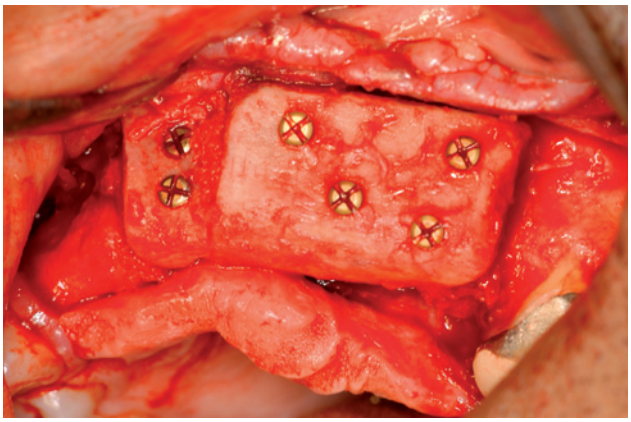


FIGURE 3-21 **P,** Bone grafts are harvested from the iliac crest and secured in position with screws.

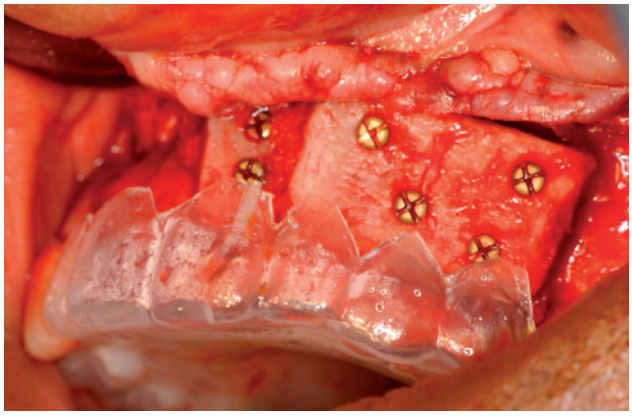


FIGURE 3-21 **Q,** Bone grafts are placed to allow appropriate positioning of the implants and bone available to support interdental papilla.

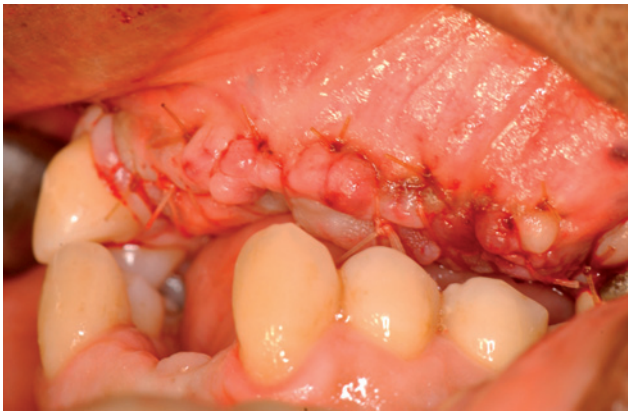


FIGURE 3-21 **R,** Incision is closed without tension after periosteal release.

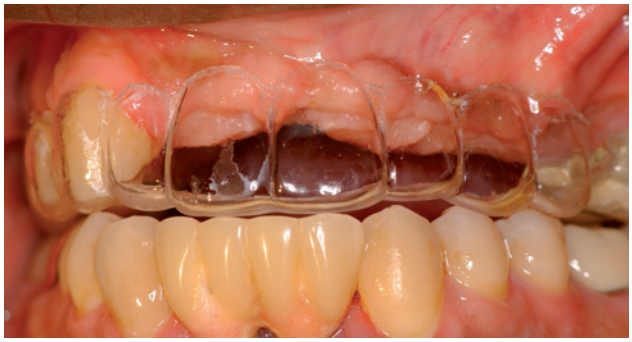


FIGURE 3-21 **S,** After 4 months, a template is made to guide implant placement.

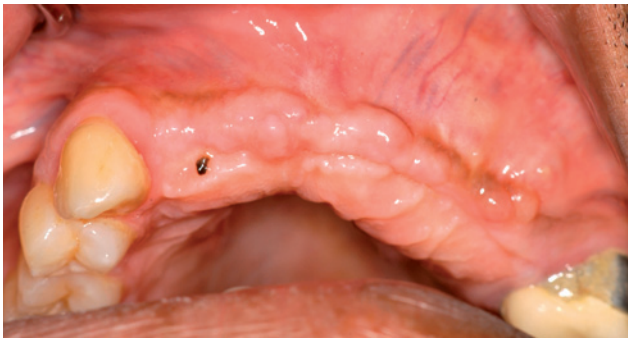


FIGURE 3-21 **T,** Alveolus now has improved bone dimension in both the vertical and horizontal aspects.

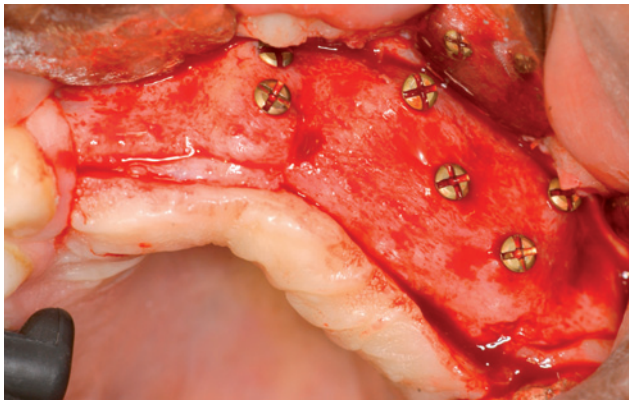


FIGURE 3-21 **U,** Crestal incision allows for removal of the screws and observation of the grafts.

were removed, and implants were placed in each tooth position (Figure 3-21, V-W).

Another 4 months were allowed for integration, and the patient then was ready for implant exposure (Figure 3-21, X). A crestal incision made slightly palatal allowed placement of the healing abutments (Figure 3-21, Y). After transfer impressions had been made, abutments were prepared and placed (Figure 3-21, Z-AA). A second set of final impressions of the abutments was made, and the final crowns were fabricated (Figure 3-21, BB-FF).

At placement, the patient was satisfied with the appearance of the restoration. His smile line covered the small gingival discrepancies that often occur with this severe defect (Figure 3-21, GG-HH).

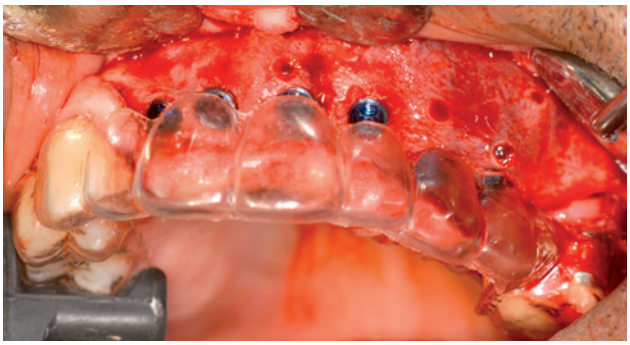


FIGURE 3-21 V, Template is used to place implants approximately 3 mm apical to the planned gingival margin.

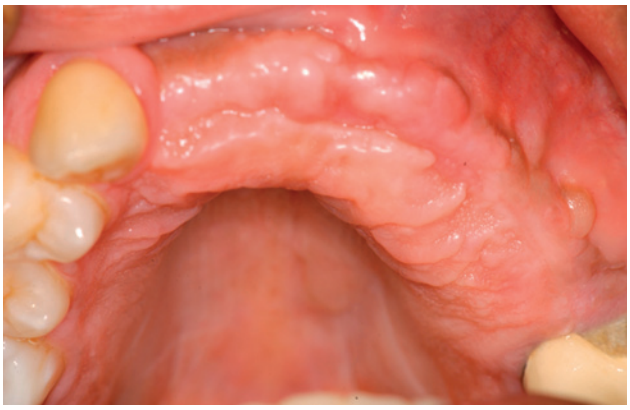


FIGURE 3-21 X, Four months later, the ridge is ready for exposure of the implants.

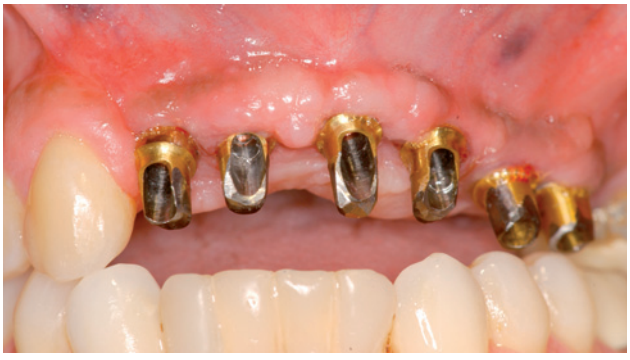


FIGURE 3-21 Z, Transfer impressions and custom abutments are made.

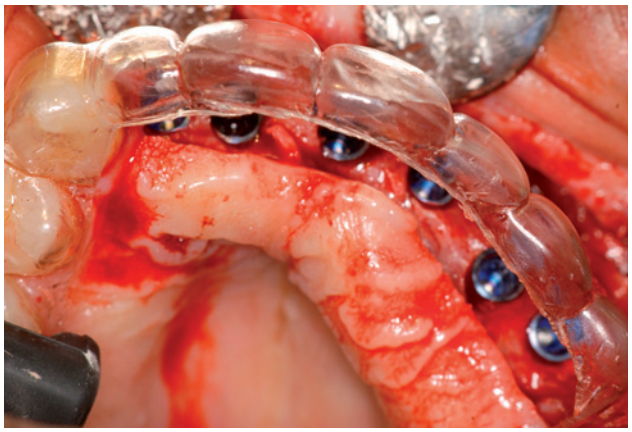


FIGURE 3-21 W, Placement of one implant per tooth.

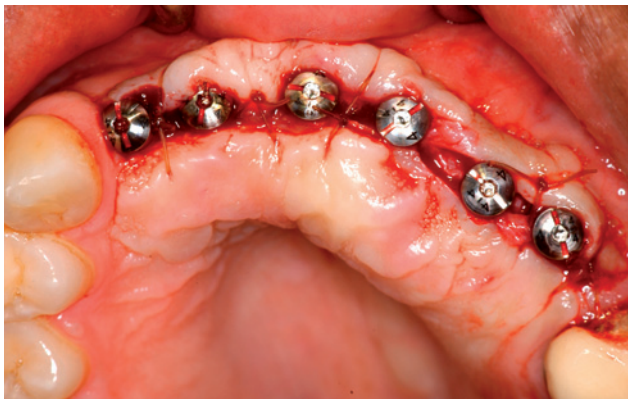
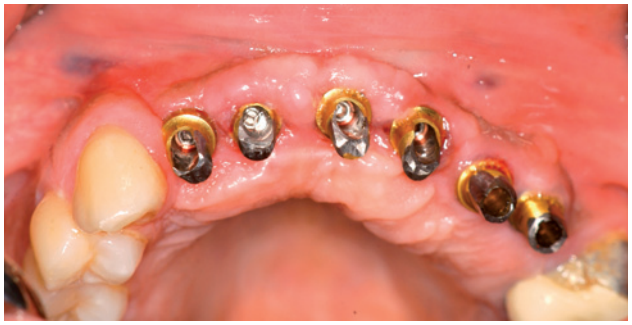
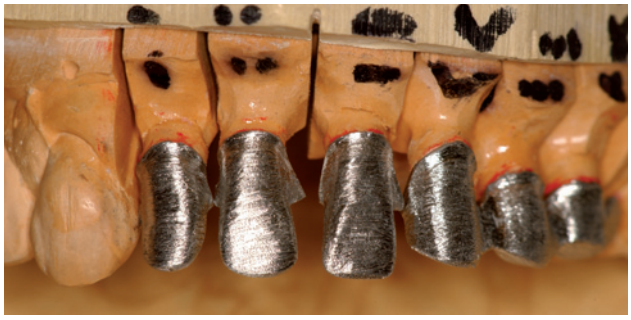


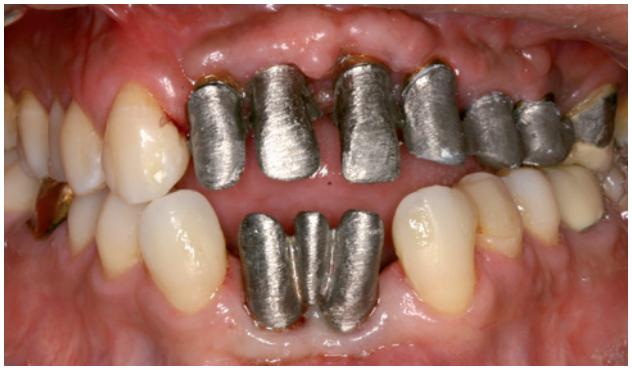
FIGURE 3-21 Y, Palatal incision allows for transposition of the attached gingiva to the labial surface of the healing abutments.



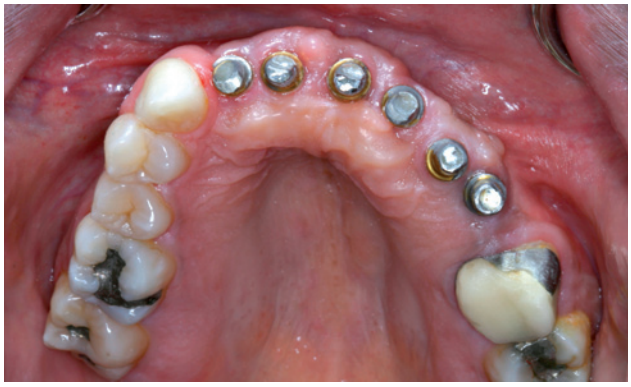
● **FIGURE 3-21** **AA,** Occlusal view showing the position of the implants.



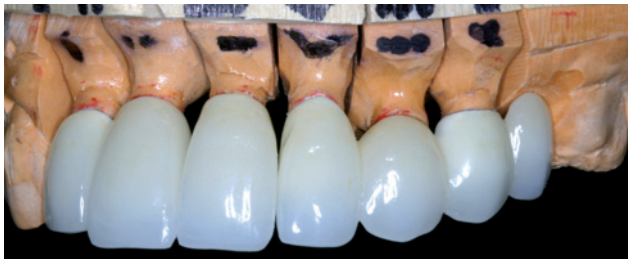
● **FIGURE 3-21** **BB,** Metal cores are fabricated for each crown.



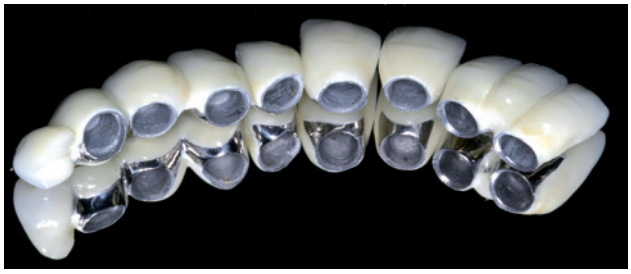
● **FIGURE 3-21** **CC,** Metal cores are tried in the mouth before final preparation.



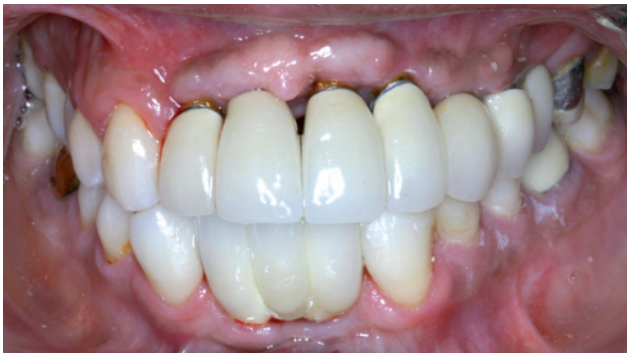
● **FIGURE 3-21** **DD,** Final implants after the patient has been wearing a new provisional prosthesis.



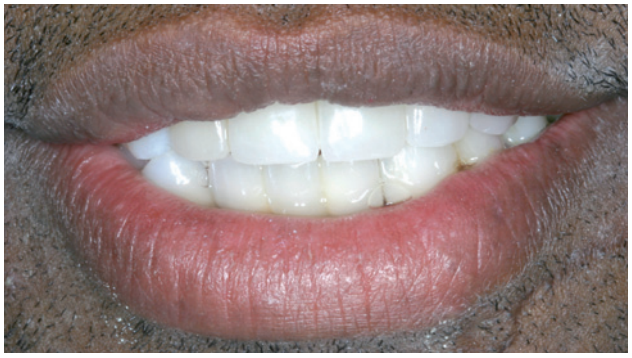
● **FIGURE 3-21** **EE,** Final porcelain crowns on the model.



● **FIGURE 3-21** **FF,** Each crown has been designed as a single replacement tooth, without splinting.



● **FIGURE 3-21** **GG,** Final restoration in place.



● **FIGURE 3-21** **HH,** Small gingival defects are hidden by the patient's low smile line. (Prosthetics by Dr. Paulino Castellon.)

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Maxillary Sinus Grafting

Chapter 4

Chapter Outline

Background, General Principles, and Techniques

Bone availability is the key to successful placement of endosseous implants 10 mm or longer in the posterior maxilla. When the thickness of the bone between the maxillary sinus and the alveolar crest is less than 10 mm, increasing the thickness of the alveolar sinus floor by bone grafting is one option that will support implants and prosthetic restoration. The graft material chosen must provide adequate viable bone to stabilize the implant initially and encourage osseointegration. Materials used for sinus floor grafting include autogenous bone, allogeneic bone, xenograft anorganic bone preparations, and alloplastic materials. Autogenous bone fulfills the criteria for an ideal graft.[1]

Long-term assessment of the amount of bone remaining around the implants has not been included in initial reports.[2-24] However, a more recent report examined the use of tomography to assess the bone level (relative to the apical portion of the implant) and the height of alveolar ridge.[25] This report indicated that after 5 to 10 years of function, bone formed in autogenous bone–grafted sinuses and was retained.[25-33] The population in this study had simultaneous placement of hydroxylapatite (HA)–coated implants (e.g., cylinders, screw shapes) with autogenous bone grafts. After 5 to 10 years of function, bone was still present around the implants. Of the implants studied, 90% had bone covering the apical portion of the implant. This study supports the use of autogenous bone for sinus grafting. The techniques described in this chapter are similar to those mentioned in the long-term tomography study.[25]

In the tomography study, no attempt was made to differentiate prosthesis design, length and diameter of implants, or small variations in surgical technique (e.g., antibiotic coverage, flap design, type of implants used). Nevertheless, failure of the implants and grafts was rare. The prostheses fabricated for these patients followed well-known techniques. However, the effects of specific prostheses on graft maintenance and implant survival were not evaluated.[25]

The differences among types of grafts indicate that the addition of *demineralized, freeze-dried bone* (DFDB) to the iliac grafts slightly lowered the eventual bone level. Although this difference was statistically significant, the clinical difference was small, because the implants were still covered with bone. In some clinical situations, the amount of bone harvested from the donor site is less than ideal. In these cases, DFDB is added to increase the volume of the

graft. Interestingly, the addition of DFDB does not increase the eventual graft volume on a long-term basis.

The *autogenous cancellous bone graft* contains endosteal osteoblasts that can survive the transplantation process when handled appropriately, and this graft subsequently forms bone.[34-37] A *corticocancellous block graft* provides transplanted osteoblasts and growth factors, as well as structural rigidity, which frequently is required when implants are placed simultaneously.[38] However, the cortical portion of the graft is slow to revascularize. The structural rigidity of the graft allows accurate implant placement, independent of the thickness of the sinus floor. The healing of these bone grafts follows a course that starts with basic wound healing and proceeds with bone remodeling.[39-42]

What alternatives might be used instead of autogenous bone and demineralized bone? Evidence is mounting that bovine bone (a xenograft) combined with autogenous bone or used by itself can induce bone formation within the graft and support implants.[43-45] The use of fibrin glue creates cohesion of the composite particles, which limits their migration after placement of the graft in the sinus. Another alternative for the primary graft material is bone morphogenetic protein (BMP).[46,47] BMP can be used to form bone within the sinus without the use of other materials. However, at this time, BMP combined with allografts do not have evidence-based clinical data on the incidence of bone formation in the sinus. It is expected that other combinations of materials that promote bone formation with the use of a scaffold will prove effective at solving the problem of vertical height deficiency in the future.

The residual alveolar bone thickness at the time of sinus grafting guides the surgeon to choose a particulate or solid block bone graft. Vertically deficient ridges (less than 3 mm), for which the treatment plan includes simultaneous grafting and implant placement, are augmented by placement into the sinus of iliac crest block grafts rather than particulate cancellous bone grafts. If particulate bone is used, implant placement is delayed for at least 6 months until the graft has consolidated. If the patient has 3 mm or more of bone height, the surgeon can perform simultaneous autogenous bone grafting and insert HA-coated implants rather than wait 6 months or longer.

Presurgical Screening

Presurgical screening of patients in preparation for sinus grafting must include questions about factors that affect the successful formation of bone within the graft material chosen for the sinus augmentation procedure.

Exclusion criteria that should be considered include the following:

1. *Smoking or use of a nicotine patch.* Cessation of smoking and nicotine use must occur a minimum of 4 weeks before sinus surgery.
2. *Uncontrolled systemic diseases.* Patients with uncontrolled diabetes or other uncontrolled systemic diseases involving bleeding or the immune system are not candidates for the procedure.
3. *Active pathologic conditions.* Endoscopic sinus surgery may be necessary to remove polyps, mucoceles, or purulent exudate. If the patient maintains a healthy sinus after removal, sinus graft surgery can be performed.
4. *Excessive nasal pathologic conditions.* Conditions that obturate the mouth of the maxillary sinus may indicate the need for intranasal surgery before the sinus graft procedure.
5. *Radiation therapy.* Patients with a history of radiation therapy to the maxilla are not candidates for the procedures.

Preoperative Radiographic Screening

The preoperative radiographic examination begins with a panoramic radiograph. The clarity of the maxillary sinus, the presence of septa in the proposed surgical site, and an approximation of the thickness of the alveolar bone are visualized. Periapical radiographs do not usually contribute to the screening of the patient for sinus grafts. However, the panoramic radiograph has approximately 20% magnification error; also, detail is lacking on the facial-palatal thickness, morphologic structure of the alveolar bone and sinus floor, and status of the sinus membrane. Therefore, a reformatted computed tomography (CT) scan may be indicated for selected patients when more detail is desired (Figure 4-1, A-B).

CT scans are especially recommended for patients in whom the surgeon suspects multiple sinus septa or a pathologic condition in the sinus. The scans can document the thickness of the alveolar crest at the surgical sites and the thickness of the membrane. Before a CT scan is taken, all presurgical prosthetic planning should be complete, and a radiopaque stent indicating the positions of the planned restoration should be made. The scan is used to identify the specific locations of the planned implant sites and to provide the surgeon with an accurate understanding of the anatomy in the surgical location (see Figure 4-1).

Surgical Technique

The surgical procedure involves the removal or medial rotation of a window of cortical bone over the lateral aspect of the maxilla without perforation of the sinus membrane. Incisions should be made so as to allow adequate exposure of the surgical site and to avoid the placement of the incisions over the sinus window. After the lateral wall of the maxilla has been exposed, four linear ostectomies are performed to outline the window. The inferior horizontal ostectomy should be made as close to the floor of the sinus

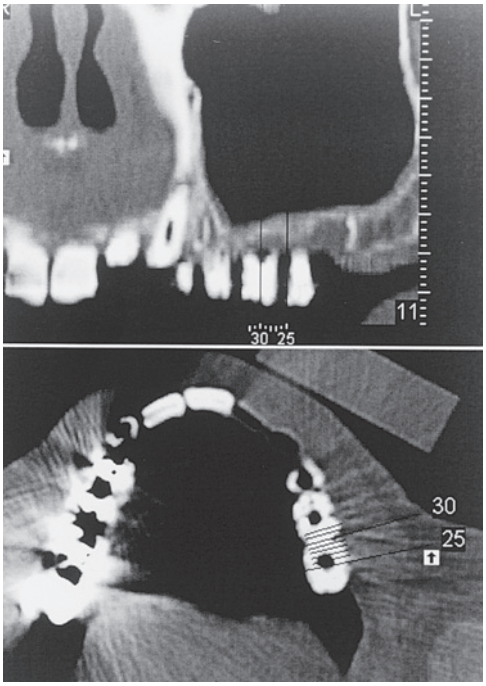


FIGURE 4-1 **A,** Computed tomography (CT) scan of the maxilla showing the reconstructed panoramic image and the axial cut. Before the bone graft is placed, a radiopaque stent with holes drilled into the planned implant site are used to determine the bone thickness at the proposed site.

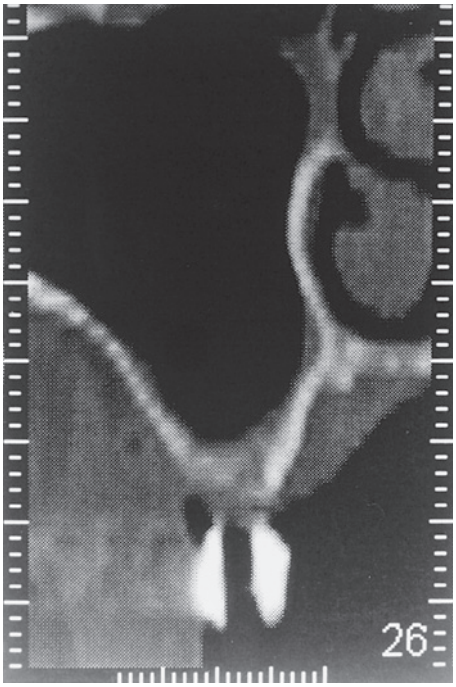


FIGURE 4-1 **B,** Reformatted cross section of the maxilla shown in Figure 4-1, A, showing the location of the cross section by number as it relates to the proposed implant location. The crosshatches at the bottom represent 1-mm increments, which allow thickness measurements of the bone. The proposed implant axial emergence is clearly evident in the stent.

as possible to facilitate membrane dissection. The vertical ostectomies should be made close to the maxillary buttress and lateral nasal wall, again to facilitate membrane elevation. The superior horizontal cut should be made at the level of the planned augmentation height, which should allow placement of implants 15 mm long (DVD Figure 4-1, A). After the window has been created, the lateral bone still adherent to the sinus membrane can be either rotated medially (DVD Figure 4-1, B) or removed.

DVD Images 4-1, A-B

Surgery is performed in the operating room (OR) with the patient under general nasoendotracheal anesthesia or in an outpatient setting using local anesthesia and sedation as necessary. At surgery, an antibacterial rinse or povidone-iodine (Betadine) solution (or both) is used to reduce the bacterial count in the mouth. Steroids and antibiotics can be given intravenously before surgery. A local anesthetic, typically 2% lidocaine (Xylocaine) with 1:100,000 epinephrine and a longer-acting anesthetic, is administered to the maxillary vestibule and crestal tissues.

After a minimum of 5 minutes is allowed for the vasoconstrictor to take effect, a crestal incision is made. For the totally edentulous maxilla, two incisions are made, one on each side, sparing the anterior incisive canal region. Each incision is made on the crest, with anterior release starting in the lateral incisor region and extending vertically past the junction of the attached and unattached gingivae. Posteriorly, a vertical releasing incision is made in the second or third molar region and extending into the unattached gingiva. Incisions that cross the midline are avoided unless anterior onlay grafting is also planned.

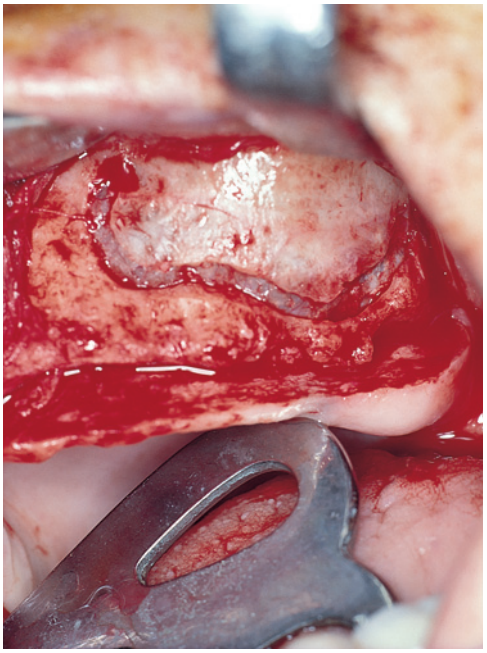
For the patient with a partially edentulous maxilla with retained anterior teeth, the incision is crestal with the vertical release made anteriorly, avoiding the band of attached gingiva on the teeth, into the unattached gingiva. Posteriorly, the release is similar to that in the patient with a totally edentulous maxilla, but it may be directed over the tuberosity if tuberosity bone harvest is planned.

After the periosteum has been reflected superiorly, exposing the lateral wall of the maxilla, the planned ostectomy is visualized to start at the level of the maxillary sinus floor. The vertical osteotomies are parallel to both the lateral nasal wall and the anterior border of the maxillary tuberosity, where the maxilla curves posteriorly. The superior horizontal ostectomy is located where the vertical position of the augmentation is planned. A fiber-optic light source can be placed in the nose or against the palate to illuminate the sinus, allowing the surgeon to visualize the

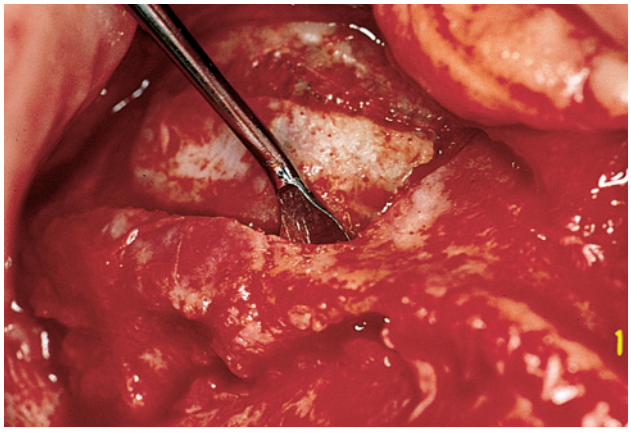
specific landmarks (e.g., floor of the sinus) and to perform an accurate ostectomy.

A round bur with irrigation is used to remove cortical bone and expose the gray, glistening sinus membrane (Figure 4-2, A). The lateral maxillary wall can be left intact and rotated inward as the new floor of the maxillary sinus, or it can be removed, depending on the clinician's preference. A smooth, relatively new elevator is used to peel the sinus membrane from the floor of the maxillary sinus and lateral nasal wall (Figure 4-2, B). The membrane is elevated to the height of the desired augmentation. The edges of the sinus membrane are elevated initially, gradually increasing the distance of membrane elevation. Excessive elevation of one isolated portion of the membrane is avoided, because this would result in tension on the nonelevated membrane. The membrane must be sufficiently elevated to avoid excessive pressure when the sinus graft material is placed.

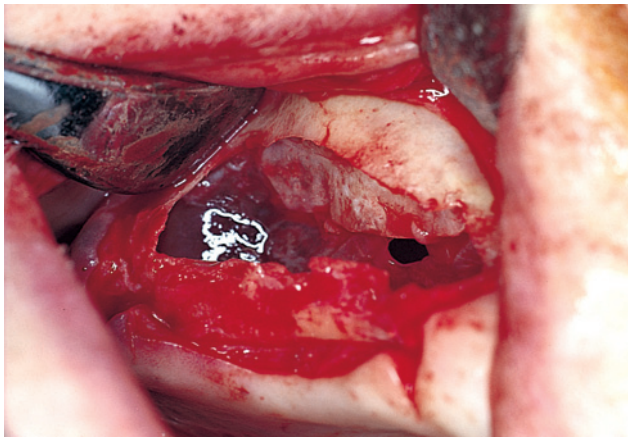
Perforations of the sinus membrane may occur, depending on the experience of the operator, location of the horizontal ostectomy, presence of septa, and thickness of the sinus membrane (Figure 4-2, C). Small perforations are left untreated. If large perforations are present, the procedure is aborted and attempted at a minimum of 4 months later. Use of a patch, such as a collagen membrane or other resorbable membrane, is at the discretion of the operator, with the understanding that the addition of such materials may increase the chances of postoperative infection. If solid blocks of bone are to be used, an intact sinus membrane may be less important. After the membrane has been elevated, the bone harvest procedure is performed.



● **FIGURE 4-2 A,** Surgical photograph showing an incision at the crest of the ridge, followed by a full-thickness, mucoperiosteal reflection to expose the lateral wall of the maxilla. A round bur has been used to remove the cortical bone, exposing the underlying sinus membrane.



● **FIGURE 4-2 B,** Small Woodson elevator is used to elevate the thin sinus membrane from the inner aspect of the maxillary sinus.



● **FIGURE 4-2 C,** Sinus membrane is raised, and the lateral wall of the maxilla is then rotated medially into the sinus. The membrane is elevated with a small perforation. Small perforations (such as the one shown) can be left alone with no treatment. If a large perforation is made, the procedure may be aborted, unless a solid block of bone is used rather than particulate bone. When the membrane is elevated and positioned in the superomedial aspect of the sinus, it often folds on itself; this folding closes over any perforations.

Bone-Harvesting Techniques

Jawbone Grafts

A small amount of marrow (1 to 2 ml) can be harvested from the *maxillary tuberosity* in the area of the third molars. An incision is made posterior to the hamular notch, with anterior or posterior release as needed. If the surgeon anticipates using the maxillary tuberosity as the graft harvest site, the crestal incision made to expose the maxilla is extended posteriorly to allow harvesting of the posterior maxillary bone. The periosteum is reflected to expose the posterior aspect of the maxilla. Rongeur forceps are used to harvest the bone, with care taken to avoid the sinus membrane and the large blood vessels located in the pterygoid fissure. Often, up to 2 ml of cancellous bone can be harvested from a maxillary tuberosity.

Another source of bone from the jaws is the *symphysis*. To gain access to the chin, the surgeon can make a sulcular or vestibular incision. The periosteum is elevated to place the osteotomy 10 mm inferior to the apex of any incisor teeth. The bone then can be collected with the use of a trephine, and the cortical plate can be removed and the marrow harvested. A collecting device can be used in the suction line when bone is drilled from the chin or ramus regions or bone scrapings are produced. The goal is to harvest viable endosteal osteoblasts, which can participate in the first phase of bone formation.

For the patient undergoing unilateral sinus graft surgery, the surgeon usually can harvest bone from the posterior maxilla, the mandibular third molar site, or the chin to obtain sufficient autogenous bone, mixed with an equal amount of DFDB, to augment one sinus (Figure 4-3, A-H).

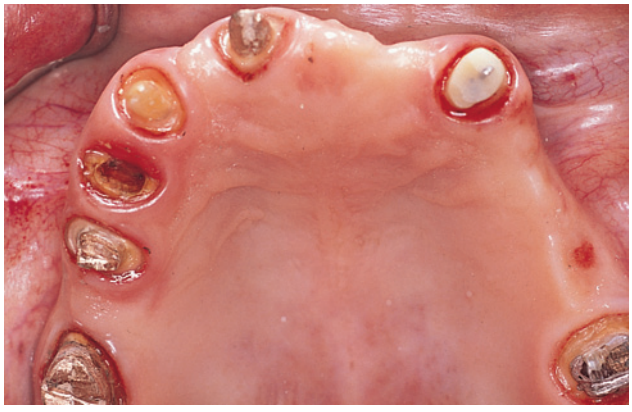


FIGURE 4-3 **A,** This 50-year-old man was referred for a left sinus graft to allow placement of three implants 15 mm long for an implant-borne restoration. This occlusal view shows a long span between the maxillary left canine and the maxillary left second molar. Both teeth are marginal abutments secondary to bone levels and root contours.

A scraping device can be used on the mandibular third molar sites to harvest cortical bone and a small amount of cancellous bone (Figure 4-4, A-H). The cortical portion of the mandible has very few viable osteoblasts. To gain additional bone, the surgeon also can use the chin as a harvest site. The chin cortex is removed with a round bur, and a sieve collection device is placed in the suction line. The round bur then is used within the confines of the cortical bone to harvest cancellous bone, which should contain viable osteoblasts.

When bone from the jaws is used, the volume of the graft usually must be augmented with either an allograft or a xenograft, depending on the clinician's preference. Future

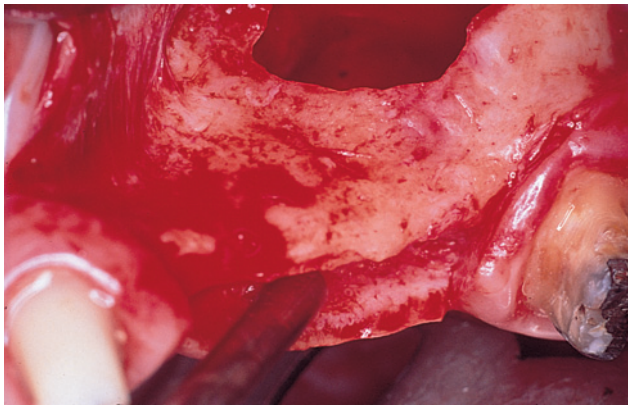


FIGURE 4-3 **B,** Crestal incision is made with anterior and posterior vertical release. After the lateral wall of the maxilla has been exposed, the ostectomy is performed; the sinus membrane is elevated with no perforations.

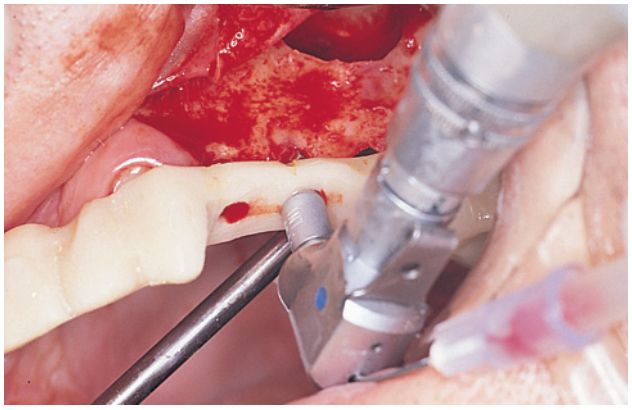


FIGURE 4-3 **C,** New temporary bridge is made, which is duplicated and used as the surgical guide. Holes are drilled as prescribed by the prosthodontist. The surgical guide is placed on the tooth preparations. The drilling sequence is completed with the membrane safely elevated superiorly.

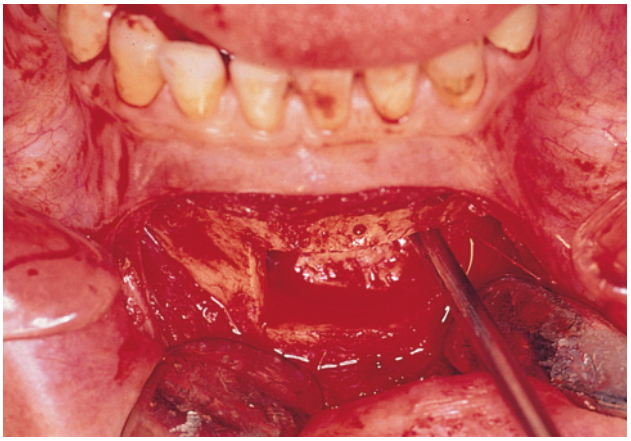


FIGURE 4-3 **D,** Bone graft is harvested from the chin. After a local anesthetic has been infiltrated, a vestibular incision is made, followed by sharp and blunt dissection to expose the symphysis. A sagittal saw is used to perform corticotomies, and the cortical plate is removed. The cancellous bone under the cortex of the symphysis is removed with the aid of a curette and an osteotome. After the bone graft has been harvested, the mentalis musculature is anatomically reapproximated, and the mucosa is closed with polyglactin 4-0 sutures using an atraumatic needle.

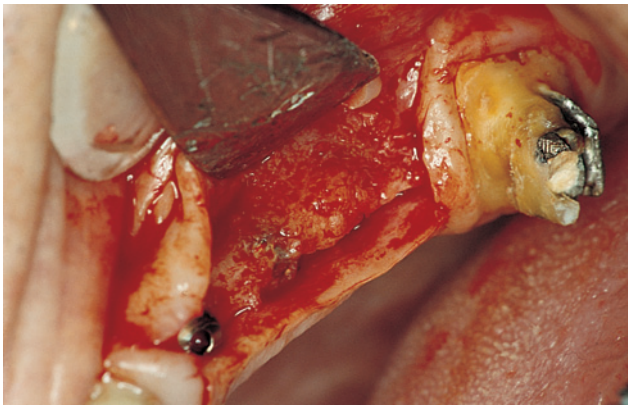


FIGURE 4-3 **F,** After 6 months, the implants are exposed through a crestal incision. The implants are covered with bone.

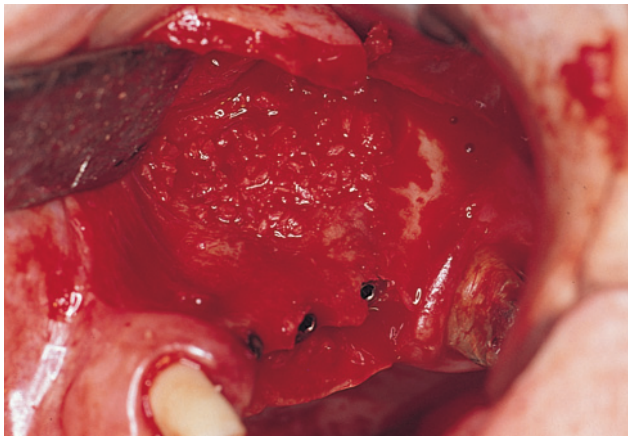


FIGURE 4-3 **E,** Bone graft is combined with demineralized, freeze-dried bone (DFDB) in a 1:1 ratio to yield approximately 8 ml of graft. The graft is placed into the medial aspect of the sinus, followed by the implants and additional graft material. Additional material then is placed to augment the thin alveolar ridge.

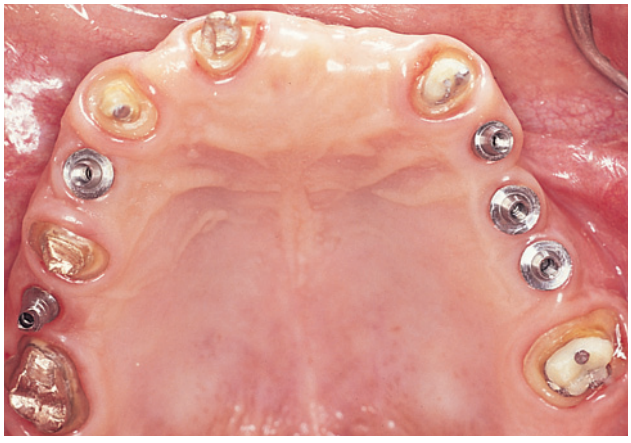


FIGURE 4-3 **G,** Occlusal view showing the implants just before placement of the final restoration.

use of alloplasts in various forms or recombinant proteins may affect the need for harvesting cancellous marrow.

Tibia Bone Grafts

The advantages of harvesting bone from the tibia are decreased postoperative morbidity and the ease with which the procedure can be performed under intravenous sedation in the surgical office. Disadvantages of tibia graft harvesting are the potential risks of leg fracture and possible prolonged edema in overweight patients.

In either the surgical office or the OR, the leg and foot must be prepared with meticulous sterile scrub, paint, and sterile wraps to ensure a sterile field. Often the sinus membrane elevation is accomplished first; the surgeons then rescrub, regown, and prepare the tibia for graft harvest. If attention to sterile detail is thorough, infection at the graft harvest site is rare.

The harvesting of tibial bone involves identifying Gerdy's tubercle, after which a sharp dissection to the periosteum

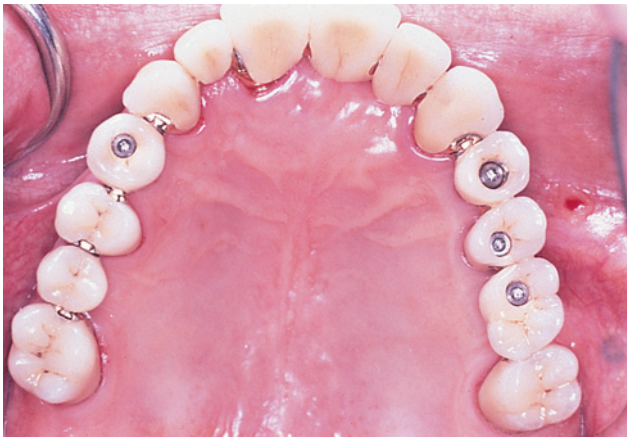


FIGURE 4-3 **H,** Final restoration in place. (Prosthetics by Dr. Gerald Chiche.)

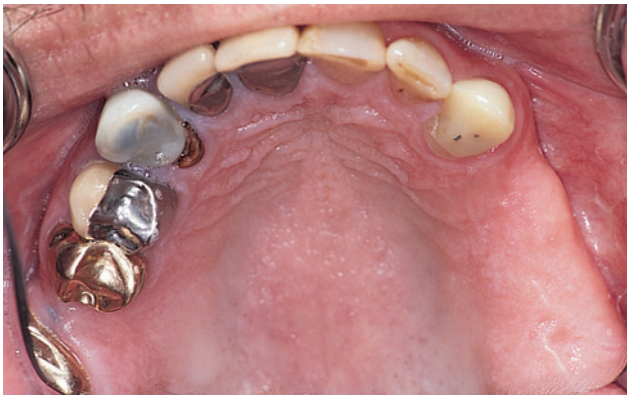


FIGURE 4-4 **A,** This patient wants a fixed prosthesis; he no longer wants to wear his maxillary removable partial denture. The width of the alveolus is adequate.

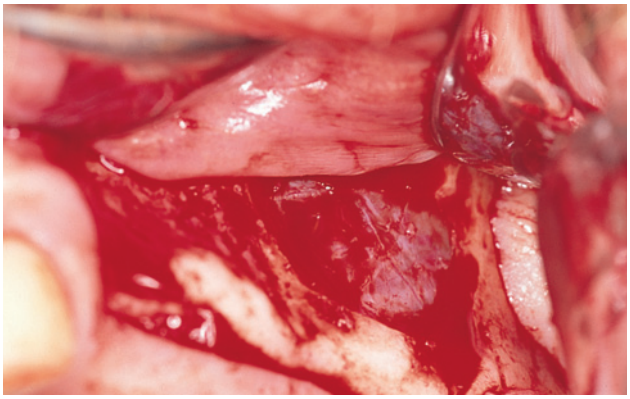


FIGURE 4-4 **B,** Incision is made slightly palatal to the crest, with anterior and posterior vertical releasing incisions proximal and distal to the sinus graft window. The ostectomy is performed, and the lateral bone is removed. The intact sinus membrane is observed.

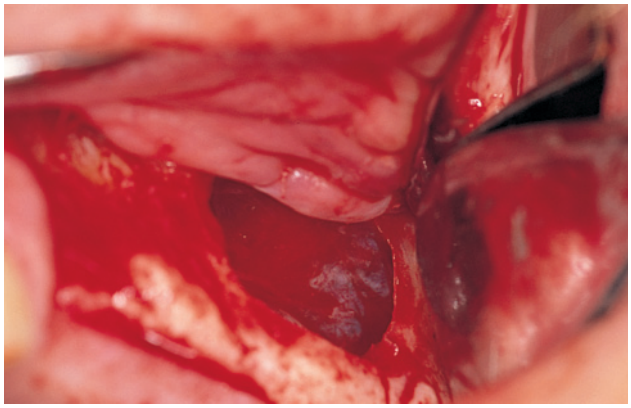


FIGURE 4-4 **C,** Membrane is carefully elevated and reflected medially into the sinus.

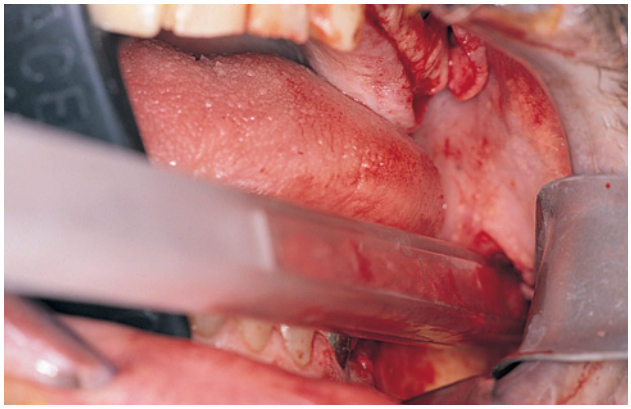


FIGURE 4-4 **D,** To harvest intraoral bone, the surgeon makes a retromolar incision to expose the external oblique ridge. A bone collecting scraping device is used to collect shavings of cortical bone from the external oblique ridge. Approximately 2 ml of cortical shavings, with a small amount of cancellous bone, is harvested from the ramus.

overlying the tibial cortex is performed (Figure 4-5, A-I). Two techniques can be used to harvest tibial cancellous bone: (1) a periosteal osteocortical flap can be elevated, based on intact periosteum along the superior aspect of the cortical window, or (2) a small cortical window can be created, which is covered with periosteum after the bone has been harvested.

Periosteal osteocortical flap

After the periosteum has been identified, a scalpel is used to score it along two vertical lines, each approximately 10 mm long, with a horizontal line at the inferior aspect of the vertical lines. A thin fissure bur is used to create a corticotomy through the three lines, leaving the superior aspect intact.

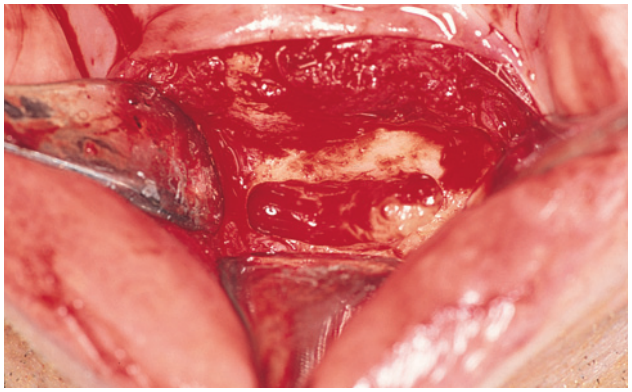


FIGURE 4-4 E, To increase the amount of available bone, the surgeon exposes the symphysis and uses a round bur at approximately 1000 rpm with a sieve in the suction line to collect cortical and cancellous bone.

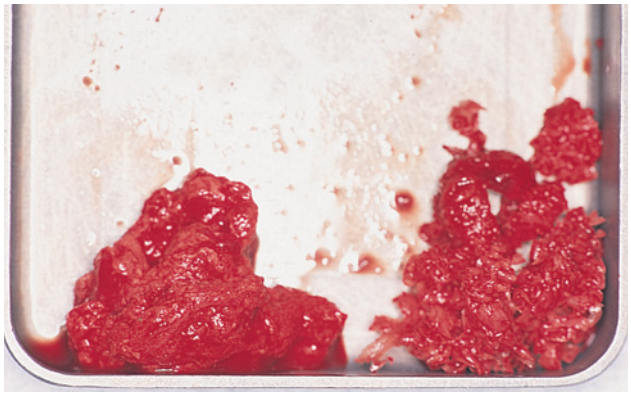


FIGURE 4-4 F, Bone harvested from the symphysis through the suction line sieve on the left and the shavings from the external oblique ridge on the right are combined.

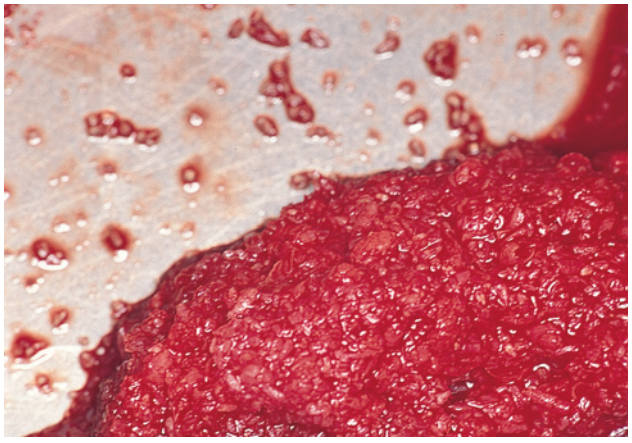


FIGURE 4-4 G, Equal volume of DFDB is combined with the final volume of autogenous bone to produce approximately 8 ml of bone graft material.

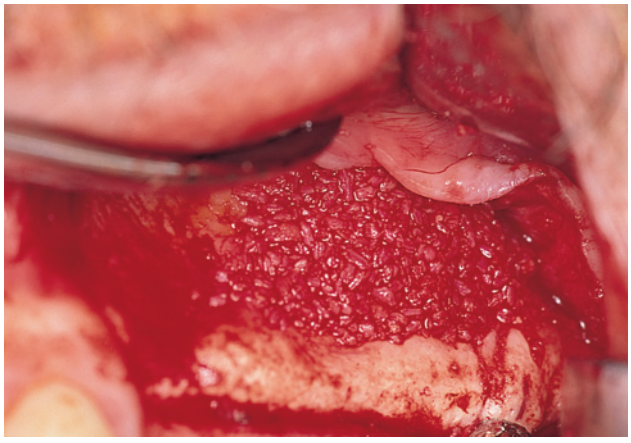


FIGURE 4-4 H, Bone graft composite is packed into the sinus site. After approximately 6 months, the implants are placed; after an additional 6 months, the final restoration is completed.

The tibial cortex is elevated by performing a greenstick fracture of the cortex, exposing the cancellous bone within the tibia. The marrow is removed from the cancellous space along the level of the window—inferiorly, not superiorly. After the marrow has been harvested, the area is irrigated thoroughly and closed in layers. The periosteum is sutured to reapproximate the cortical window and close the cortical defect. The subcutaneous tissues are closed, and the skin is closed with a subcuticular suture, with or without the addition of skin sutures as necessary.

Cortical window

After the skin has been incised and the periosteum has been exposed with blunt and sharp dissection, an incision is made in the periosteum, and the periosteum is elevated to expose the cortical bone at Gerdy's tubercle. A T-shaped periosteal incision facilitates reflection of the periosteum, which can be quite tenacious. Under copious irrigation, a bur is used to remove a cortical window 8 to 10 mm in diameter, and the cancellous bone is then harvested. After irrigation, the periosteum is sutured, and the wound is closed in layers.

Postoperative management

For either technique, the patient is instructed to avoid impact loading of the leg for at least 6 to 8 weeks. The leg should be elevated, and ice should be applied to the surgical site for 24 hours. The patient is warned to avoid soaking the leg in a bath for at least 10 days. The patient is examined the next day so that the dressing can be cleaned and

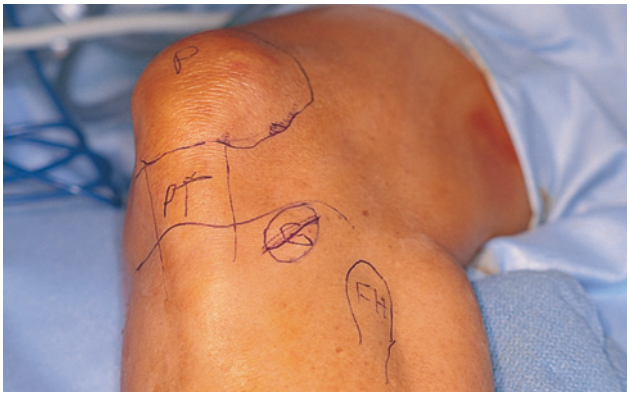


FIGURE 4-5 **A,** Tibia can be used as the bone graft harvest site. The leg is prepared and draped. The anatomic landmarks, including the head of the fibula, the patellar tendon, and Gerdy's tubercle, have been drawn on the leg. The incision line drawn across Gerdy's tubercle is shown.

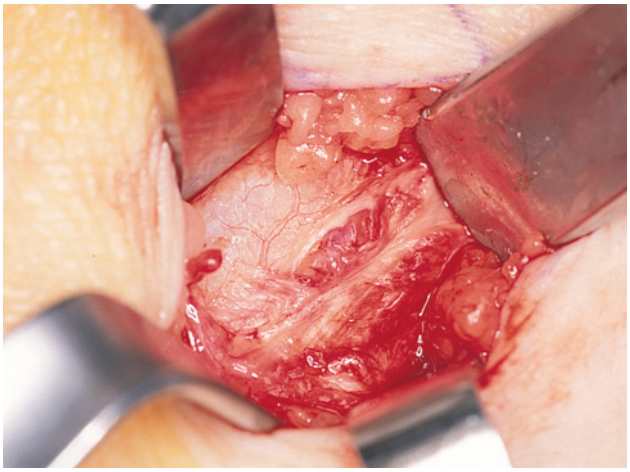


FIGURE 4-5 **C,** After administration of a local anesthetic to anesthetize the periosteum of the tibia, a skin incision is made. Hemostasis is meticulously maintained with electrocautery. Sharp dissection is used to reach the periosteum of the tibia overlying Gerdy's tubercle.

questions addressed. Antibiotics to cover gram-positive cocci and pain medication are prescribed for postoperative management.

Iliac Crest Grafts

In addition to the tibia, the iliac crest can serve as the source of large amounts (more than 20 ml) of cancellous marrow. The technique for harvesting iliac crest cancellous marrow involves elevation of the iliac cortical crest and curettage of the marrow. The cortical plates are replaced and sutured back into position.

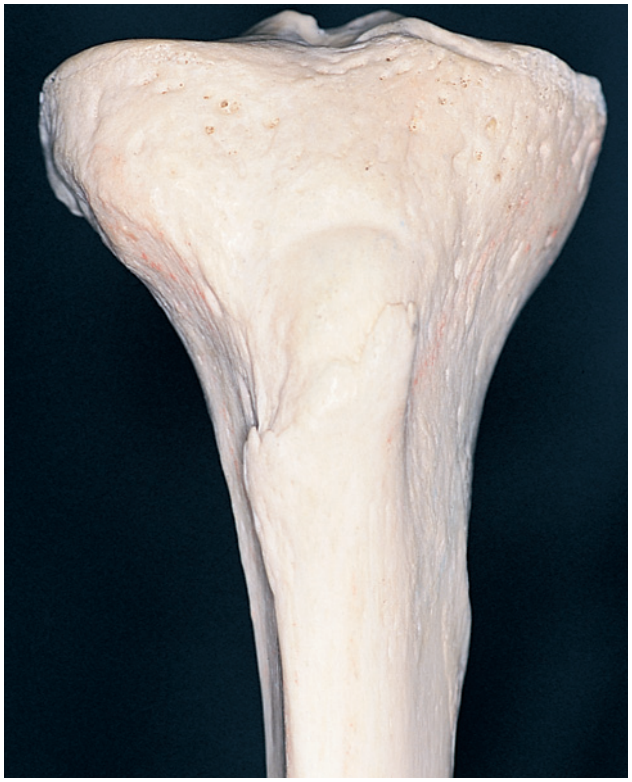


FIGURE 4-5 **B,** Tibia has a wide plateau region with a bump (Gerdy's tubercle), which is the entry site into the cancellous portion of the tibia. The bone is harvested across the wide portion of the tibia and inferiorly; in this way, thinning of the superior, weight-bearing portion of the tibia is avoided.

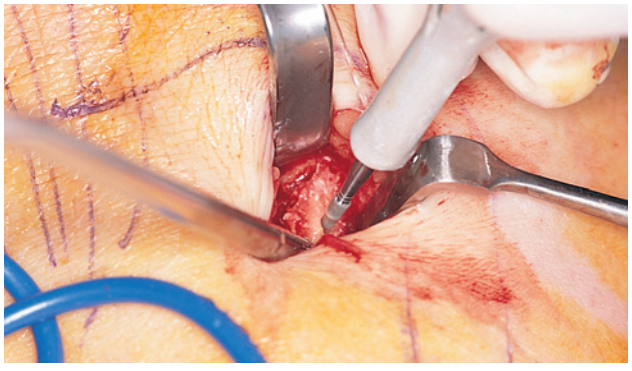


FIGURE 4-5 **D,** If a periosteal osteocortical flap is to be raised, incisions are made through the periosteum to expose the bone along two vertical sites and one horizontal location. A fissure bur can be used to create a trough through the cortex. The cortex is elevated from the tibia with the periosteum intact on the flap of bone. This elevation allows replacement of the cortex, maintaining its vascularized attachment to the periosteum.

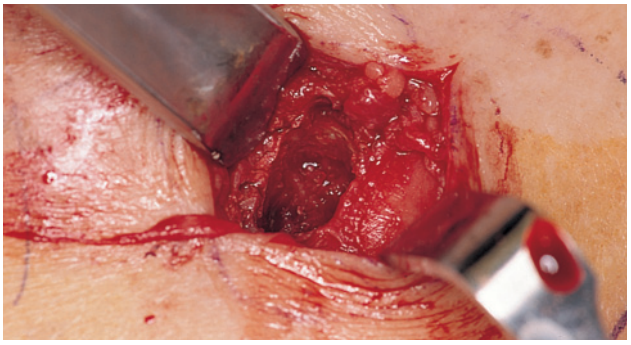


FIGURE 4-5 E, In a second approach, the periosteum is raised from the bone. A bur is used to remove a piece of cortical bone 8 mm in diameter over Gerdy's tubercle.

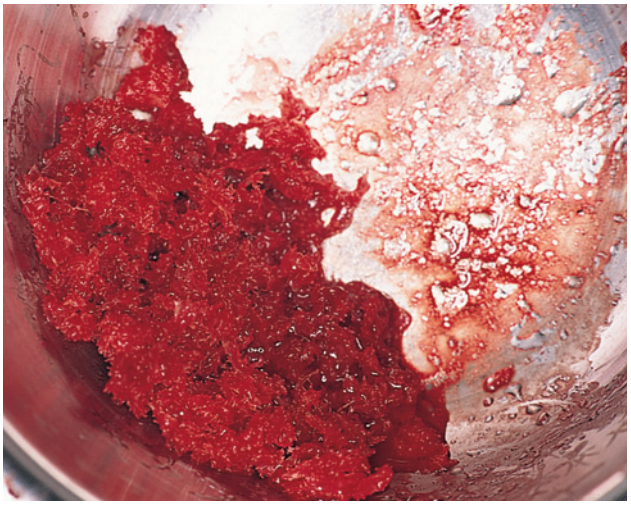


FIGURE 4-5 G, Up to 22 ml of cancellous bone can be harvested from one tibia, which is sufficient to graft bilateral sinuses.

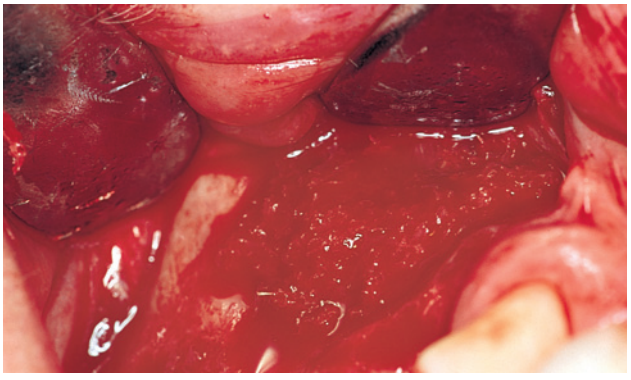


FIGURE 4-5 I, Membrane has been elevated, and the tibia bone has been placed.

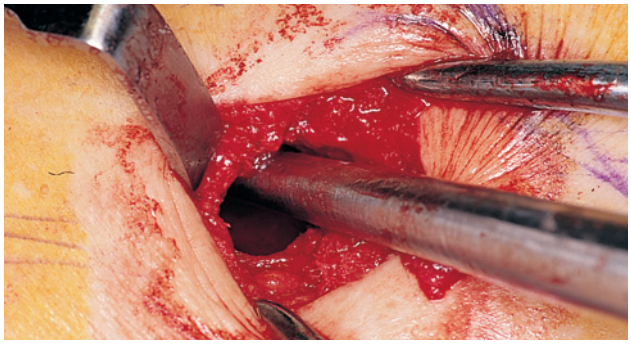


FIGURE 4-5 F, Bone curette is used to collect cancellous bone from within the tibia.

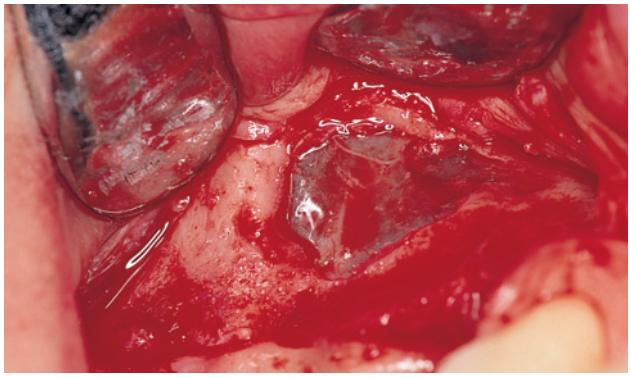


FIGURE 4-5 H, Lateral aspect of the maxilla is shown after the lateral aspect of the maxillary wall has been removed, exposing the intact sinus membrane.

Multiple approaches can be used to reach and harvest bone from the iliac crest. For sinus grafting, the *anterior approach* usually is performed, because it does not require turning the patient after the sinus elevation has been completed. In addition, a satisfactory amount of bone usually can be harvested from the anterior approach. To limit blood loss and minimize gait disturbances, the technique most often used involves a relatively avascular approach, with great care taken to avoid the sensory nerves that traverse the iliac crest region. After a sterile preparation and draping of the anterior iliac crest, a local anesthetic is administered. Blunt dissection with hemostatic control using electrocautery is used to approach the anterior iliac crest. The approach should be performed from the lateral anterior aspect to prevent reflection of the insertion of the tensor fasciae latae muscle, which will minimize long-term gait disturbances. The muscles are separated rather than incised, with the dissection medial to the gluteus medius muscle and lateral to the iliacus muscle. In the area

of the iliac tubercle, fibers from the external oblique and other muscles may need to be elevated when large pieces of bone are harvested, but these fibers should be left intact if possible. The sensory nerves usually pass over the anterior and posterior spines and are encountered in fewer than 2% of patients. Usually they can be retracted, and sensory loss thus is a rare complication from iliac crest bone harvest.[48]

For the harvesting of *cancellous bone* only, the iliac crest is approached, and the periosteum is not reflected. Incisions through the periosteum are made only where the osteotomes are used to create a linear bony incision with two anterior and posterior bony releases. These cortical cuts can be made with a saw or sharp osteotomes. The cortical plates of the crest then are outfractured, maintaining the soft tissue attachments to the periosteum. The cancellous bone is collected with bone curettes; suturing of the periosteum reapproximates the crestal bone cuts, and the wound is closed in layers.

For the harvesting of blocks of *corticocancellous bone,* either the lateral or the medial cortical plates of the iliac bone are stripped of periosteum (Figures 4-6, A-E, and 4-7, A-M). A saw with copious irrigation or sharp osteotomes are used to outline and remove a piece of bone. Additional cancellous bone can then be collected, after which the wound is closed in layers.

DVD Images 4-2, A-G

If the patient requires either inferior or superior repositioning of the maxilla, a Le Fort I osteotomy can be performed with simultaneous sinus grafting (DVD Figure 4-2, A-G). For this procedure, the incision is made in the vestibule, and the maxillary osteotomy is performed. The sinus membrane is removed after the maxilla has been downfractured. The bone of the maxilla is removed as necessary for the planned skeletal movements, and a wax pattern of the sinus is made. Corticocancellous blocks are harvested from the posterior or anterior iliac crest. The grafts are carefully trimmed to mortise into the sinus. Implants may be placed to secure the grafts in position. The maxilla then is plated to its planned location.

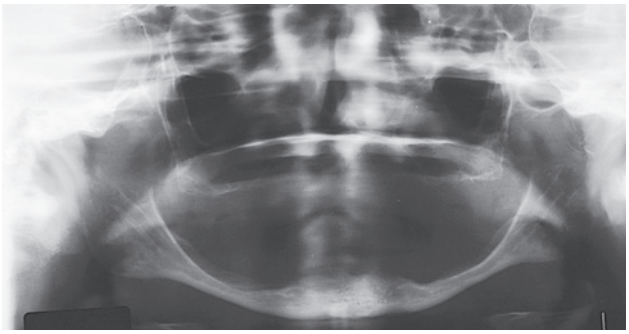


FIGURE 4-6 **A,** Panoramic radiograph showing a patient with less than 2 mm of maxillary bone between the oral cavity and sinuses. The treatment plan calls for harvesting blocks of bone from the iliac crest and simultaneous placement of eight implants.

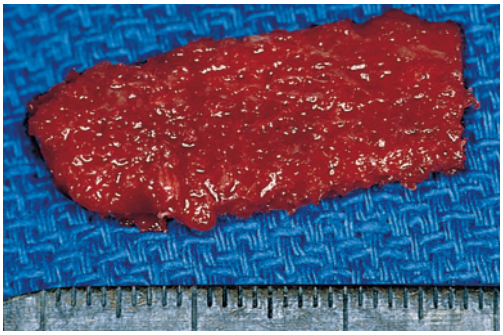


FIGURE 4-6 **B,** Block of cancellous bone is harvested from the hip. The bone is 22 mm long, 10 mm wide, and 10 mm thick.

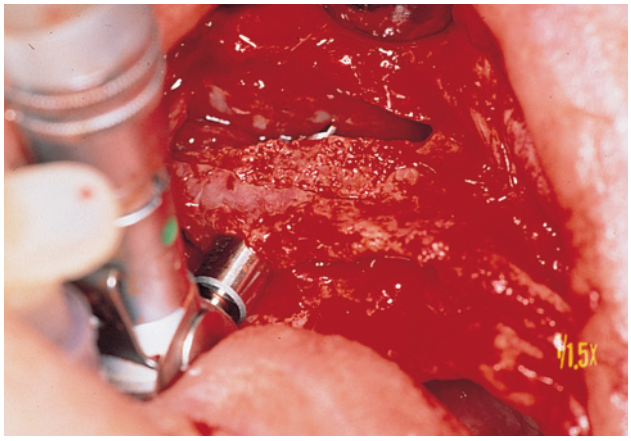
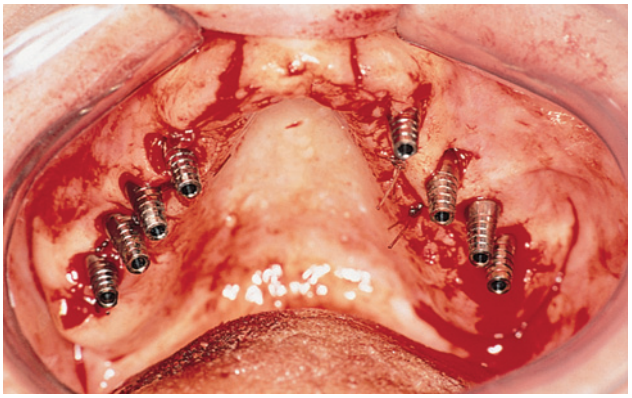


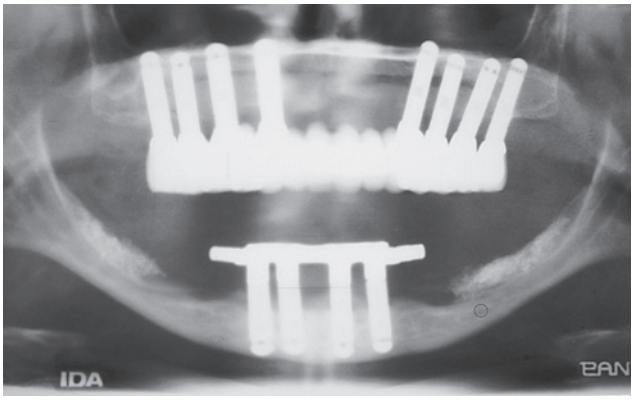
FIGURE 4-6 **C,** After conventional sinus membrane elevations have been performed bilaterally, the blocks of bone are placed onto the floor of the sinus, and the implant sites are prepared through the block of bone. Implants then are placed sequentially to stabilize the bone graft in position. Because the block of bone completely covers the implants coronally, particulate cancellous bone is placed over the implants.

Placement of Bone Graft into the Sinus

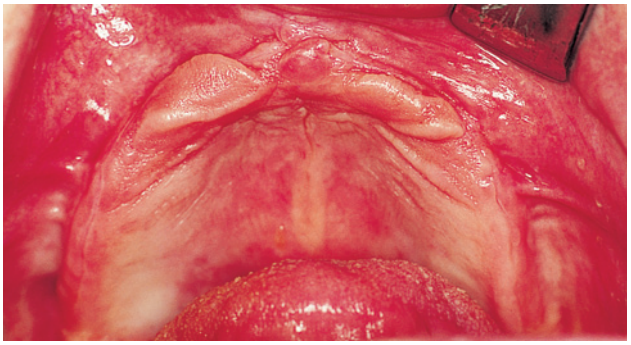
Before performing the surgical procedure involving sinus membrane elevation and grafting, the surgeon must decide whether to place implants at the same time as the sinus graft. Factors that may affect the success of simultaneous implant and graft placement include the thickness of the



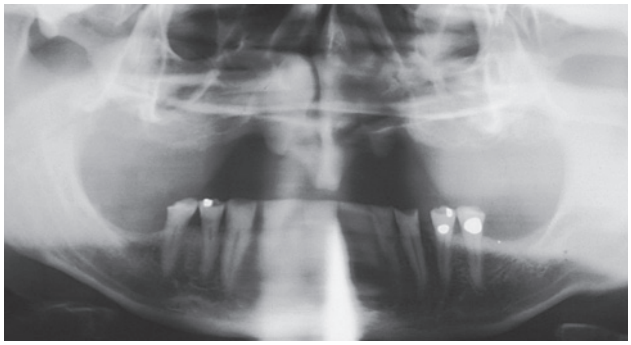
● **FIGURE 4-6** **D,** After 6 months, the implants are exposed and the abutments placed. Note the parallelism of the implants, which allows a single-unit prosthesis to be fabricated.



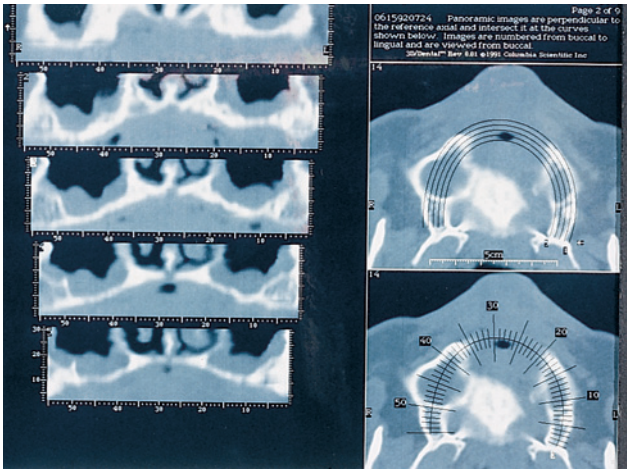
● **FIGURE 4-6** **E,** Panoramic radiograph showing the implants and fixed prosthesis.



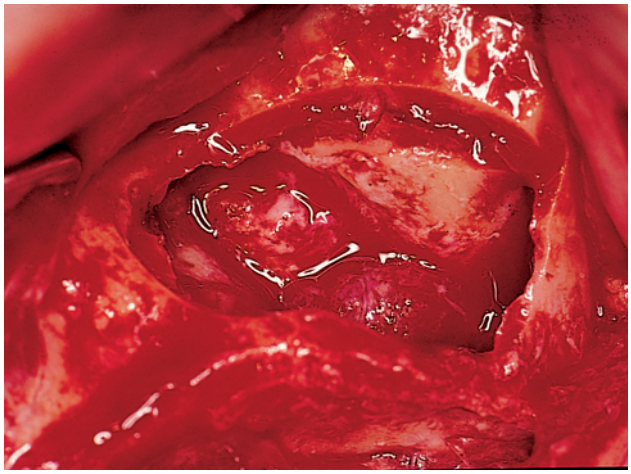
● **FIGURE 4-7** **A,** This 45-year-old man complained of being unable to retain his maxillary prosthesis. Physical examination reveals flabby, loose anterior maxillary tissue and severe resorption of the anterior maxilla. The anterior nasal spines are easily palpable near the residual alveolar ridge.



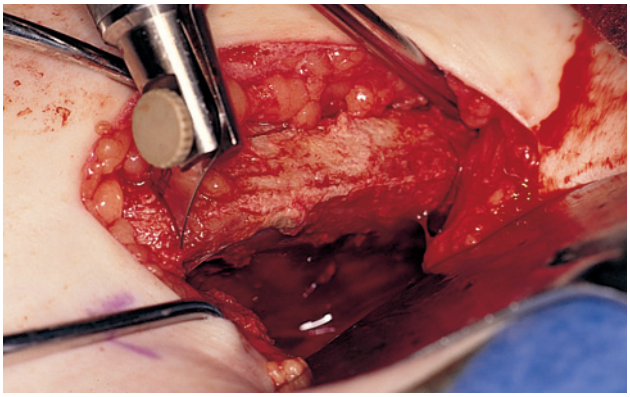
● **FIGURE 4-7** **B,** Panoramic radiograph showing a lack of anterior maxillary bone and minimal bone posteriorly.



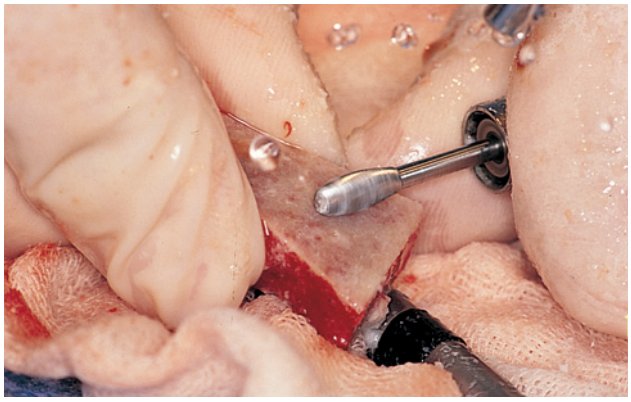
● **FIGURE 4-7** **C,** Reconstructed CT scan showing minimal bone anteriorly and posteriorly.



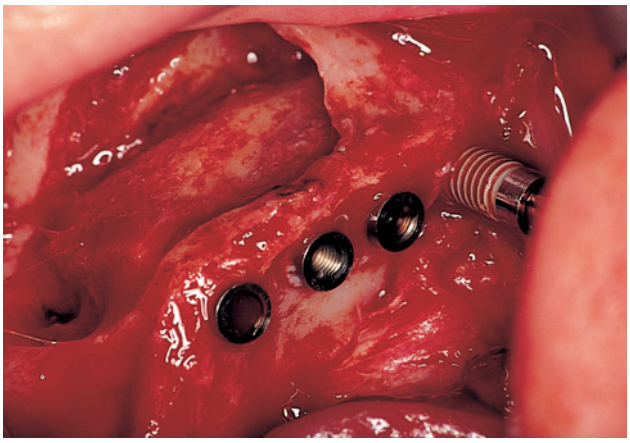
● **FIGURE 4-7** **D,** Treatment plan calls for bilateral sinus grafts with iliac corticocancellous blocks of bone and simultaneous placement of eight endosseous, threaded implants. Elevation of the sinus membrane is shown.



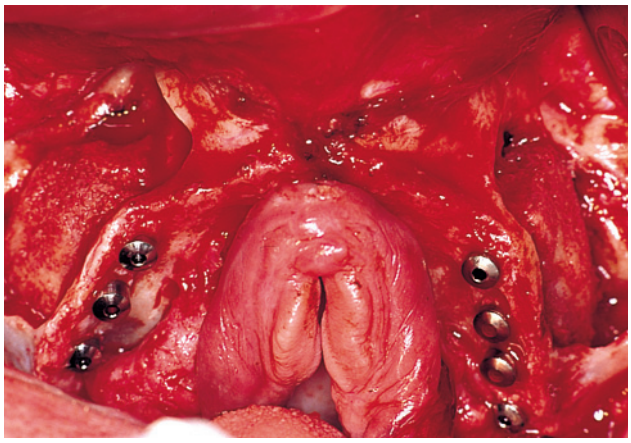
● **FIGURE 4-7** **E,** Iliac crest is exposed. A sagittal saw is used to harvest a block of bone, which will include portions of cortical bone from the crest and lateral cortex. The cancellous bone remains intact on the bone graft. Another cut is made to allow retention of the medial cortical plate of the iliac crest.



● **FIGURE 4-7** **F,** After harvesting, the bone graft is sectioned into two pieces. If it is thick, the cortical bone is thinned to allow rapid revascularization while the structural integrity of the bone is maintained.



● **FIGURE 4-7** **G,** Block of bone is placed into the sinus cavity. As necessary, it is trimmed (often by compressing the marrow without removing it) so that it can be meticulously mortised against the bone of the sinus floor. Implants then are placed to stabilize the graft.



● **FIGURE 4-7** **H,** Completed bilateral sinus grafts with the implants in place. The severe atrophy of the anterior maxilla is shown.

alveolar bone, the status of the sinus membrane, and the type of implant chosen by the restorative dentist.

If alveolar bone is sufficient to stabilize the implants, they can be placed simultaneously with the graft. The Academy of Osseointegration Sinus Consensus Conference data indicate that simultaneous placement of implants has a success rate similar to that of delayed placement of implants.

When the implants are placed at the same time as the graft, the implant sites are prepared after the membrane has been elevated, following the manufacturer's recommendations. After the implant site is prepared, the graft material is placed into the medial aspect of the sinus preparation site, and the implants are placed. Additional graft material is placed between the implants—over the superior aspect of and lateral to the implants—filling in the window.

If implants are not placed at the same time as the graft, the graft material is placed into the sinus preparation site. The graft should fill the sinus vertically to allow for 20% loss of graft volume and the placement of implants 14 mm or longer 6 months after graft placement. The incisions are closed carefully, avoiding excessive tension.

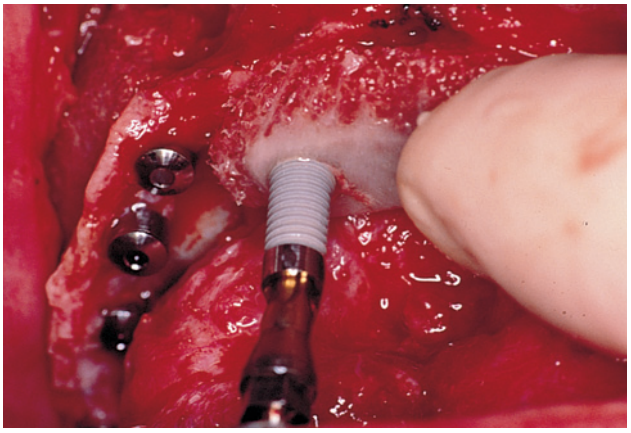


FIGURE 4-7 I, Piece of iliac bone is adapted to fit over the atrophic anterior maxilla and is retained in place with two threaded implants. These implants engage the cortex of the graft and the cortical bone of the residual anterior maxilla.

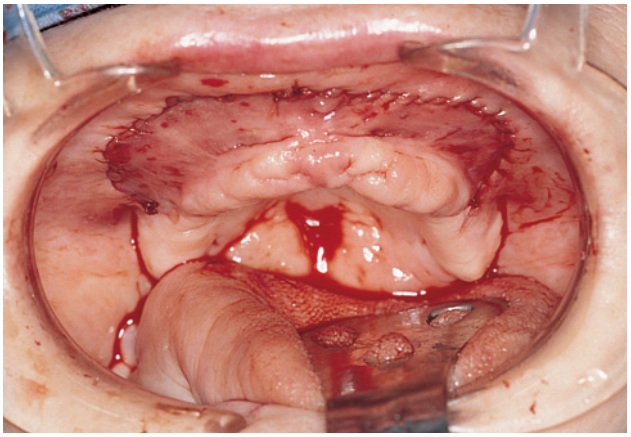


FIGURE 4-7 K, Vestibular Le Fort I incision is closed with resorbable sutures using a tapered needle.

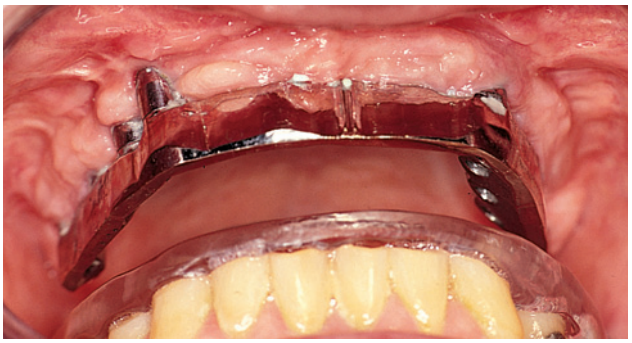


FIGURE 4-7 M, Spark erosion bar is in place. The patient is doing well after 7 years of follow-up. (Prosthetics by Dr. Israel Finger.)

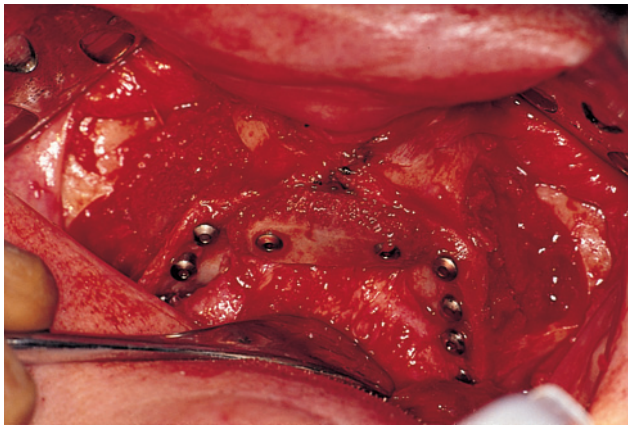


FIGURE 4-7 J, Bone grafts in place, before closure.

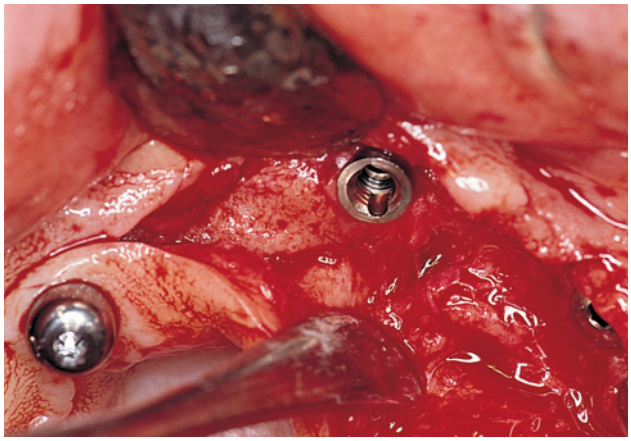


FIGURE 4-7 L, After 6 months of healing, the implants are exposed. The anterior region with integrated implants is well consolidated.

Postoperative antibiotics are recommended, as are decongestants for up to 2 weeks after surgery. Postoperative care should include either delayed use of a maxillary prosthesis or generous relief of the crestal and labial portion of the prosthesis to prevent trauma to the operative site. Nose blowing or other Valsalva's maneuvers are not allowed.

The implants are placed approximately 6 months after the graft and exposed after 4 to 6 months; or, the implants are placed at the time of graft placement and exposed after 6 months of healing.

Bovine Particles Combined with Autogenous Bone and Fibrin Glue

Deproteinized bovine bone (DBB) is an anorganic, pathogen-free bovine bone. It is a carbonate-containing apatite with few hydroxyl groups. It has a crystalline architecture and

calcium phosphate ratio similar to natural bone mineral in humans. Osteoblasts form on the DBB particles in calvarial and femoral bone defects, with greater bone formation than synthetic HA.[49,50] Schmitt et al.[51] showed that DBB promoted greater bone formation in critical-sized calvarial defects than did bioactive glass. Significant bone growth around teeth and endosseous implants and in ridge augmentation has been reported with DBB in animal and human clinical trials.[52-54] When DBB is implanted, the absence of proteins results in minimal immune response in vivo.[55] DBB has been reported to be a satisfactory material for an implanted bone substitute.[56] DBB in the sinus in the dog stimulated new lamellar bone formation and bone apposition on simultaneously placed titanium implants and subsequently was replaced by newly formed bone.[57,58] Yildirim et al.[59] combined DBB and venous blood for use as sinus grafts. After 6.8 months, trephine biopsies were performed. New bone formation equaled 14.7%. The proportion of residual DBB was 29.7%, and 29% of the surface of the DBB was in direct contact with newly formed bone.

This author follows the technique described by Hallman et al.[43-45] The surgical approach is similar to that for other sinus augmentation procedures, using a lateral window approach to raise the sinus membrane (Figure 4-8, A-F). If small perforations are present in the sinus membrane, the membrane is elevated to allow the holes to become partially or completed covered by the folding of the membrane. If the perforation is moderate, a sheet of collagen membrane is placed. The advantage of the technique using

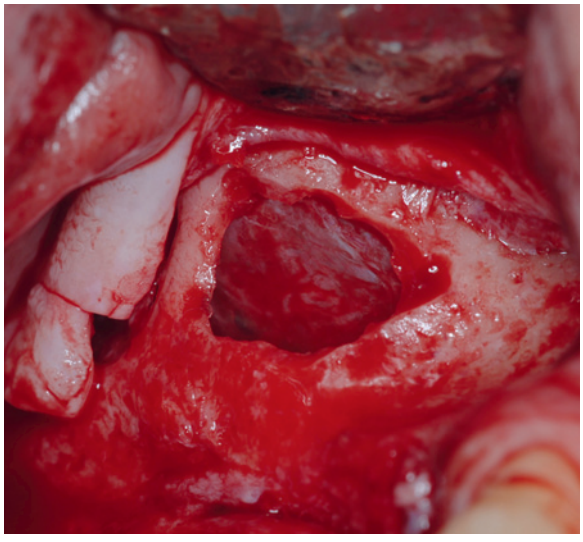


FIGURE 4-8 **A,** Lateral window is created using standard techniques, and the membrane is elevated. Because the bone thickness was less than 3 mm, implants were not placed simultaneously in this site.

FIGURE 4-8 **B,** Autogenous bone is collected from the maxillary tuberosity. It will be combined with the bovine bone particles in this small bowl.

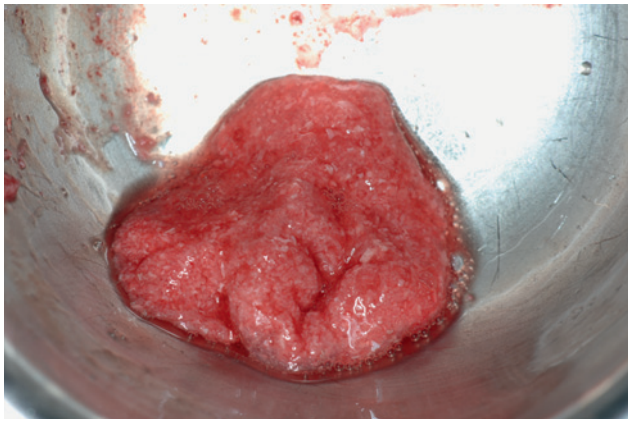


FIGURE 4-8 **C,** Composite graft is mixed with the viscous liquid. The less viscous liquid then is added to the graft mixture. The graft forms a well-congealed, moldable mass.

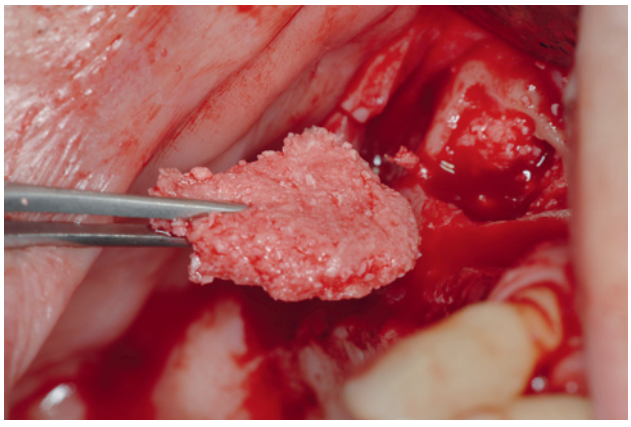


FIGURE 4-8 **D,** Resulting composite is firm enough to be held with pickups while maintaining its form.

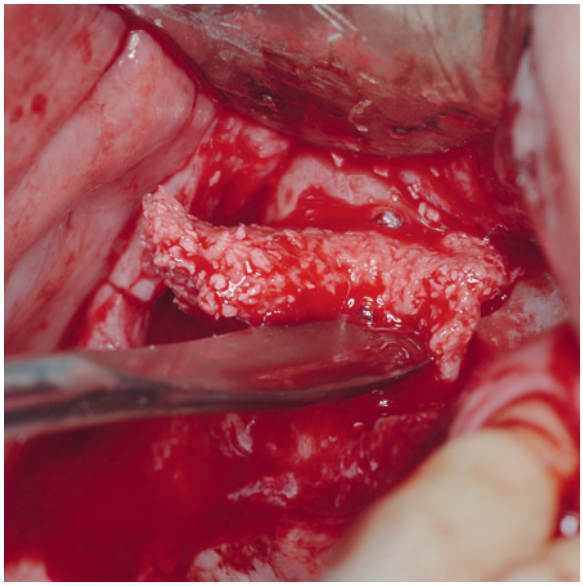


FIGURE 4-8 E, Composite graft is placed into the sinus and compressed against the bone. Usually several pieces are placed to gain graft adaptation to the bone site.

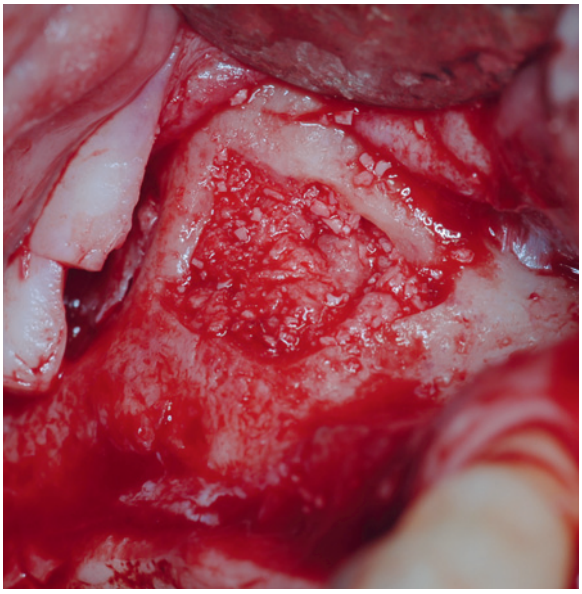


FIGURE 4-8 F, Graft is placed within the lateral window. It also can be placed to augment thin bone.

fibrin glue is that the composite graft is held together by the fibrin for glue for up to 30 days.

The bovine bone is placed into a small container. Autogenous bone usually is collected by using a sieve in the suction line during bone removal to create the lateral window. This author raises the membrane and then prepares the implant sites, as long as 3 mm of bone is present to stabilize the implants. Bone also is collected during the implant site preparation. The collected autogenous bone is placed into the tray or bowl with the bovine bone particles. If necessary, additional autogenous bone can be harvested from the maxillary tuberosity or by shaving the ramus. Collection of additional autogenous bone depends on the size of the sinus graft.

The composite graft particles are thoroughly mixed in the tray or bowl. If necessary, a few drops of sterile saline can be used to wet the bovine bone, but excessive fluid should be avoided. The fibrin glue is prepared according to the manufacturer's recommendations. Usually, a viscous liquid containing the fibrinogen and a less viscous liquid containing the thrombin, calcium chloride, and other agents are used. After warming, the viscous liquid is combined with the composite graft and thoroughly mixed. The less viscous liquid then is added and quickly mixed in. The composite structure congeals within a few seconds. The mass is divided and placed medially within the prepared sinus site. The implants are then placed. The composite graft placed medially most likely will rise upon implant placement and should be pushed inferiorly. The remaining graft then is placed over the implants to the lateral wall. If necessary, the graft composite can be placed over thin regions of the alveolar bone to augment its width. The periosteum is released as necessary and closed without tension using a tapered needle. No membrane is placed over the lateral wall. This author instructs the patient to take antibiotics for 2 weeks and to use nasal decongestants. After 6 months have been allowed for bone formation and implant integration, the implants are exposed for restoration.

Bone Morphogenetic Protein for Sinus Augmentation

BMPs are members of the family of transforming growth factors. Several BMPs have been identified, all with varying degrees of cellular activity, including cartilage- and bone-inductive properties.[60] Two recombinant human (rh) proteins currently are available: rhBMP-2 and rhBMP-7. These products are used as an alternative to autogenous bone grafts in a variety of clinical situations, including spinal fusion, fracture repair, treatment of bone defects, and reconstruction of maxillofacial conditions. Reconstruction in the maxillofacial region includes alveolar ridge augmentation, mandibular reconstruction of continuity defects and large cystic cavities, and maxillary sinus augmentation.[61,62]

Recombinant bone morphogenetic protein administration

The BMP product is packaged as a lyophilized powder in a sterile vial. At surgery, the powder is reconstituted with sterile water and applied to a carrier.

RhBMPs must be delivered to the bone grafting site on a carrier material. *Carrier systems,* which are absorbed over time, maintain the concentration of the rhBMP at the treatment site, provide temporary scaffolding for osteogenesis, and prevent extraneous bone formation by causing the BMP to adhere to the carrier material. Carrier systems have included inorganic materials, synthetic polymers, natural polymers, and bone allografts.[60] Most of the clinical trial data available concern the use of a collagen sponge for augmentation of the maxillary sinus. However, the collagen carrier does not have sufficient mechanical strength to maintain a specific form when it is needed for specially sized defects that do not have borders in all dimensions. For interbody spinal fusion, the BMP delivery system is an interbody fusion cage.[63]

Currently, two rhBMP-associated carrier/delivery systems have been approved by the U.S. Food and Drug Administration (FDA). OP-1 (Stryker Biotech, Hopkinton, Massachusetts) consists of rhBMP-7 and bovine collagen, which is reconstituted with saline to form a paste. The addition of carboxymethylcellulose forms a putty. The InFuse system (Medtronic Sofamor Danek, Boston, Massachusetts) consists of rhBMP-2 on an absorbable bovine type I collagen sponge carrier. The labeled indications (as of May 2005) for these devices are as follows:

1. OP-1 putty is indicated for use as an alternative to autograft in recalcitrant long bone nonunions where use of autograft is not feasible and alternative treatments have failed.
2. OP-1 putty is indicated for use as an alternative to autograft in compromised patients requiring revision of posterolateral (intertransverse) lumbar spinal fusion, for whom autologous bone and bone marrow harvesting are not feasible or are not expected to promote fusion.
3. In conjunction with a lumbar-thoracic cage, lumbar-tapered fusion, the InFuse system is indicated for spinal procedures in skeletally mature patients with degenerative disk disease at one level from the fourth lumbar (L4) to the first sacral (S1) vertebrae.
4. The InFuse system is indicated for the treatment of acute, open fractures of the tibial shaft.

The use of BMP is considered investigational for all other indications, including (but not limited to) the following [63,64]:

1. As an alternative to autograft in compromised patients requiring revision of posterolateral intertransverse lumbar spinal fusion, for whom autologous bone and bone marrow harvesting are not feasible or are not expected to promote fusion (i.e., labeled indication for OP-1).
2. Treatment of spinal fusion or fusion in the thoracic or cervical vertebrae.
3. As an alternative or adjunct to bone grafting in other locations, including craniomaxillofacial surgeries.

RhBMP-2 and BMP-7 are contraindicated for patients with a known hypersensitivity to either of these proteins or to components of the formulation. These proteins are not recommended for use in the area of a resected or existing tumor, in patients who have any active malignancy or who are undergoing treatment for a malignancy, in skeletally immature patients, in pregnant women, or in patients with an active infection at the surgical site.

Antibody formation to rhBMP-2 and its influence on fetal development have not been assessed. The safety and effectiveness of these devices have not been established in nursing mothers. Women of childbearing age should be advised not to become pregnant for 1 year after rhBMP treatment.

Literature review

A few studies have reported on maxillary sinus augmentation using BMPs. Boyne et al.[64] were one of the first groups to augment the maxillary sinus with rhBMP-2 using an absorbable collagen sponge (ACS) in humans. Twelve patients underwent maxillary sinus augmentation, with total doses of rhBMP-2 (Genetics Institute, Cambridge, Massachusetts) ranging from 1.77 to 3.4 mg (mean, 2.89 mg) per patient. Significant bone growth was documented by computed tomography. The overall mean height response for the maxillary sinus floor augmentation was 8.51 mm after 16 weeks (95% confidence interval of 6.07 to 10.95 mm). The most common adverse effects were facial edema, oral erythema, pain, and rhinitis. Eight of 11 patients had adequate bone for placement of dental implants of the desired size after 6 months of healing. However, 11 of the 12 patients received dental implants without additional bone grafting procedures. Core biopsies obtained at placement of dental implants revealed moderate to large amounts of osseous trabecular bone.

Hanisch et al.[65] performed sinus augmentation in four cynomolgus monkeys using rhBMP-2 (0.19 mg/implant) in an ACS. The study provided evidence for considerable vertical bone gain in the subantral space after surgical implantation of rhBMP-2. The newly formed bone in rhBMP-2 and control sites showed a trabecular pattern indistinguishable from residual bone. Polarized light microscopy suggested that the new bone was predominantly lamellar. Bone contact to the titanium implants was similar in newly formed bone and residual bone. A statistically significant difference in mean vertical bone gain was seen between rhBMP-2

(6.0 ± 0.3 mm) and control sites (2.6 ± 0.3 mm; $P < .002$). Cancellous bone density within newly formed bone averaged 14.4% ± 2.9% for rhBMP-2 and 13.9% ± 4.6% for control sites, with no significant differences.

Maxillary sinus augmentation comparing rhBMP-2/ACS (12.5 μg) to iliac crest particulate cancellous bone (control group) with subsequent dental implant placement was performed in 30 rabbits.[66] After 12 weeks of subantral augmentation, titanium dental implants were placed and allowed to integrate for 3 months. Histologic and histometric evidence of bone formation was comparable between the two groups. The mean vertical bone gain was significantly greater in rhBMP-2 sites than in control sites ($P < .002$). Bone density and bone-implant contact in the rhBMP-2 and the control groups were similar. The rhBMP-2–induced bone appeared to be of similar quality and as suitable for osseointegration as the residual bone.

Roldan et al.[67] evaluated the benefit of platelet-rich plasma (PRP) in sinus grafting compared with rhBMP-7 (420 μl) using anorganic bovine bone as an osteoconductive medium in five miniature pigs. The mean bone-implant contact using rhBMP-7 was 45.8% and under PRP was 5.7% ($P = .002$). The mean height of newly mineralized bone in the augmented area using rhBMP-7 was 8.3 mm, compared with 3.6 mm under PRP ($P = .013$). RhBMP-7 led to superior outcomes with regard to the osseointegration of dental implants and the height of new bone compared with PRP. Terheyden et al.[68] performed a similar study, with comparable results.

Margolin et al.[69] evaluated the healing response and bone formation stimulated by three doses of recombinant human osteogenic protein-1 (rhOP-1; 0.25, 0.6, and 2.5 mg/g collagen matrix), natural bone mineral, and collagen matrix alone (control) placed in the maxillary sinus of adult chimpanzees. Sinus augmentation with natural bone mineral or 2.5 mg rhOP-1/g collagen matrix induced comparable radiographic and histologic evidence of bone formation. McAllister et al.[70] showed that 2.5 mg OP-1/g effectively stimulated bone formation in the maxillary sinus in chimpanzees. Van den Bergh et al.[71] used 2.5 mg of rhOP-1 and collagen carrier versus autogenous iliac crest bone grafts in three patients (total of five sinus sites). One patient's core biopsy showed mature, lamellar-type bone. In the second patient, no bone was found. The third patient had bilateral maxillary sinus augmentation, histologically similar to normal bone, and successful implant integration.[72,73]

BMP-2 in an ACS carrier has been evaluated in a Phase 2 and a Phase 3 trial for augmentation of the sinus in preparation for dental implants, as well as for extraction site grafting.[74-76] The Phase 2 trial established that the dosage necessary for sinus augmentation was 12.5 mg of BMP per sinus. Lower doses resulted in bone formation, but it was marginal for implant use.[76] Based on the results of the Phase 2 trial, a multicenter pivotal trial was initiated.

The pivotal trial involved two groups of patients. In one group, BMP was placed alone for sinus augmentation; in the other group, autogenous bone was used as the augmentation material. The sinus grafts all were performed from a lateral window approach, with the bone from the lateral window removed and only the membrane reflected and elevated. The patients were randomized to each group, cores were taken for histologic evaluation, and CT scans were evaluated preoperatively and 6 months after graft placement. Implants were positioned after the graft had been in place for 6 months. Implants were loaded 4 to 6 months after placement. Evaluation of the bone levels and implant success was completed at 2 years after placement.

The results of this pivotal trial are awaiting publication but have been submitted to the FDA for approval. The results were consistent with the use of BMP for orthopedic purposes. Patients who did not respond to BMP in its current recombinant form represented approximately 10% of the sample. After the 10% of nonresponders was taken into consideration, no significant difference was seen in bone formation, implant success, complications (except for harvest site morbidity), and bone levels between the patients with BMP sinus grafts and those with autogenous bone.

Based on the pivotal study using BMP alone for sinus grafting, it is expected that this material will become another viable option for patients who need augmentation of the sinus. The advantages include no harvest site morbidity, ease of use, enhanced soft tissue healing because of the growth factor influence of BMPs, and possible use in patients who are not candidates for autogenous grafts because of systemic problems.

Technique

For the purposes of this discussion, the technique described is that for BMP-2 applied to a resorbable collagen sponge.

4-3, A-F

The procedure for sinus grafts with recombinant BMP-2 is similar to that for other sinus grafts (Figures 4-9 through 4-11; and DVD Figure 4-3, A-F). However, the data available apply only to the use of BMP placed through a lateral maxillary wall window, not through an intraalveolar "socket" approach.

After infiltration of the local anesthetic (typically 1% or 2% lidocaine with 1:100,000 epinephrine) to the maxilla and vestibule, a crestal incision is made, combined with appropriate vertical release to allow a full-thickness, subperiosteal elevation to expose the lateral wall of the maxilla. A round bur is used to create the outline of the window, and the sinus membrane is elevated carefully to

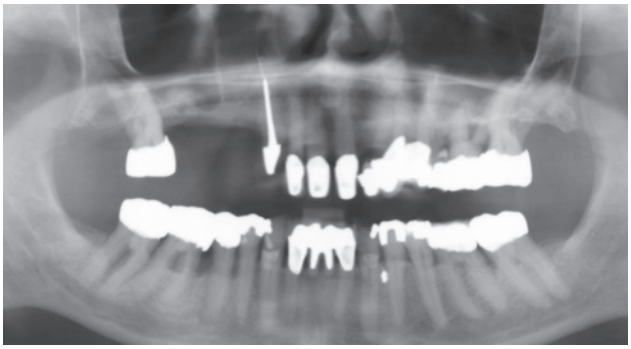


FIGURE 4-9 **A,** Preoperative panoramic radiograph showing an edentulous region in the right maxilla, with less than 4 mm of bone available for implant placement.

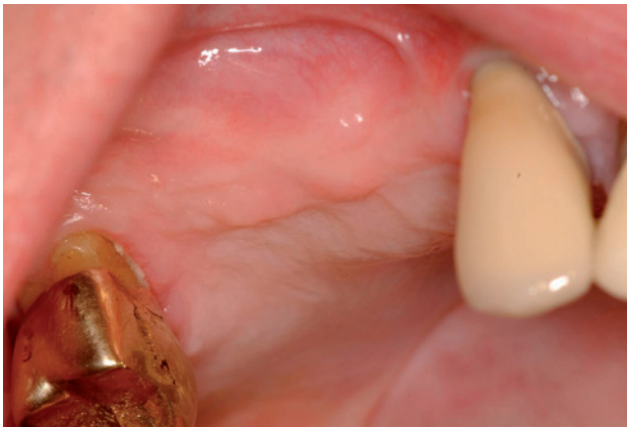


FIGURE 4-9 **B,** Preoperative photograph showing the flat ridge before grafting.

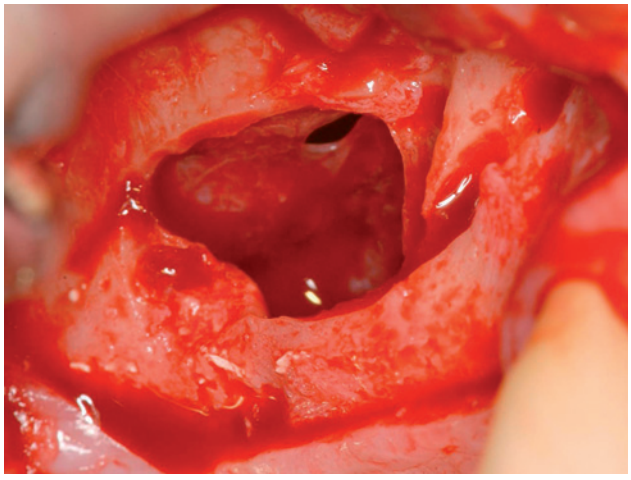


FIGURE 4-9 **C,** Crestal incision is combined with anterior and posterior vertical release incisions to allow exposure of the lateral wall of the maxilla. The lateral wall of the sinus is rotated medially with membrane reflection. A small perforation is present.

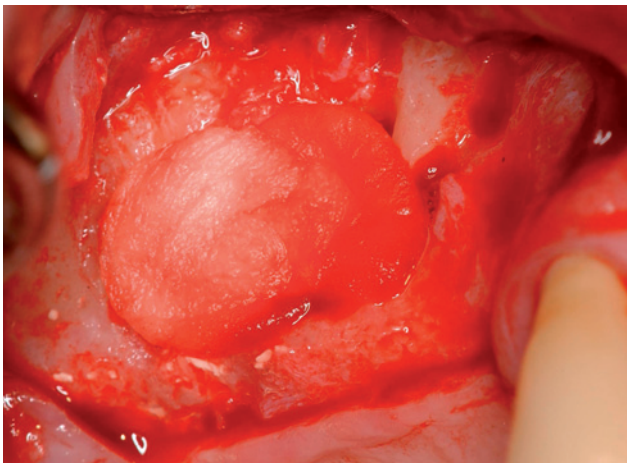


FIGURE 4-9 **D,** Approximately 12 mg of recombinant human bone morphogenetic protein-2 (rhBMP-2) is applied to a collagen sponge (large kit), which is placed into the sinus previously exposed (Figure 4-9, C).

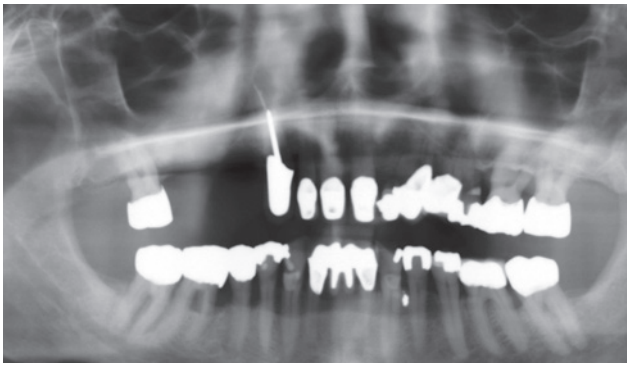


FIGURE 4-9 **E,** After 6 months, bone formation in the sinus is excellent.

prevent or minimize membrane tears. Preserving the lateral wall of the maxilla or maintaining it as the roof of the sinus floor graft is based on the clinician's preference. This author's surgical team does not obturate membrane tears with membranes.

The BMP is supplied as a lyophilized powder in a vial. Based on the size of the BMP to be used, the manufacturer's recommendations are followed meticulously to reconstitute the BMP powder into solution. The resultant solution containing BMP is transferred to a sterile syringe and then applied to the collagen sponge (see Figure 4-10, C-D).

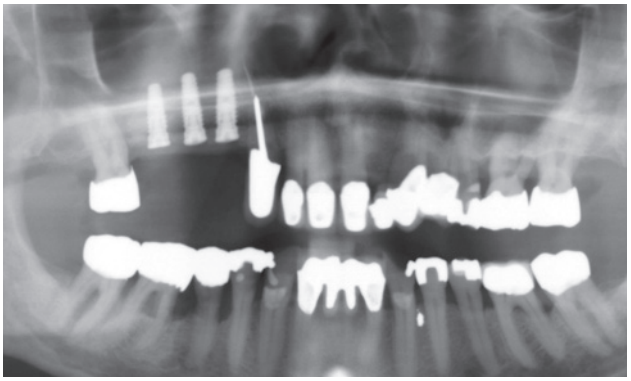


FIGURE 4-9 **F,** Panoramic radiograph taken immediately before exposure of the implants. A three-unit, fixed restoration has been placed. The patient has had 2 years of uncomplicated follow-up.

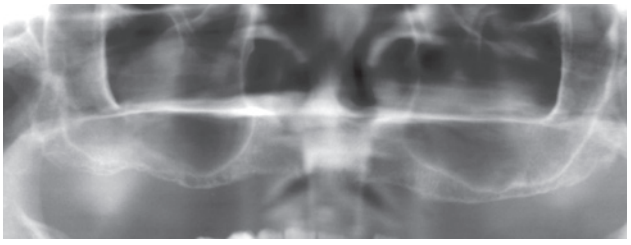


FIGURE 4-10 **A,** This patient wants a fixed restoration in the maxilla. A preoperative panoramic radiograph shows extremely atrophic maxillary bone, with anterior bone available only anterior to the canine locations. The treatment plan includes bilateral anterior sinus grafts in preparation for a CT-generated stent and titanium-milled, hybrid prosthesis using the "Teeth in an Hour" method (Nobel Biocare, Goteborg, Sweden).

In an organized manner, liquid drops are applied to the sponge to distribute the BMP equally. All the liquid is applied, and at least 15 minutes is allowed for the BMP in solution to adhere to the collagen sponge. The sponge then is cut into strips approximately 15 mm wide. The sponge strips are placed into the sinus between the bony floor and the elevated membrane (see Figures 4-9, D; 4-10, E; 4-11, B; and DVD Figure 4-3, D). After placement of the sponge, the surgeon closes the incisions with appropriate suture, typically silk or chromic.

The postoperative instructions are similar to those for any sinus graft, and the patient must be advised not to perform any Valsalva-type maneuvers, such as blowing the nose. Antibiotics are administered for 1 week.

Serial panoramic radiographs are not necessary to evaluate bone formation. A 4-month postoperative panoramic radiograph will show bone formation, in preparation for implant placement 6 months after graft placement.

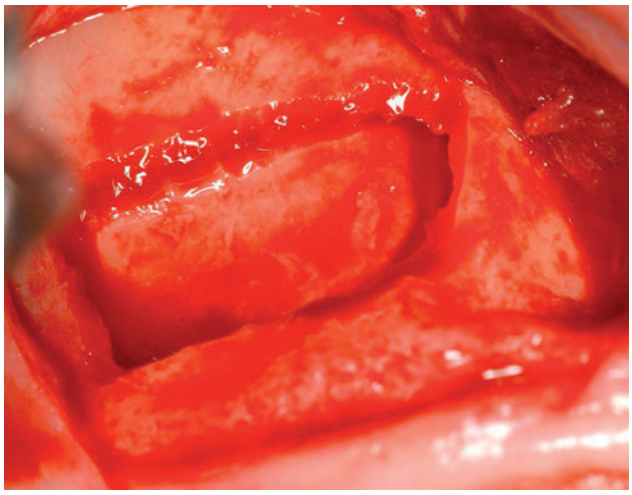


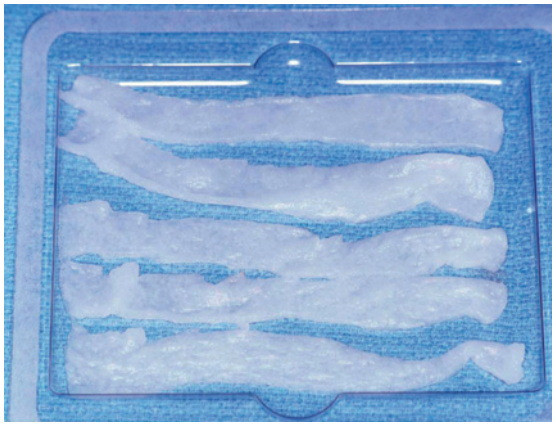
FIGURE 4-10 **B,** Bilateral sinus membrane elevation is performed to allow placement of approximately 7.5 mg of BMP on each side of the maxilla.

FIGURE 4-10 **C,** After the sinus membrane elevations have been completed and the surgeon has verified that the graft will be performed, the BMP is reconstituted and evenly distributed on the collagen sponge (shown here before application of the BMP).

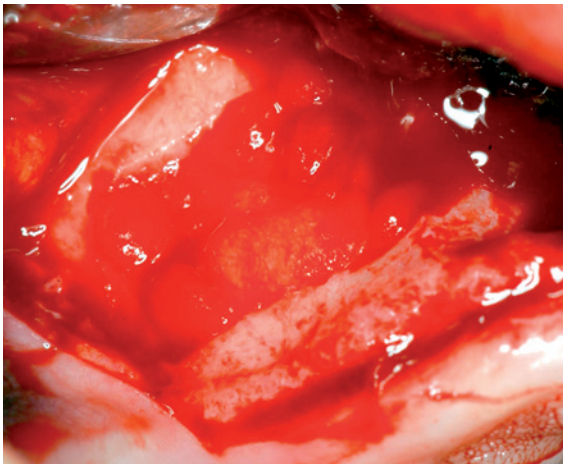
When implants are placed into a sinus grafted with BMP, the bone may feel soft or hard, depending on the density of bone formed by the patient. A period of 4 to 6 months is allowed for implant integration, based on the density of bone felt at the time of implant placement.

Laser-Assisted Surgery for Intraimplant Site Sinus Elevation

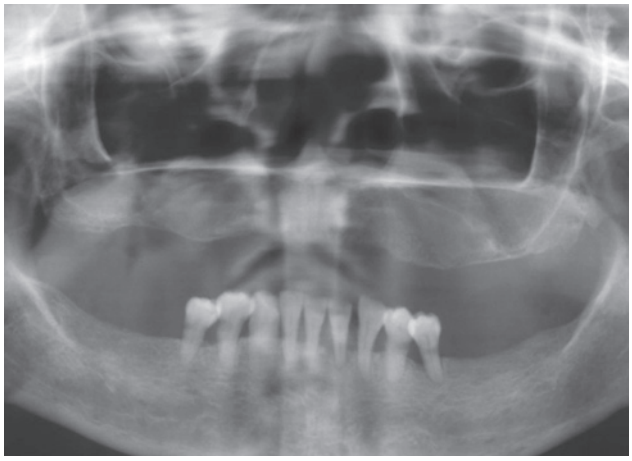
For the patient with approximately 7 mm of vertical bone height in the maxillary molar region, vertical augmentation is best provided by sinus membrane elevation and



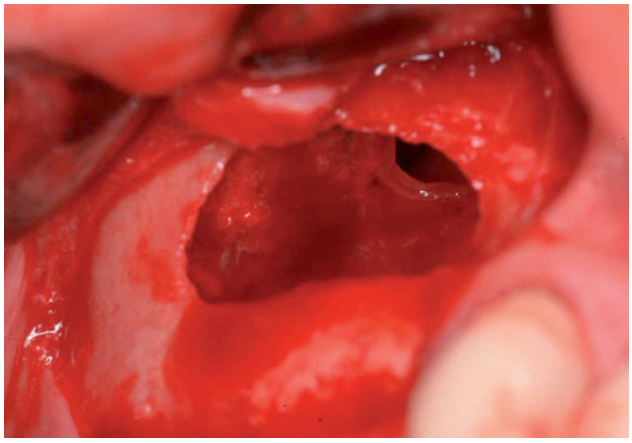
● **FIGURE 4-10** **D,** After the BMP has been placed on the collagen sponge, the sponge is cut into five or six strips to facilitate placement in the sinus membrane elevation sites.



● **FIGURE 4-10** **E,** BMP-impregnated collagen has been placed to graft the sinus.



● **FIGURE 4-10** **F,** Panoramic radiograph taken after 6 months shows excellent bone formation in the sinus. Implants were placed and the maxilla immediately reconstructed with the "Teeth in an Hour" method.



● **FIGURE 4-11** **A,** This 65-year-old woman received treatment planning for sinus grafting in preparation for implant placement and a fixed restoration in the posterior right maxilla. A local anesthetic has been administered, and the sinus membrane has been elevated.

grafting. A lateral window approach provides excellent augmentation but involves intrinsic morbidity. An alternative technique is to elevate the sinus floor from within the implant site preparation. This author's experience using an osteotome-only approach has been mixed; unanticipated floor fracture and less-than-ideal bone augmentation have resulted. A laser-assisted approach (introduced to the author by Dr. Bret Dyer, Houston, Texas) has proved very successful for providing floor elevation with bone adapted to the sinus (Figure 4-12, A-B). The implant site is prepared so that 2 mm of floor thickness remains superior to the prepared site (e.g., the implant site is prepared 5 mm for a 7-mm-thick alveolus). The Biolase laser tip then is used to score the peripheral aspect of the inner core, graft material is placed within the site, and flat-ended osteotomes are used to elevate the floor. Bone is placed into the site, and the implant then is placed; as a result, an implant 10 to 12 mm tall can be placed in a ridge 7 mm tall.

Use of Bone Morphogenetic Protein for Posterior Augmentation with Anterior Teeth

A patient presents with anterior maxillary teeth in good repair except for the left lateral incisor. The posterior premolars and the first molar are missing. The patient

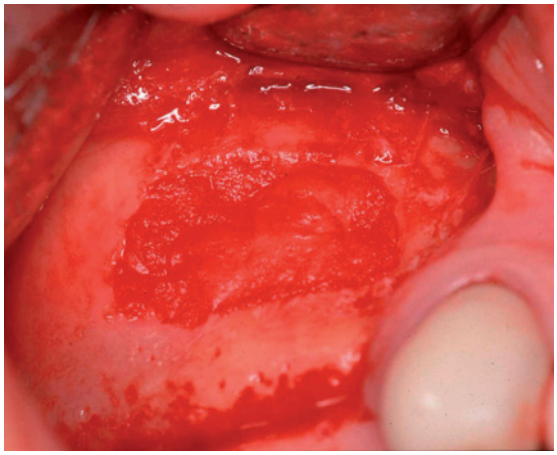


FIGURE 4-11 **B,** As described in Figure 4-9, the BMP-impregnated collagen membrane is placed into this normal-sized sinus; 12 mg of BMP is used. No membranes are used to cover the sinus graft site.

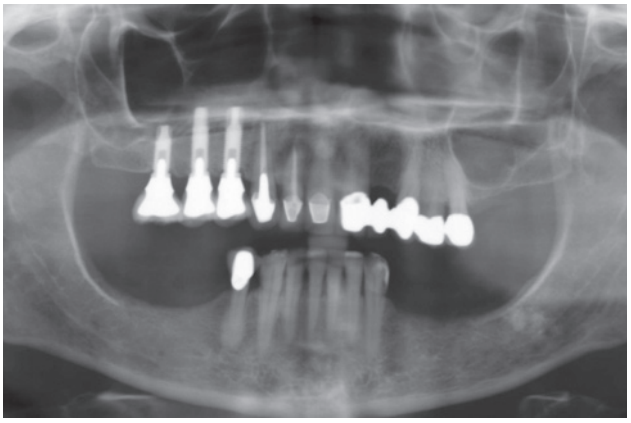


FIGURE 4-11 **D,** Immediate postrestoration panoramic radiograph shows bone formation at the apical portion of the implants.

wants a fixed prosthesis (Figure 4-13, A-T). Her dentist (Dr. Mary Beilman) plans a restoration with single crowns on the anterior maxilla and fixed prosthetics posteriorly based on implants. The problem is deficient bone in the posterior maxilla. This case illustrates the techniques of sinus augmentation using BMP, extraction site grafting with BMP, and implant placement into the formed bone.

After infiltration of a local anesthetic, a crestal incision is made with vertical release incisions anteriorly and posteriorly. The vertical release incisions avoid the attached gingiva of the adjacent teeth. A full-thickness reflection is made, exposing the lateral wall of the maxilla.

A water-cooled laser is used to create the lateral window. The laser settings are 2.5 watts, pulse rate 25 cycles/sec, with

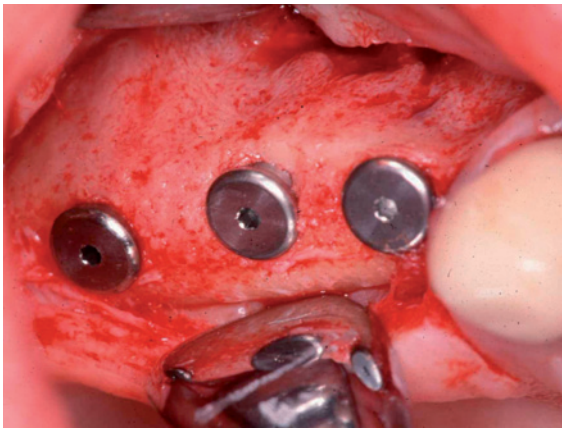


FIGURE 4-11 **C,** Three implants are placed 6 months later. Note the excellent bone formation over the previously made window.

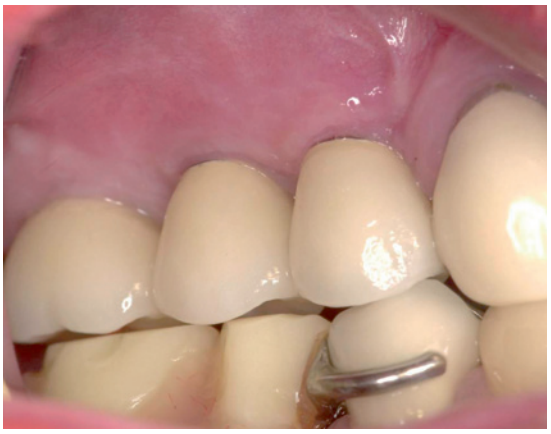


FIGURE 4-11 **E,** Three-year postrestoration photograph shows excellent soft tissue reaction to the implants.

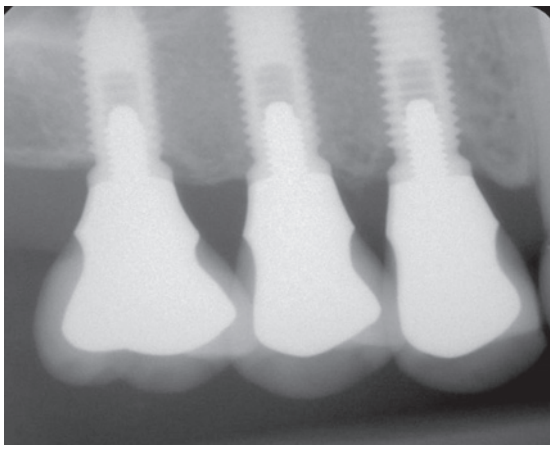
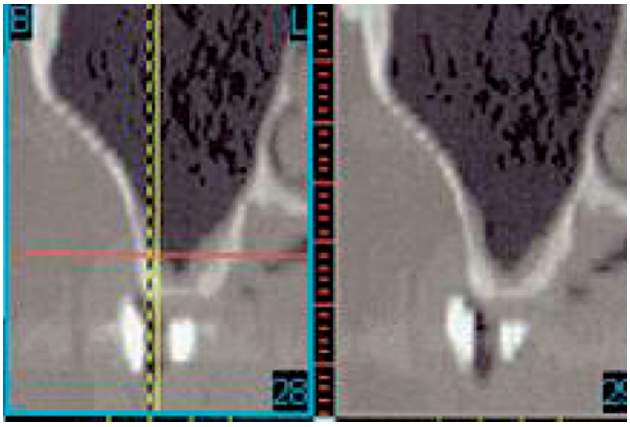
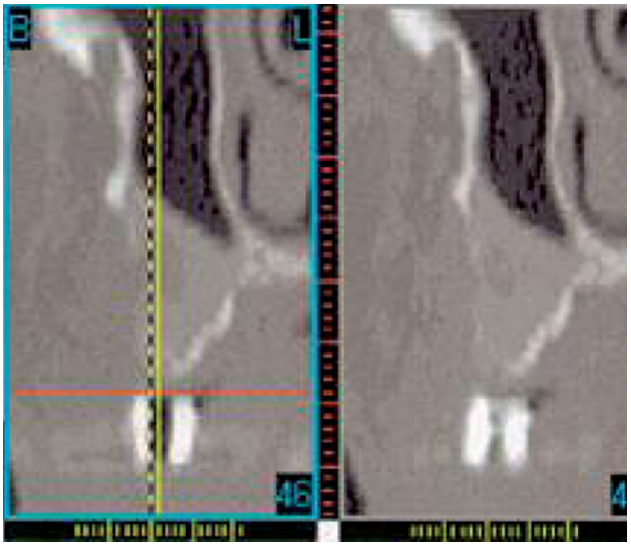


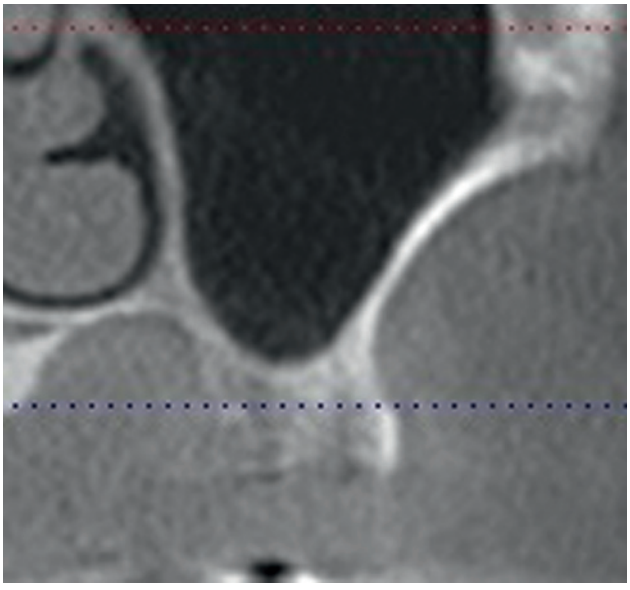
FIGURE 4-11 **F,** Three-year postrestoration radiograph of the implants shows dense bone formation in the grafted sites.



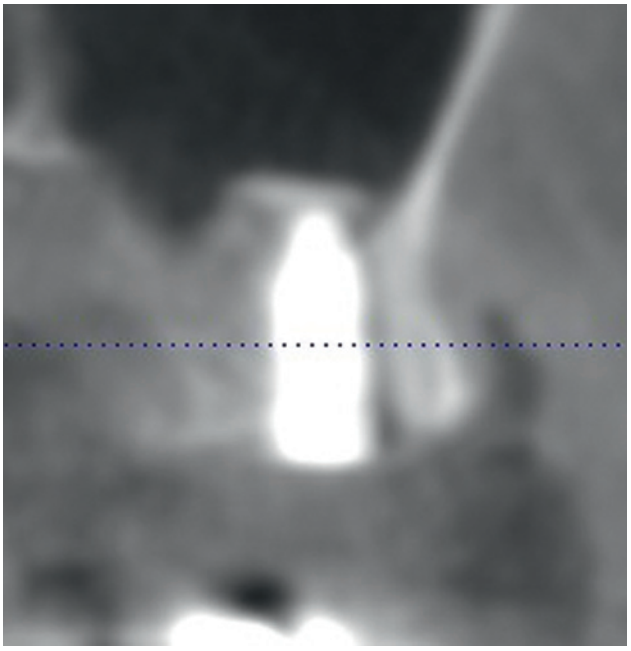
● **FIGURE 4-11** **G,** Preoperative reformatted CT scan in the area to be grafted with BMP.



● **FIGURE 4-11** **H,** Six months after BMP grafting of the sinus, bone formation is seen.



● **FIGURE 4-12** **A,** Preoperative cone beam section of a left second molar site with 7 mm of bone thickness.



● **FIGURE 4-12** **B,** After sinus floor elevation with simultaneous implant placement. Note the flat bone floor elevation and the 12-mm-tall implant, with bone graft around the implant.

20% air and 30% water. After the window has been carefully made, the lateral bone is removed, with care taken to prevent trauma to the membrane. The sinus membrane then is elevated. Placement of the inferior horizontal ostectomy at the level of the maxillary sinus floor allows a relatively easy elevation. Use of the water-cooled laser also aids membrane elevation. After the membrane has been elevated, the BMP is reconstituted. Because it must sit undisturbed for 15 minutes, the BMP is prepared after successful elevation of the membrane with the understanding that the surgeon may need to wait a few minutes before placing it. The opposite side also is prepared.

The laser also is used to create a trough between the gingiva and then between the tooth and bone. The lateral incisor is elevated and removed, and the remaining labial bone is preserved.

After the BMP has been reconstituted onto the collagen, the collagen sponge is cut in approximately 1-cm widths.

Text continues on page 219

Laser-Assisted Intraimplant Site Sinus Elevation Surgery

DVD Video 4-1

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for laser-assisted intraimplant site sinus elevation surgery performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient will have extraction of the left maxillary second premolar and insertion of two dental implants, one in the second premolar site and one in the first molar site. Because the bone height in the molar location is 7 mm, a laser-assisted sinus elevation will be used to place an implant 11.5 mm tall.

After removal of the provisional restoration, a water-cooled laser (Biolase MD, Biolase, Irvine, California) is used to create a trough in the sulcus of the premolar tooth to be extracted. The laser is used to separate the tooth from the bone; this allows atraumatic removal and preservation of the thin labial bone. The laser is used in a slowly deepening path, or it can be used to "punch" holes between the tooth and bone. After the tooth has been mobilized, elevators and forceps are used to remove the fractured tooth.

A probe is used to confirm the presence of the labial bone. The incision is extended on the crest, and a small posterior vertical incision is made to allow reflection of the flap just to expose the lateral and palatal aspects of the posterior maxilla.

A round bur is used to mark the implant site for the molar implant and to initiate the osteotomy along the palatal slope of the extraction site for the premolar implant. The pilot drill then is used to depth for the premolar site and only to a 5-mm depth for the molar site. This preserves 2 mm of bone at the sinus floor. The next series of drills is used to prepare the premolar site to depth and the molar site to 5 mm, maintaining the 2 mm of bone between the implant preparation site and the sinus floor. After each drill is used, the bone within the flutes of the drill is collected for use as a graft. Allograft can be used if necessary, but in this case sufficient autogenous bone was harvested from the drills.

The Biolase long tip is used to score the bone in the apical aspect of the implant site. The tip is placed adjacent to the walls of the osteotomy near the superior aspect of the preparation site. With the laser off, the tip is felt on the floor and then removed approximately 1 mm. With the wattage at 2 to 2.5 and air and water set at 20% to 30%, the bone is scored in a circular motion. Graft material is placed into the implant site, and an osteotome with a flat tip is gently used to elevate the sinus floor to the desired height. Because of the dense bone present in this case, a thread-former is used to a depth of 7 mm. Additional graft material then is placed, and the implant is placed in a routine manner. The cover screw is placed as planned, and the incisions are closed.

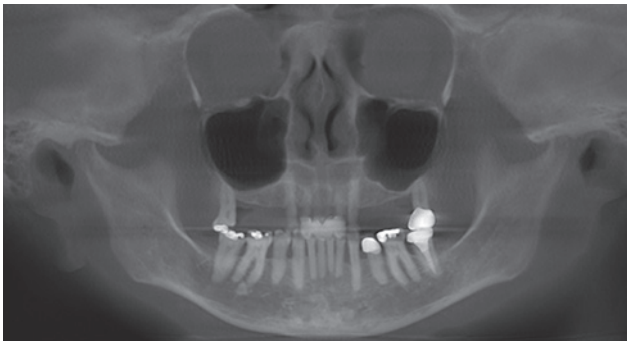


FIGURE 4-13 A, Preoperative panoramic reconstruction from a cone beam CT scan. Note the vertical bone height, which is deficient for posterior dental implants.

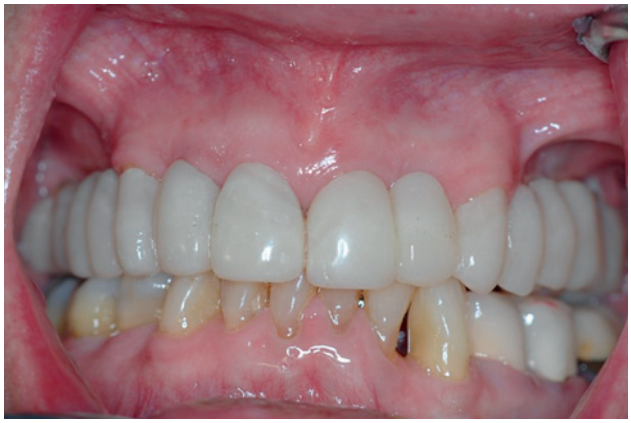
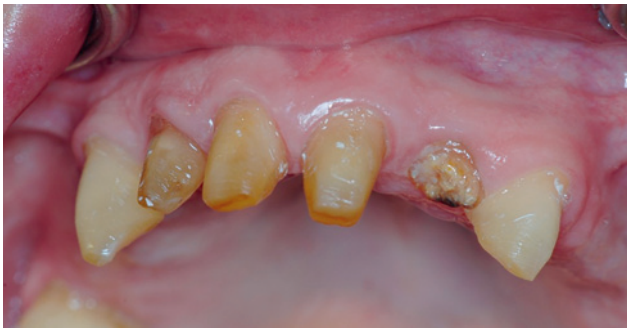
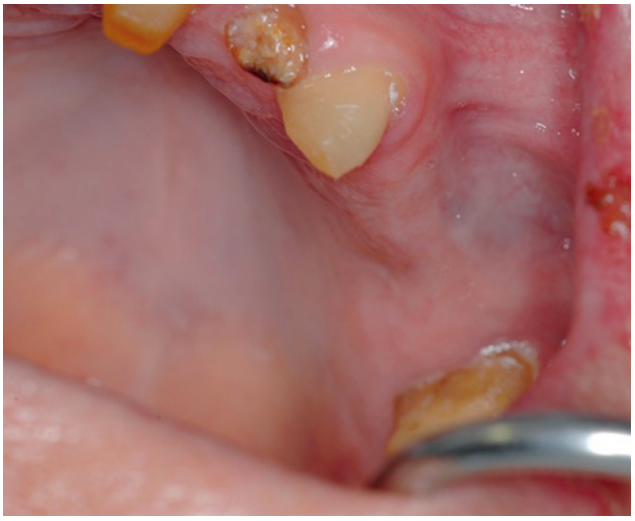


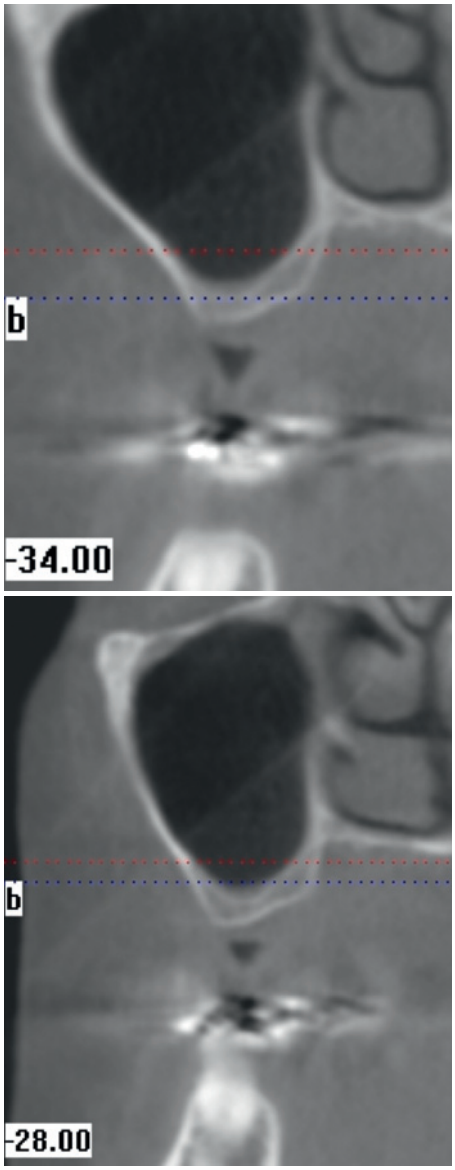
FIGURE 4-13 B, New temporary prosthesis was fabricated by the patient's general dentist (Dr. Mary Beilman). This was cemented to five anterior teeth (6, 7, 8, 9, and 11) and the maxillary second molars bilaterally.



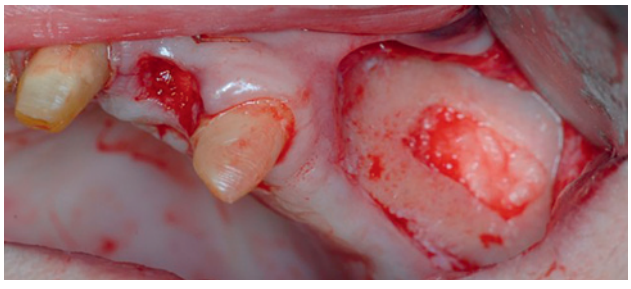
● **FIGURE 4-13** **C,** Anterior dentition was in good repair except for a severely carious and fractured left lateral incisor. The treatment plan called for extraction of the incisor and socket grafting in anticipation of an implant in the future.



● **FIGURE 4-13** **D-E,** Posterior edentulous regions show healthy, wide ridges with sufficient space for three implants.



● **FIGURE 4-13** **F-G,** Cross-sectional views of the posterior maxilla show less than 2 mm of bone thickness in the second premolar and molar regions.



● **FIGURE 4-13** **H,** Grafts composed of rhBMP-2 and collagen sponge in the extraction site of the left lateral incisor and in the left sinus.

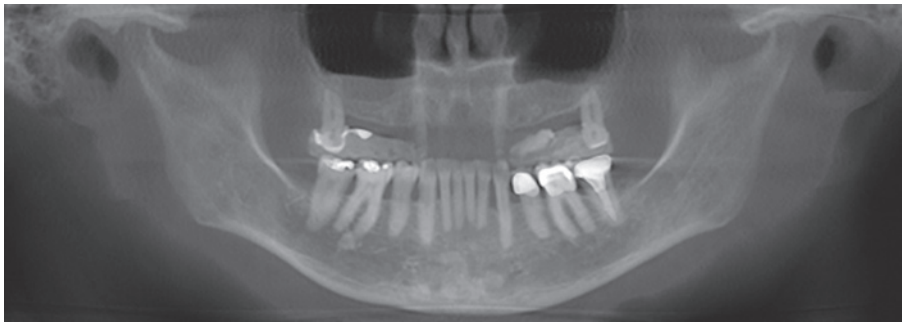


FIGURE 4-13 **I,** At 4 months, panoramic image from the cone beam scanner shows excellent bone formation in the sinuses.

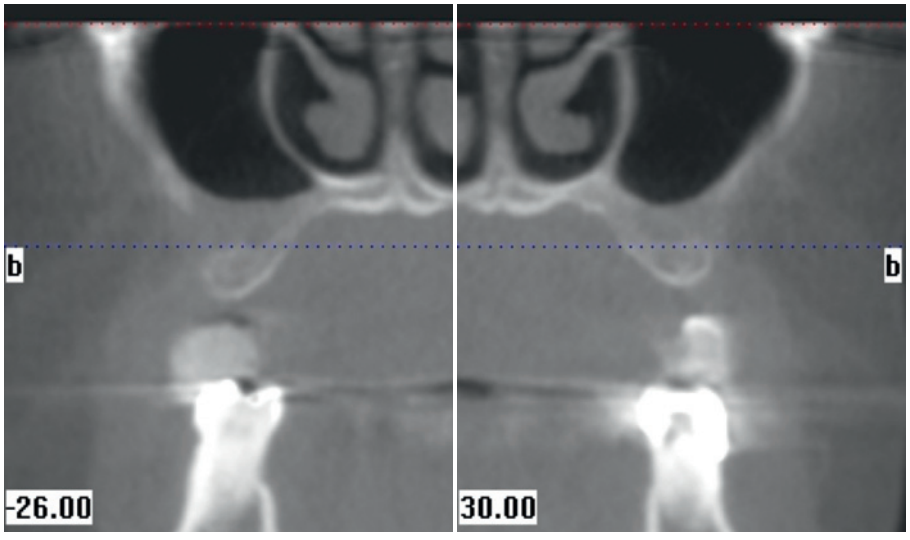


FIGURE 4-13 **J-K,** Cross sections 4 months after grafting show sufficient bone formation for implants 10 and 11.5 mm long.

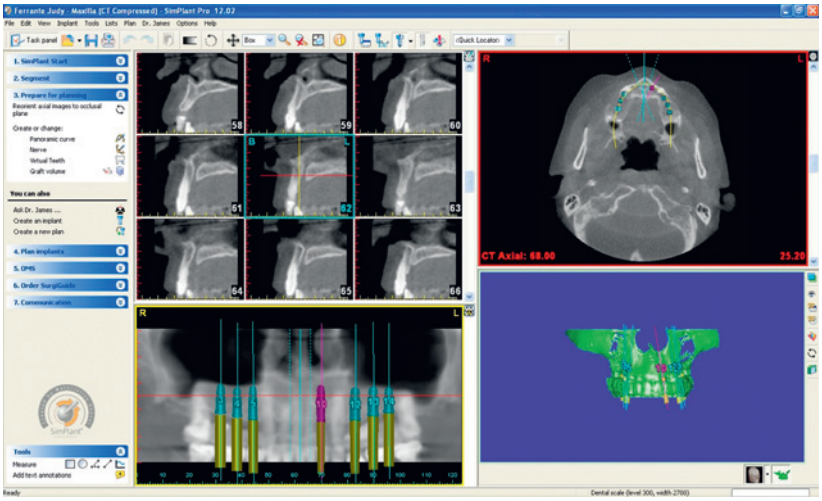


FIGURE 4-13 L, DICOM data are used by the CT planning software (Simplant Pro 12.02, Materialise, Brussels, Belgium) to plan the implant surgery.

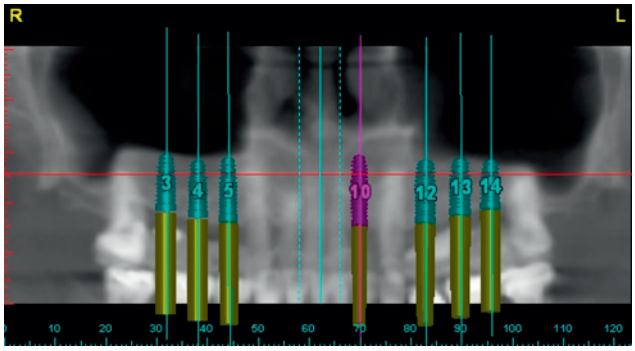


FIGURE 4-13 M, Virtual panoramic image shows the placement of seven implants. The implant's length is establish using planning software to ensure that the optimal lengths are used. This also confirms that three implants can be positioned with sufficient interimplant space.

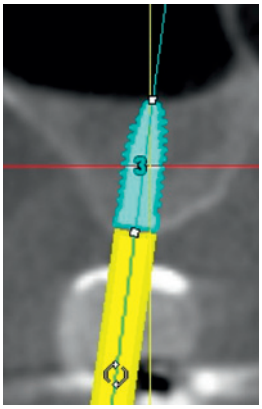


FIGURE 4-13 N, Cross section of one of the implants placed in the planning software. Note that this implant, which is 4 mm in diameter, tapered, and 11.5 mm long, engages the entire vertical height of the alveolar bone.

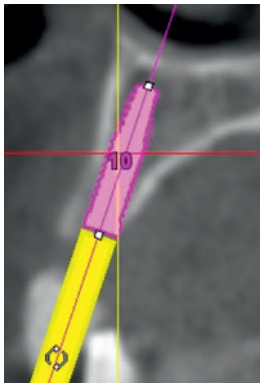
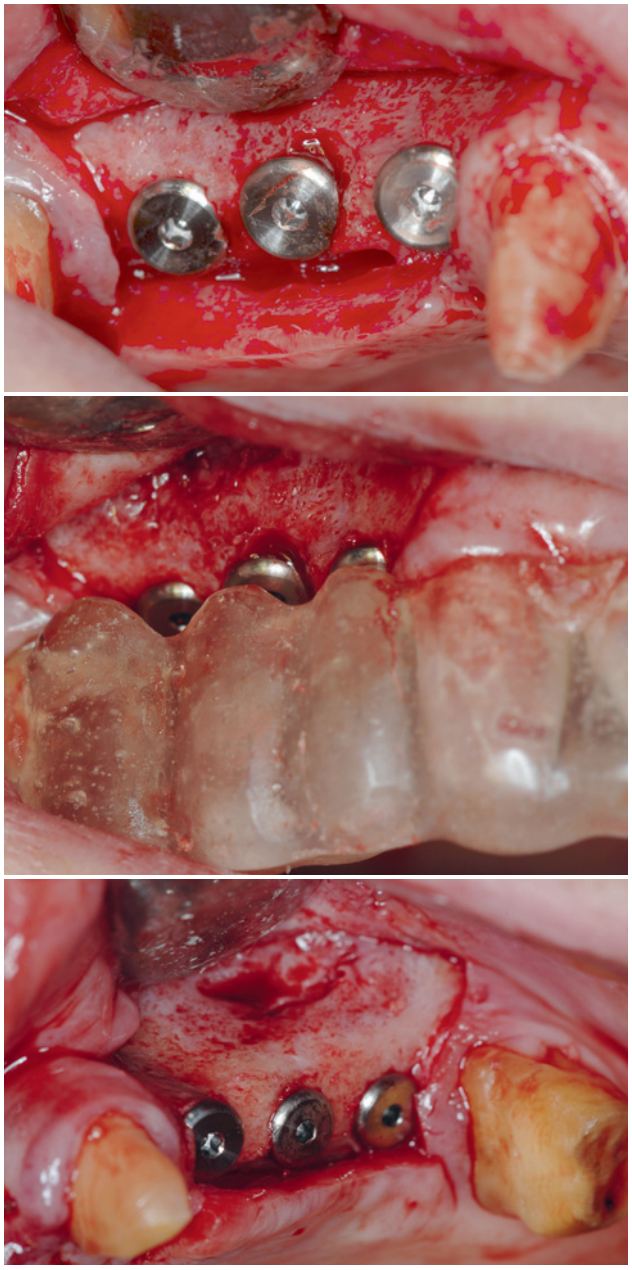
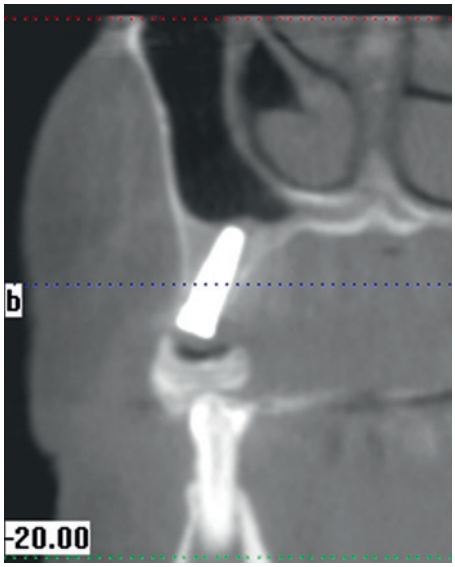


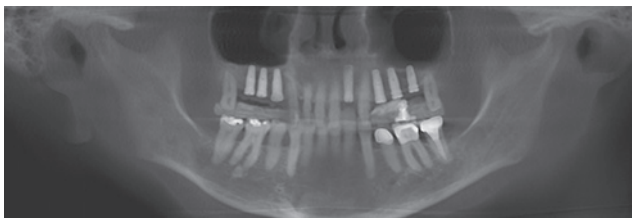
FIGURE 4-13 O, Implant planned for the lateral incisor position. Note the bone density on the labial aspect, the result of the BMP socket graft.



● **FIGURE 4-13** **P-R,** Implants were placed with the use of a stent that was fabricated by the restorative dentist as planned.



● **FIGURE 4-13** **S,** Cross section from the postoperative cone beam scan shows implant positioned as planned.



● **FIGURE 4-13** **T,** Postoperative panoramic image shows the position of the seven implants placed into BMP-formed bone.

Each piece is placed into the sinus site. If blood engages the collagen, the incidence of bone formation is very high. If the sinus site is extremely dry and has minimal bleeding, the incidence of bone formation is lower.

A small piece of the BMP-impregnated sponge is placed into the extraction site. The site then is partially closed with a horizontal mattress suture without elevation of the gingiva. The incisions at the sinus graft sites are closed without tension.

Implant placement

After 6 months have been allowed for bone formation and consolidation, implants are placed in a routine manner. The following are a few observations the surgeon will make:

- Unlike with autogenous grafts, the lateral window often is not completely covered with bone. However, the graft is well formed and dense to drilling.
- The pilot drill is used until lack of resistance occurs, with the surgeon noting the depth according to the drill markings. This confirms the length of the implant to be used in this site.
- After placement of the implants, radiofrequency readings typically are in the mid-60s rather than the high 70s. This probably reflects the remodeling of the bone matrix and ongoing calcification. This is consistent with the results from the FDA trial, which showed an ongoing increase in bone density between 6 and 12 months after BMP graft placement.
- This author waits 4 to 6 months before exposing the implants, depending on the radiofrequency values and the density of bone at placement.

Sinus Augmentation Using Bovine Morphogenetic Protein and Laser Assistance

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for sinus augmentation using bovine morphogenetic protein and laser assistance performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient is to have bilateral sinus augmentation with bone morphogenetic protein (BMP) in a resorbable collagen sponge. The window will be created with a laser, and the left lateral incisor will be extracted, followed by socket grafting with BMP.

After a local anesthetic has been infiltrated to the maxilla, a crestal incision is made combined with vertical release incisions to allow exposure of the lateral walls of the maxilla. A Biolase laser with a medium-length tip is used on moderate power settings, a relatively low pulse rate for bone removal, and air and water settings at 20% to 30%. This allows for minimal laser penetrance, yet the air and water remove the bone material and prevent inadvertent membrane tears. The water and air actually aid membrane elevation.

The laser is used to score the window. With the laser off, the tip can be gently used to determine bone removal. The laser is used in a linear motion to remove bone in small thicknesses along a line. After the ostectomy, the lateral window can be removed or elevated with the membrane. Here, it is removed.

Sinus elevation instruments then are used to elevate the membrane from the sinus. It is easily elevated in this patient, because the horizontal osteotomy is performed close to the floor of the sinus, and the water used with the laser aids membrane elevation. After the membrane has been elevated, its movement can be seen to correspond to the patient's breathing.

For removal of the lateral incisor, the Biolase is used at similar settings to trough around the neck of the tooth and separate the tooth from the bone. The lateral incisor is removed with the aid of elevation and forceps.

After the sinus membrane has been elevated, the BMP powder is dissolved in the supplied water and spread over the collagen sponge. Fifteen minutes is allowed for bonding of the BMP to the collagen sponge. The collagen sponge then is cut into strips and placed into the sinus with the membrane elevated from the floor. The BMP-impregnated sponge pieces are placed and gently compacted into the anterior and posterior recesses or wherever the augmentation is needed.

A small piece of the collagen sponge with BMP is placed firmly into the extraction site to form bone in the socket, which had labial bone loss. The incisions are closed with sutures in a tension-free manner.

Placement of Implants into Augmented Sites 6 Months After Grafting with Bone Morphogenetic Protein

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for the placement of implants into augmented sites 6 months after grafting with bone morphogenetic protein performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

A crestal incision is made combined with sulcular incisions around the adjacent teeth, and a full-thickness envelope flap is elevated. The periosteal elevator (e.g., Hirschfeld #20) is positioned with the bevel toward the bone, and care is taken to prevent trauma to the gingival margins.

A drill guide is placed to provide information about the position of the planned incisor edge and the facial gingival margin. A pilot drill is used, and a parallel pin is placed to allow careful evaluation of the planned implant site. The tapered drill then is used to establish the final-sized hole for the implant. Because the crestal bone is dense, a thread-former is used to allow complete seating of the implant. The cover screw is placed, and the incisions are closed with 4-0 chromic suture on a short half-circle (SH) needle. Vertical mattress–type suturing is used to evert the papilla.

A crestal incision is then made on the right side of the maxilla with vertical release incisions. The crest is exposed, and the sinus window is seen with approximately 1 mm of soft tissue on its outermost region; bone hard material is present in the grafted regions. A guide stent is used to locate the implant sites. Small adjustments are made to place the implant in the center of the crest of bone. The drilling sequence for the tapered implants is followed. Implants 4 mm in diameter are placed and spaced according to the surgical guide stent (fabricated by Dr. Mary Beilman). The implant stability quotient (ISQ) value is found to be 70 for each implant, and the cover screws are placed.

An incision is made on the crest on the left quadrant with vertical release incisions. A full-thickness flap is elevated. The surgical guide stent is used to create three holes, all exactly in the center of the crest. Because of the limited interocclusal space, the drill is placed into the guide stent out of the mouth and then placed over the teeth to allow the surgeon to use the stent to mark the planned implant sites.

The drilling sequence includes a pilot drill and two tapered drills, each of the appropriate length for the implant length. The implants are placed level with the crestal bone. The radiofrequency smart peg is placed into each implant to determine the ISQ index. Bone from the drills is used to graft thin bone over the anterior implant. The incisions are closed, and the patient's provisional full-arch restoration is cemented.

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Chapter 5

Zygomaticus Implants and Angled Implants for the Edentulous Maxilla

Chapter Outline

Placement of Zygomaticus Implants Combined with Anterior Implants

General Considerations

Examination of the patient with a totally edentulous maxilla may reveal a lack of adequate bone in the posterior maxilla for the placement of standard endosseous implants. These patients may desire an implant-borne, full-arch maxillary restoration without grafting of the sinus. Bone grafting can be avoided by using placement of a longer implant, the *zygomaticus fixture,* as an alterative method. The zygomaticus implant is a threaded titanium implant that is 3.75 mm in diameter, graduating in size to 4 mm. It is available in lengths up to 55 mm.

Branemark has reported the use of the zygomaticus fixture with follow-up of function for 10 years in a small number of patients; follow-up of function has been reported in larger numbers for 5 years. The patient population treated by Branemark includes those with totally edentulous, intact maxillae and those who have undergone maxillectomies after tumor resection. The reported success rate is greater than 96%.[1-3]

The recommended protocol includes placement of two zygomaticus implants—one on each side of the maxilla—in combination with two to four anteriorly placed, standard-length endosseous implants (Figure 5-1; also DVD Figure 5-1, A-B, which shows text Figure 5-1 along with a diagram of the intended location of the zygomaticus implants). After 6 months has been allowed for integration of the zygomaticus fixture to the zygomatic bone, the restoration is completed with the fabrication of a rigid bar connecting the two zygomaticus implants to the anterior implants. Rigid cross-arch stabilization is the key to the success of this system. The final prosthesis is an implant-supported, full-arch fixed prosthesis or a fixed-removable prosthesis.

The advantages of the zygomaticus implants are that (1) they eliminate the need for a sinus bone grafting procedure, (2) they eliminate the morbidity of harvesting bone from the iliac crest or the tibia, and (3) fewer implants are required than with the conventional eight implant–borne maxillary restoration.

The disadvantages of this longer implant are (1) the need for deep sedation or general anesthesia for placement

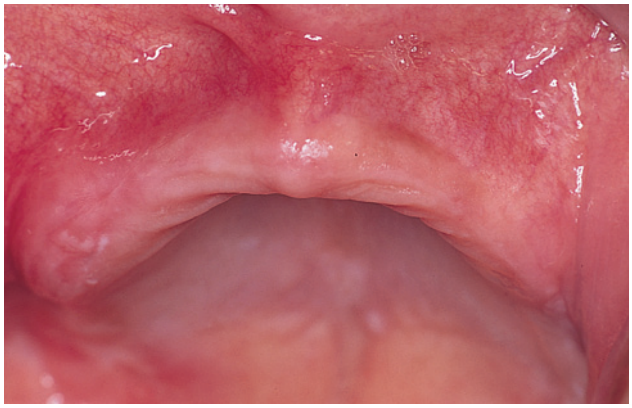


FIGURE 5-1 Preoperative view of edentulous maxilla.

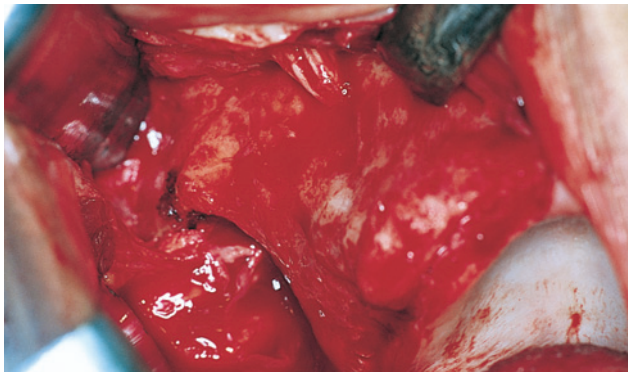


FIGURE 5-2 Incision is made slightly palatal to the crest, and a full-thickness reflection is performed to expose the lateral aspect of the maxilla, orbital rim, superior and medial aspects of the zygoma, and zygomatic arch.

of the prosthesis and (2) the lack of stability if one of the zygomaticus implants fails.

As the 10-year, 95% success rate data from Sweden are confirmed by other clinicians, this implant technique may eliminate the need for sinus augmentation procedures for the patient with an edentulous maxilla.

Preoperative Workup

The patient must have satisfactory health to undergo deep sedation or general anesthesia. The patient also must have sufficient anterior bone for the placement of two to four anterior implants to stabilize the restoration. Preoperative radiographs should reveal a healthy maxillary sinus without polyps or other significant pathologic conditions. Axial and reconstructed computed tomography (CT) scans should indicate 8 to 12 mm of bone in the zygomas, as well as appropriate morphologic bone structure to allow placement of the zygomaticus implants within the confines of the lateral aspect of the maxilla. A consultation with the restorative dentist should confirm that immediate fabrication of a temporary cross-arch bar will be possible at the time of exposure, ensuring the stabilization of the maxillary implants.

Surgical Procedure

As mentioned, the patient may have either general anesthesia or deep sedation for this surgery. The incision is made and released to allow the subperiosteal reflection to extend over the superior aspect of the zygoma (Figure 5-2; and DVD Figure 5-2, A-B, which shows text Figure 5-2 along with a diagram of the extent of dissection). The incision can be made in the vestibule, directly over the alveolar crest, or slightly palatal to the crest. This author prefers the incision to be slightly palatal to the crest. The incision extends from the second molar region to the midline with a vertical release in the midline of the maxilla. One side of the maxilla is operated on first; the contralateral dissection then is performed.

DVD Images 5-2, A-B

After the incision has been made, a full-thickness mucoperiosteal flap is elevated. Occasionally, a posterior release incision is necessary. The subperiosteal reflection is performed to expose bilaterally the following:

1. Piriform rim
2. Infraorbital nerve and foramen
3. Lateral and inferior aspect of the orbital rim
4. Anterior portion of the zygomatic arch
5. Medial aspect of the zygoma
6. Superior aspect of the zygoma

After exposure of the lateral aspect of the maxillary bone, the palatal mucosa is elevated from the first molar to the incisive canal region for placement of the implants. An instrument is aligned from the palate to the zygoma to approximate the planned path of the zygomaticus implant. This path enables the surgeon to locate the proposed implant site and perform the sinus membrane elevation (Figure 5-3).

This author uses a round bur to prepare the site for the maxillary sinus membrane elevation. A rectangular piece of bone, approximately 8 × 20 mm, is carefully removed while the integrity of the underlying sinus membrane is maintained. The sinus membrane is elevated from the inner aspect of the maxillary sinus to allow direct visualization of the entry of the zygomaticus drills, to place the implant into the zygoma, and to prevent membrane entrapment between the implant and bone (Figures 5-4 and 5-5).

After the membrane has been elevated, the long round bur is used. The drill is angled to place the entry point in the maxilla within the crest of the alveolus, often palatal to the crest (Figure 5-6). The drill should enter the maxillary sinus and engage the inner aspect of the zygoma. The drill should be completely within the confines of the lateral wall of the maxilla. The round bur is used to create a purchase point for the next drill.

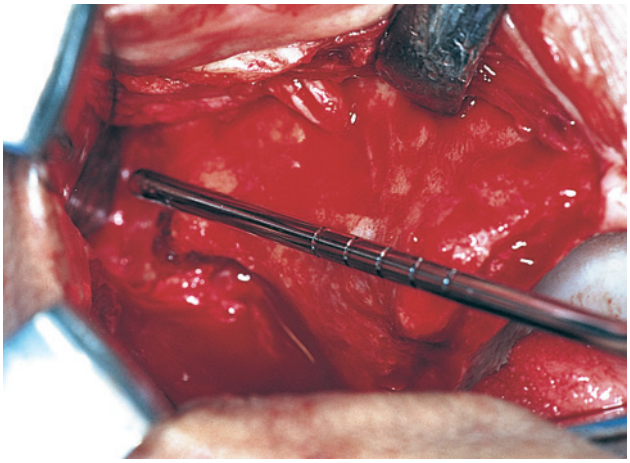


FIGURE 5-3 Depth gauge from the zygomaticus instrument set is aligned over the planned path of the zygomaticus implant to give the surgeon direct visualization of the location for the sinus window.

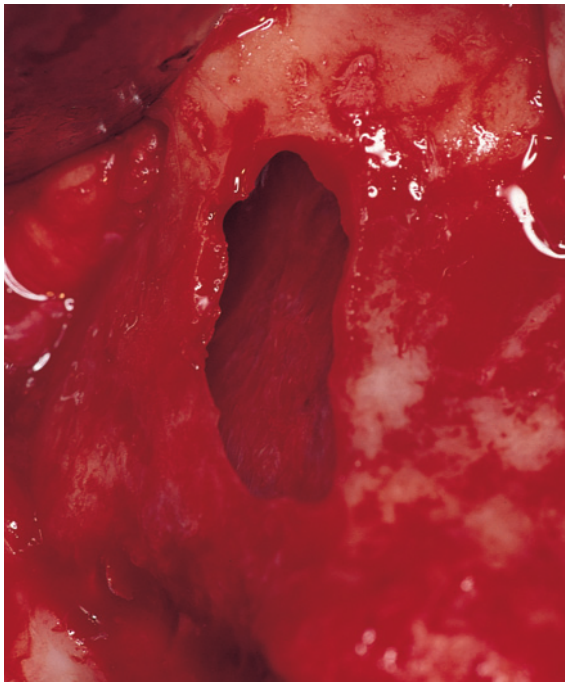


FIGURE 5-5 Sinus membrane is elevated from the bone and allowed to retract into the sinus. The elevation should allow direct visualization of the inner aspect of the zygoma.

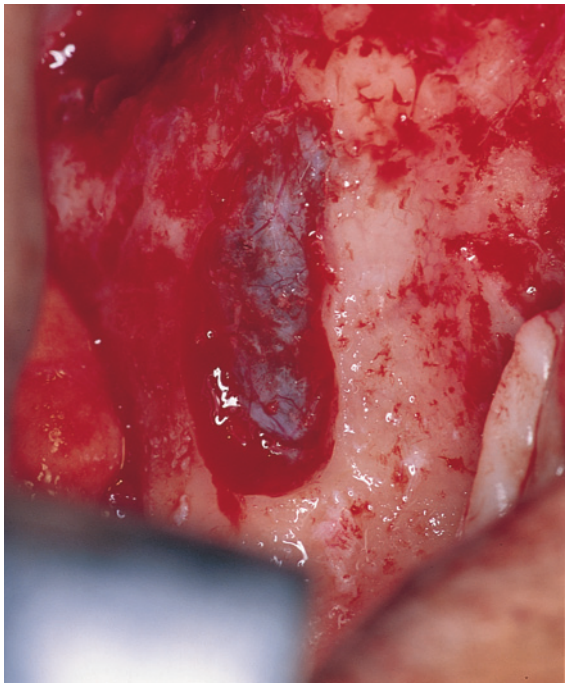


FIGURE 5-4 Cortex of the lateral maxilla is removed to expose the sinus membrane. The window is approximately 20 × 8 mm.

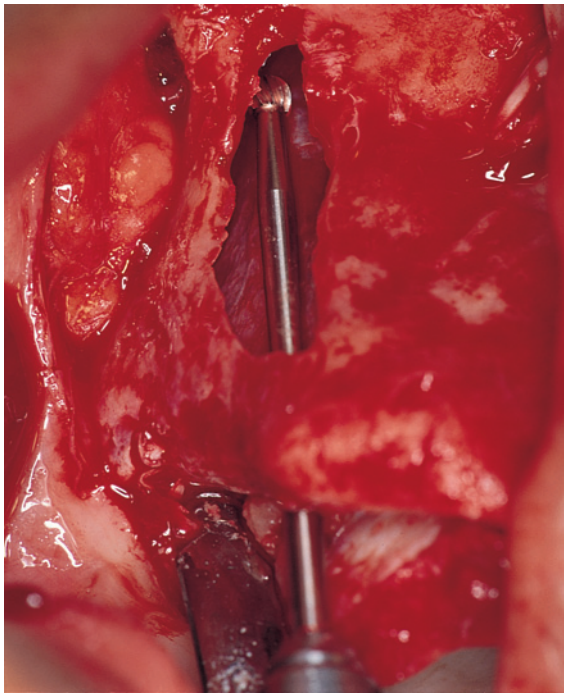


FIGURE 5-6 Round bur is used to enter the maxilla from the palatal aspect of the ridge, to transverse the sinus, and to score the inner aspect of the zygoma.

DVD Images 5-3

The next drill is 2.9 mm in diameter, matching the diameter of the previously used round bur (DVD Figure 5-3). This drill is taken through the palatal site, traversing the maxillary sinus, to prepare the implant site from the inner aspect of the zygoma; it passes through the lateral aspect of the zygoma superiorly. The orbital rim must be avoided.

The next drill is a transition drill, which has a guide to enter the 2.9-mm-diameter hole in the palate and zygoma (Figure 5-7). This drill opens the hole to the final size in the zygoma. This transition drill is not intended to complete the implant site. The next drill is the 3.5-mm-diameter twist drill, which is taken through the superior aspect of the zygoma. If the palatal bone is thick, the 4.0-mm twist drill can be used to complete the palatal site. If the maxillary alveolar bone is thin, the 3.5-mm drill is used, and the 3.5-mm drill is used in the zygoma.

At this point in the procedure, the surgeon is ready to place the zygomaticus implant. However, the necessary length of the implant must be confirmed before an implant is removed from its container. The measuring instrument, which has the implant's length etched by sequential lines, is placed into the site, entering the palatal hole and exiting the zygoma site. The length of the implant is determined by identifying the line of corresponding length at the palatal site (Figure 5-8; and DVD Figure 5-4, A-B, which shows Figure 5-8 along with a diagram of the delivery of the zygomaticus fixture).

DVD Images 5-4, A-B

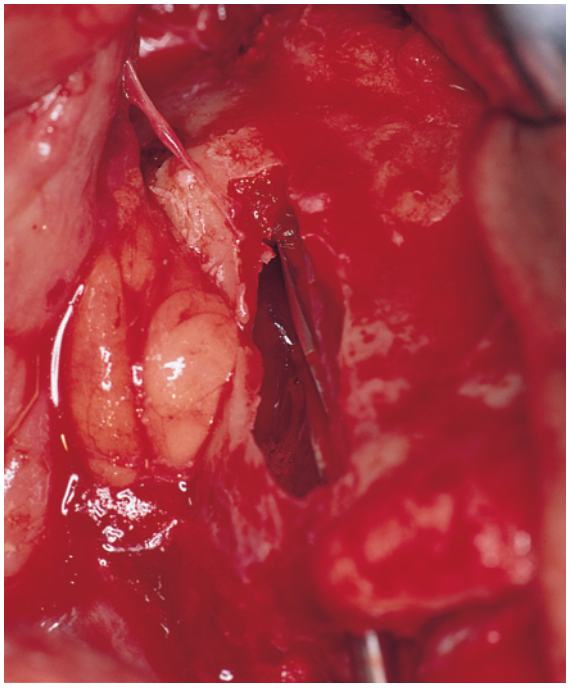


FIGURE 5-7 Guide drill is used to start the hole in the zygoma, which will be 3.5 mm in diameter.

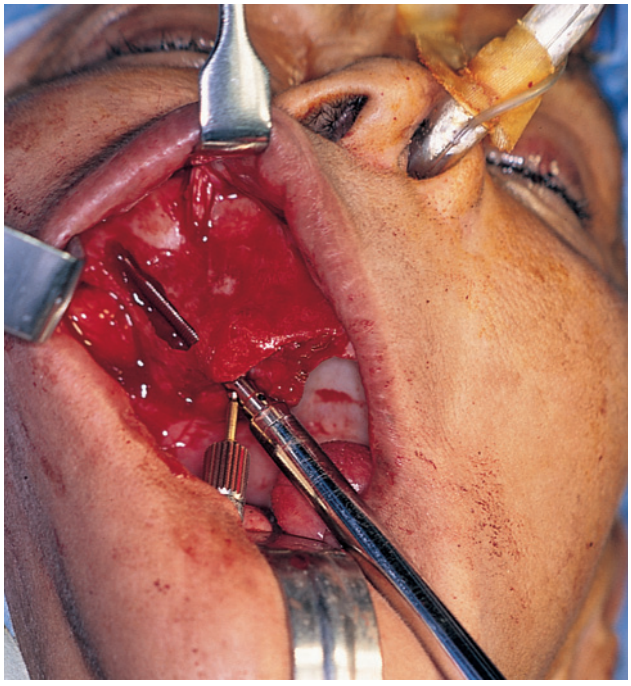


FIGURE 5-8 After the final twist drill has been used, the length of the zygomaticus fixture is determined by direct measurement using the depth gauge. The implant is chosen and removed from its sheath. The cover screw is removed and placed in a safe place. The implant is delivered either with a rotating handpiece at 10 rpm or with the hand instrument.

The appropriate-length implant is chosen and placed onto the sterile field. The glass container is opened, and the implant is carefully removed with its sheath. The two wings of the sheath are expanded and removed, exposing the cover screw on the implant. The cover screw is removed and placed onto a sterile tray. The implant is mounted on the delivering handpiece adapter and is placed into the palatal site. As the implant enters the dense zygoma bone, the torque of the drill most likely will be exceeded. The handpiece adapter is removed, and the manual turning instrument is used to complete placement of the implant. The angle of the driving mount screw should be inferiorly oriented. The driving mount is removed, and the external hex of the implant is visible. The cover screw is placed to cover the external hex. The same procedure is performed on the contralateral side of the maxilla (Figures 5-9 through 5-13; and DVD Figures 5-5 and 5-6, A-B). After the two zygomaticus implants have been placed, two to four anterior implants are placed. The wound is irrigated thoroughly and closed. Nonresorbable sutures are recommended.

DVD Images 5-5 5-6, A-B

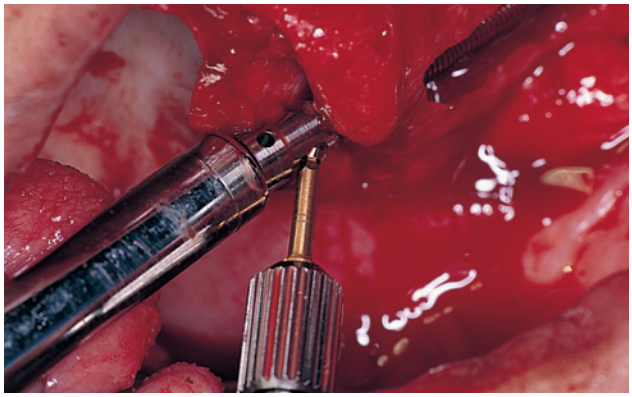


FIGURE 5-9 Hex drive instrument is placed into the retaining screw of the driving mount to ensure that the final orientation of the zygomaticus implant is correct. Confirmation of the correct position of the implant is important before the driving mount is removed, because replacement of the driving mount to the implant is difficult.

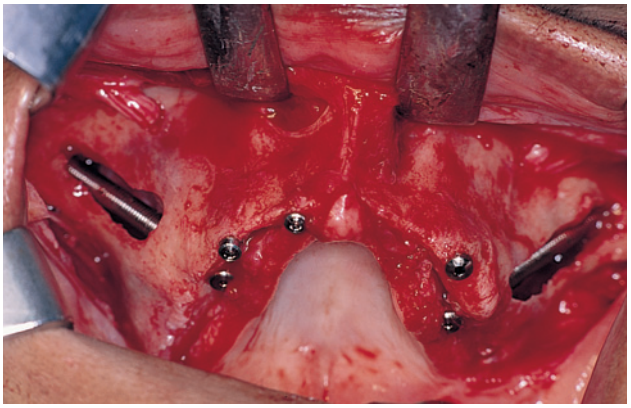


FIGURE 5-10 **B,** Two zygomaticus implants and anterior implants in a patient whose restoration was an implant-retained, fixed-removable prosthesis.

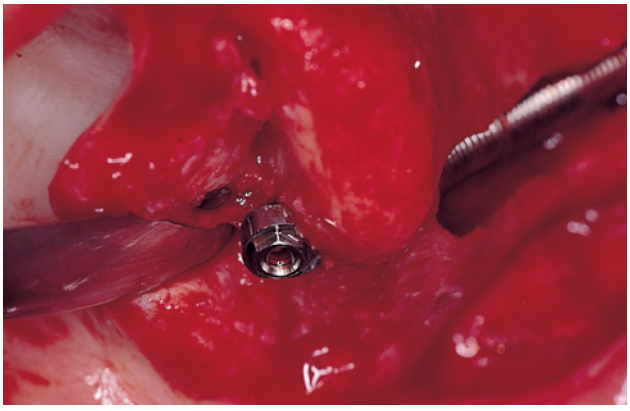


FIGURE 5-10 **A,** Close-up view shows the external hex of the implant before placement of the cover screw. The position of the implant palatal to the crest is shown.

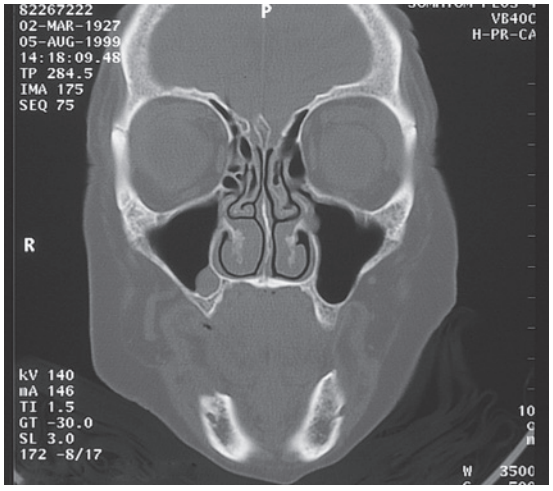


FIGURE 5-11 Preoperative imaging should include a computed tomography (CT) scan with frontal cuts to show a healthy sinus and an appropriate contour of the lateral maxilla. If the lateral wall of the maxilla is severely concave, placement of the zygomaticus implant may not be possible.

Six months are recommended for integration. At the time of exposure, temporary gingival abutments are placed. It is critical for the success of these implants that they be connected rigidly to the anterior implants within a few days of exposure, because they probably will integrate only in the dense zygoma bone, not in the thin palatal bone. Therefore, making an index of the implants at exposure facilitates the fabrication of a temporary rigid bar. At exposure, the palatal tissue may need to be thinned.

After the temporary rigid bar has been placed and the patient's denture has been relined, the restorative

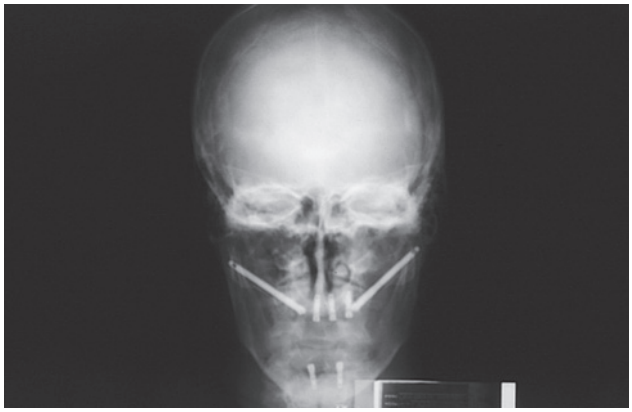


FIGURE 5-12 Radiograph of a patient with zygomaticus implants shows the angulation necessary to place these fixtures.

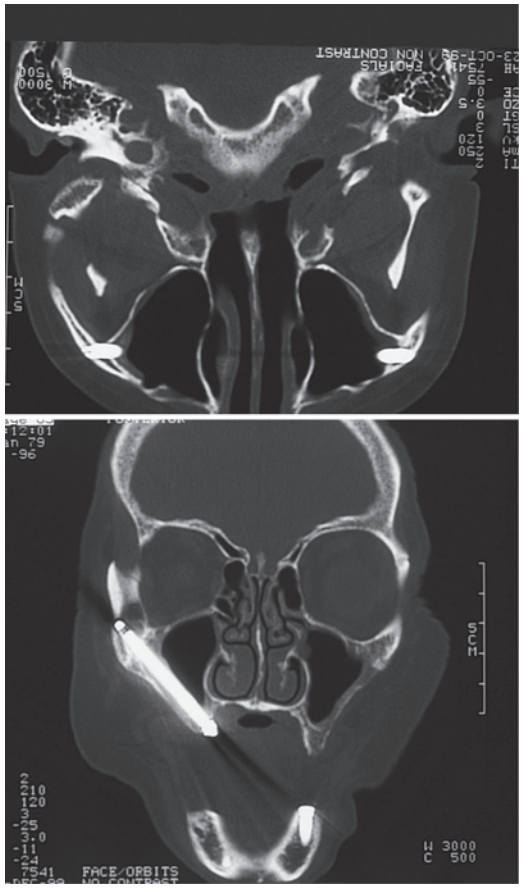


FIGURE 5-13 Six-week postoperative CT scan *(top)* shows the accurate position of the zygomaticus implants in the zygoma. Frontal CT image *(bottom)* shows the zygomaticus implants traversing the maxillary sinus and entering the zygoma. Note the healthy, well-aerated sinus, which shows no evidence of pathologic changes.

dentist can fabricate a final rigid bar cross-arch to stabilize the implant as a single unit. The outcome is a totally implant-borne prosthesis (Figure 5-14, A-G; the entire case is presented in DVD Figure 5-7, A-J).

DVD Images 5-7, A-J

Placement of Four Angled Implants to Support a Full-Arch Prosthesis

Patients with an edentulous maxilla can be treated with a variety of methods. If they have at least 10 mm of vertical bone in the anterior maxilla, several options are available, depending on the goals of treatment, the clinician's experience with different restorative and surgical techniques, and financial considerations. When less than 10 mm of bone is present in the anterior maxilla, grafting of the anterior

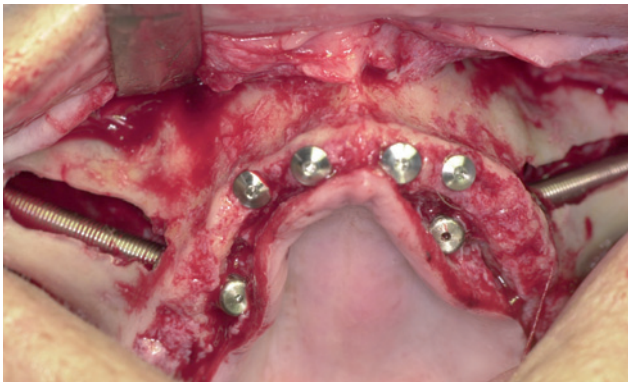


FIGURE 5-14 A, Remaining drill sequence is followed, and the bilateral zygomaticus implants and anterior implants are placed.

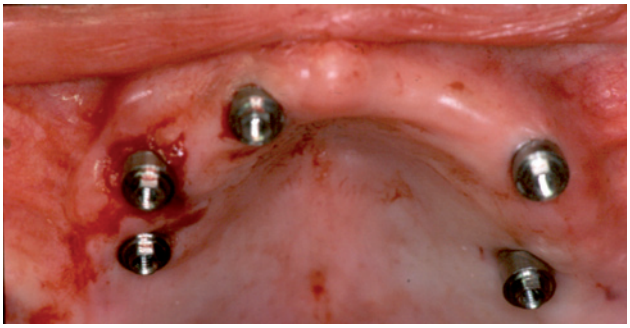


FIGURE 5-14 B, At the time of exposure, the abutments are placed.

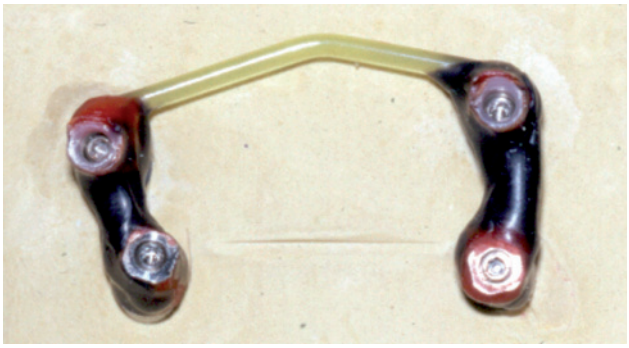


FIGURE 5-14 **C,** Abutments are indexed so that a temporary bar can be fabricated. The temporary bar is cast in the laboratory.

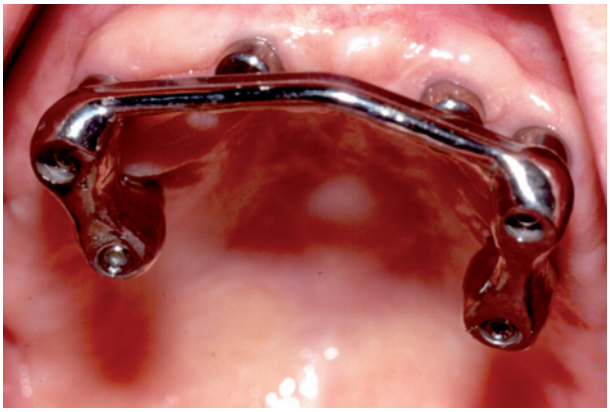


FIGURE 5-14 **D,** Temporary bar is cast and placed to stabilize the implants across the arch. This prevents excessive cantilever forces on the implants.

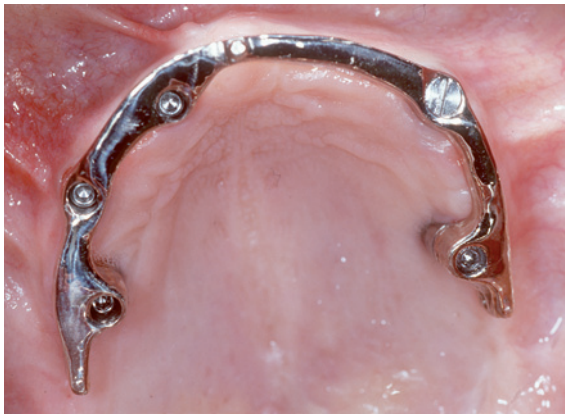


FIGURE 5-14 **E,** Final bar is made on the implants, resulting in a fixed-removable prosthesis held in position with plunger attachments.

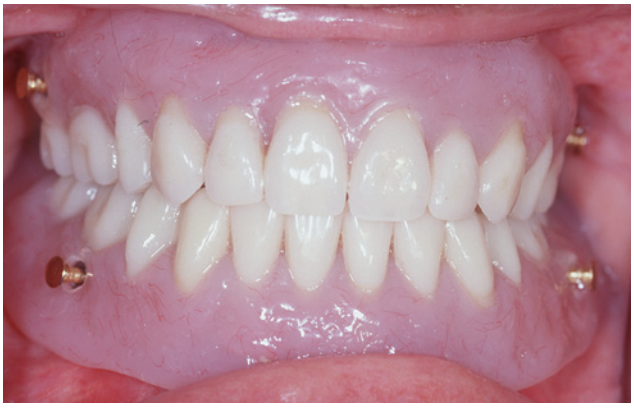


FIGURE 5-14 **F,** Frontal view of final prostheses.

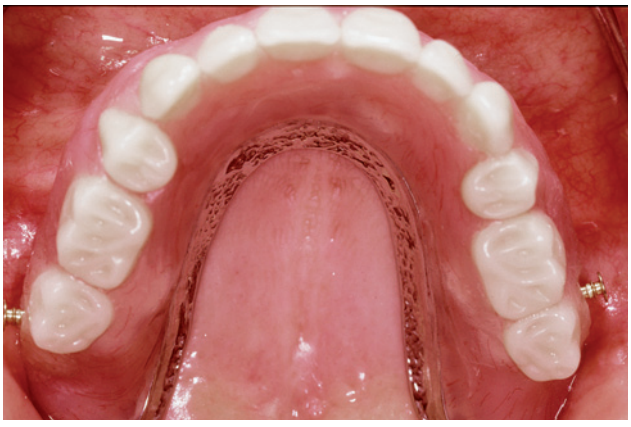


FIGURE 5-14 **G,** Occlusal view of final maxillary prosthesis. (Prosthetics by Dr. Tom Salinas.)

maxilla is one option, or sinus grafting may be necessary. In the severely atrophic patient, in whom systemic contributions to the bone atrophy (e.g., osteoporosis) frequently are a factor, anterior maxillary grafting may be chosen as an option.

For the patient with anterior bone but no posterior bone, the decision to provide a fixed implant–borne restoration necessitates a process of recommendations for the placement of multiple implants, which requires sinus grafting; placement of six implants if bone is present in the second premolar region; or nongrafting alternatives using zygomaticus or angled implants. This section demonstrates a case using angled implants.

A patient presents with adequate bone in the anterior maxilla for the placement of two implants but has limited bone in the first premolar region. One nongrafting option

is the placement of four implants into the maxilla, with the posterior implants intentionally angled to place the coronal portion of the implant in the second premolar location, with the implant paralleling the piriform rim.

This technique, called "all-on-four," was introduced and popularized by Malo et al.[4,5] Clinical follow-up in multiple institutions to confirm this method is ongoing.

Single Zygomatic Implant for Salvaging a Full-Arch Case

The zygomatic implant must be connected to integrated implants in the maxilla with cross-arch stabilization. One zygomatic implant can be placed when implants have been lost in one quadrant, yet there are sufficient remaining implants to satisfy the mechanical requirements of the zygomatic implant.

This patient lost all of the implants in the right posterior maxilla. Enough implants remained in the anterior and left posterior maxillae for cross-arch stabilization of one zygomatic implant. Figure 5-15, A, shows the preoperative situation after removal of the posterior failed implants. Figure 5-15, B, shows the single zygoma implant in place. After 6 months was allowed for integration, the implant was exposed and a new full-arch maxillary fixed prosthesis was fabricated (Figure 5-15, C-F).

Use of Double Zygoma to Salvage a Full-Arch Prosthesis After Severe Bone Loss

This case example involves an elderly woman with osteoporosis who had multiple implants for a fixed maxillary prosthesis. Multiple implant failures occurred, resulting in severe bone loss (Figure 5-16, A-G). The treatment plan called for removal of the mobile implants and placement of three zygomatic implants. The patient was not a bone graft candidate because of her general medical condition. Because all the implants on the right side of the maxilla had been lost, double zygomas were planned. One zygoma implant was used on the left, because a conventional implant could be placed in the piriform region, and the two implants remaining would provide additional stability.

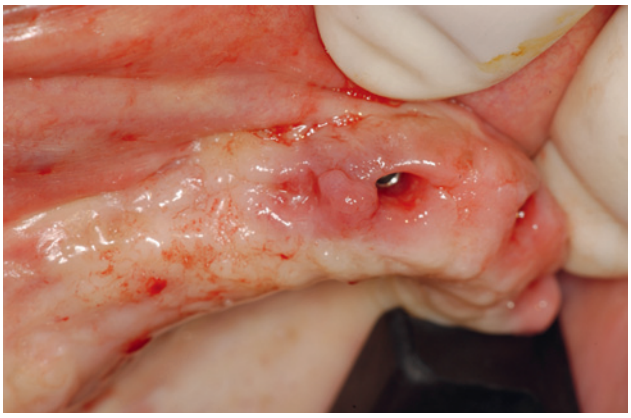


FIGURE 5-15 **A,** Preoperative view of the right maxilla showing one implant in place in the right lateral incisor location.

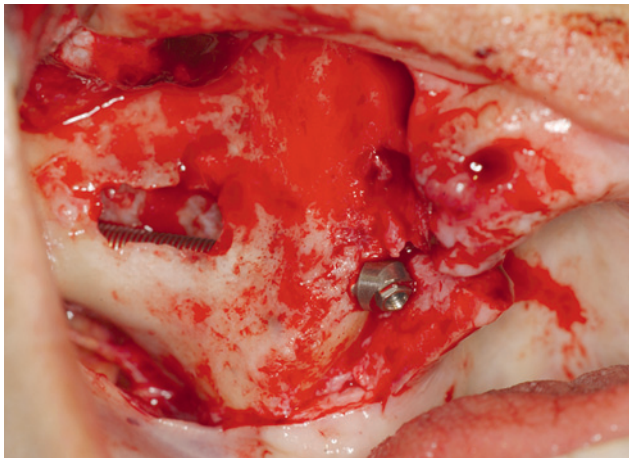


FIGURE 5-15 **B,** Crestal incision is made with vertical release. One zygomatic implant is placed to provide posterior support for a new full-arch prosthesis.

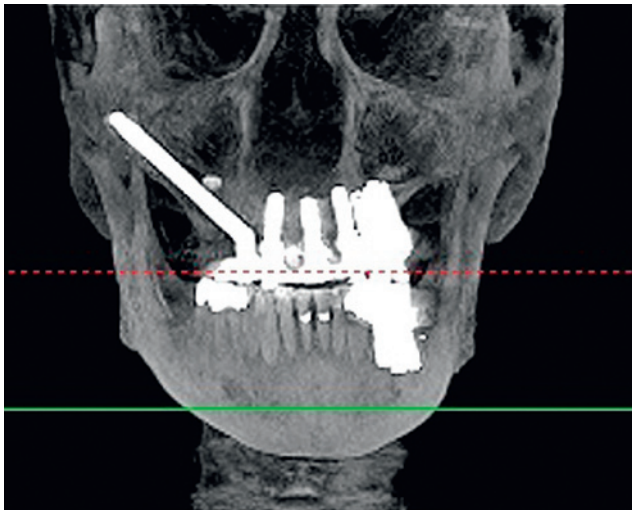


FIGURE 5-15 **C,** Antero-posterior (AP) radiograph from the cone beam scan shows the right zygoma implant supporting the right side of this screw-retained prosthesis.

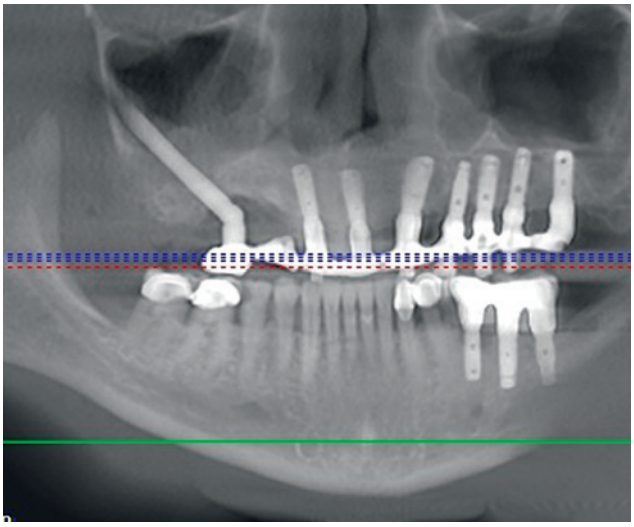


FIGURE 5-15 **D,** Panoramic image from the cone beam scan shows the use of the zygoma to support the right quadrant of this full-arch fixed prosthesis. This is a 4-year follow-up radiograph.

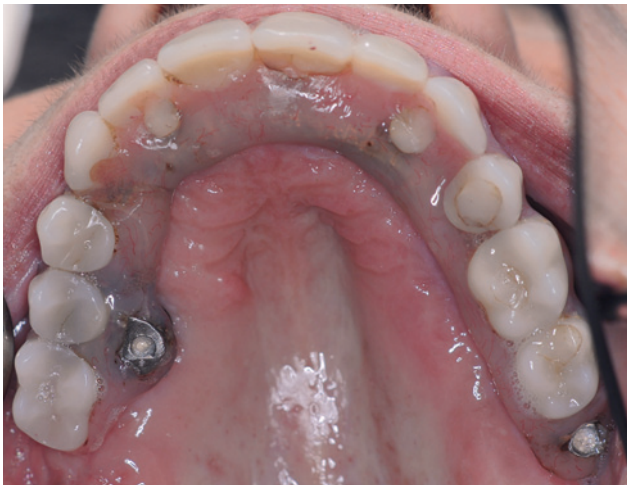


FIGURE 5-15 **E,** Occlusal view of the screw-retained prosthesis. Note the slightly palatal position of the zygomatic implant, as expected. This is well tolerated by the patient.

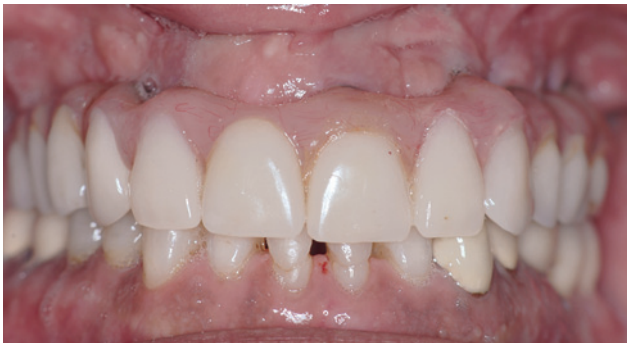


FIGURE 5-15 **F,** Frontal view shows a balanced occlusion, which has been stable and functional for 4 years. This patient is able to clean the implants nicely.

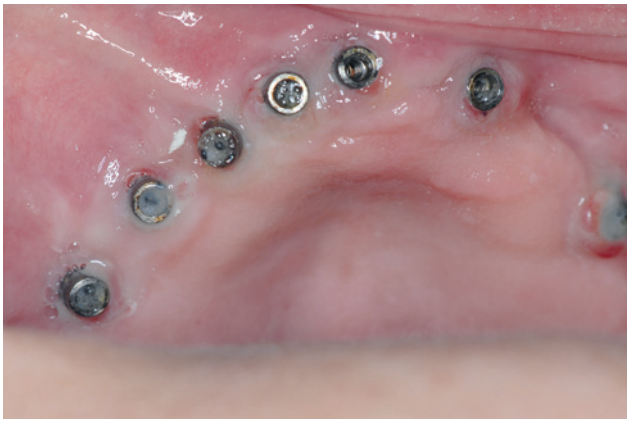


FIGURE 5-16 **A,** Preoperative view showing implants that are mobile or have excessive bone loss and require removal. The loss of these implants compromises the patient's ability to have an implant-supported prosthesis, which she enthusiastically desires.

Use of Zygomatic Implants to Support a Nasal/Maxillary Prosthesis

Patients who lose the nose, maxilla, or other facial units as a result of irradiation, health issues, or other factors require reconstruction through a variety of methods. Maxillofacial prosthetic devices can provide the patient with a reconstruction that allows him or her to live a relatively normal lifestyle. The patient in this case lost his nose and maxilla after removal of a squamous cell carcinoma (Figure 5-17, A). He also had radiation therapy. His initial maxillary and nasal prostheses used adhesive, but chronic skin irritation and mechanical problems led him to seek surgical options.

A CT scan was obtained (Figure 5-17, B), which showed intact bone in the nasofrontal region and orbital rims. The treatment plan was designed to use the remaining facial bone (Figure 5-17, C). Imaging showed sufficient bone for implants 12 mm long in the nasal region and for zygomatic implants 55 mm long that would enter from the infraorbital region and exit through the left and right zygomas. The lack of parallelism was approved by the patient's prosthodontist (Dr. Thomas Salinas).

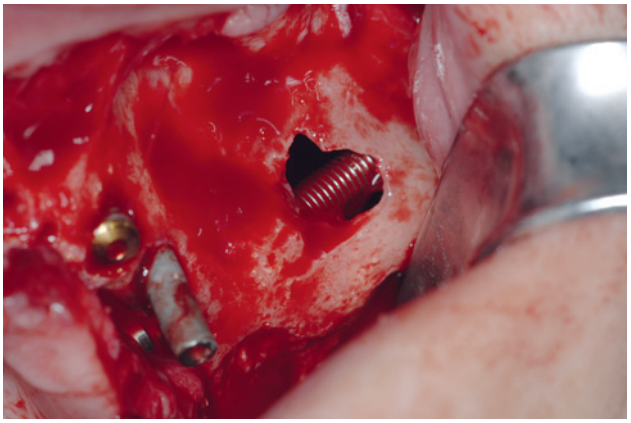


FIGURE 5-16 B, Placement of the left single zygoma implant with placement of one new implant in the left piriform region.

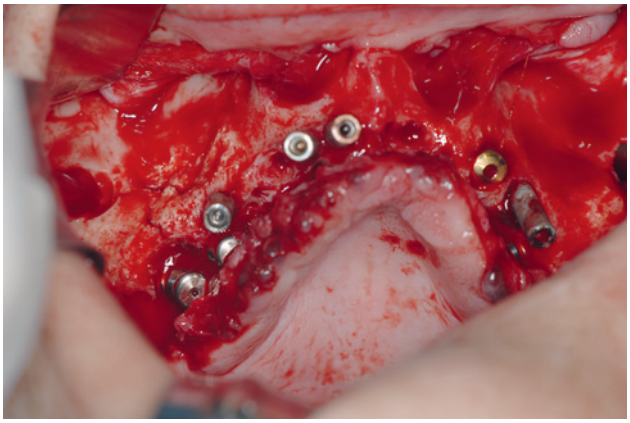


FIGURE 5-16 C, Two zygoma implants emerging from the palate. The adjacent implant has 75% bone loss and a poor long-term prognosis. The two implants in the right maxilla also have 75% bone loss and a poor prognosis. The use of two zygomas on the right, plus the implant in the left piriform region, combined with the zygoma on the left, should provide long-term support.

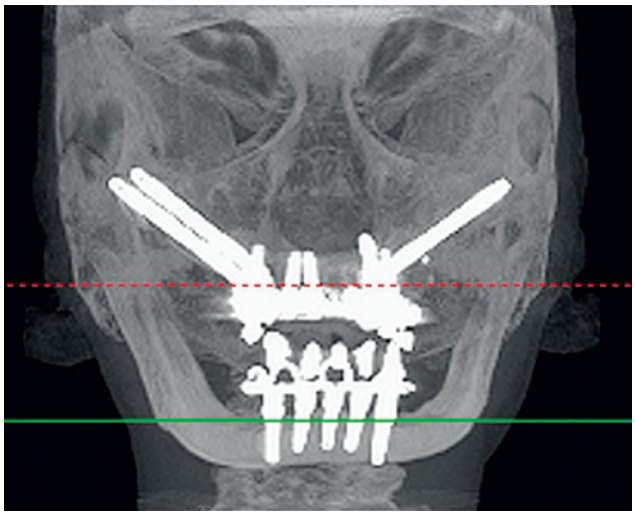


FIGURE 5-16 D, AP radiograph showing the double zygomas on the right and a single zygoma on the left, an arrangement intended to salvage the loss of implants and to give the patient the alternative of a fixed-hybrid prosthesis.

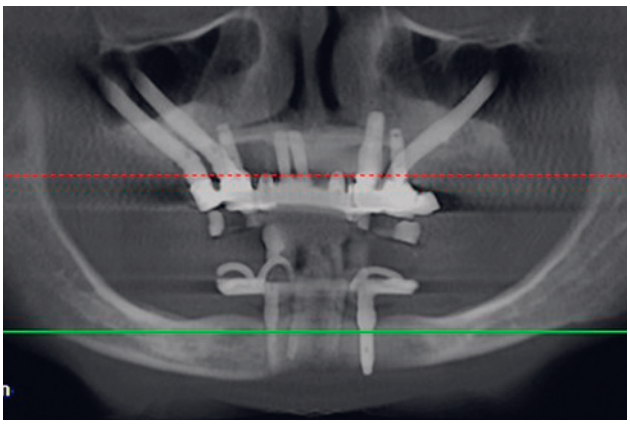


FIGURE 5-16 E, Panoramic image from a cone beam scan showing the prosthesis screw retained to the three zygomatic implants and the remaining implants, which had not shown further bone loss at the time of this 2-year follow-up radiograph.

Prior to surgery, the patient had hyperbaric oxygen treatments. At the time of surgery, incisions were made over the intact bone, and the remaining bone was exposed. The orbital rims were exposed, and the orbital floor also was exposed to allow the surgeon to visualize the depth of the floor while preparing the zygoma sites. This helped prevent perforation of the orbital floor. The nasal implants were placed, with care taken to control for depth and to avoid entering the cranial cavity. After the nasal implants had been placed, the left and then the right zygoma implants were placed, with care taken to enter intact bone, avoid the orbital contents, and exit from the thickest bone of the zygomas (Figure 5-17, D-F). The 55-mm-long implants were used. The zygoma platforms were turned to minimize off-axis parallel problems. The incisions were closed, and the hyperbaric treatments continued for 10 days after surgery. All incisions healed uneventfully. Postoperative radiographs confirmed the implants' locations (Figure 5-17, G).

Six months was allowed for integration. The implants then were exposed, and healing abutments were placed. Facial impressions were made, as were transfer impressions

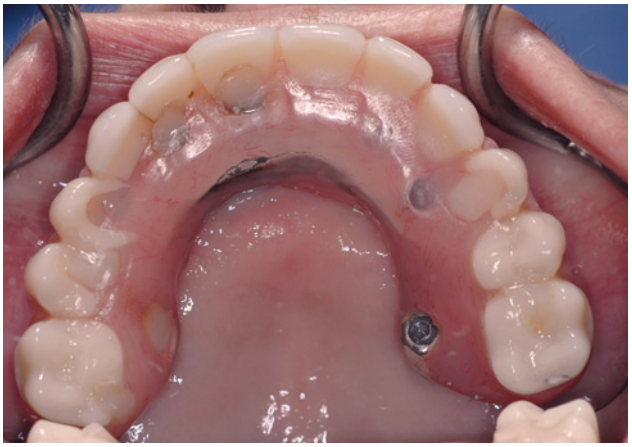


FIGURE 5-16 **F,** Final prosthesis screw retained directly to the implants without intervening abutments. The screw engages directly with the implant platform.

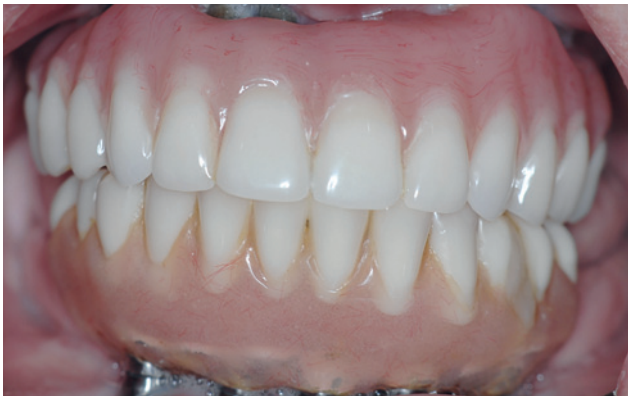


FIGURE 5-16 **G,** Balanced occlusion has been achieved without the need for removable prostheses, which satisfies the restorative goals for this patient. (Prosthetics by Dr. Noel Pilie).

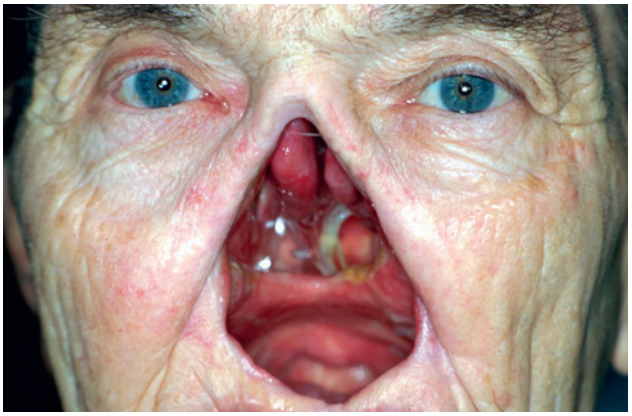


FIGURE 5-17 **A,** Preoperative view showing nasal defect and maxillary defect secondary to tumor removal. This patient has difficulty wearing a conventional, glued-on facial prosthesis.

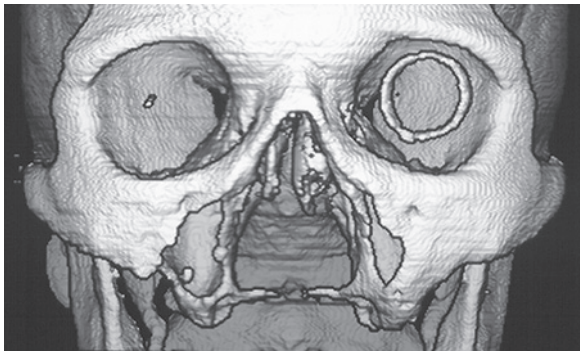


FIGURE 5-17 **B,** Three-dimensional reconstruction of a CT scan showing loss of bone structures. However, the nasal crest near the frontal process is intact, the lateral zygomas are intact, and bone is present along the orbital rims.

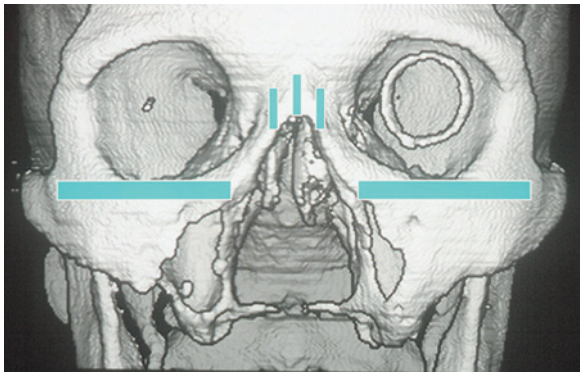


FIGURE 5-17 **C,** Treatment plan calls for three implants placed vertically in the nasal process and bilateral, horizontally oriented zygoma implants placed within the inferior orbital rim, engaging the lateral zygomas.

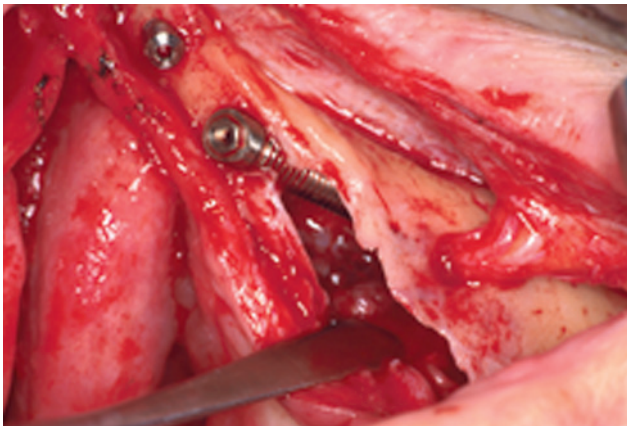


FIGURE 5-17 **D,** Surgical view after placement of the left zygomatic implant. Note that the implant has been placed superior to the infraorbital nerve.

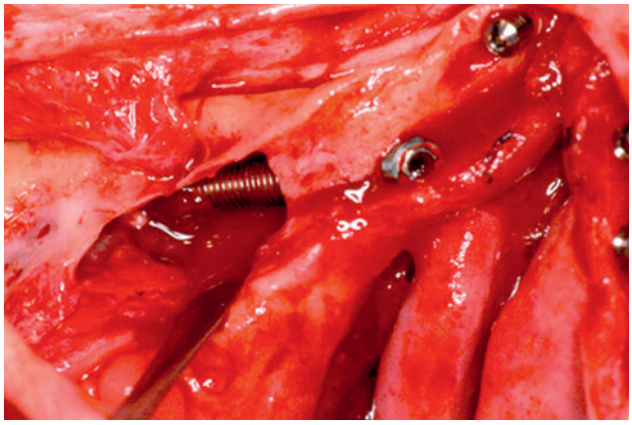


FIGURE 5-17 E, Surgical view after placement of the right zygomatic implant, which has been placed just inferior to the infraorbital nerve because of the availability of bone.

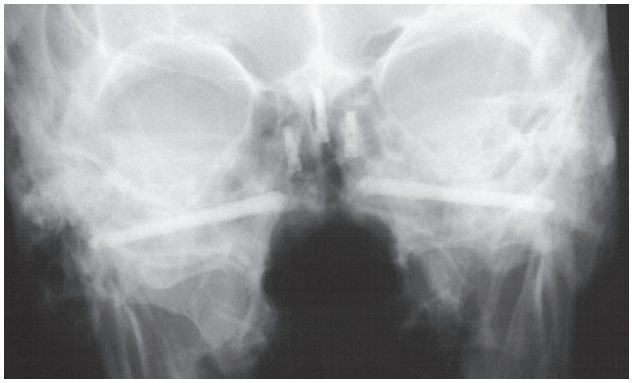


FIGURE 5-17 G, AP radiograph showing the location of the implants. Note the zygomatic implants engaging the lateral bone of the zygoma.

of the implants. A framework was cast for screw retention of the framework to all five implants. Clips were placed on the new maxillary and nasal prostheses for retention of the facial prostheses (Figure 5-17, H-L). (Prosthetics by Dr. Thomas Salinas.)

Assessment and Treatment Plan

Preoperative assessment begins with evaluation of the edentulous maxilla to appraise the available bone in the anterior and posterior maxilla for implant placement. The algorithm described next is useful (Figure 5-18).

If the patient has adequate anterior and posterior bone, implants can be placed without grafting. If the patient has adequate anterior bone but less than 6 mm of posterior bone, with anterior bone available from second premolar to second premolar, the clinician can place implants from premolar to premolar without posterior grafting. Usually, six to eight implants are placed to support an implant-borne prosthesis.

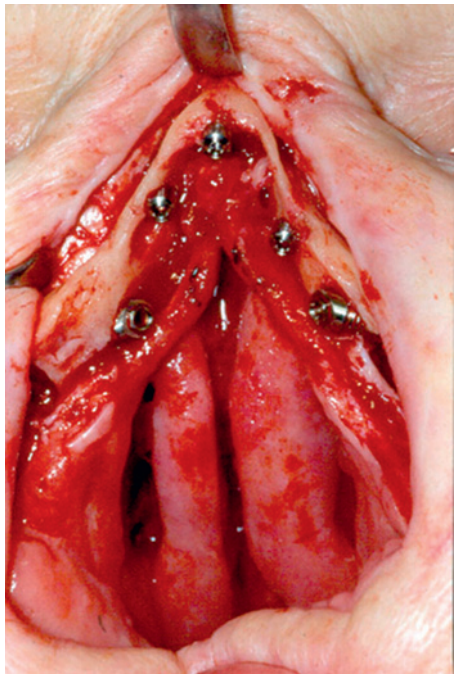


FIGURE 5-17 F, Three nasal implants and the two zygoma implants prior to soft tissue closure.

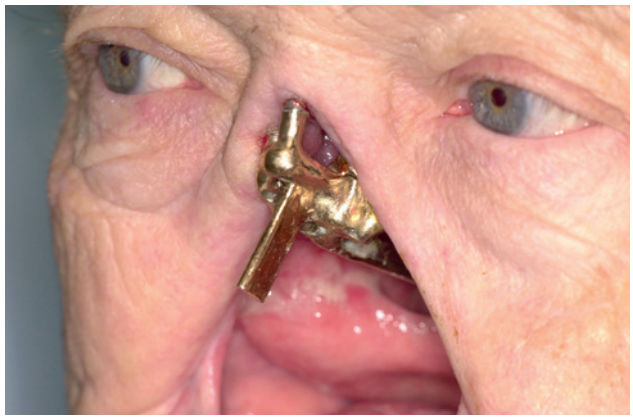
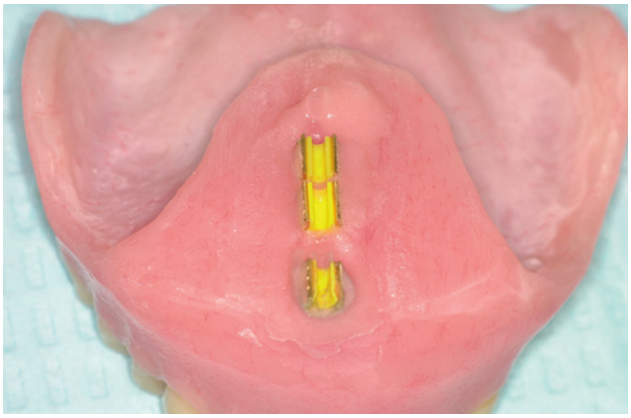
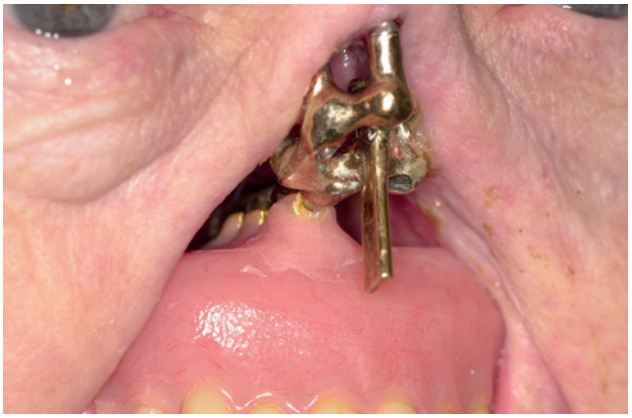


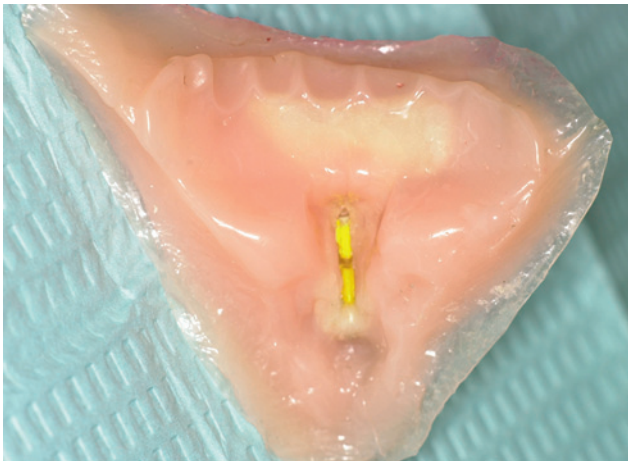
FIGURE 5-17 H, After 6 months have been allowed for integration, the implants are exposed, and sectional impressions are made. A one-piece framework with two bars is fabricated. One bar supports the maxillary prosthesis, and the other bar supports the nasal prosthesis. This one-piece framework was screw retained directly to the implants.



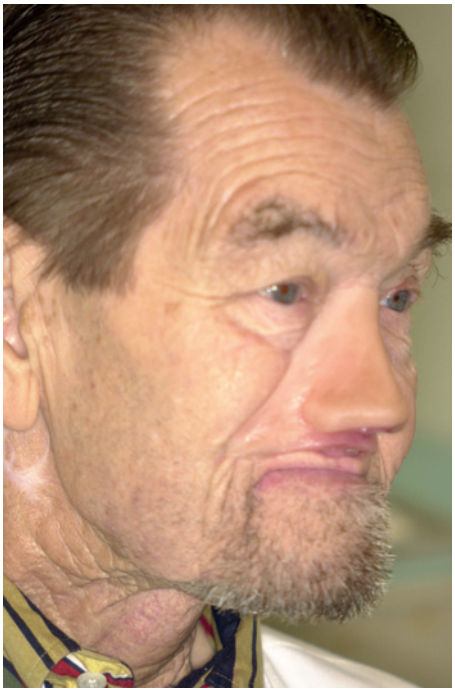
● **FIGURE 5-17** **I,** Plastic clips are used in the maxillary prosthesis to engage the bar on the framework.



● **FIGURE 5-17** **J,** Patient places the maxillary dental prosthesis to engage the horizontally oriented intraoral bar.



● **FIGURE 5-17** **K,** Clips are placed in the intaglio surface of the nasal prosthesis for retention; adhesive is not required.



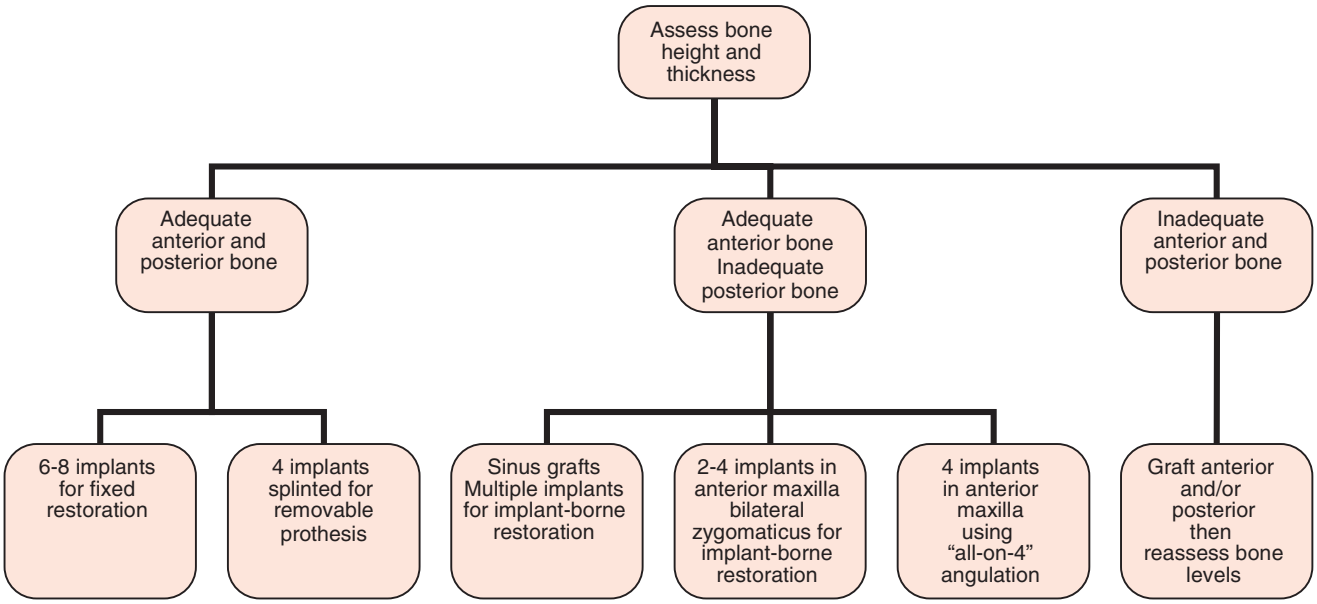
● **FIGURE 5-17** **L,** Facial view of the final prostheses in place.

If anterior bone is available from first premolar to first premolar, options include placement of anterior implants and one of the following:

1. Placement of posterior zygomatic implants.
2. Grafting of the sinus for placement of posterior conventional implants.
3. Placement of four implants with the distal implants angled anteriorly.

Occasionally, anterior bone is available from canine to canine, with less than 6 mm of bone posterior to the canines. In this patient, the placement of six to eight implants requires grafting; options include the following:

1. Placeement of sinus grafts and then six to eight implants for an implant-borne prosthesis.
2. Use of angled anterior implants to parallel the piriform rim, with two implants in the incisor locations, resulting in platforms in the premolar regions and the incisor region. This option eliminates the need for bone graft harvesting and sinus grafts and reduces the time from initial treatment to final restoration.



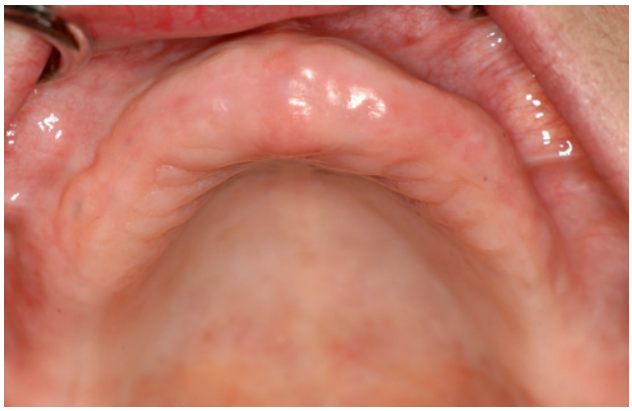
● **FIGURE 5-18** Treatment algorithm for implants in the edentulous maxilla.

Case Study

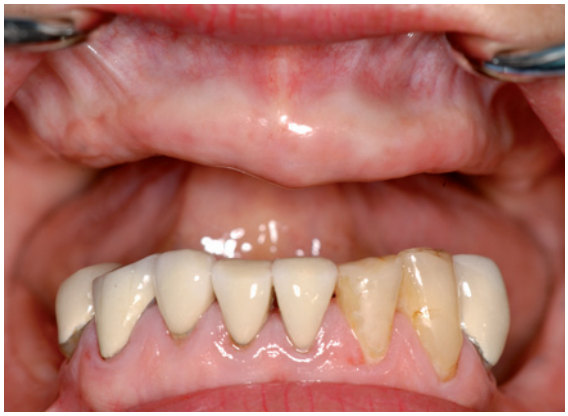
DVD Images 5-8, A-L

The following case demonstrates the placement of four implants into the maxilla of a patient who lacks bone posterior to the right canine (Figure 5-19, A-I; the entire case is presented in DVD Figure 5-8, A-L). Bone is present in the left maxilla over the left first premolar.

A diagnostic setup of the planned restoration is needed for accurate positioning of the implants. The planned restoration is duplicated in clear acrylic for use as a surgical template. The implant platforms must be slightly palatal to the teeth to allow appropriate space for the framework. Angled abutments will be used for the posterior angled implants to allow for parallel draw for abutment-level impressions.



● **FIGURE 5-19** **A,** Occlusal view of the ridge. This patient has adequate ridge width for implants but does not have sufficient height in the regions posterior to the premolars.



● **FIGURE 5-19** **B,** Frontal view showing adequate ridge relationships between maxilla and mandible.

A CT scan can be used to fabricate a surgical guide, placing the implants within the bone parallel to the piriform rim. Otherwise, surgical exposure of the bone is necessary.

At surgery, a crestal incision is combined with posterior releasing incisions. A full-thickness subperiosteal flap is raised to expose the ridge, the lateral walls of the maxilla, and the piriform rim. The nasal mucosa can be elevated, but this usually is not required.

To allow placement of the implants accurately into the bone in the piriform rim, the lateral wall of the maxilla is

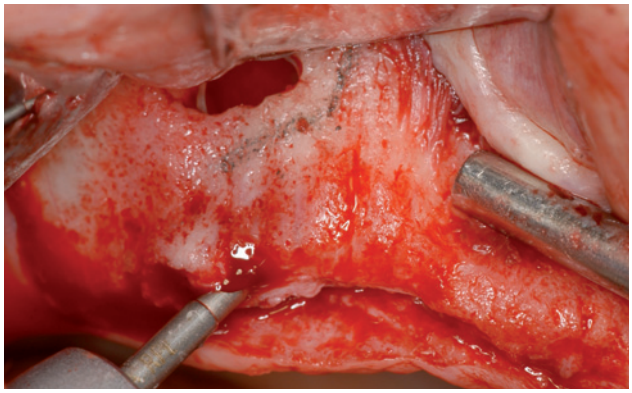


FIGURE 5-19 **C,** At surgery, a bur is used to enter the sinus. The lateral nasal wall is identified from within the sinus, and a pencil line is drawn on the bone to indicate the floor of the sinus and the location of the bone of the lateral nasal wall, into the piriform rim. The drills are used to parallel the bone at an angle.

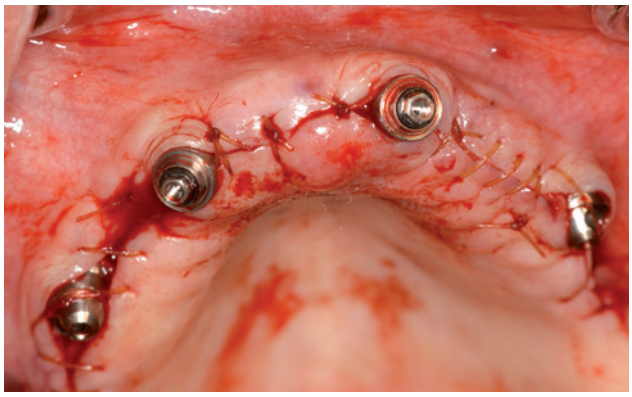


FIGURE 5-19 **E,** Two vertically positioned implants are placed in the anterior maxilla anterior to the angled implants. Angled abutments are placed to create similar draw for all four implants.

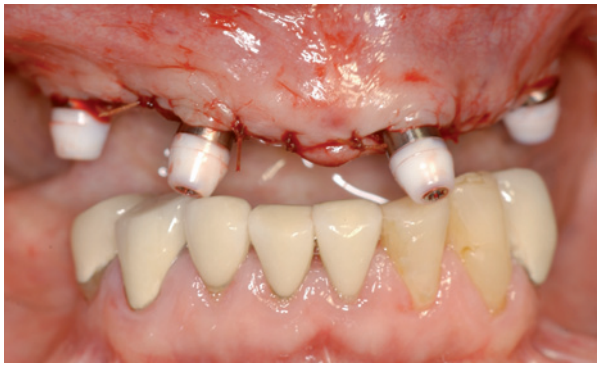


FIGURE 5-19 **G,** Four implants in correct position in relation to the mandible.

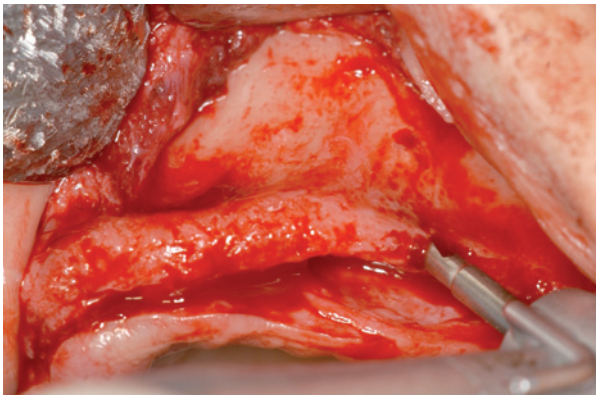


FIGURE 5-19 **D,** Similar procedure is performed on the opposite side. Transillumination is used to identify the sinus floor and lateral nasal wall.

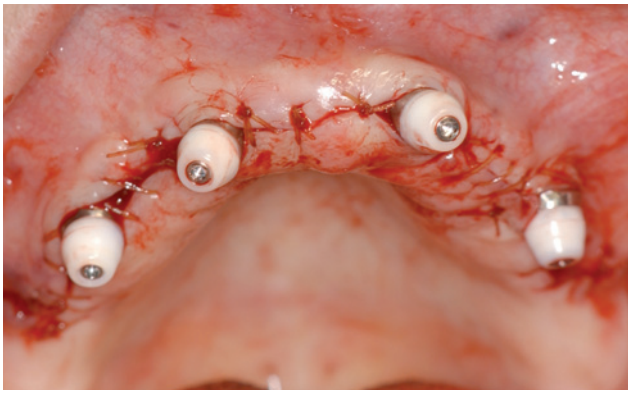


FIGURE 5-19 **F,** Plastic caps are placed on the abutments to prevent trauma to the tongue and cheeks.

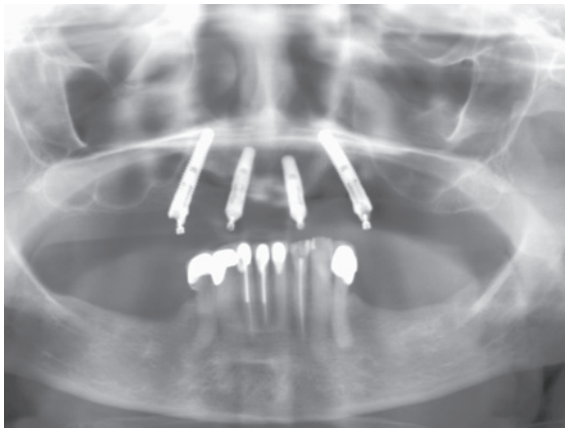
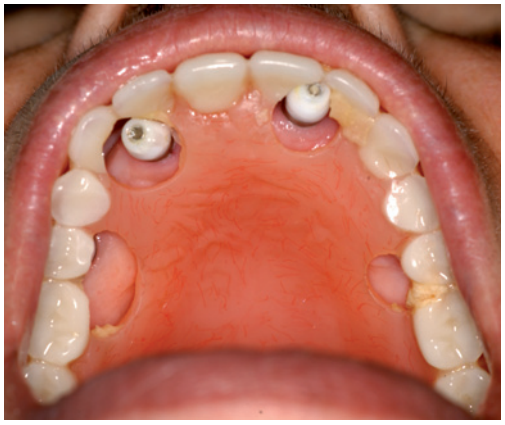


FIGURE 5-19 **H,** Panoramic radiograph showing the placement of the four implants, including the posterior angled implants.



● **FIGURE 5-19 I,** During the healing period, holes are drilled through the denture.

opened into the sinus. From this exposure, a pencil line is drawn over the bone within the piriform rim. The implant is placed following this line, with care taken to avoid placement of the implant into the sinus. Direct exposure of the rim from the sinus allows direct placement of the implant into bone.

The bone is exposed, and a round bur is used to enter the sinus. The membrane need not be preserved. The hole into the sinus should be linear and parallel to the lateral nasal wall but superior to the bone and large enough to allow palpation or clear visualization of the bone.

A sterilized pencil is used to draw a line on the bone. The implant then is placed and positioned so as to put the platform within the prescribed location of the planned teeth. Two anterior implants are placed, with care taken to position them medially to avoid contact with the distal angulated implants.

Angled abutments are placed into the distal angled implants. Abutments can be placed into the anterior implants. A fixed provisional restoration is fabricated with a balanced occlusion. Another option is to place the cover screws and stage the restoration. However, cross-arch stabilization with a balanced occlusion should be predictable.

The benefit of this procedure is that it eliminates grafting and the use of conventional implants. The disadvantage is the lack of posterior support. However, clinical data from Europe indicate that success should be expected.

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Techniques for Grafting the Extraction Site

Chapter 6

Chapter Outline

When a tooth requires extraction, the planning for its replacement may include placement of an implant to replace the extracted tooth. At the time of tooth extraction, a delayed approach may be selected because of concurrent infection or loss of supporting bone structure. This chapter describes in detail methods of grafting the extraction site to provide an ideal site for implant placement after the graft has healed.

The normal sequence of events in socket healing takes place over approximately 40 days, beginning with clot formation and culminating in a bone-filled socket with a connective and epithelial tissue covering.[1,2] Ideally, an extraction site heals with bone formation that completely preserves and also recreates the original dimensions of the bone. Unfortunately, bone resorption is common after tooth extraction; therefore, intervention is necessary with a method that provides ideal bone for implant placement and reconstruction of the patient with an esthetic and functional restoration.

Bone resorption usually is greater in the horizontal plane than in the vertical plane.[3,4] Horizontal bone loss may be enhanced by thin facial cortical bone over the roots or bone loss from extension of local infection, such as caries or periodontal disease. Ideal placement of a dental implant centers the implant over the crest in a line connecting the fossae of the adjacent posterior teeth or, for anterior teeth, palatal to the emergence profile of the planned restoration. Unless the horizontal bone dimension is reconstructed or preserved after tooth extraction, implant placement is compromised.

Grafting Material

The clinician should consider the following points when choosing materials to graft the extraction socket:

1. Space should be maintained so that bone can repopulate the graft and thus recreate a bone volume similar to the original.
2. The bone formed should be dense enough to allow stable placement of the implant; therefore, the material placed should have osteoconductive features to enhance bone formation.
3. The material should be relatively inexpensive and readily available and should not transfer pathologic conditions.

Bovine Mineralized Bone

Bovine-derived bone is a xenograft. It is a carbonate-containing apatite with crystalline architecture and a calcium/phosphate ratio similar to that of natural bone mineral in humans.[5] With time, bovine mineralized bone graft material becomes integrated and is slowly replaced by newly formed bone, with the bovine graft present after 18 months.[6-9] When bovine mineralized bone material is used to graft an extraction site, 6 to 9 months may need to be allowed before placement of the implant, especially if the clinician plans to provisionalize the implant immediately.

Mineralized Bone Allograft

Human mineralized bone in particulate form can preserve an extraction site's bone bulk and volume in preparation for the placement of implants. The advantages of an allograft are (1) the graft material is readily available without the need for a second surgical harvest site, and (2) the material is osteoconductive. Over time, the allograft resorbs and, it is hoped, is replaced with bone.

Human mineralized bone is available as particulate cortical or cancellous bone. The recommended particle size is 350 to 500 μm. Particles smaller than 350 μm tend to flow with blood out of the site, and larger particles are not as easily placed because of their size. Allografts are prepared by bone banks. Sterile procedures are used to harvest the bone, which is washed with a series of

delipidizing agents (e.g., ethers, alcohol), lyophilized, and then sieved to the particle size necessary for a specific indication. The freeze-dried mineralized bone allograft usually is irradiated to sterilize it. Comparative reports and clinical results involving different methods of processing mineralized bone are limited. The choice of allograft should be based on the ease of delivery, cost, consistency in the appearance of the graft material, and quality of the bone bank.

When placed in an extraction site, mineralized bone graft material is present at 4 months.[10] However, the bone forming around the mineralized bone particles usually is sufficiently hard to allow immediate provisionalization, with a radiofrequency index greater than 60 after placement of the implant.

One goal of grafting of the extraction site is retention and preservation of the original ridge form and maintenance of the crestal bone after the implants have been restored. In one study in which no membrane was used at the time of extraction site grafting, the grafted sites felt "bone hard" at 4 months and appeared to be filled with bone.[10] The average mesial crestal bone level was -0.66 ± 0.67 mm (range, 0 to -1.27 mm) at implant placement and 0.51 ± 0.41 mm (range, 0 to -1.91 mm) at final restoration. The average distal crestal bone level was -0.48 ± 0.68 mm (range, 0.64 to -1.91 mm) at implant placement and 0.48 ± 0.53 mm (range, 0 to 1.27 mm) at final restoration. A measurement of 1.27 mm from the top of the shoulder of the implants correlated to the level of the first thread of the implant.[10] Bone heights were maintained with mineralized bone graft material.

The current technique for premolars, canines, incisors, and the maxillary palatal root sites advocates the additional use of a fast-resorbing material to retain the graft and promote epithelialization over the graft. The graft can be covered with a collagen material (e.g., CollaPlug, Zimmer Dental, Carlsbad, California) that resorbs in less than 7 days.[10] In mandible molar sites and for coverage of the buccal root sites for maxillary molars, coverage with advancement of the gingiva is recommended.

Autogenous Bone

Clinicians believe that the ideal bone replacement graft material has always been autogenous bone.[11-14] For grafting of the extraction site, autogenous bone can be harvested from the symphysis, ramus, or maxillary tuberosity, or bone removed during alveoloplasty can be used. Bone can be scraped from adjacent sites, collected in a sieve after the bone has been shaved with a bur, collected with rongeur forceps from adjacent sites or the alveolar ridge, or collected as a block from the symphysis or ramus/body region.[15]

The decision to harvest autogenous bone usually is made before the tooth is extracted. Incision designs should consider the need for subperiosteal tunneling or separate incisions to allow harvesting of bone. When multiple teeth are extracted, alveoloplasty can be performed and the particulated bone placed within the extraction sites. An alternative to using alveoloplasty bone is to use a subperiosteal tunnel and one of the available bone-scraping devices to collect bone from the external oblique ridge. Another alternative is to collect bone into a sieve placed in a suction line. Bone particles can be collected from implant preparation drills or by the use of a round bur in the chin or body/ramus region.[5]

Clinical studies and case reports indicate that comparable end results may be obtained with appropriately used nonautogenous grafting materials.[15-18]

Anterior Maxillary Teeth

This section discusses methods of grafting the single-rooted incisor tooth site, with consideration for an eventual esthetic restoration. The preoperative evaluation of the anterior maxillary tooth should include assessment of the following:

- Gingival margin position
- Level of bone on adjacent tooth
- Presence or absence of root prominence
- Proportions of tooth to replace with regard to adjacent teeth
- Levels of bone around the tooth to be extracted, including apical bone, labial bone concavities, loss of labial or palatal cortical bone, and the presence of apical bone lucencies secondary to previous surgery

Gingival Margin Position

The final gingival margin over the implant is influenced by the gingival level before tooth extraction. If the gingival facial margin is ideal, the final implant restoration has an excellent prognosis, especially in a patient with a thick gingiva biotype. However, if the facial gingival margin position is not ideal because of crestal bone loss from periodontal disease, attrition, or decay, the facial gingival margin levels have a guarded prognosis unless interventional treatment is performed to correct or mask the gingival margin levels before tooth extraction (Figure 6-1, A-J).

If the gingival margin on the tooth to be extracted is apical to the ideal position for the planned esthetic restoration, the tooth must be extruded orthodontically or the bone must be moved using distraction osteogenesis or interpositional osteotomies. Isolated labial bone defects can

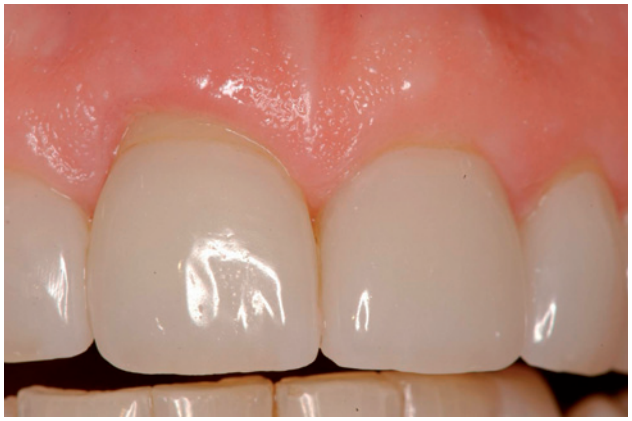


FIGURE 6-1 A, This patient's right central incisor requires extraction secondary to a coronal fracture and composite repair. Excellent interproximal bone is present between the lateral incisor and central incisor and in the interdental area between the two central incisors. However, 2 to 3 mm of labial bone loss has occurred over the facial aspect along the distal line angle of the tooth, with resultant gingival recession.

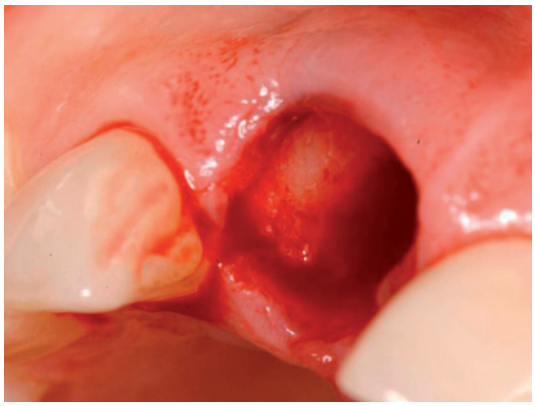


FIGURE 6-1 C, Bone adjacent to the lateral incisor is present at the cementoenamel junction (CEJ) of the lateral incisor. This is a good prognostic sign for the final papilla. However, bone loss has occurred along the distal-labial aspect of the tooth, as predicted from the initial preoperative examination.

be grafted. However, if the tooth is extracted and the gingival margin is apical to the ideal level, the gingiva will be at a compromised location on the final restoration. Grafting bone defects at the time of tooth extraction does *not* correct problems with the gingival margin location (DVD Figure 6-1, A-D). Adjunctive procedures to mask this may require crown lengthening for the adjacent tooth to create symmetry.

DVD Images 6-1, A-D

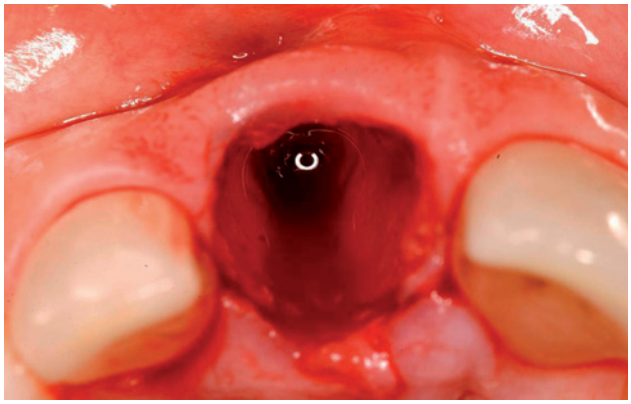


FIGURE 6-1 B, Tooth is extracted atraumatically with osteotomes. Incisions are made only around the neck of the tooth.

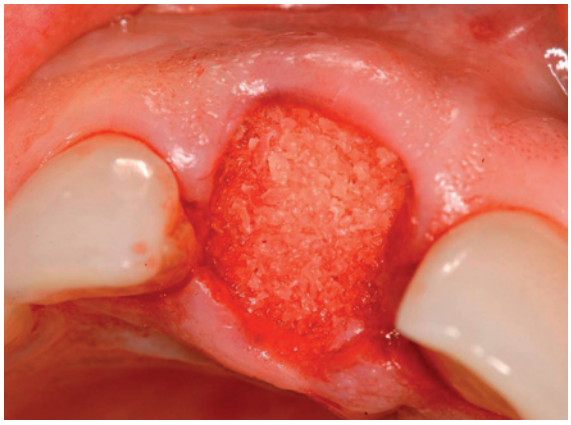


FIGURE 6-1 D, Human mineralized bone is placed into the extraction site and compacted firmly to reform the root prominence and to graft the 3-mm vertical defect along the distal-labial aspect of the tooth.

Level of Bone on Adjacent Tooth

Clinical evaluations by Tarnow et al.[19] and Ryser et al.[20] have indicated that the most important factor that predicts the presence of papilla between a tooth and an implant is the distance from the contact point of the final restoration to the level of bone on the adjacent tooth. The distance from the contact point to the level of bone on the implant itself is less discriminating. If the bone level on the adjacent tooth is at the cementoenamel junction (CEJ), the papilla will be adequate as long as the proportions of the final restoration are reasonable.

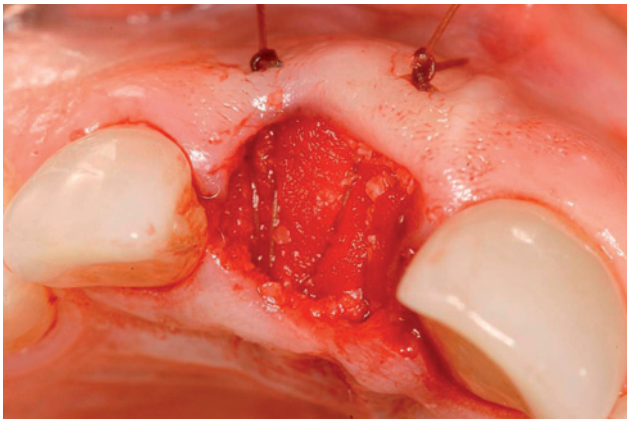


FIGURE 6-1 **E,** Piece of collagen is placed over the extraction site and held in position with mattress-type chromic sutures.

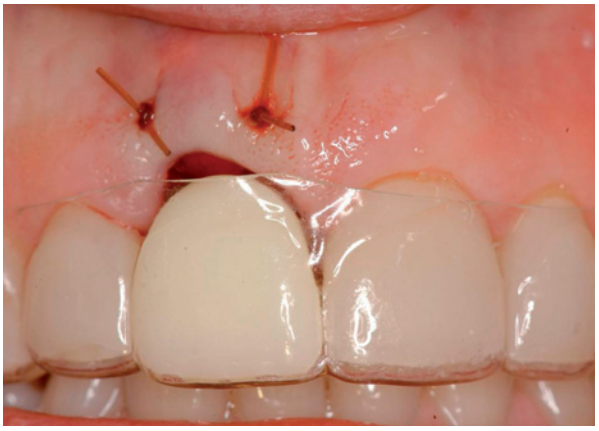


FIGURE 6-1 **F,** Temporary prosthesis is placed with the temporary tooth in the appropriate form, intentionally leaving a space between the tooth and the gingiva.

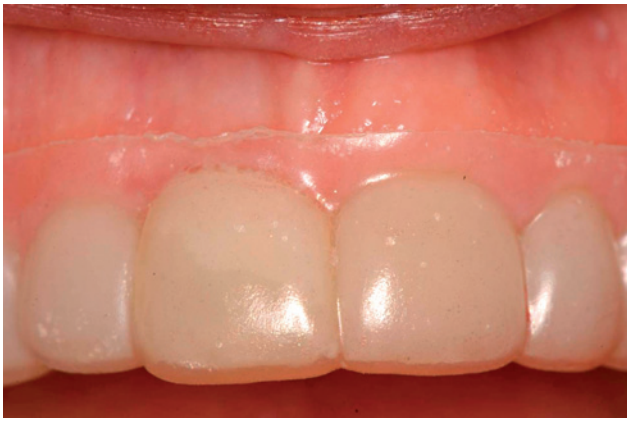


FIGURE 6-1 **G,** New temporary prosthesis is made to allow the vacuform plastic material to extend over the labial aspect of the gingiva. This creates suction, which guides the soft tissue to form underneath the temporary right central incisor.

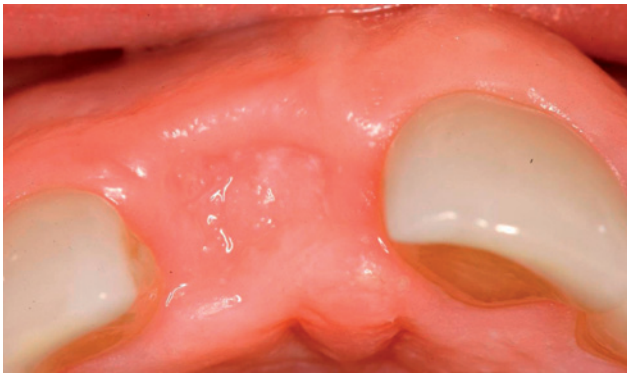


FIGURE 6-1 **H,** Preoperative view immediately before placement of the implant, using a flapless technique, approximately 4 months after graft placement.

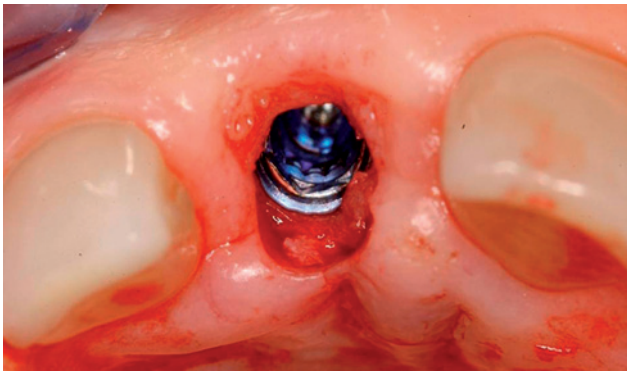


FIGURE 6-1 **I,** Implant is in position using a flapless approach. At this point, the abutment and provisional crown are placed.

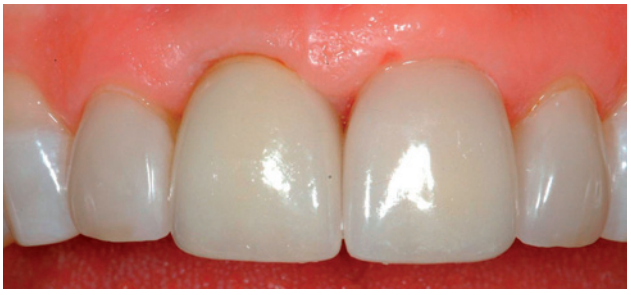


FIGURE 6-1 **J,** Final restoration in place, showing maintenance of the gingival profile. (Prosthetics by Dr. Mike Malone.)

Presence or Absence of Root Prominence

For a patient with a high smile line, the gingival morphology apical to the gingival margin usually has a convex form, known as the *root prominence.* When a tooth is extracted and the site is not grafted, some degree of labial bone loss occurs, resulting in a flat ridge form rather than the convex root prominence. Grafting the extraction site may help preserve the prominence of the root, which enhances the esthetics of an implant restoration in the esthetic zone. If sufficient bone is present for implant placement but the ridge form is still flat, the ridge form is augmented with a nonresorbable material, such as hydroxylapatite (HA), or a slowly resorbing material, such as bovine xenograft. Patients of a thick gingiva phenotype have less need of augmentation of the root prominence, because the thickness of the gingiva aids the final esthetic appearance. Root prominence augmentation is important primarily in patients with high smile lines and the thin gingiva phenotype.

Proportions of Tooth to Replace with Regard to Adjacent Teeth

In the preoperative evaluation, if the new tooth restoration is planned to be longer or shorter than the tooth to be extracted, the implant's position may need to take into consideration the position of the planned gingival margin, which may be more apical than the current tooth's position. If the tooth proportions indicate that a more coronal positioning is required, appropriate grafting may be necessary to achieve the desired result. If the implant is placed too superficially and if the esthetic restoration requires lengthening of the tooth without moving the incisive edge, the resultant problem is caused by improper vertical positioning of the implant. It is critical to place the implant with the final crown form, as determined from preoperative planning using ideal crown proportions (DVDFigure 6-2, A-P).

6-2, A-P

Local Deficiency of Bone in the Implant Site

If bone loss has occurred anywhere around the tooth to be extracted, including apical bone, labial bone concavities, and labial or palatal cortical bone, grafting of the site is indicated. If previous surgical procedures have been performed on the tooth to be extracted, such as an apicoectomy or periodontal bone reduction, or if the tooth has a history of previous avulsion and replacement, the clinician must assume that the bone around the tooth has a local deficiency. Apical procedures may result in concavities, which have a direct effect on implant positioning and stability. If an apical bone concavity or labial bone loss is expected, grafting can be performed at the time of the extraction to augment the site before the implant is placed. Careful evaluation of these sites is critical so that the necessary surgical procedures can be performed and the desired result achieved. Imaging may be necessary with a tooth in the planned position to assess bone.

Labial defects

A labial defect is a common finding when a tooth is extracted. Labial defects can be classified according to the amount of bone loss.

With less than 3 mm of labial bone loss, the gingival margin may be adequate or may be apical after the bone loss. If apical, the final esthetic result will benefit from orthodontic extrusion; otherwise, the patient and restorative dentist must realize that the final result may have a gingival margin slightly more apical than ideal. In these situations, depending on the lip line and the adjacent teeth, adjunctive masking procedures can be used. The adjacent tooth can be lengthened to match the implant crown. Pink material can be placed on the labial surface of the restoration. No treatment is considered if the final result is satisfactory to the patient. Because the implant is placed 3 mm apical to the gingival margin of the planned restoration, a small amount of labial bone loss may not be an esthetic disaster, especially in patients with a relatively normal starting gingival margin position.

With more than 3 mm but less than 6 mm of labial bone loss, the implant usually can be placed in the appropriate position, but a bone defect may exist, with exposure of the implant threads. The clinician has two choices with labial bone loss after extraction of the tooth: (1) the site can be grafted with mineralized bone, with the patient returning 16 weeks later for implant placement (Figure 6-2, A-U), or

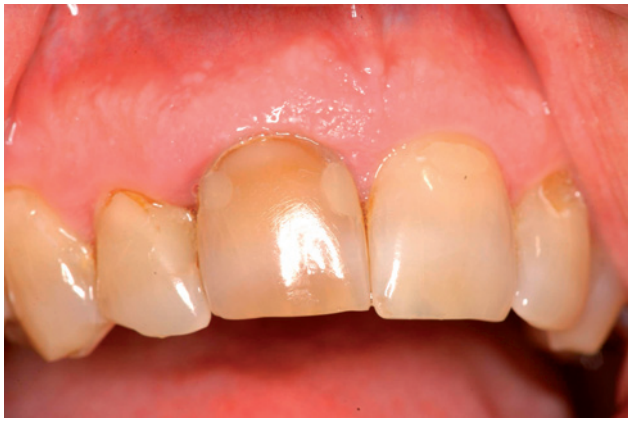


FIGURE 6-2 **A,** Pre-extraction view of right central incisor planned for extraction and grafting secondary to lingual external resorption.

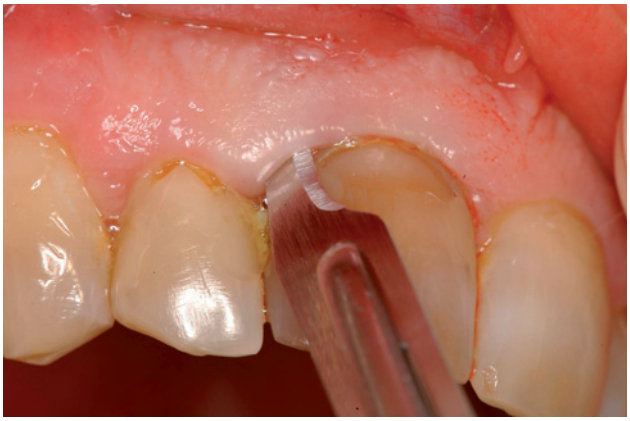


FIGURE 6-2 B, Gingival attachments are incised with a 15c blade at the junction of the bone and tooth.

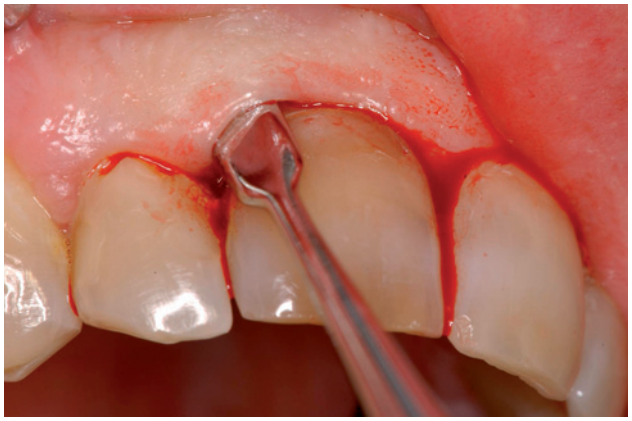


FIGURE 6-2 C, Hirschfeld #20 periosteal elevator is gently used to retract the gingiva to the junction of the tooth and bone; the periosteum is not elevated.

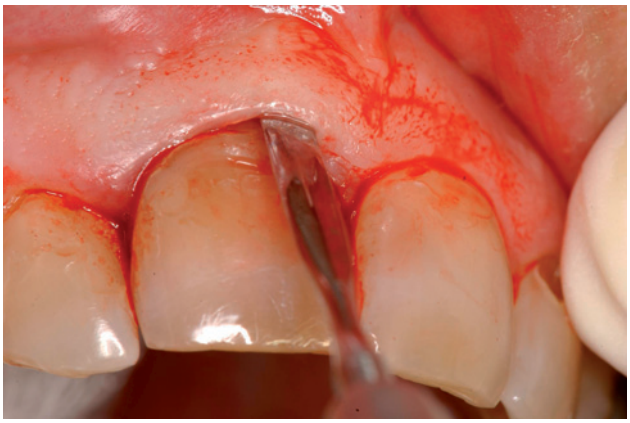


FIGURE 6-2 D, Periotome is placed at the junction of the tooth and bone and gently tapped to form a separation of the bone from the tooth. A periotome tip on a piezotome can also be used.

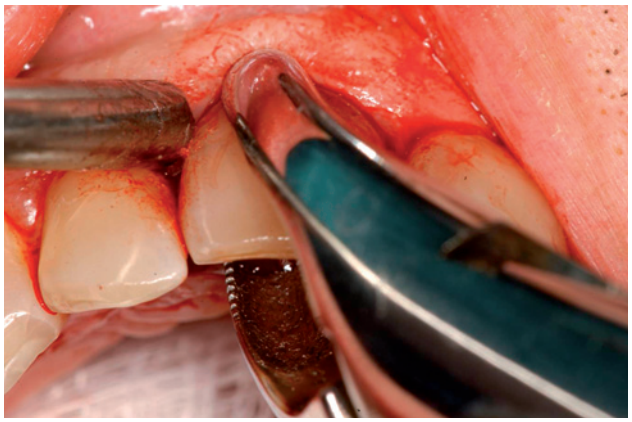


FIGURE 6-2 E, After the periotome has been used to create mobility of the tooth, the tooth is extracted with small forceps; rotary movements are used to prevent trauma to the labial bone.

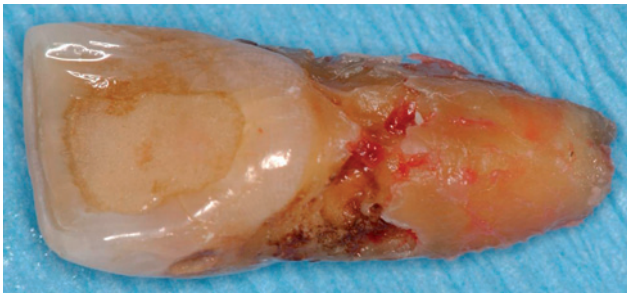


FIGURE 6-2 F, Tooth with lingual external resorption.

(2) the implant can be placed and the labial defect grafted with placement of a membrane to maintain the graft's position. However, with moderate labial bone loss (3 to 6 mm), immediate provisionalization of the implant should be performed only if the radiofrequency index is greater than 60.[21]

With greater than 6 mm of labial bone loss, implant placement is not as predictable, because less labial bone is present, and the chance of micromotion affecting implant integration is higher. In this scenario, the site is grafted, and after the graft has consolidated, an implant is placed (DVD Figure 6-3, A-G).

DVD Images 6-3, A-G

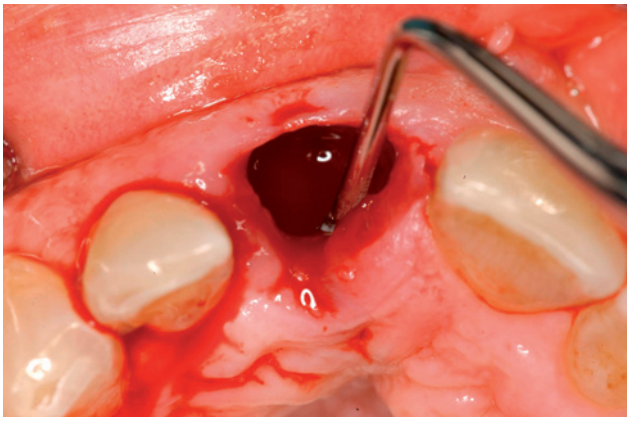


FIGURE 6-2 G, Spoon-shaped curette is used to remove the granulation tissue that has replaced the tooth structure, which was resorbed externally.

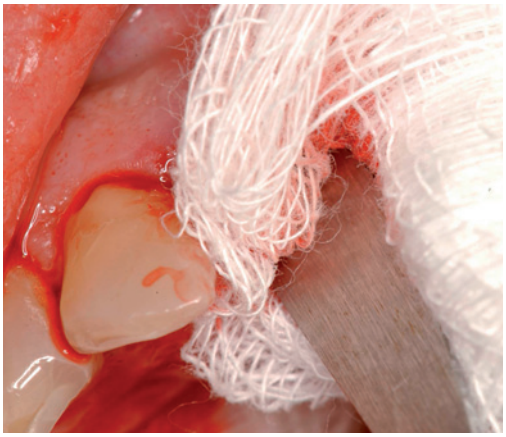


FIGURE 6-2 I, Gauze is used to absorb fluid expressed from the socket and to compress the graft farther under the gauze.

FIGURE 6-2 K, Scissors are used to cut a piece of collagen sponge 3 to 4 mm thick.

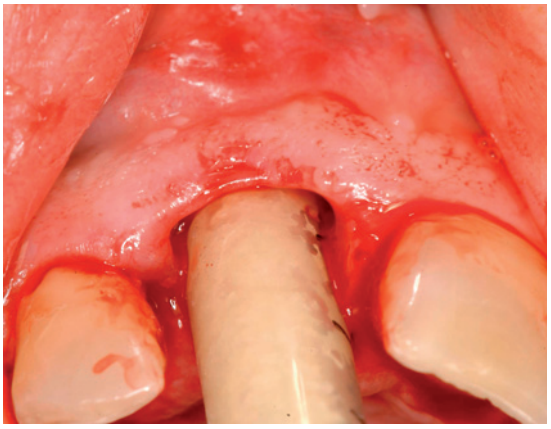


FIGURE 6-2 H, Tip is removed from a 1-ml plastic syringe, and the syringe then is packed with the particulate graft. The syringe is placed into the depth of the socket, and the particulate graft is condensed into the socket.

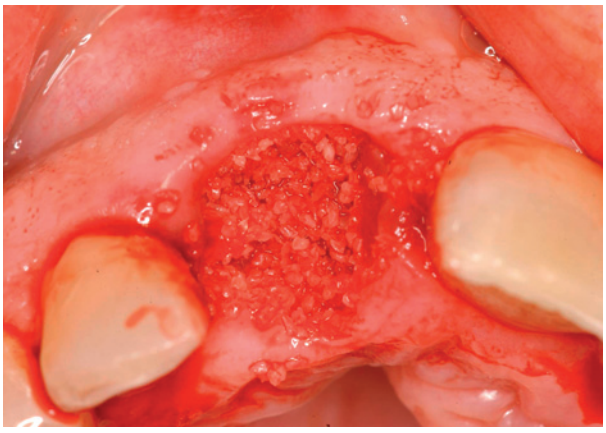


FIGURE 6-2 J, Graft is further compressed with the small end of a periosteal elevator or other blunt instrument. Here, the graft is seen before placement of the collagen.

Palatal defect or concavity

After exposure of the ridge in the anterior maxilla, specific circumstances can cause a palatal concavity or depression, resulting in adequate labial bone contour but insufficient palatal bone for implant placement. The width of the crestal bone may be adequate, but the palatal bone may have a concavity superiorly, which would result in implant dehiscence. Alternatively, the crestal bone may be too thin because of palatal bone loss. Palatal defects or concavities are found in younger patients in the region of retained deciduous teeth, without the presence of a permanent tooth.

FIGURE 6-2 **L,** The collagen sponge is compressed between the fingers to form a thin disk, which will be placed over the compressed graft.

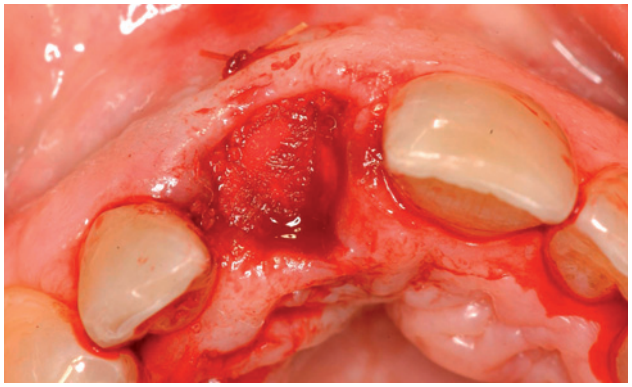


FIGURE 6-2 **M,** Suture (4-0) is placed first through the labial gingiva, superficial to the collagen sponge, and then through the palatal gingiva, back through the palatal gingiva, and then again through the labial gingiva to form a horizontal mattress suture. The suture is tied gently to approximate the gingiva to its original position. The temporary restoration then is placed.

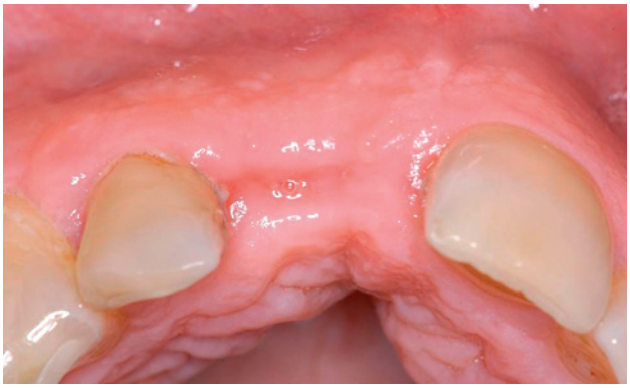


FIGURE 6-2 **N,** Four months after grafting, the patient is ready for the implant and provisional crown.

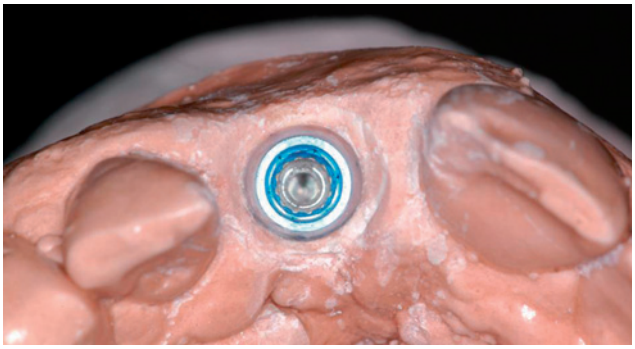


FIGURE 6-2 **O,** Diagnostic cast is used for placement of the implant analog.

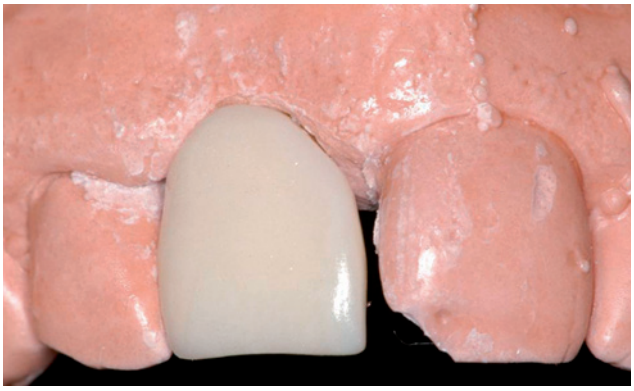
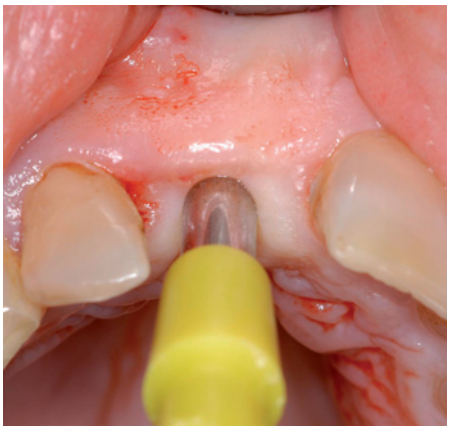


FIGURE 6-2 **P,** Abutment is prepared and a provisional crown is fabricated. The margins are smooth, and the tooth is not in contact with the opposing dentition.

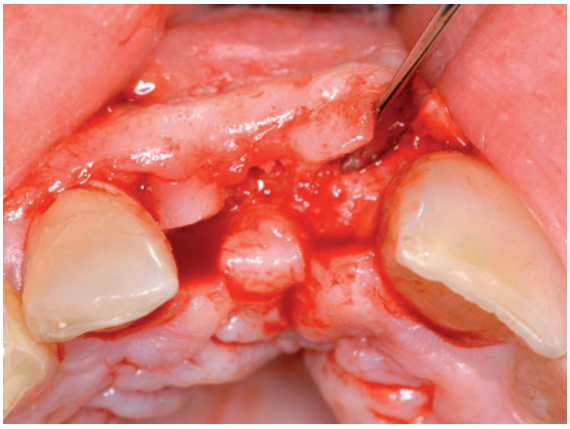
The palatal bone defect is difficult to graft because of tension from the palatal tissue. The defect can be exposed and grafted with particulate bone and a membrane or with a solid onlay piece of bone. In both circumstances, the labial tissue must be relieved to prevent tension over the graft. The success rate for grafting of palatal defects is lower than for labial defects and is not well documented in the literature.

Apical holes

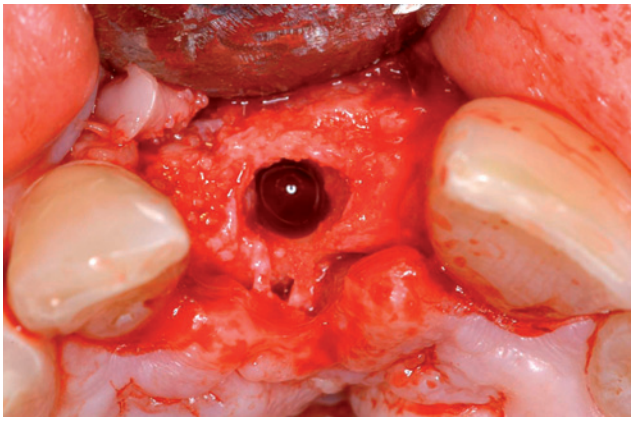
Apicoectomy results in a defect in the apical region of the tooth. Often these defects are easily found at the time of tooth extraction. At extraction, granulation tissue is removed from the bone, and the area is irrigated. The extraction site is grafted from within the site. If necessary,



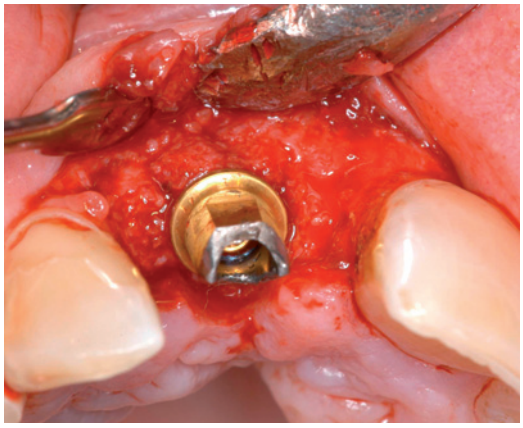
● **FIGURE 6-2** **Q,** At surgery, a tissue punch is used to provide ridge access and to contour the gingiva so that it lies smoothly against the abutment, allowing release of the papilla to the preoperative position.



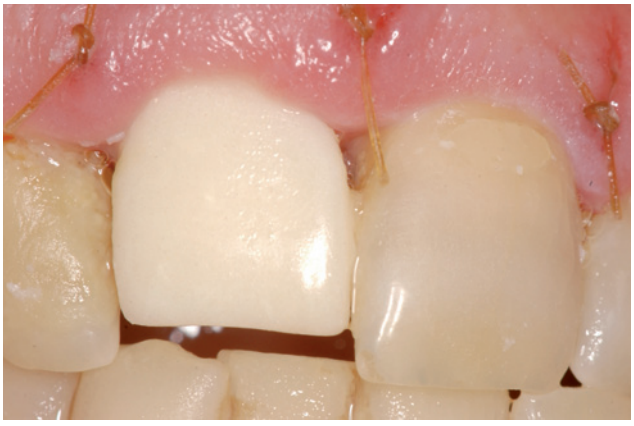
● **FIGURE 6-2** **R,** After the punch has been made, the incision is completed across the crest and halfway around the adjacent teeth. The flap is raised to expose the labial edge of the ridge.



● **FIGURE 6-2** **S,** Implant site is prepared. Note that sufficient bone is present for restoration of this site.



● **FIGURE 6-2** **T,** Implant is placed and shows a radiofrequency index of 72. The prepared abutment is placed and secured to the implant with a screw.



● **FIGURE 6-2** **U,** Provisional restoration.

a subperiosteal dissection can be performed from within the extraction site to provide space for the graft material. This author prefers to perform the dissection from within the socket and avoid labial dissection, if possible. In situations involving more than one adjacent tooth, an envelope flap can be made and a particulate graft placed with a resorbable membrane. Implants are placed in approximately 4 months, after the graft has consolidated.

Surgical Technique

When the treatment plan calls for extraction and grafting without immediate implant placement, an Essix type (clear thermoformed plastic material) of temporary prosthesis should be made to provide the patient with immediate

temporization with a removable device. The crown within the Essix gently approximates to the papilla to provide support without putting pressure on the crestal aspect of the ridge. Tissue-borne tempories are not recommended. Sixteen weeks after extraction and grafting, the implant can be placed and immediately provisionalized, if indicated (Table 6-1).

Tooth extraction protocol

A local anesthetic is administered, including infiltration around the tooth for improved hemostasis. A 15c scalpel blade is used to make sulcular incisions around the tooth to be extracted, with care taken to minimize trauma to the gingiva. The scalpel blade should be angled to follow the curvature of the tooth closely and to avoid cutting the gingiva. A series of thin elevators (e.g., periotomes) is used to separate the bone from the labial, interproximal, and palatal surfaces of the tooth; this allows the tooth to be removed without removing the surrounding bone. It is important to preserve the thin labial bone, which can serve as an edge of bone to which to compress the graft. If necessary, rotary instruments are used, with copious irrigation, to section the tooth and prevent removal of labial bone. After the tooth has been extracted, the bone levels on the palatal and labial aspects of the socket are examined. It is important to place the graft so as to reconstruct the osseous defects. Soft tissue remnants are removed from the socket with a dental curette, and the graft is then placed.

Graft placement

Approximately 0.5 ml of mineralized bone is wetted with sterile saline and placed into a 1-ml syringe (a tuberculin-sized, 1-ml plastic syringe also can be used). A scalpel blade is used to score the tip of the plastic syringe, and the smaller-diameter portion of the delivery edge is removed. The reconstituted graft material then is mechanically placed into the syringe. The graft material is human mineralized cancellous or cortical particulate bone, 350 to 500 μm in diameter. The sterile bone is provided in a sterile container. Quantities of 0.5 ml usually are the volume purchased, because extraction sites rarely require more than 0.5 ml for grafting of the socket.

TABLE 6-1 Grafting the Extraction Site: Anterior Teeth, Including Premolars

Procedural Steps	Comments
Make an incision in the sulcus around the tooth.	Use a small scalpel blade; maintain all gingiva.
Use a small periosteal elevator (Hirschfeld #20) to identify the junction of tooth and bone.	A small periosteal elevator prevents trauma to the gingiva. Dissect only to identify the bone-tooth junction by feeling, without elevation of the periosteum.
Use a periotome instrument to separate the bone from the tooth.	Use gentle pressure or gentle mallet to preserve the labial bone. The tooth should be mobile after this step.
Extract the tooth.	Remove the tooth without trauma to the labial bone. Use rotary movements and pull the tooth rather than sublux it.
Gently curette granulation tissue from the socket.	Remove only the granulation tissue. Do not scrape the bone excessively.
Evaluate the levels of bone on the mesial, labial, distal, and palatal aspects of the socket.	This step provides insight into the timing of future procedures.
Place particulate graft material into a 1-ml syringe.	Reconstitute the graft material according to the recommendations of the tissue bank.
Place the syringe into the socket and firmly compress the graft material into the socket.	Remove excess fluid with sterile gauze. Pack defects from within the socket to reconstruct the original bone morphology.
Cut and form a disk of collagen material. Place it over the graft site and tuck it under the edges of the gingiva. Place 4-0 suture in a horizontal manner to compress the gingiva to the site.	This material aids retention of the graft during the first week and promotes re-epithelialization of the site. Primary closure is *not* performed so as to prevent disruption of the gingival architecture.
Place a removable temporary prosthesis.	The temporary prosthesis may be tooth borne using an Essix-type retainer or a removable partial denture (RPD) type. Place gentle pressure on the papilla and avoid pressure on the graft. Do not use plunging pontics, or part of the graft will be lost.

The syringe with graft material is placed into the socket. The syringe is pushed to deliver the graft firmly into the socket. The graft is compacted into the extraction site with a blunt-ended instrument. The liquid expressed from the graft is absorbed by a piece of gauze, which also is useful for helping to compact the graft material within the socket. The graft is compacted to within 1 mm of the planned gingival margin of the restoration, as determined by a surgical stent, or the current gingival margin, if satisfactory, as determined by the preoperative esthetic evaluation.

After the graft has been compressed, a piece of collagen sponge material is placed over the graft within the extraction socket and tucked gently under the margins of the labial and palatal gingiva. It is important to prevent elevation of the gingival margin from the underlying labial bone to preserve the blood supply to the thin labial cortical bone. One or two 4-0 resorbable chromic sutures are placed in a horizontal mattress fashion to conform the gingiva gently to the collagen material and to cover the collagen to prevent immediate displacement. No attempt is made to achieve primary coverage of the esthetic extraction site. Disruption of the gingival architecture results in a poor esthetic gingival appearance. The labial gingiva is *not* elevated from the underlying periosteum. A removable temporary restoration is placed and modified to provide gentle pressure on the papilla with minimal pressure on the crest.

Grafting of large bone defects

With an anterior tooth that has extensive bone loss, usually over the labial aspect with the palatal bone intact, the surgical technique is similar to that previously described.

Incisions are made only around the tooth, maintaining the soft tissue envelope over the tooth roots and avoiding elevation of a flap. This preserves attachments peripherally and helps maintain a graft in an ideal position, using the original tooth space as the pocket of the graft. The tooth and roots are removed carefully. After removal, any granulation tissue is removed. With teeth with large external resorption areas, granulation tissue may be taking up the volume lost by the tooth during the resorption process.

The particulate graft is placed with a 1-ml syringe and compacted into the socket to recreate the root form and volume of the extracted tooth site. The apical region is reconstructed from within the socket.

Molar Sites

The molar tooth has roots that diverge and are separated by an isthmus of bone. The thickness of the bone between the roots may not be sufficient by itself for immediate implant placement. However, the labial and lingual cortical bone plates may be engaged to stabilize an implant in the molar site. The bone surrounding the molar tooth may be completely intact, or chronic infection may have caused large areas of bone loss, which if not grafted result in inadequate bone available for implant placement (Figures 6-3 through 6-5; and DVD Figure 6-4, A-G).

6-4, A-G

If the treatment plan includes placement of an implant into a posterior tooth site, it often is advantageous to graft the molar site to provide ideal bone volume for a wide-diameter implant. The goal is to have sufficient bone for an appropriately sized implant with regard to the molar-sized restoration.

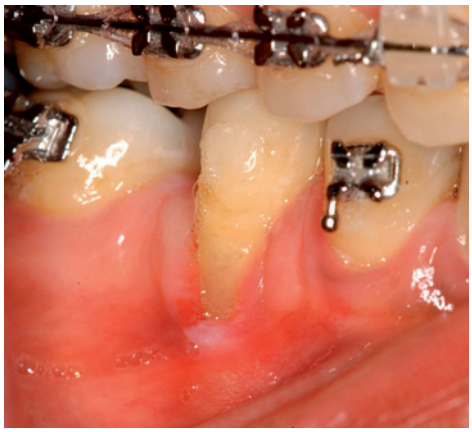


FIGURE 6-3 **A,** This patient had orthodontic therapy to create space and to realign her dentition. The mandibular right second premolar has a large area of labial bone loss, as well as soft tissue loss.

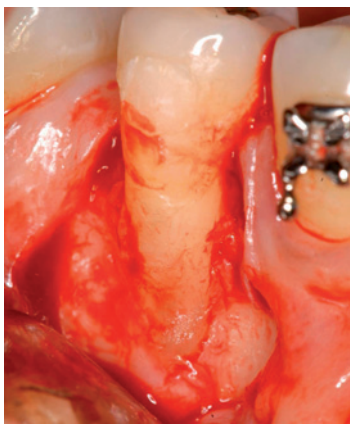


FIGURE 6-3 **B,** Vertical releasing incision is made after an incision has been made around the tooth, and a full-thickness reflection is performed. The labial root of the tooth is exposed from the bone. The interdental bone adjacent to the adjacent teeth is intact.

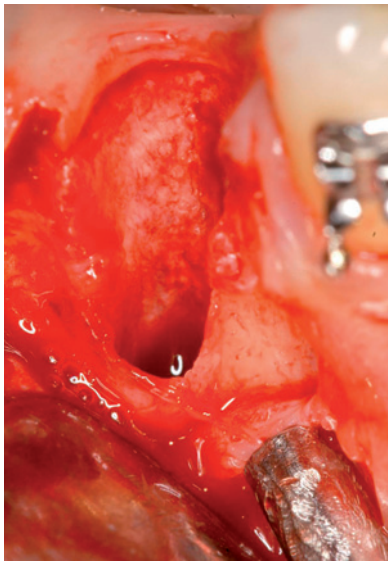


FIGURE 6-3 **C,** Tooth is extracted, leaving a large, vertical labial gap. Restoration of both the height and width of the socket is required.

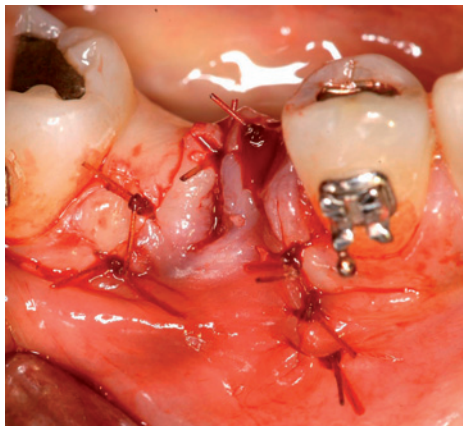


FIGURE 6-3 **E,** Initial V-shaped gingival defect is de-epithelialized. The periosteum is scored inferiorly, with great care taken to avoid the inferior alveolar nerve. The flap is advanced and sutured with 5-0 chromic and 6-0 chromic sutures to achieve primary closure.

The technique described next has proved useful for grafting of the posterior molar site.

Incision Design

A multirooted tooth leaves a significant defect in the bone after extraction. When the defect and socket are grafted with particulate material, the bone volume created and preserved depends on the density and retention of the graft

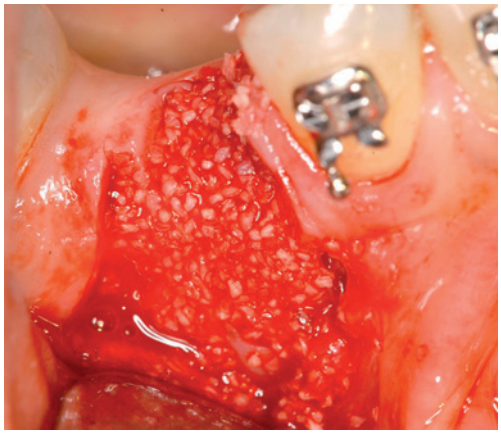


FIGURE 6-3 **D,** Graft of mineralized human bone is placed into the site and compacted firmly. The graft is formed to match the labial contour of the cortical bone.

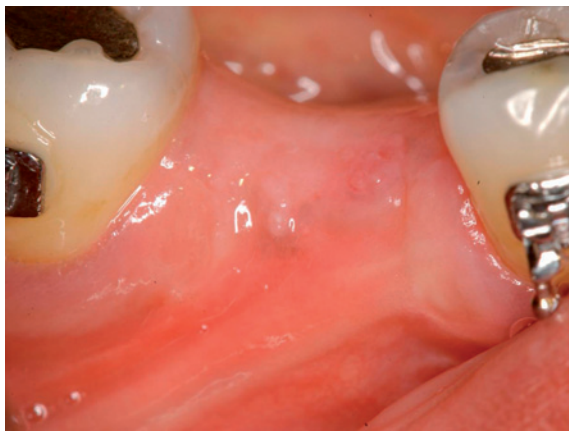


FIGURE 6-3 **F,** Ridge before placement of the implant. Note that the defect has healed with epithelium over it.

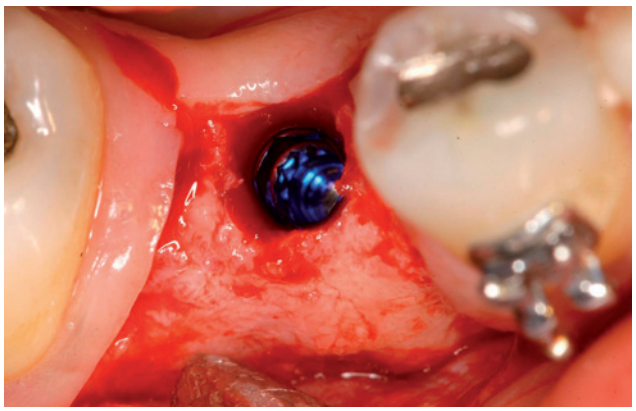


FIGURE 6-3 **G,** Interdental implant is placed into the grafted bone. Note that the width of the grafted alveolar ridge allowed an implant 4 mm in diameter to be placed easily.

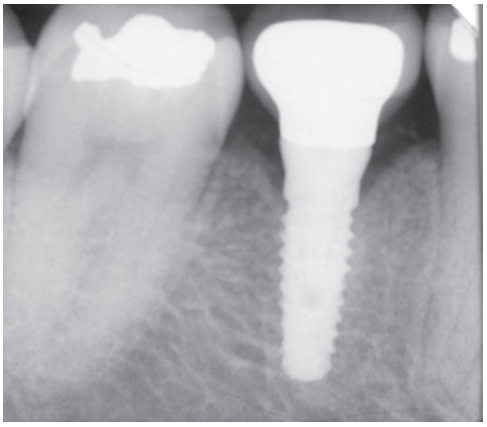


FIGURE 6-3 **H,** Implant after restoration.

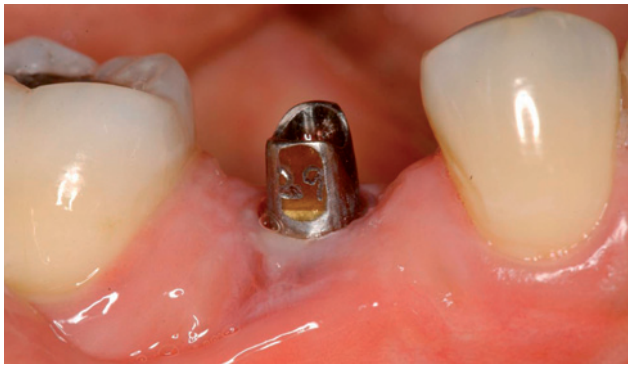


FIGURE 6-3 **I,** Fixed abutment is prepared in the laboratory and placed to restore this tooth.

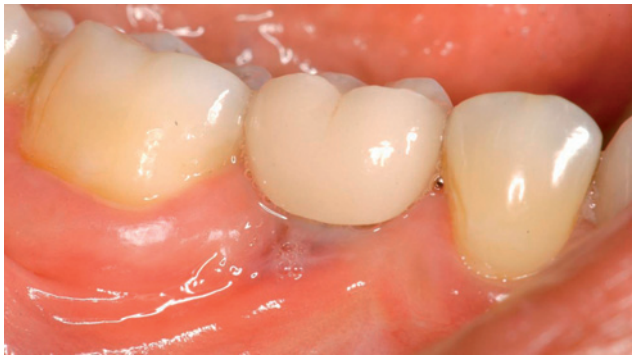


FIGURE 6-3 **J,** Final restoration is placed over the previously compromised site. (Prosthetics by Dr. Markus Blatz.)

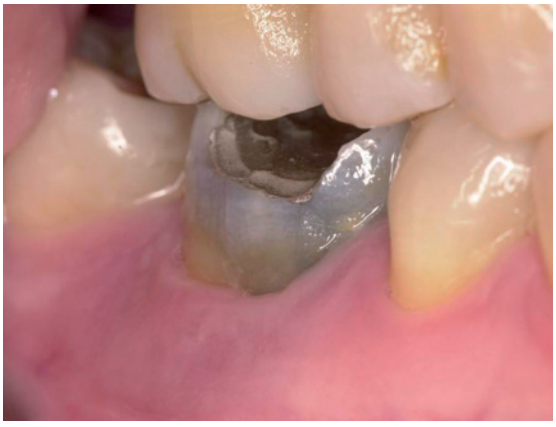


FIGURE 6-4 **A,** This patient's mandibular first molar requires extraction. The patient had been using antibiotics and chlorhexidine rinses preoperatively to reduce the bacterial flora around this tooth as much as possible.

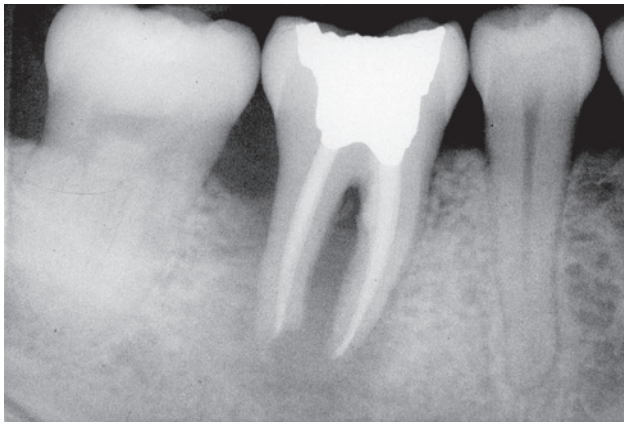


FIGURE 6-4 **B,** Periapical radiograph shows large areas of bone loss extending across the entire labial aspect of the tooth.

within the socket. In contrast to single-rooted or premolar sites, which can be treated with a collagen plug over the socket, leaving the molar site "open" results in loss of a portion of the graft. Therefore, primary closure is performed to retain the graft in molar sites. The incision design is critical for achieving primary closure of the site after placement of the graft.

The incision design allows advancement of the labial keratinized gingiva (KG) without advancement of the papilla and fixed gingiva on the adjacent teeth. The incision is made in the sulcus to within 2 mm of the interdental papilla. Vertical release incisions are made for full-thickness flap elevation to expose the lateral aspect of the alveolus and advance the flap to cover the site after graft material has been placed. When resorption of the labial or facial cortical

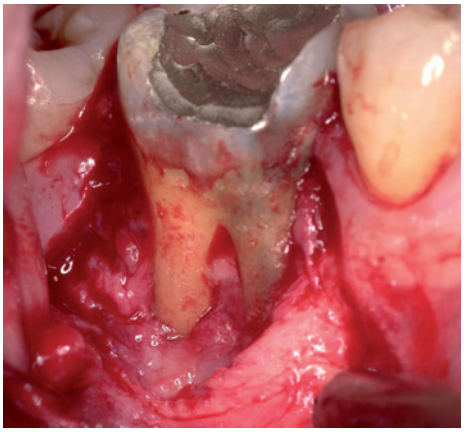


FIGURE 6-4 **C,** Incision is made around the labial surface of the tooth and linked with two vertical extensions. The vertical releasing incisions are made within the site of the first molar, with care taken to avoid raising the attached tissues on the adjacent teeth. A full-thickness exposure is performed, exposing the lateral aspect of the tooth and the extensive bone loss.

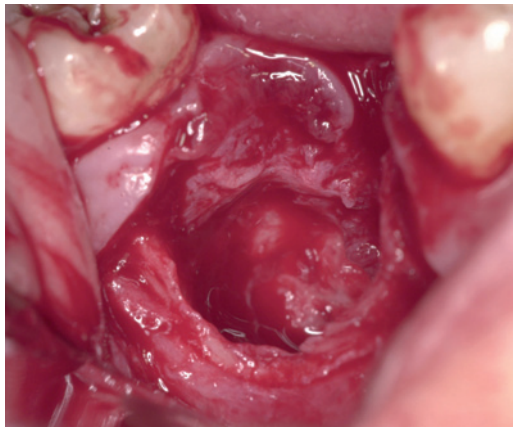


FIGURE 6-4 **D,** Tooth is removed, along with a small amount of granulation tissue. The area is irrigated thoroughly. Note the intact lingual plate of bone and the loss of the labial plate to the root apices. This defect has intact mesial and distal walls, as well as the lingual plate; therefore, this can be characterized as a three-wall defect.

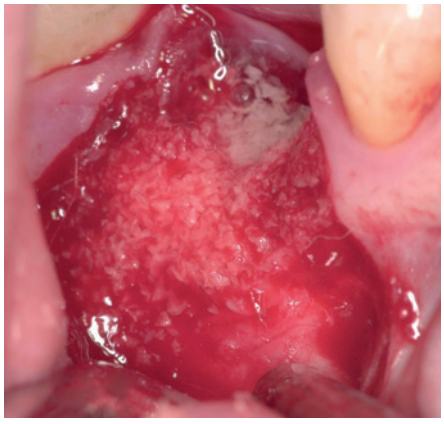


FIGURE 6-4 **E,** Graft of human mineralized bone is placed into the defect to reconstruct both the height and the width of the socket. After compaction of the graft material, the area is closed primarily.

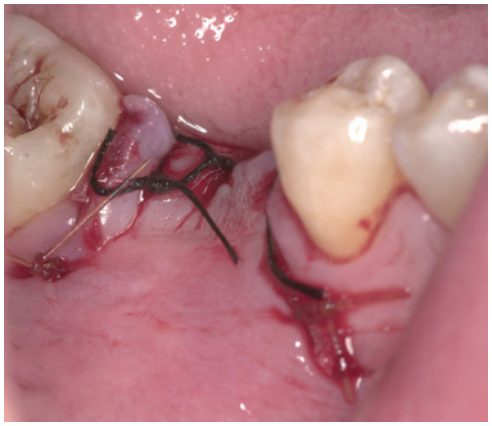


FIGURE 6-4 **F,** Primary closure of the wound with the keratinized gingiva (KG), previously on the labial aspect of the tooth, now advanced over the site, to be sutured to the lingual aspect of the ridge. Chromic sutures are used in the vertical releasing incisions. To advance the flap, the periosteum is scored to provide mobilization of the flap, allowing tension-free closure.

bone has been extensive, elevation of the flap is performed with sharp dissection, with care taken to prevent perforation of the labial gingiva. After the flap has been raised, the periosteum is scored and relieved to allow passive advancement of the flap for primary closure.

Tooth Extraction and Grafting Procedure

The tooth is elevated gently and removed with minimal lateral subluxation. Every effort should be made to preserve the lateral cortical bone. As necessary, the tooth can be sectioned to facilitate bone preservation. If present, granulation tissue is curetted. The site is irrigated gently with sterile saline, and the flap is tested to ensure passive rotation to the lingual tissues.

Particulate graft material is placed into a small dish and dampened with sterile saline. A 1-ml plastic syringe is used to deliver the graft. The tip of the syringe is removed with

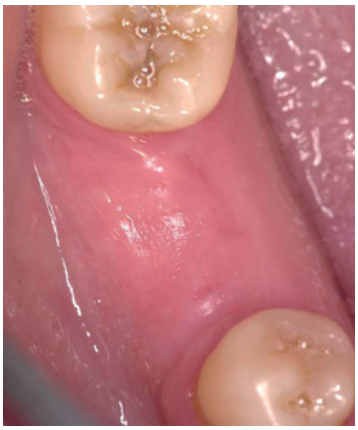


FIGURE 6-4 G, Sixteen weeks after the graft procedure, just before placement of the implant. The KG that had been advanced to the lingual aspect of the ridge is still present. Ridge form and height are excellent.

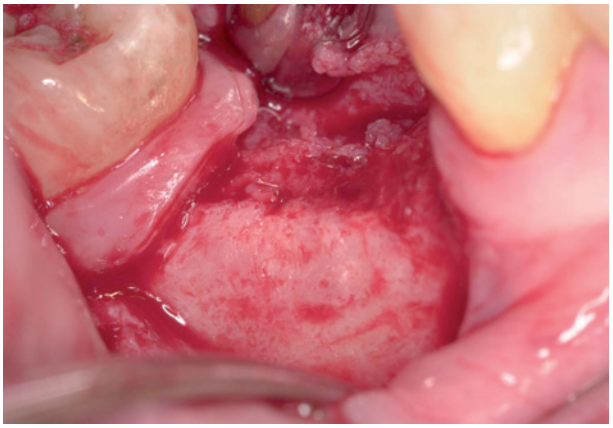


FIGURE 6-4 H, Incision is made at the junction of the keratinized tissue near the lingual mucosa to allow the KG to be transposed labially. Full-thickness reflection reveals the bone graft and confirms the reconstructed width and height of the ridge. In this case, a dental implant is placed, as well as a provisional abutment and crown.

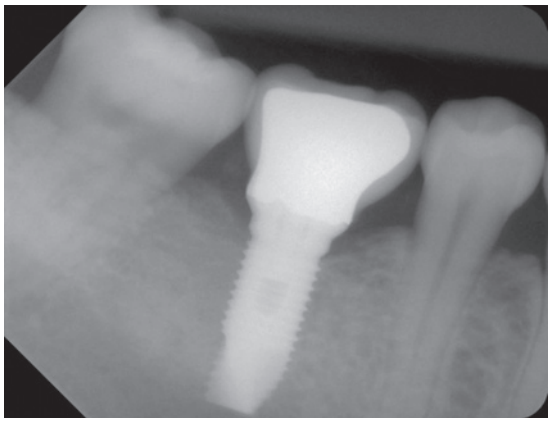


FIGURE 6-4 I, Periapical radiograph approximately 3 years after restoration of the tooth. Note the restoration of bone in all aspects.

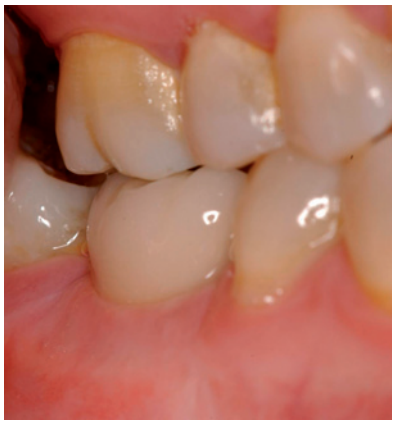


FIGURE 6-4 J, Final crown approximately 2 years after placement. Note the healthy gingiva around this tooth. (Prosthetics by Dr. Israel Finger.)

a scalpel and rongeur forceps. The particulate graft is packed into the syringe and then placed into the extraction site. The graft material is compacted with a blunt instrument, and gauze is used to remove excess fluids. After the socket and bone defects have been restored to original form by the graft, the flap is advanced over the site.

A resorbable suture (4-0 chromic on a tapered needle) is used to approximate the edge of the labial KG across the socket to the lingual gingiva. After two or three interrupted sutures have been placed, the vertical incisions are closed. Using this design, the labial KG is "banked" toward the lingual aspect of the ridge; it will be transposed to the labial surface of the abutment after the implant has been placed and exposed for restoration. Occasionally, advancing the gingiva across the broad base of a maxillary molar is difficult. In this situation, a collagen material is placed over the palatal root site, and the buccal sockets are primarily closed with the KG, with sutures holding the collagen material in position similar to anterior sites (Table 6-2).

Postoperative instructions

The patient is given antibiotics and pain medication. Antibacterial rinses are started 1 to 2 weeks after graft placement. The patient also is given instructions for following a soft diet.

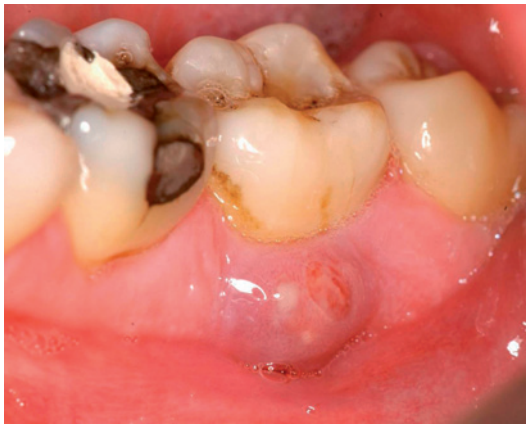


FIGURE 6-5 **A,** This patient's mandibular second molar has obvious abscess formation secondary to a fractured mesial root. The third molar is healthy posteriorly but malposed, and the first molar has a large restoration.

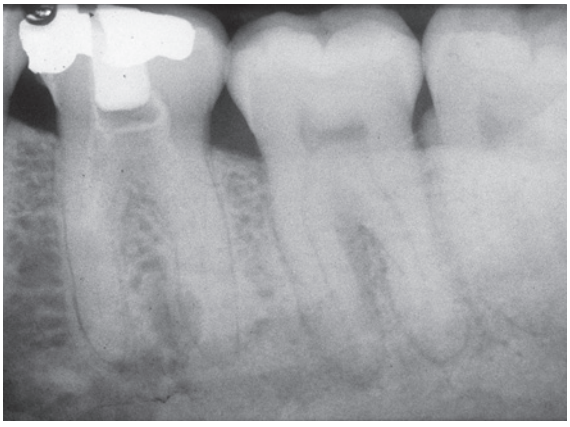


FIGURE 6-5 **B,** Periapical radiograph shows the large area of radiolucency on the labial aspect of the mesial root, as well the furcation area.

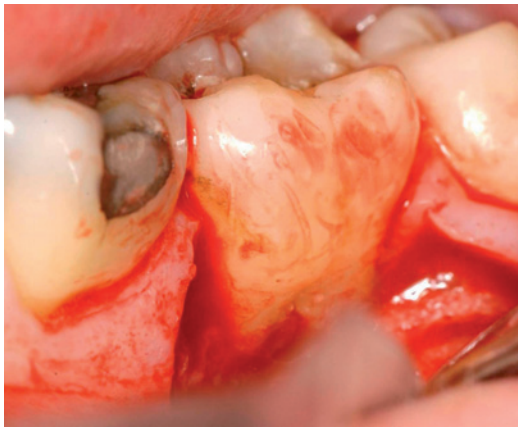


FIGURE 6-5 **C,** Incision is made around the neck of the tooth, with two vertical releasing incisions and a full-flap reflection. The tooth is removed atraumatically, and a fracture is found extending to the end of the furcation.

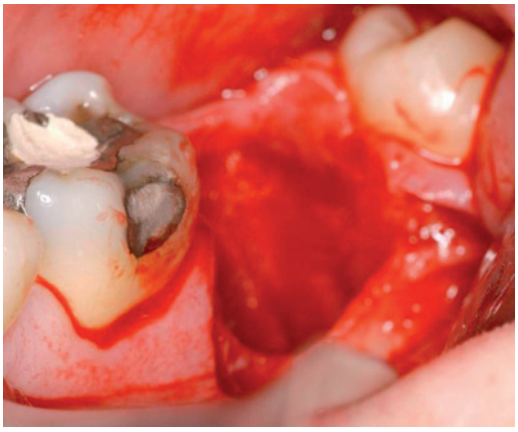


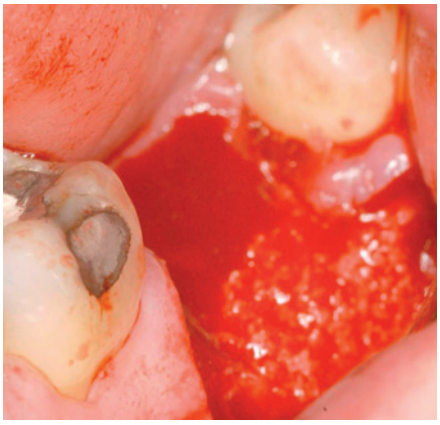
FIGURE 6-5 **D,** View of the extraction site. The lingual plate is intact, as is the mesial and distal interproximal bone. However, the labial bone is not prevalent. After irrigation and debridement of granulation tissue, the site is grafted. The periosteum is released before placement of the graft to allow tension-free closure.

The sutures are removed 7 to 10 days after graft placement. Radiographs are taken 3 months after graft placement for evaluation of the bone height for implant placement. Implants are placed 4 months after graft placement.

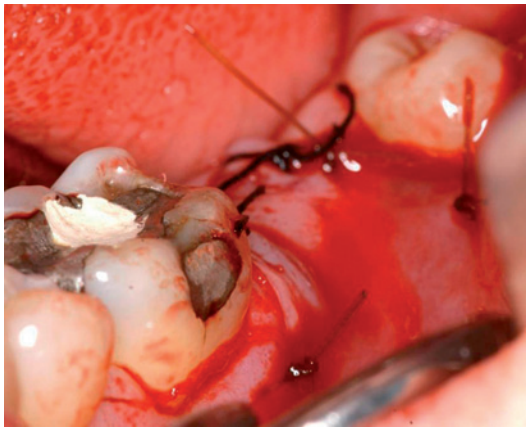
Immediate Placement of Implants at Tooth Extraction

Indications and Contraindications

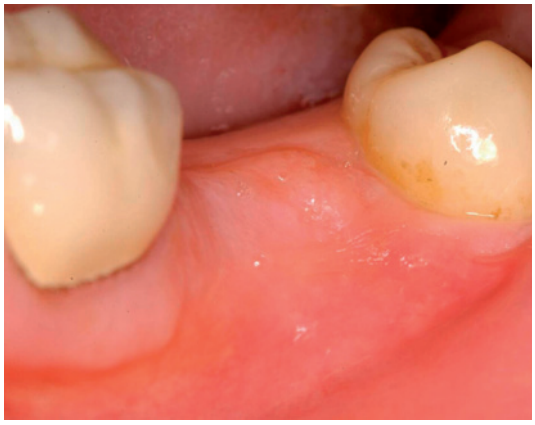
At the time of tooth extraction, the clinician may find purulent discharge, active periapical pathology, unhealthy gingiva with gingivitis and active periodontal disease in the mouth, a patient history of poor wound healing (e.g., uncontrolled diabetes, chronic steroid use, immunocompromise, alcoholism, drug dependence), or a lack of bone to stabilize an implant. In these cases, the tooth should be extracted, the site treated appropriately, and the implant placed *after* the infection and other local problems have resolved. However, if the tooth requires extraction and the site is relatively healthy, an implant may be placed, provided the indications for treatment outlined in this chapter are followed.



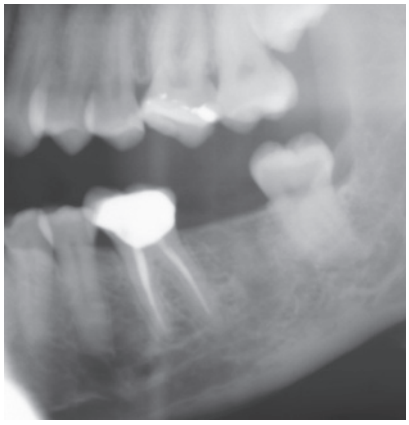
● **FIGURE 6-5 E,** Graft of human mineralized bone is placed into the molar site for reconstruction of both height and width.



● **FIGURE 6-5 F,** Flap is advanced to achieve primary closure.



● **FIGURE 6-5 G,** KG has been mobilized to the lingual aspect of the crest. Here, the ridge is shown approximately 4 months later, just before placement of the dental implant. Note the "banking" of KG on the crest of the ridge.



● **FIGURE 6-5 H,** Radiograph of the restoration of the bone in the second molar area, before placement of the implant.

With regard to the esthetic zone of the maxilla, which includes the premolars, canines, and incisors, patients often present with teeth in need of extraction. Reasons for extraction of a single-rooted maxillary tooth in an adult include internal or external resorption after trauma, a breakdown of post and cores that were placed because of trauma, caries, root canal failure, and periodontal disease.[22] Traditional protocols for restoring these sites rely on bone deposition to fill the extraction site before the implant is placed.[23,24] Hard and soft tissue grafting often is necessary to provide an ideal functional and esthetic restoration. Grafts compensate for the bone resorption that accompanies the natural healing process in an extraction socket.[25-28] When implants are placed 8 to 16 weeks after tooth extraction, the clinician must compensate for the loss of labial bone that occurs during the early phase of extraction site healing.[29-31] To prevent the need for hard or soft tissue grafting with a delayed approach, some have advocated placement of an osteoconductive graft material within the extraction site to promote bone fill, to prevent labial bone loss, and to maintain bone for improved implant placement.[32]

When an implant is placed into a fresh extraction site, all these problems with resorption of thin bone are still relevant. Therefore, grafting of a space between the implant and facial bone is indicated to maintain a hard tissue space

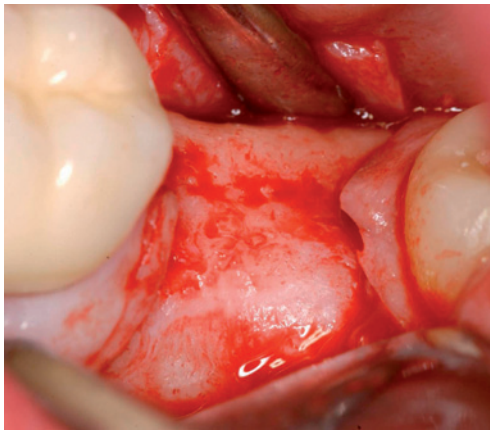


FIGURE 6-5 I, Incision is made along the lingual aspect at the junction where the KG and lingual mucosa are primarily reapproximated. The gingiva then is reflected labially, exposing the healed bone graft. Sufficient bone is present for placement of an ideal wide-diameter implant.

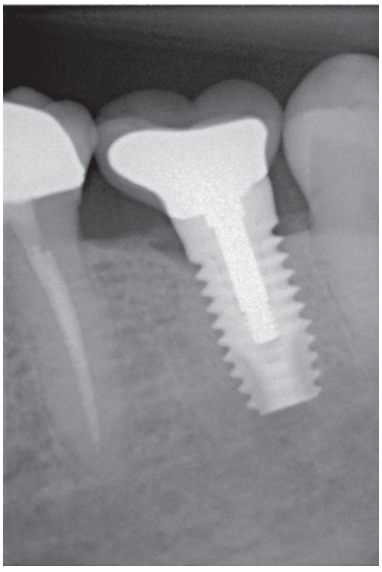


FIGURE 6-5 K, Radiograph taken 2 years after restoration shows maintenance of bone around the implant.

labial to the implant for optimal esthetics and health of the tissues around the implant. If the bone thins labial to an implant, threads may be exposed, the ridge form may become flat, and the ideal restoration of the tooth will not be realized. The natural process of bone remodeling occurs even when the implant is in place. Implants are placed into the extraction site to accelerate treatment for the patient, not to preserve bone.

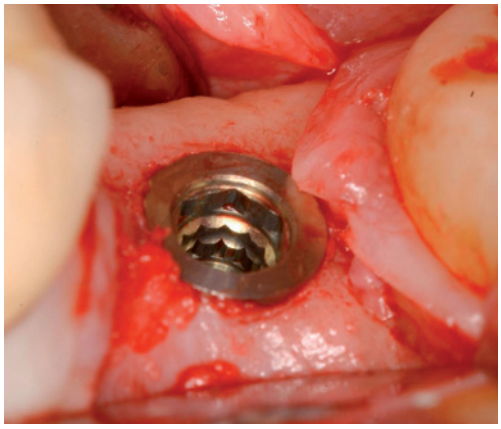


FIGURE 6-5 J, Dental implant 5 mm in diameter is placed. An abutment and provisional crown also are placed to provisionalize the restoration immediately, because greater than 20 N-Cm of torque was required to place the implant.

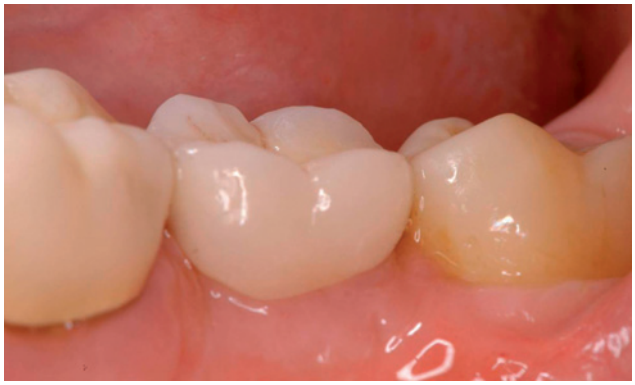


FIGURE 6-5 L, Final restoration, showing maintenance of excellent tooth form and gingival health. (Prosthetics by Dr. Markus Blatz.)

One-Stage Implants Placed in Fresh Extraction Sites

Reports indicate a high incidence of success in integration and function with implants placed immediately into extraction sites, as long as the site has no purulent exudate, a healthy collar of gingival tissue is present around the tooth, and minimal lucency is seen at the apex of the tooth to be extracted.[33-37] The placement of implants into the extraction site immediately after tooth removal has been anecdotally recommended to eliminate an additional surgical procedure, to prevent labial bone loss, and to preserve the labial root form of the esthetic site.[24,38-46] Exposure of the implant into the oral cavity does not seem to result in a decrease in crestal bone levels.

TABLE 6-2 Step-by-Step Surgical Method: Molar Teeth

Procedure	Comments
Make incision in sulcus around tooth, but limit to labial gingiva without incising interdental region.	Use small scalpel blade, maintain all gingiva. The goal is to reflect a labial-based flap without disrupting the adjacent interdental gingiva.
Make releasing vertical incisions to avoid elevation of the interdental gingiva.	The flap will be advanced to achieve primary closure.
Elevate a full-thickness, labial-based flap to expose the lateral aspect of the tooth to be extracted.	Often sharp dissection may be necessary if significant bone loss is present. Prevent tears in the flap.
Extract the molar tooth. Use sectioning if necessary. Maintain all labial and lingual cortical bone.	The goal is extraction of the tooth with minimal bone loss. Sectioning of the tooth may be required to preserve the cortical bone.
Gently curette the granulation tissue from the socket.	Remove only the granulation tissue. Do not scrape the bone excessively.
Evaluate the levels of bone on the mesial, labial, distal, and palatal aspects of the socket.	This provides insight into the timing of future procedures.
Prior to placing graft material, score the periosteum at the base of the flap to allow *passive* advancement of the flap.	The goal is tension-free closure. Keep the periosteal release limited to the periosteum; do not dissect the adjacent musculature.
Periosteal release may also be necessary along the vertical release incisions.	This limits bleeding and patient postoperative morbidity.
Place particulate graft material into a 1-ml syringe.	Reconstitute graft material according to recommendations of the tissue bank.
Place syringe into socket and firmly compress the graft material into the socket.	Remove excess fluid with sterile gauze and pack the defects from within the socket to reconstruct the original bone morphology.
Advance the flap and suture with 4-0 material using tapered needles.	Primary closure keeps the graft in position and is less prone to graft escape than is using only CollaPlug to cover the molar site.

Preoperative Evaluation and Implant Placement in Esthetic Zone

For the patient who requires extraction of teeth in the esthetic zone, the preoperative evaluation determines the specific surgical procedures necessary to achieve an ideal result and helps provide a high degree of predictability. The evaluation steps described in this section can be managed as a checklist for every patient (Table 6-3).

Smile line

The clinician should evaluate the patient's smile line and the lip line at rest with the mouth slightly open. In general, three levels of smile line are seen. First, the patient with a low smile line shows a limited amount of tooth on smiling. This patient typically just smiles weakly when asked to show the teeth. The patient probably can tolerate gingival margin discrepancies and also long teeth, if necessary.

The second smile level is seen in the patient who shows most of the teeth and some of the interdental papilla, but less than 1 mm of gingiva. This patient must be treated with the same caution and extensive planning as the patient with a high smile line. Gingival discrepancies and mismatched tooth length affect symmetry and are noticeable. This patient must know the realistic expectations before starting the treatment.

The third level is a high smile line. This patient exposes the facial gingival margin when smiling and also during general conversation. This patient will reveal any discrepancies in the ridge shape, levels of the gingival margin, and loss of papilla, as well as small differences between the teeth that affect symmetry. This patient most likely will require horizontal ridge augmentation with connective tissue grafts and synthetic materials, such as HA. Patients who show excessive gingiva at rest or at smile ("gummy smile") need an evaluation of the teeth, bone, and lips for surgical procedures such as crown lengthening, root coverage, orthognathic surgery to reposition the maxilla, and lip augmentation or shortening. Tooth length measurement and an accurate cephalometric analysis are important before determination of the final treatment plan.

Patients who use their hands to raise their lips when asked to show their teeth must be considered to have a high smile line. Even though these patients have a low smile line during animation, they look at their gingiva differently; therefore, their expectations and satisfaction are the same as for patients with a high smile line.

TABLE 6-3 Checklist for Preoperative Evaluation of Esthetic Tooth Sites

Category	Finding	Effect on Treatment
Smile line	High	Care must be taken; use all available options to achieve a perfect result.
	Low	Minimal effect on treatment.
	Low but patient raises lip to check gingival appearance	Treat similar to a high smile line, because patient looks at gingiva in the mirror daily.
Esthetic evaluation	Analysis of the teeth	
	Proportions	Treat adjacent tooth.
	Gingival margins	Adjust as needed, including adjacent teeth.
	Papilla	Be ready to explain realistic expectations or extrude adjacent tooth.
	Symmetry	Preoperative setup is essential.
	Ridge shape	May need to augment flat ridge with nonresorbable material and/or soft tissue graft.
Periodontal biotype	Thick	Easier to treat; soft tissue is resistant to recession.
	Thin	Care must be taken; recession occurs with minimal trauma, incisions heal with scars.
Probing	Adjacent teeth	Exposes bone levels for preoperative expectations and need for grafting.
	Facial	Exposes need for grafting.
Occlusal analysis	Deep bite	Not easy to keep out of occlusion.
	Open bite	Easy immediate provisionalization.
	Normal	Shorten immediate provisional 1 mm.
	Skeletal dysmorphia	Correct prior to final restoration.
Radiographic evaluation	Bone height	Provides expectation of papilla and need for grafting.
	Palatal bone thickness and shape	Aids decision on whether implant can be immediately provisionalized; in high vault or with concavities, stage procedure.
Gingival health	Gingivitis, active periodontal disease	Do not place implants into an area with active infection.
Patient psychiatric profile	Patient should be aware of the reality of the final result	False expectations lead to practice-patient problems.

Modified from Meltzer A: Personal communication, July 2, 2006.

Esthetic evaluation

The esthetic evaluation is discussed in detail throughout this book. The areas described next should be included in the evaluation.

Tooth Analysis. The teeth in the arch need to be proper in form, proportion, color, and position. The central incisors should dominate. The centrals should be 10.5 to 11.5 mm long, depending on the patient's skeletal form. The width of the centrals should be in proportion to their height, avoiding square, "squatty-shaped" teeth. Crown lengthening may be necessary to achieve ideal tooth proportions. The lateral incisors should be sized to appear similar to the patient's facial form. The gingival margin of the lateral incisor should be coronal to the margins of the central incisor and adjacent canine teeth. The canines should be shaped according to male or female gender.

The *gingival margins* should be esthetic and level, without asymmetry. The papilla should be level. If a line is drawn across the anterior quadrant, all the papillae should be at the same vertical level. The band of attached gingiva should be level without vertical discrepancy. The surgeon, therefore, should avoid disrupting the band of attached tissue by not creating extensive flaps. If the color of the gingiva is red rather than pink and if the appearance of the gingiva is flat and shiny rather than stippled, a connective tissue graft must be placed under the facial gingiva within a pouch. The gingival form, knife edge or blunted, follows the gingiva biotype.

The *papilla* should fill the interdental regions. If present on the adjacent tooth, gingival recession likely reflects bone loss on the interdental aspect of the adjacent tooth. Because papillary support is based on the bone levels on

the adjacent tooth, this preoperative finding is important in the treatment planning. The adjacent tooth can be extruded to move the bone and soft tissue coronally, the tooth can be extracted and the area grafted, the prosthetics can be made to mask a small papilla by moving the contact area apically, or the patient can accept a missing or small papilla.

Symmetry is critical for esthetic appearance. Asymmetric teeth or gingiva and ridge deformities produce a poor esthetic result. When evaluating the patient, the surgeon and restorative dentist should plan for adjunctive procedures on the adjacent teeth to achieve symmetry. Procedures may include crowns, laminates, crown lengthening, root coverage, orthodontics to align or extrude teeth, ridge augmentation under pontics, and extraction of teeth if strategically necessary to achieve symmetry.

Ridge shape is important to consider in the patient with a high smile line. Root prominence exists because of the shape of the tooth root under thin labial bone. In the patient with a high smile line, it is important to plan for horizontal ridge width augmentation with hard or soft tissues to achieve the appropriate ridge shape.

Gingival biotype

The patient's gingival biotype must be assessed because certain biotypes must be treated differently.[47]

Patients with a *thick biotype* have the following characteristics:

- Tooth form is square.
- Labial cervical region is convex.
- Contact points are long and wide.
- Volume of the interdental region is large.
- Gingival soft tissue responds to "insults" with pocket depth development rather than with recession.

A patient with a thick biotype is easier to treat than a patient with a thin biotype. Incisions heal with less indentation from scarring in the former. When the gingival margin is satisfactory before extraction of a tooth, even in the presence of labial bone loss, an excellent chance exists that the final gingival level will be similar to the original. If labial bone loss is present, the patient with a thick biotype may have a 5-mm pocket that appears healthy, without bleeding on probing.

Patients with a *thin biotype* have the following characteristics:

- Tooth form is tapered.
- Labial convexity is small.
- Distance between peak of the interdental papilla and labial gingival margin is great.
- Periodontal tissues are thin, with tooth dehiscence through the bone.
- Contact areas are small because of the tooth form.
- Volume of the interdental space is small.
- Gingival margin reacts to "insults" with recession.

For patients with a thin biotype, the original tooth should be maintained rather than extracted if at all possible. In these patients, endodontic therapy, apicoectomy, and other procedures to preserve the tooth often increase the chance of preventing a poor esthetic result, because the gingival response to surgical insult is poor. For these patients, incisions are prone to heal with retraction, resulting in gingival recession. A flapless or minimally invasive approach is preferred. Vertical incisions should be avoided. Incisions made with raising the papilla may result in papillary loss if the bone on the adjacent tooth is not ideal. If labial bone loss is present, the final level of the facial gingival margin will be close to the final level of the bone, because the pocket depth in thin gingiva may not exceed 2 to 3 mm.

Probing

In the preoperative assessment, probing of the sulcus to determine bone levels provides an assessment of the facial gingival margin levels and of the final levels of the papilla. If labial bone loss is present, the subsequent therapy must include grafting. If loss of the labial plate has occurred, immediate implant placement is not scheduled until the bone can be restored.

Occlusal analysis

When tooth extraction and immediate implant placement are planned, the clinician must base the decision on immediate provisionalization on several factors. Occlusal contacts that load the implant repeatedly during the day must be avoided for at least 8 to 12 weeks after implant placement. In the patient with a deep bite, shortening of the crown may still result with contacts during protrusive movements. Use of a bite-opening device may be necessary, and it must be worn 24 hours a day. Some patients will not be compliant, however, and for these patients a two-stage procedure is indicated, with the implant buried. If a significant Class II or Class III skeletal deformity is present, the location of the implant changes, depending on the decision to correct the skeletal deformity with orthognathic surgery. It is important to include orthognathic surgery in the treatment planning before implant placement, because orthodontics and the skeletal changes may alter the ideal position of the implant.

Radiographic evaluation

The initial assessment of bone usually is performed with a panoramic and periapical set of radiographs. The height of bone on the adjacent teeth and the vertical height of bone are easily assessed on these radiographs. A critical assessment of the thickness of the palatal aspect of bone in the anterior maxilla is necessary, because palatal bone shape

and bulk affect the decision on whether to provisionalize the implant immediately.

Cross-sectional tomograms, reformatted computed tomography (CT) scans, sounding, and even palpation are all accepted methods of assessing the palatal bone morphology. For each patient, one of these methods will be sufficient; the other methods may be more difficult to use for accurate assessment because of soft tissue thickness. If the palatal bone is thick and the vault of the palate is shallow anteriorly, the implant is placed engaging significant bone. This implant can be provisionalized immediately (see Figure 6-10, G-H).

If the palate has a high vault and a narrow palatal bone bulk, the implant engages less bone and may not be sufficiently stable for immediate provisionalization. The volume of bone the implant can engage allows the implant to be angled along the axis of the tooth or to be placed in palatal orientation. Ideally, the axis of the implant should angle the implant to exit slightly palatal to the incisive edge, between the edge and the cingulum. The bulk of palatal bone affects the ultimate placement and stabilization of the implant, which directly influence the decision on whether to provisionalize the implant immediately.

Practical methods are available for determining bone thickness. Many clinicians and patients do not have ready access to reformatted CT scans but need to determine bone thickness. Elevation of the overlying soft tissues and direct examination of the bone are not recommended because of the morbidity and scarring involved. Using local anesthesia, a sharp probe (e.g., endodontic instrument) can be used to map the thickness of the soft tissues, creating a three-dimensional image of the thickness and shape of the underlying bone. The most precise technique is the reformatted CT scan, which is accurate to within 0.5 mm.

Anatomic Configurations after Tooth Extraction

After a tooth has been extracted, the resultant defect in the bone may have several anatomic configurations that directly influence implant placement. This section discusses 10 findings that may be seen after tooth extraction. Each finding may be isolated or may be one of several morphologic observations (Box 6-1).

1. Loss of all labial bone to the apex of the tooth. If the bone on the facial or labial aspect of the socket is not present, the clinician should graft the socket and delay implant placement. The predictability of success decreases even when a graft and membrane are placed, because implant stability at the time of placement is compromised by the loss of bone. A mobile implant at the time of placement does not reliably integrate.

BOX 6-1 Anatomic Configurations after Tooth Extraction

1. Loss of all labial bone to the apex of the tooth
2. Loss of a portion (3 to 6 mm) of the labial bone
3. Loss of less than 3 mm of labial bone at the crest
4. Lack of bone superior to the apex of the socket, with extreme proximity of adjacent vital structures (e.g., inferior alveolar canal, mental foramen, floor of the nose, and floor of the sinus)
5. Lack of palatal or lingual bone
6. Concavity along the palatal or labial contours of the extraction site
7. Socket that is larger than the proposed diameter of the implant in all dimensions
8. Socket that is oval in shape, with the long dimension palatal to facial and the short dimension mesial to distal
9. Very thin surrounding bone
10. Bone adjacent to the neighboring tooth (or teeth) absent, and root surface of adjacent tooth exposed

2. Loss of a portion (3 to 6 mm) of the labial bone. In this situation, a graft is necessary to restore the labial portion of the missing bone. If the implant can be placed with its palatal, mesial, and distal surfaces in contact with bone and at least 5 mm of apical bone is present to secure the implant, the lost bone is reconstructed with particulate graft material, such as autogenous bone, allograft bone, xenograft bone, or HA. The compromise in this situation is that the soft tissue over the extraction socket usually cannot be closed without disruption of the gingival architecture. Therefore, a piece of resorbable collagen material or a piece of tissue harvested from the palate can be used to obturate the hole left by the tooth. If the surgeon is unsure of the esthetic result in these cases and 50% of the labial bone has been lost as a result of the pathology associated with the tooth, the suitable treatment is to graft the socket and have the patient return after 4 months for implant placement (Figure 6-6, A-B; the complete case is presented in DVD Figure 6-5, A-I).

6-5, A-I

3. Loss of less than 3 mm of labial bone at the crest. This is a very common situation when a tooth with extensive caries or a fracture is extracted. After the tooth has been extracted, the crestal resorption is limited to 3 mm from the planned gingival margin of the final restoration. In this situation, the implant is placed at the level of the bone, with attention to implant collar design. The height of the collar of the implant from the abutment interface to the first thread determines the ultimate bone levels adjacent to the implant. This is most critical along the facial aspect of

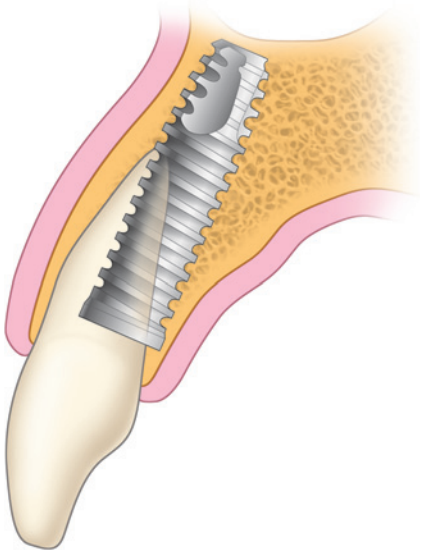


FIGURE 6-6 **A,** Diagram of a cross section of the central incisor site with excellent palatal bone thickness. In this situation, the implant can be placed immediately after tooth extraction with assurance of its stability, as was found in the patient depicted in DVD Figure 6-5.

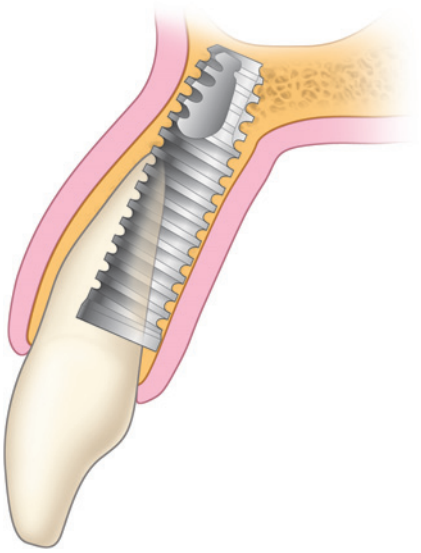


FIGURE 6-6 **B,** Diagram of a cross section of a central incisor site with narrow palatal bone thickness. In this clinical situation, an implant placed immediately may not be stable because of the lack of available bone, and a delayed approach may be appropriate.

the implant. Especially in a patient with a thin gingiva biotype, loss of facial bone results in gingival recession rather than pocket formation. Thus use of an implant that preserves crestal bone is important in this area. Implants with tall, straight collars are more prone to apical migration of bone. Because the height of the interdental papilla depends on the level of bone attachment on the adjacent tooth, the facial bone levels are less important for the papilla. New implant designs move the inflammatory zone present at the abutment-implant interface away from the bone to help preserve the bone at the top of the implant.

4. Lack of bone superior to the apex of the socket, with extreme proximity of adjacent vital structures, such as the inferior alveolar canal, mental foramen, floor of the nose, and floor of the sinus. After tooth extraction, the mental foramen may be close to the apex of the first or second mandibular premolar. These extraction sites need grafting to prevent placement of the implant into the nerve canal. Apical extension of the implant beyond the root apex results in sensory nerve disruption. In the maxilla, preoperative radiographs can determine whether the apex of the tooth to be extracted is close to the nasal floor or sinus. When apical bone is not present to stabilize an implant, implant stability is achieved only if the implant's diameter is greater than the diameter of the root of the extracted tooth. This may be the case with premolars, but it is a rare finding with central incisors and canines. In this situation, grafting of the extraction site and delayed implant placement are preferable.

5. Lack of palatal or lingual bone. This is an uncommon finding, because palatal or lingual bone is the last to resorb during inflammation around a tooth. If the palatal or lingual bone is not present, a graft is necessary before placement of an implant. If the mesial and distal bone is present on the adjacent teeth, a delayed approach with membrane assistance can successfully restore the bone defect. Another viable option is to delay grafting for 4 weeks and then place an onlay graft harvested from the symphysis.

6. Concavity along the palatal or labial contours of the extraction site. This finding is seen in younger individuals and is associated with congenitally missing teeth and retention of the deciduous teeth in the anterior maxilla. The buccal bone may be normal in shape, with a concavity of the palatal aspect either along the entire palatal cortex or 3 to 5 mm from the crest, with an indentation along the palatal bone contour in the axial plane for the implant. A graft is necessary in this situation, and in a location with dense palatal tissue, obtaining an excellent result is difficult. Membrane-assisted particulate grafting with a long-term bone replacement material (e.g., anorganic bovine bone) may be successful but is not completely predictable. Onlay grafts are difficult to place along a palatal concavity. The continued pressure from the dense palatal tissue often causes graft resorption. A year may be necessary from placement of a bovine graft with membrane until the bone is sufficiently formed for implant placement (Figure 6-7, A-D).

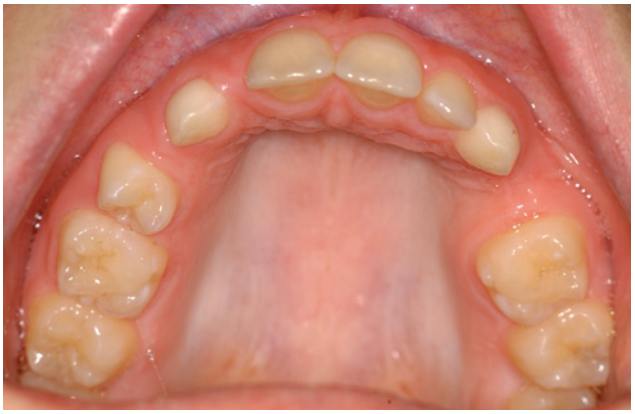


FIGURE 6-7 **A,** This 21-year-old woman's maxillary left deciduous canine is to be extracted in anticipation of receiving implants for a fixed restoration. Note the concavity on the palatal aspect of the ridge.

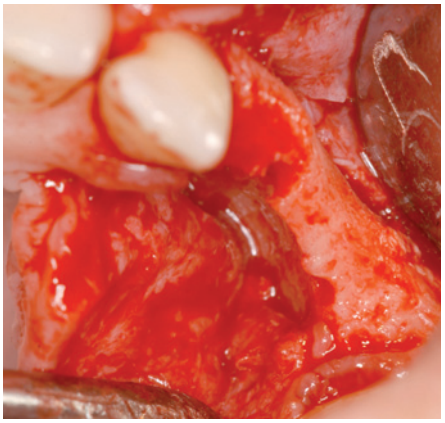


FIGURE 6-7 **B,** At surgery, after exposure of the crest and extraction of the deciduous canine, a significant palatal concavity is present with a palatal undercut. This site is grafted with bovine bone and a membrane, but the resultant ridge width allows placement of only one implant in the first premolar region and not in the canine location.

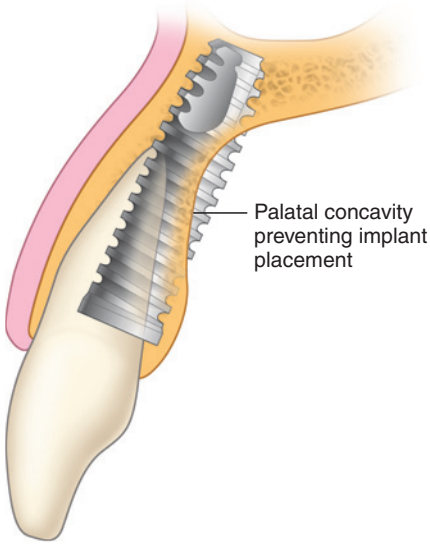


FIGURE 6-7 **C,** Diagram showing the palatal concavity problem; the implant would have a palatal dehiscence if the crest were sufficiently wide for placement of the implant.

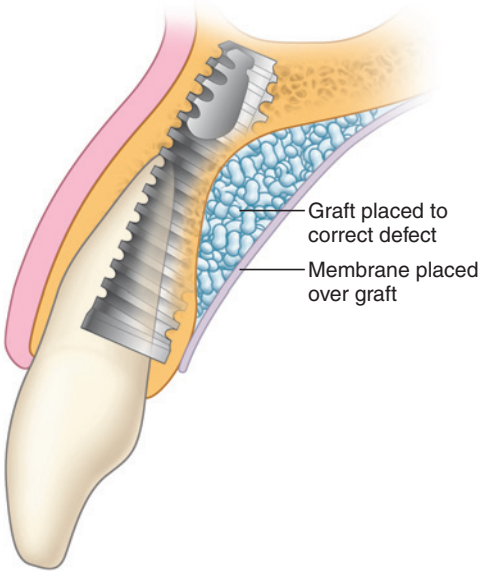


FIGURE 6-7 **D,** Diagram showing an ideal graft placed with the aid of a membrane. Unfortunately, the success rate for grafting of palatal defects is low.

7. Socket that is larger than the proposed diameter of the implant in all dimensions. When an implant is placed into an extraction site, the normal drill sequence is used to prepare the implant site; bone is removed until the implant can be placed and stabilized. When the diameter of the root of the tooth is larger than the implant in all dimensions, stabilizing the implant is most difficult unless more than 5 mm of bone is present beyond the apex of the socket. In these cases, grafting of the large extraction socket provides the surgeon with an ideal site for placement of an implant after the graft has healed with bone formation in the socket (DVD Figure 6-6).

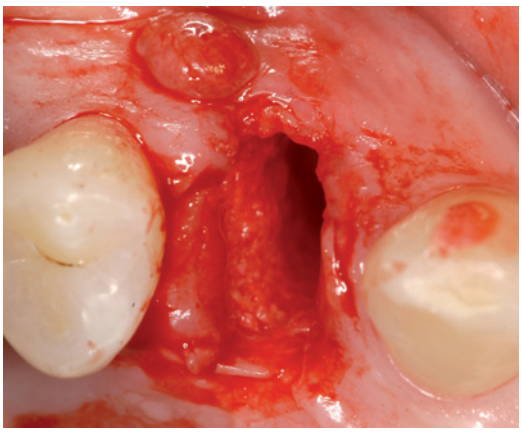
DVD Images 6-6

8. Socket that is oval in shape, with the long dimension palatal to facial and the short dimension mesial to distal. The oval, or figure-eight–shaped, socket typically is found in premolar sites. The implant site is prepared in the oval portion adjacent to the palatal aspect of the socket,

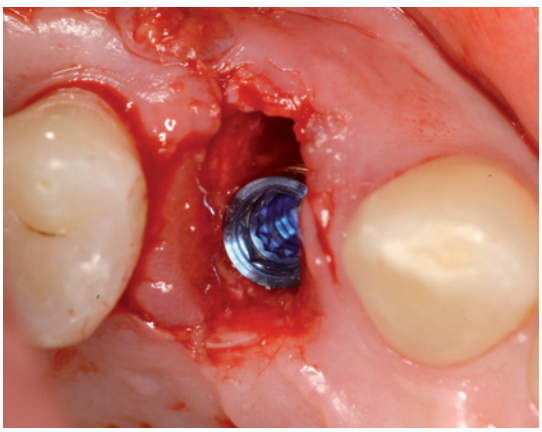
because this usually is the ideal location to place the axis of emergence in the fossa of the premolar or under the palatal working cusp. After the implant has been placed, the gap between the implant and labial cortex can be grafted to prevent epithelial migration. The choice to graft or not to graft depends on the clinician; this author grafts the spaces in an attempt to maintain thickness of the labial aspect of bone and prevent thin bone over the labial aspect of the implant site[34] (Figure 6-8, A-D).

9. Very thin surrounding bone. After extraction of the tooth, the remaining labial bone may be exceptionally thin, even when careful methods were used, including the use of periotomes or other extraction devices designed to preserve bone. In this situation, as long as the implant can be placed and secured in the surrounding and apical bone, the implant can be placed and the space between the implant and this bone can be grafted with particulate mineralized bone material. If insufficient bone is present to stabilize the implants, a graft is indicated and a delayed response is planned.

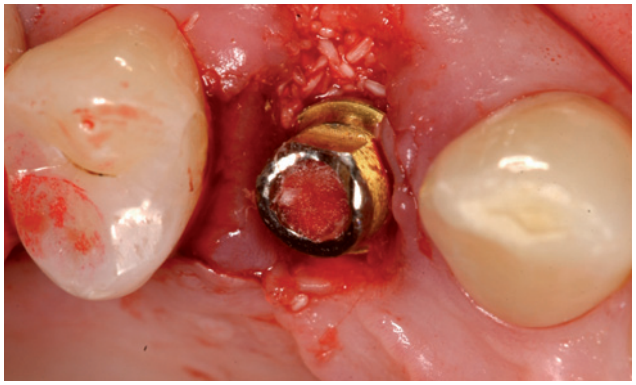
The thinner the bone, the greater the chance of resorption during the postextraction period. The clinical debate concerns what to do with the gap that occurs after an implant has been placed immediately into an extraction site. The goal is to maintain or create tissue thickness labial to the implant so as to provide the appearance of a root prominence and enhance gingival form with the emergence of the restoration. The thicker the labial plate, the greater the chance to maintain labial thickness. Unfortunately, minimal evidence relates final form to bone thickness.



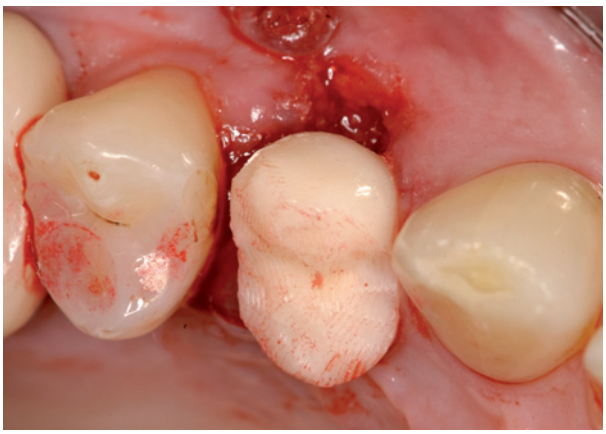
● **FIGURE 6-8** **A,** This first premolar site shows the common morphology of a single-rooted, biconcave premolar root.



● **FIGURE 6-8** **B,** Implant is placed along the palatal aspect of the biconcave root socket.



● **FIGURE 6-8** **C,** Space between the implant and the labial bone is grafted with mineralized bone. The periotome is a properly sized instrument to pack the graft particles into the thin defect.



● **FIGURE 6-8** **D,** After placement of the graft, neither a collagen membrane nor primary closure is necessary, because the immediate temporary crown obturates the opening and prevents loss of the graft.

10. Bone adjacent to the neighboring tooth (or teeth) absent, and root surface of adjacent tooth exposed. In the esthetic zone, support of the interdental papilla comes from the bone level on the adjacent tooth. If the bone on the adjacent tooth is not present, with exposure of the root surface into the extraction socket, the prognosis for optimal papilla is poor (DVD Figure 6-7, A-D). In this situation, the socket can be grafted, with the understanding that the final crestal bone level in the interdental area will be apical to the ideal position. The adjacent tooth can be extruded to move the bone attachment coronally; the tooth can be extracted and grafts placed to augment the vertical height of the ridge; or the tooth can be extracted and a fixed crown and bridge restoration made with pontics in the edentulous sites.

6-7, A-D

Indications and Implant Stability

The indications for placement of an implant into a tooth site at the time of extraction include the following:

- Absence of purulent drainage
- Healthy gingiva without gingival hyperplasia or erythema
- Lack of active apical infection
- Adequate bone present to allow ideal implant placement and stability
- Presence of bone apical to the root apex when the root diameter is greater than the diameter of the implant to be placed

How does the clinician determine whether the implant has been placed into bone with sufficient stability for an excellent prognosis? A drill unit that shows the torque necessary for implant placement may be helpful for confirming implant stability. Another instrument that can be used is the radiofrequency device. This device provides a number that can be correlated to implant stability. A value of 60 or greater is associated with successful levels of implant stability for provisional loading and uneventful healing.

Surgical Techniques for Specific Teeth

General considerations

For this section, it is assumed that the treatment plan calls for extraction of a tooth with immediate placement of an implant. Preoperative planning includes the method for temporizing the space of the missing implant. An Essix-type vacuform template with a tooth can be used. A resin-bonded provisional device can be used, as long as it can be placed without trauma to the surgical site and can be removed for future surgical procedures. A removable partial denture (RPD) can be used but is less ideal because of pressure placed on the palatal aspect of the implant site, or a provisional crown can be placed on the implant immediately after implant placement.

The preoperative evaluation begins with a radiograph of the tooth to be extracted. The bone superior to the tooth's apex needs to be visualized; therefore, a panoramic radiograph may be necessary. Use of a reformatted CT scan for a single-tooth site depends on the clinician's preference. The clinical examination should confirm the lack of purulent drainage and other signs of active, acute infection. A method for temporization of the site should be determined in the presurgical consultation visits. If necessary, a pre-extraction impression can be taken and an Essix-type stent made quickly in the office. After extraction, the crown of the tooth can then be trimmed and placed into the vacuform stent for immediate temporization. Another option is the use of a laboratory-prepared abutment and crown, or chairside techniques can be used, but excessive pressure must not be put on the implant just placed into the extraction site.

A local anesthetic is administered to the overlying tissues. After sufficient time has elapsed for the local anesthetic and the vasoconstrictor to take effect, an incision is made in the sulcus of the tooth to be extracted with a small (15c) scalpel blade. The blade is oriented against the tooth to the junction of the bone and tooth, without cutting the gingiva. No releasing incisions are made.

A thin instrument is used to identify the junction of the bone and the tooth. Care is taken to avoid periosteal elevation over the labial aspect of the tooth. A Hirschfeld #20 elevator is ideal for this procedure. A thin periotome is placed within the sulcus to the junction of the tooth and bone, and with gentle pressure or a mallet, the periotome is introduced between the tooth and the bone. This is accomplished along the direct facial interdental line angles and direct palatal regions. The periotome is taken to a depth necessary to create a mobile tooth, typically two thirds the length of the tooth. The tooth is removed gently, with minimal labial subluxation, to prevent trauma to the labial cortex. The extraction forceps are rotated in a circular movement, and the tooth is pulled vertically, without pressure on the labial bone. After the tooth has been removed, a spoon-shaped curette is used to remove granulation tissue, if present, and to sound the bone to confirm bone presence, as discussed previously. In the near future, fine laser points will be used instead of the periotome for atraumatic extraction of teeth.

After the presence of bone has been confirmed, the drilling sequence is initiated. A round bur is used to make a hole, following the ideal position of the implant and depending on the specific site. After the implant has been placed, labial defects are grafted, and the cover screws or abutments are placed and then the provisional crown.

Central incisors

After administration of a local anesthetic, the surgeon makes an incision within the sulcus of the tooth. The sulcus involving the papilla can be incised, but the incision does

not cut through the papilla; it is left intact. A thin elevator (Hirschfeld #20) is used to identify the bone-tooth junction, and a periotome is used to separate the bone from the tooth. No subluxation is used, to prevent trauma to the labial bone. The tooth is removed, along with granulation tissue, if present. The cells along the extraction site are not removed.

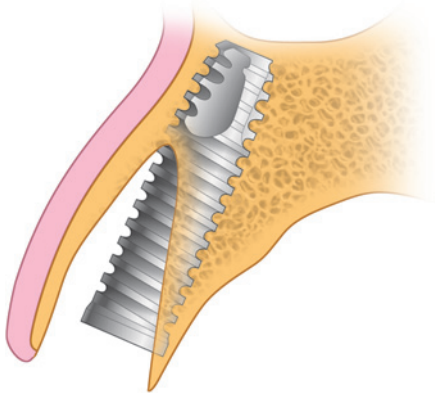
The surgeon irrigates the site with sterile saline and inspects it. The presence of bone is confirmed using a spoon curette and direct visualization. Occasionally, the palatal periosteum must be elevated to allow placement of a periosteal elevator to confirm adequate bone along the palatal aspect, because the implant often is placed into the palatal slope of the extraction site. The bone can be sounded by a needle or felt with the thin periosteal elevator, depending on the surgeon's experience and preference.

It is critical to place the implant in the ideal position with the final restoration in mind. If the bone does not allow this, the surgeon grafts the site and returns after the bone has healed, when ideal implant placement can be achieved. Placement of the implant in a compromised location is not appropriate.

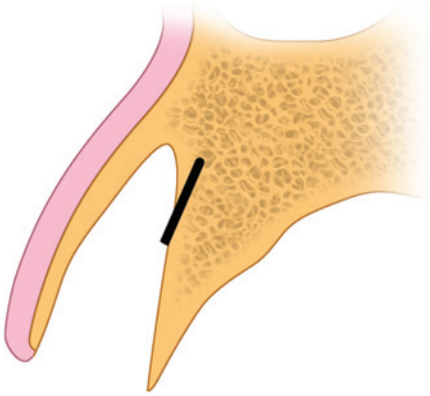
In the central incisor location, the implant should be placed into the palatal slope of the tooth site so that the implant can emerge at or palatal to the tooth's incisal edge (Figure 6-9, A). In addition, the labial edge of the implant should be 1.5 to 2 mm palatal to a line drawn from the labial surface of the adjacent teeth; 2 mm of labial space to this line allows development of the crown without excessive cervical margin bulk.

A round bur is used to make a definitive hole in the bone 1 to 2 mm deep (Figure 6-9, B). The surgeon then uses the twist drill of the implant system chosen, using the round drill's hole as a purchase point. The twist drill will not fall off the palatal slope of bone; rather, a definitive preparation in the ideal axis can be made. The remaining drills are used to finalize the site. Often a gap is present labial to the implant preparation hole. The implant needs to engage at least 5 mm of bone apical to the extraction site, the palatal bone, and the mesial and distal bone along the adjacent teeth (Figure 6-9, C). The implant is placed into the prepared hole. Care is taken to avoid allowing the implant to seat itself at the tip of the root apex; the surgeon must control the implant to make sure it is placed into the desired hole and does not follow the apex of the tooth root.

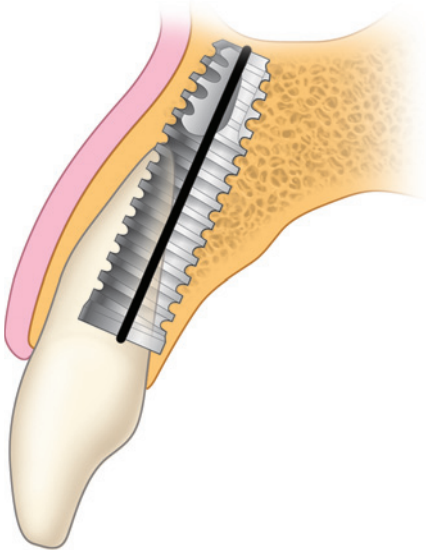
After the implant has been placed, approximately 3 mm apical to the gingival margin of the planned restoration,



● **FIGURE 6-9** **A,** After tooth extraction, the ideal position of the implant is slightly palatal to the tooth root socket.



● **FIGURE 6-9** **B,** Diagram showing the position of the first drill in the palatal slope of the extraction socket. The first drill must be positioned correctly, or the subsequent drills will exit labial to the desired position.



● **FIGURE 6-9** **C,** Diagram showing the implant placed in relation to the first drill.

mineralized bone can be grafted into the defect between the implant and labial bone. If bone is collected from the implant preparation, this bone can be used to graft the defects.

No effort is made to close the central incisor site, primarily because the surgeon does not want to disrupt the normal gingival architecture. If a flap is raised and the KG advanced, the final result will not be esthetic because of the obvious lack of KG and the lack of symmetry. A collagen material can be placed under the gingival margin and retained in position with one horizontal mattress suture to appose the gingiva gently to the collagen (see DVD Figure 6-6).

Another option is to place the healing abutment and proceed as a one-stage protocol. The abutment should be limited to 3 mm in height to avoid pressure from the temporary Essix or flipper. If a one-stage, immediate-provisionalization protocol is used, plans should include a laboratory-prepared abutment and provisional crown. Note that the provisional crown must not be in occlusion with the opposing teeth; therefore, the temporary crown may be 1 mm shorter than the adjacent central, or the patient must wear a bite-opening device 24 hours a day for at least 8 and preferably 16 weeks to prevent occlusion on the implant.

With immediate placement into a central incisor site, the surgeon also should consider the thickness of the labial bone after tooth extraction. If the labial bone is very thin (less than 0.5 mm), resorption of the labial bone occurs, and a flat ridge profile develops. This situation is found in patients with a thin biotype. If the labial bone is thicker (greater than 1 to 1.5 mm), a portion of the labial bone does not resorb, and the ridge form is maintained (Figure 6-10, A-N).

It is critical that the provisional crown be appropriately contoured to preserve the position of the facial gingival margin. The provisional crown should be slightly undercontoured to allow the gingiva to "fall down" and

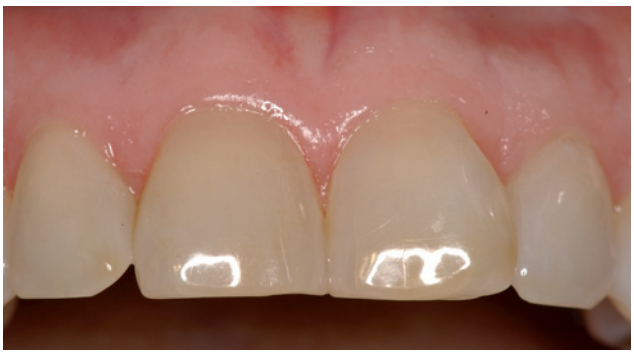


FIGURE 6-10 **A,** Preoperative view of a right central incisor with external resorption. The treatment plan calls for extraction of the tooth, immediate placement of an implant, and provisionalization of the site with a restoration.

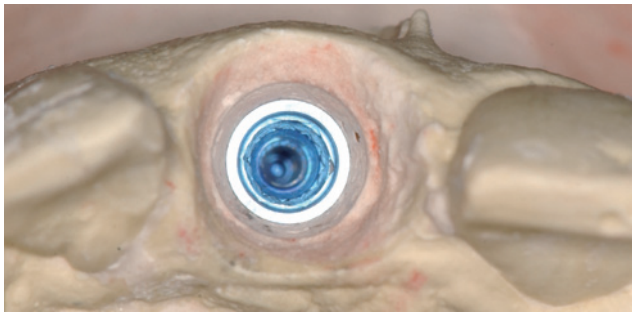


FIGURE 6-10 **B,** Preoperative models are taken, and an analog is placed. Note that the labial edge of the implant analog is 2 mm palatal to the planed emergence of the final restoration.

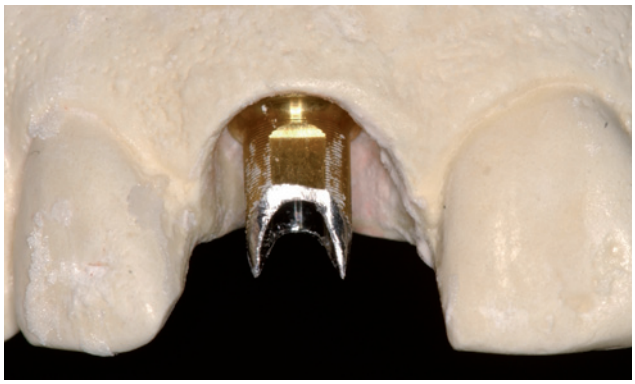


FIGURE 6-10 **C,** Fixed abutment is placed and prepared to allow 0.5-mm subgingival margins for the provisional restoration.

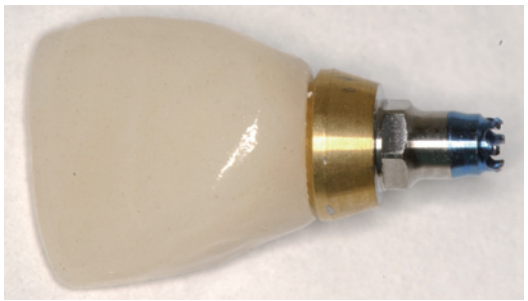


FIGURE 6-10 **D,** Provisional restoration is designed to mimic the natural tooth, which is esthetic in shape and proportions. The margins are polished to enhance gingival health. Note the natural emergence contours of the provisional restoration, with slight undercontouring at the cervical region.

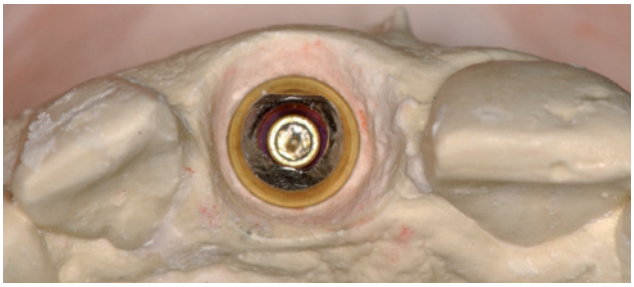


FIGURE 6-10 E, Occlusal view of the abutment in the model.

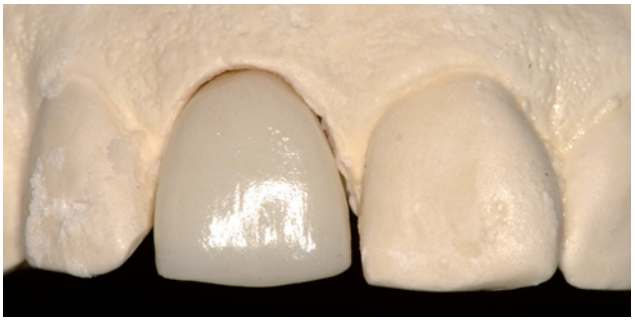


FIGURE 6-10 F, Cervical region of the provisional crown is slightly undercontoured to allow the facial gingival margin to maintain its preoperative position.

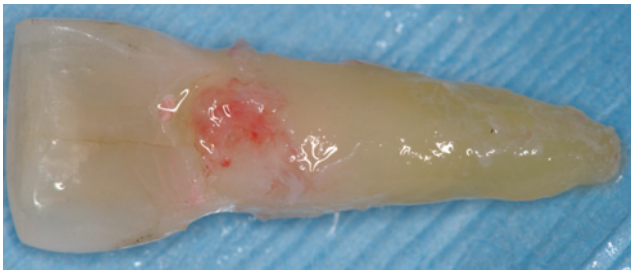


FIGURE 6-10 G, Tooth shows external resorption.

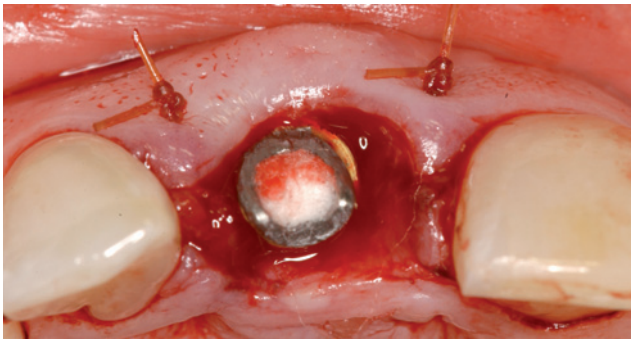


FIGURE 6-10 H, Tooth is removed as described in detail in this chapter. The implant is placed with its position the same as in the model. The abutment is placed and secured with a gold screw. No bone loss has occurred along the labial aspect, and the labial bone is at least 1 mm thick.

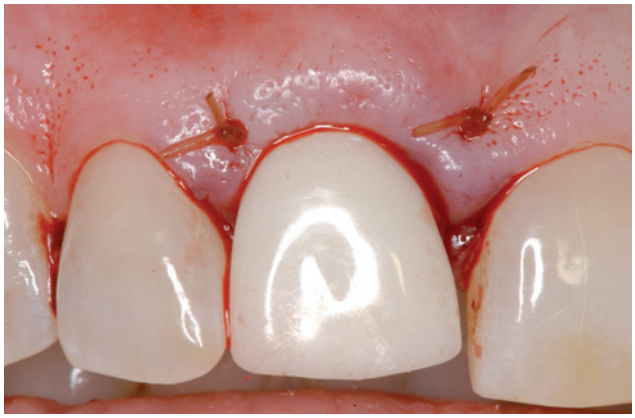


FIGURE 6-10 I, Provisional crown is placed, and vertical mattress sutures are used to evert the interdental papilla. The laboratory did not follow the shade recommendations sent by the restorative dentist.

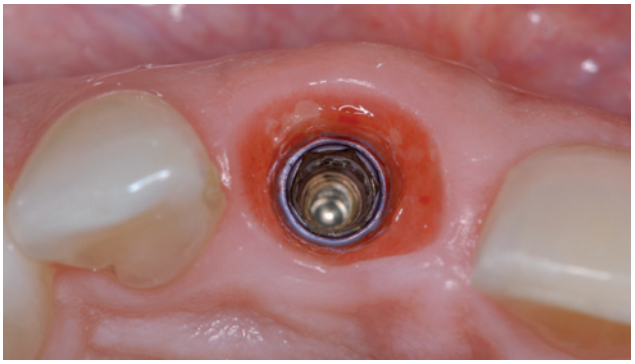


FIGURE 6-10 J, After 4 months for healing, the temporary crown and abutment are removed, revealing a natural-appearing sulcus. Note the maintenance of ridge form.

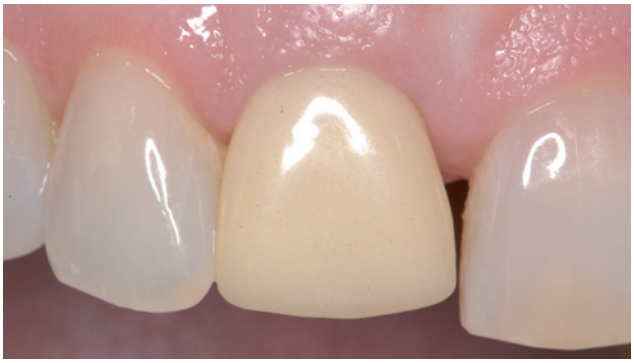


FIGURE 6-10 K, Provisional crown discolored during the 4 months of healing. The undercontouring of the cervical region helped maintain the gingival margin.

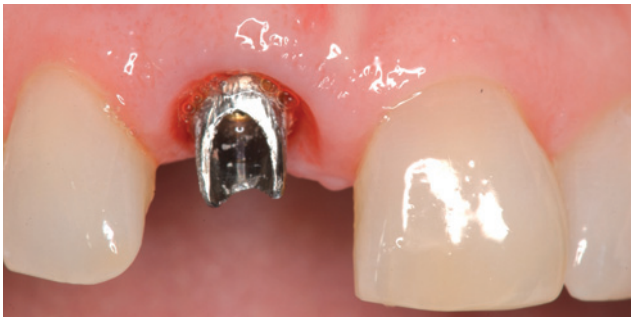


FIGURE 6-10 M, Frontal view of the final abutment. Immediate provisional restoration has allowed maturation of the soft tissue; this allows delivery of the final crown immediately after integration of the implant, without the need for extra time for sulcus development.

not be pushed superiorly (see Figure 6-10). After extraction and implant placement, the gingival margin heals and is prone to contracture similar to that seen with all soft tissues. If the cervical margin is overcontoured, the facial gingival margin will be recessed in the apical direction and will not "fall down" to produce a better final restoration.

Lateral incisors

The lateral incisor location is unique because of its size and thin bone. The same preoperative planning is performed as described for the central incisor. A bite-opening device is rarely needed, because the lateral incisor can be shorter than the adjacent teeth, and occlusal contacts therefore are easier to control after immediate provisionalization.

After the incisions have been made and the tooth removed with gentle periotome technique, the site is evaluated for the presence of bone. In the lateral incisor location,

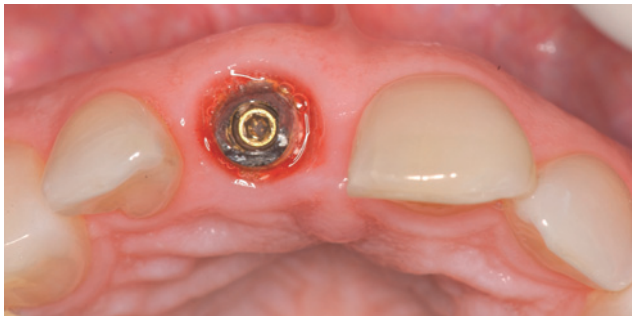


FIGURE 6-10 L, Final abutment in position. Note the ridge width.

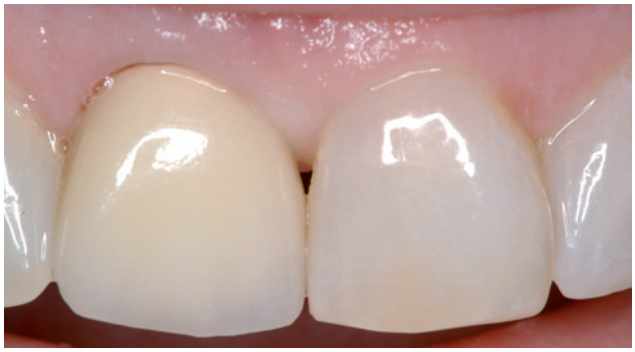


FIGURE 6-10 N, Final crown before cementation. This crown will be returned for shade adjustment in the laboratory.

confirmation of the palatal bone thickness and contour is necessary. The implant is placed into the extraction site just palatal to the apex of the tooth, depending on the inclination of the tooth. In this location, the lateral incisor's apex may be aligned adequately with the ideal location of the implant, or it may be oriented facially, requiring slight palatal adjustment of the implant to prevent perforation through the labial-apical region of the bone.

The drill extension often is needed to initiate the first hole with the round drill, because the depth of the socket is longer than the round drills supplied with the implant surgical kits.

Because the cervical width of a lateral incisor can be 4 mm or less, a small-diameter platform often is chosen for this tooth site. Even though the distance between the adjacent teeth at the bone crest may be 6 mm, a 4-mm or greater platform may result in a square-type crown emergence from the gingiva and not the ideal, tapered crown appearance. The subgingival shape of the platform affects the shape of the crown as it emerges from the gingiva. When a 3.4-mm or 3.25-mm platform is used with an

implant 3.25 mm in diameter or a tapered, narrow platform implant, the implant usually fills the lateral incisor root socket adequately without the need for grafting. Occasionally, a large lateral incisor root or a lateral incisor root with an oblong shape requires labial grafting between the implant and labial bone. After the implant has been placed, the same methods are used as described for the central incisor (DVD Figure 6-8, A-F).

DVD Images 6-8, A-F

Canines

The maxillary canine tooth has a large root in width, and the palatal-facial dimension has a different shape than the mesial-distal dimension. Extremely thin labial bone often is found after removal of this tooth, and root and labial bone dehiscence tends to be seen as well. When the bone is extremely thin and the socket is large, grafting is recommended.

In the canine site, the tooth's inclination in relation to the cingulum requires placement of the implant within the palatal slope of the socket. The thickness of the palatal bone must be confirmed, because this bone may be thin as a result of the anatomy of this site, especially with a high-vaulted palate. If the bone is thin along the palatal site and if the implant must be placed close to or within the palatal bone of the extraction site, grafting of the socket is necessary, and a delayed approach is recommended.

The mesial-distal dimension of the canine site usually determines whether an implant can be stabilized within the extraction socket. In the canine site, bone may not be available superior to the apex of the tooth. Often the apex of the tooth is at or adjacent to the floor of the nose or the floor of the sinus. If the apex lines up with the piriform rim, bone usually is available to secure a long implant farther in the canine extraction socket.

If the root diameter allows fixation of the implant to the walls of the socket, and if the implant can engage bone superior to the apex of the tooth, the implant can be placed in a manner similar to that described previously (DVD Figure 6-9, A-E).

DVD Images 6-9, A-E

Premolars

The maxillary premolar typically has a figure-eight root shape. The narrow isthmus is present either with bone, if there are two roots, or as a narrow gap, if the two roots are fused. In either situation, the implant is placed into the palatal root because this is the ideal axis, noting that the palatal cusp is the working cusp for the maxillary premolar. The round bur may be placed on the drill extension if necessary, and the implant site is prepared. Usually a 4-mm platform is used for the premolar teeth, but in isolated situations a smaller premolar space may be present. The implant site is prepared with the implant secured in at least 4 to 5 mm of bone superior to the tooth's apex. If the maxillary sinus prevents securing of the implant and if the size of the root prevents initial stabilization of the implant, grafting is recommended before implant placement. Periapical radiographs can be used to determine the diameter of the root; therefore, the surgeon should be able to determine whether the implant can be placed or whether a graft is necessary (Figure 6-11, A-K).

If the maxillary sinus is close to the apex of the root, a graft is placed into the socket. After bone consolidation is complete, a new radiograph is taken to determine whether a short implant will be used or whether a sinus graft is necessary.

Mandibular premolars are treated in a similar manner. The inferior alveolar nerve often is found close to the root apex; therefore, staging of these sites typically is done to prevent trauma to the nerve.

Mandibular incisors

The mandibular incisor site has specific anatomic characteristics that make it relatively predictable for immediate implant placement after tooth extraction. The height of the

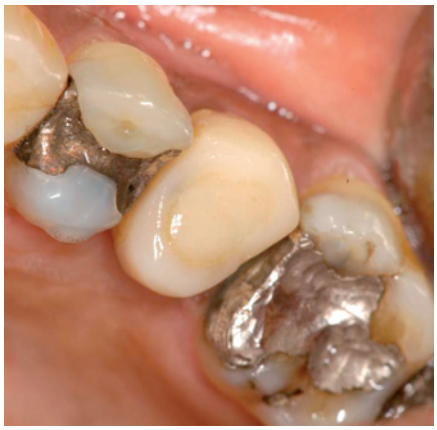


FIGURE 6-11 **A,** Second premolar before extraction.

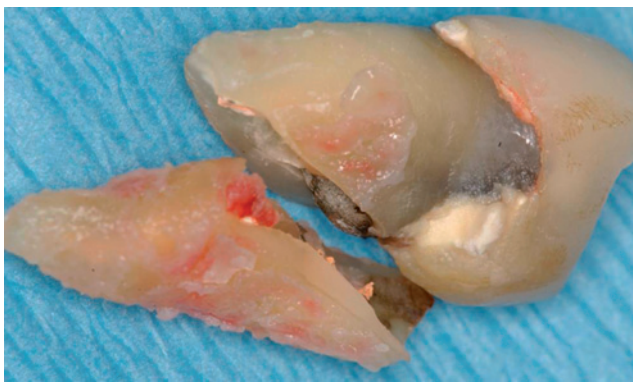
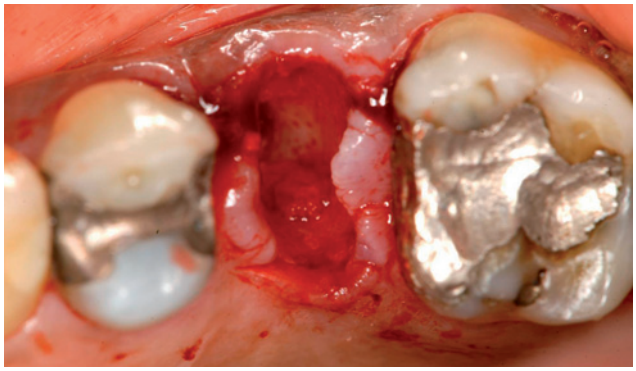
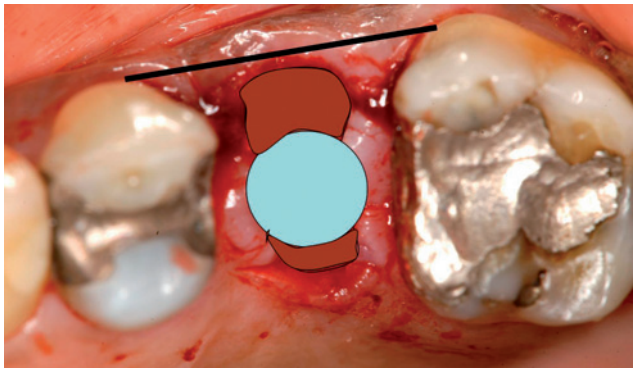


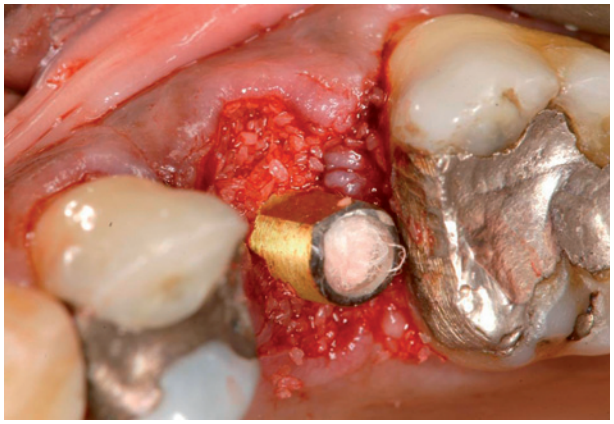
FIGURE 6-11 **B,** Tooth has a vertical fracture and is removed in two pieces with a periotome, without loss of the labial bone.



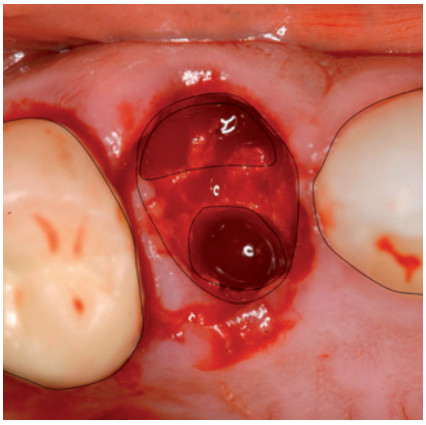
● **FIGURE 6-11** **C,** Extraction site showing a figure-eight shape.



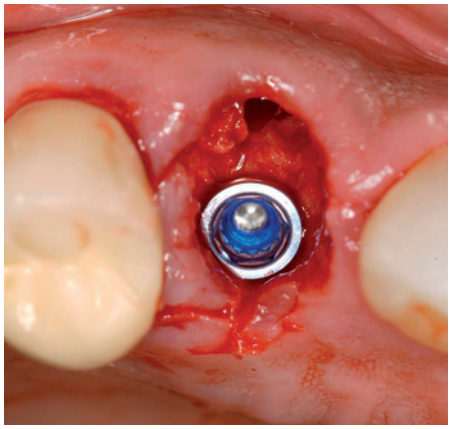
● **FIGURE 6-11** **D,** Implant should be placed at least 2 mm palatal to the labial emergence of the adjacent teeth. The labial emergence is depicted by the line.



● **FIGURE 6-11** **E,** After the implant has been placed and the abutment secured, graft material is placed between the implant and the labial bone. The abutment should be placed before the particulate material to prevent the graft from entering the internal hole of the implant.



● **FIGURE 6-11** **F,** Birooted premolar has a distinct palatal root socket and a buccal root socket.



● **FIGURE 6-11** **G,** Implant should be placed into the palatal socket, with maintenance of the interseptal bone. The labial root socket then is grafted.

bone, the thickness of the bone, and the necessary axis of the implant all are favorable after tooth removal. Sulcular incisions are used, but in this location, small vertical release incisions are used to allow visualization of the bone directly on both the labial and the lingual aspects. Identification of a lingual concavity is important to prevent perforation of the lingual cortex. The tooth is removed with gentle technique to prevent subluxation forces and loss of the labial bone. After the bone contours have been confirmed, a small-diameter implant is placed, with careful attention to avoiding the adjacent tooth roots. A straight-emergence healing abutment 2 or 3 mm tall is placed, and incisions are closed with resorbable suture on a tapered needle.

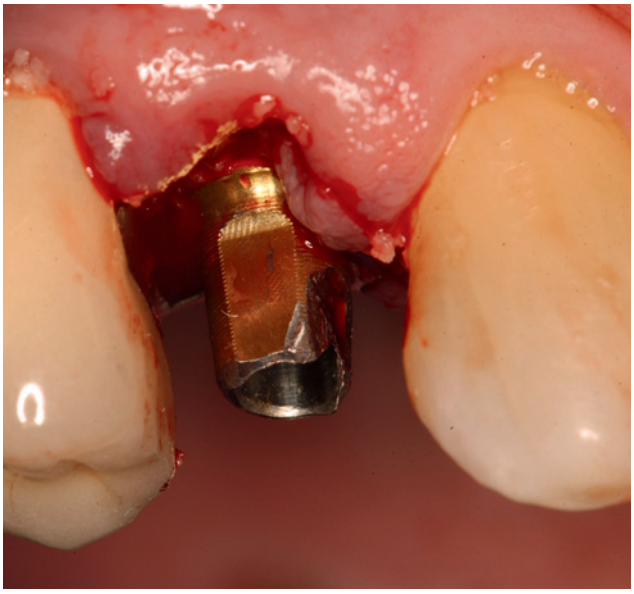


FIGURE 6-11 H, Abutment prepared in the laboratory preoperatively is placed on the implant and secured with a screw. The abutment has satisfactory occlusal clearance for placement of the provisional crown out of occlusion.

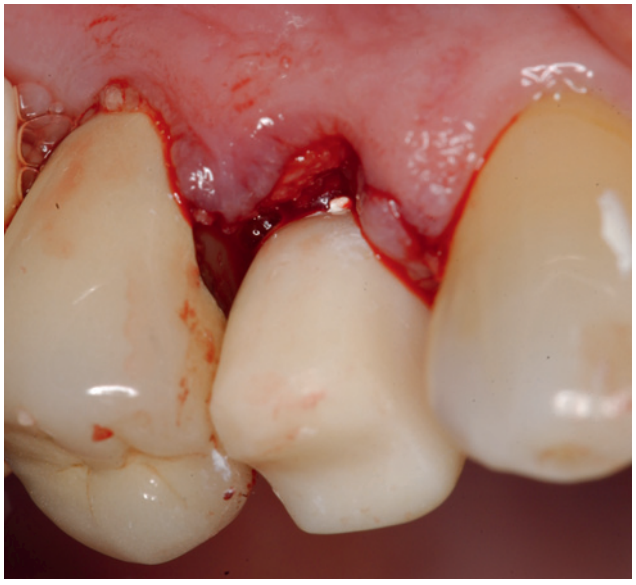


FIGURE 6-11 I, Provisional crown is placed onto the abutment. Occlusal clearance is verified and adjusted as necessary. No sutures are needed.

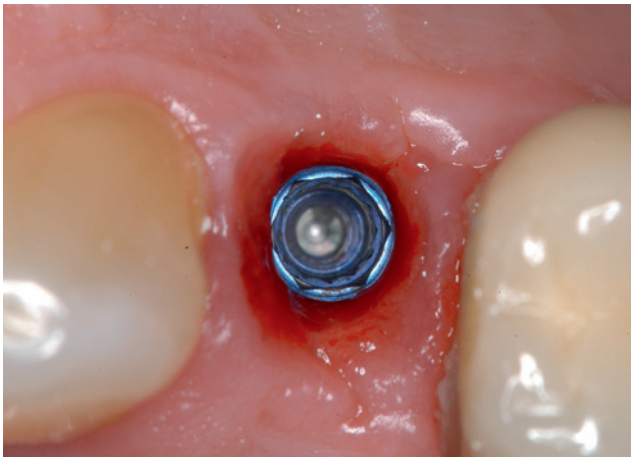


FIGURE 6-11 J, After 4 months of healing, the abutment is removed and final impressions are taken.

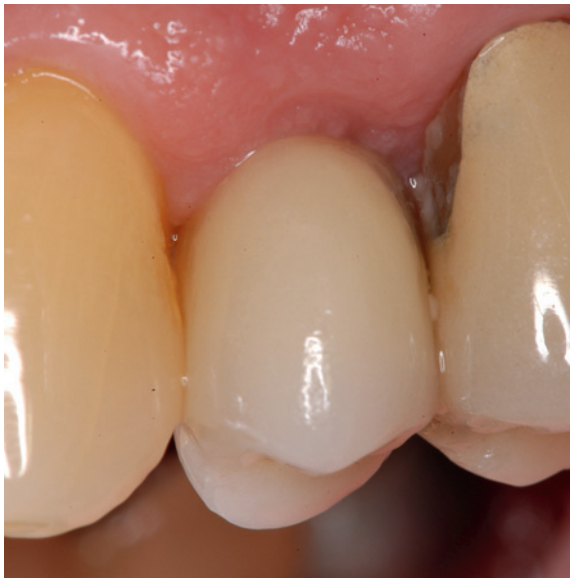


FIGURE 6-11 K, Final restoration at 2-year follow-up.

Strategies for Maintaining the Facial Gingival Margin When Extracting and Replacing an Anterior Tooth in the Maxilla

Based on the discussion in the earlier sections of this chapter, the clinician can use a relatively straightforward algorithm for deciding which procedures to perform and their timing. Several assumptions can be made about the esthetic site:

1. If the facial gingival margin is perfect at the start, it most likely will migrate superiorly 1 mm after the final implant crown has been in place for at least 6 months. This is based on studies by our group and others that clearly show that the facial gingival margin can migrate on an average 0.4 mm over a 2-year postrestorative period, with up to 1.4 mm in selected cases. Therefore, the clinician should provide the restorative dentist with a facial gingival margin 1 mm coronal to the final desired location, anticipating apical migration over time. This is very important in the patient with a high smile line and high esthetic demands. The clinical findings shown in Figure 6-12 are recorded when the central incisors are to be removed.
2. If the facial gingiva is thick, there is less chance of migration. This is based on multiple studies over time, including traditional periodontal studies in which crown lengthening procedures were performed. Clinicians observed and confirmed that patients of the thick gingiva biotype had less gingival recession with underlying bone remodeling.
3. If the facial gingiva is thin, apical migration of the facial gingival margin occurs. This assumption is based on historical references on patients of the thin biotype who developed gingival recession after bone recontouring procedures.
4. Patients with thin labial bone, or labial bone with bone defects, are more prone to gingival recession.[48]

If the facial margin is close to the final desired position, it may need to be moved coronally during the phases of treatment, with a healing abutment used as a tent. If the margin is more than 1 mm from the desired position, orthodontic extrusion is indicated prior to tooth removal. Orthodontic extrusion is a very reliable method for gaining exceptional final results.

If the labial bone is thin but present, a graft is necessary between the labial implant surface and the labial plate. The bone graft should be slow to resorb to maintain the space and maintain ridge form after the labial bone remodels. Cardaropoli et al.[49] showed that after abutment connection, labial bone thickness decreased by 0.7 to 1.3 mm. Labial bone thickness is expected to change with time until it reaches a physiologic equilibrium with functional load. Anticipation of this type of bone thinning is the rationale for grafting the labial aspect of the implant at the time of implant placement.

If the gingiva is thin, it should be converted to thick by placement of a connective tissue graft.[50] Therefore, for any tooth extraction:

1. A bone graft may be needed because of thin labial bone.
2. A connective tissue graft may be needed to convert thin gingiva to thick gingiva so as to resist gingival migration.
3. The implant needs to be placed.

The following cases present examples of ways to deal with facial gingival margin movement when an anterior tooth must be extracted.

Case Examples

Use of the piezotome to remove an ankylosed tooth and immediate implant placement

This case is presented on the accompanying DVD (see Video Box 6-1).

1. Incisor show at rest: _____
2. Incisor show on smile: _____
3. Length of incisor: _____
4. Current position of facial gingival margin: _____ Perfect
   Coronal to final plan by _____ mm Apical to final plan by _____ mm
5. Thickness of gingiva: _____ Thick _____ Thin _____ Thick/thin
6. Thickness of labial bone: _____ Thicker than 1.5 mm _____ Less than 1 mm
   Labial bone defect: _____ Small _____ Large

FIGURE 6-12 Sample clinical form for patients undergoing removal of central incisors.

Piezotome-Assisted Premolar Extraction with Immediate Implant Placement

DVD Video 6-1

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for piezotome-assisted premolar extraction with immediate implant placement performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This video shows the use of the piezotome to aid in removal of a fractured premolar with immediate placement of an implant and healing abutment. The tooth has had previous root canal therapy and is ankylosed but suffered a vertical fracture during mastication of hard textured food.

After infiltration of local anesthesia, the surgeon used a scalpel blade around the neck of the tooth. A small periosteal elevator separated the gingiva from the crest of the bone to identify the junction of the tooth with the bone. The piezotome has a cutting tip that resembles a periotome. This tip is placed at the junction of the tooth and bone and gently separates the two. Irrigation is used to cool the cutting tip. The tooth is separated from the bone along all faces of the tooth, approximately two thirds of the depth of the tooth root or until the tooth is mobilized.

A dental elevator is used to further mobilize the tooth, which is removed with the aid of forceps. After the tooth is removed, a spoon-shaped curette is used to confirm the presence of labial and palatal bone. Granulation tissue is removed if present.

A round bur is used to initiate the implant site in the center of the edentulous site in order to place the implant in the middle of the site in an ideal position. After the round bur is used, the drills are used graduating in size until the implant site is prepared.

The implant is slowly inserted into the prepared site. It is common for the initial movement to be slightly wobbly until the threads engage the site, whereupon the implant follows the preparation nicely. The implant is placed to the desired depth with the internal flat of this implant parallel with the labial bone.

The healing abutment is placed. The choice of the flare of the healing abutment is clinician dependent. Bone collected from the drills is used to graft the gap that will be present between the implant and the intact labial bone. If autogenous bone is not present, an allograft or xenograft can be used. In highly esthetic sites where resorption of the labial plate from convex to flat will decrease the esthetic appearance, a xenograft may be preferred because of its very slow resorption rate. Sutures are often not necessary but can be used if the gingival has separated from the underlying bone.

Thick gingiva, ideal facial gingival margin position, thin labial bone with apicoectomy defect

This patient had a central incisor that was subluxed and eventually treated with root canal therapy and multiple apicoectomies. The tooth was removed, which resulted in a labial defect (Figure 6-13, A-I).

Problem List:

Apicoectomy defect, including labial bone loss
Lack of bone formation in previous extraction socket
Critical need to preserve ridge form

Treatment Sequence:

Crestal incision and envelope flap
Removal of soft tissue from bone socket
Preservation of thin labial bone on crest to preserve ridge form
Placement of implant and grafting of bone defect

A crestal incision was made, combined with sulcular incisions on the adjacent teeth to allow envelope flap reflection. Care was taken in reflecting the tissue over the thin

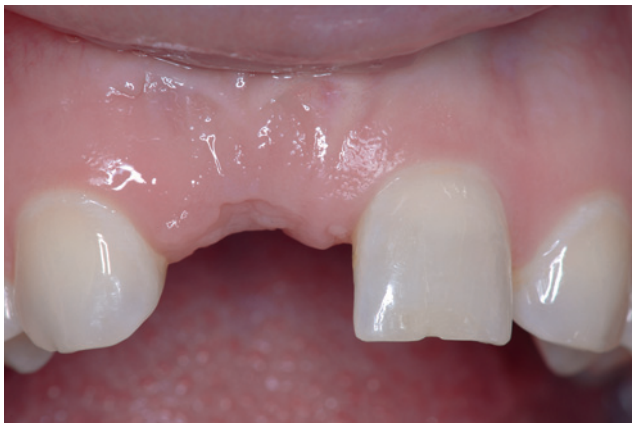


FIGURE 6-13 **A,** Preoperative view showing thick gingiva and adequate height of the facial gingival margin.

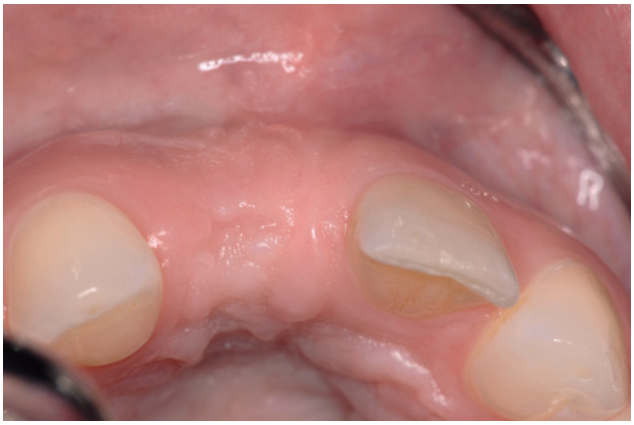


FIGURE 6-13 **B,** Occlusal view showing excellent ridge form prior to implant placement.

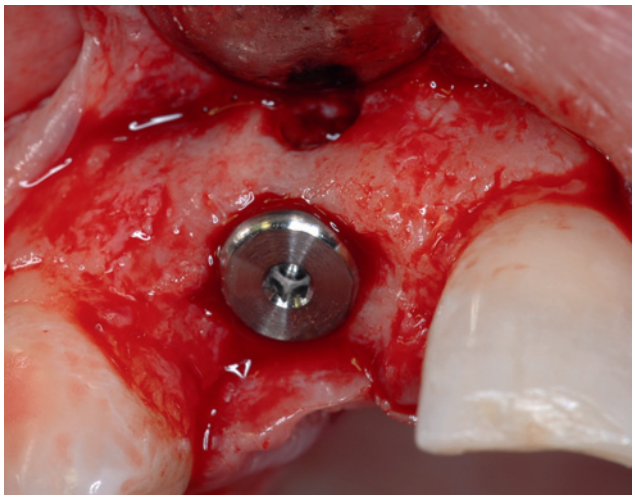


FIGURE 6-13 **D,** Implant has been placed. Note the labial hole from prior apicoectomies.

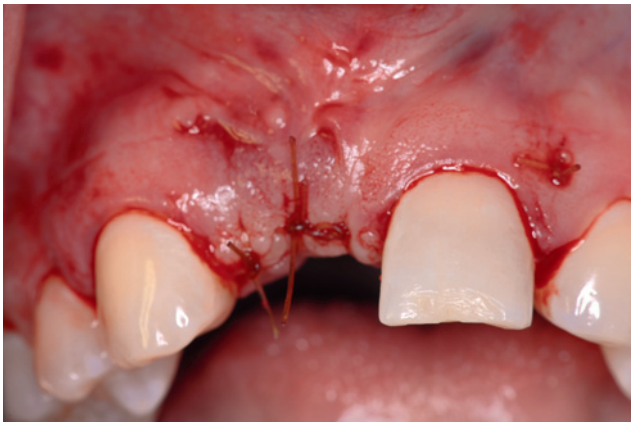


FIGURE 6-13 **F,** Incisions are closed with vertical mattress sutures.

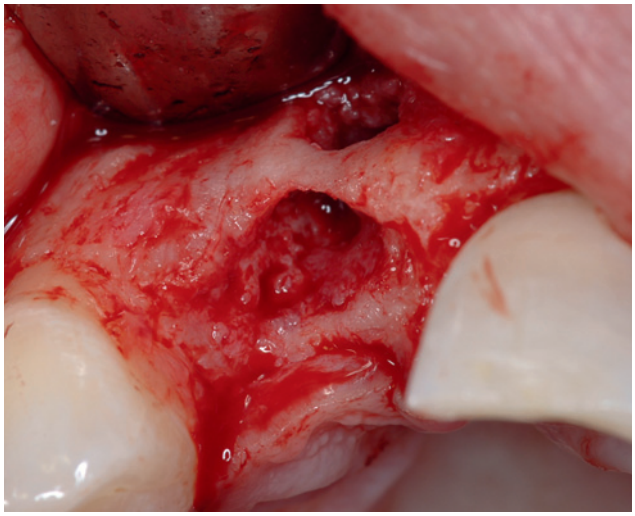


FIGURE 6-13 **C,** Crestal incision with envelope flap is used to expose the bone. The soft tissue is removed to allow for bone presence against the planned implant.

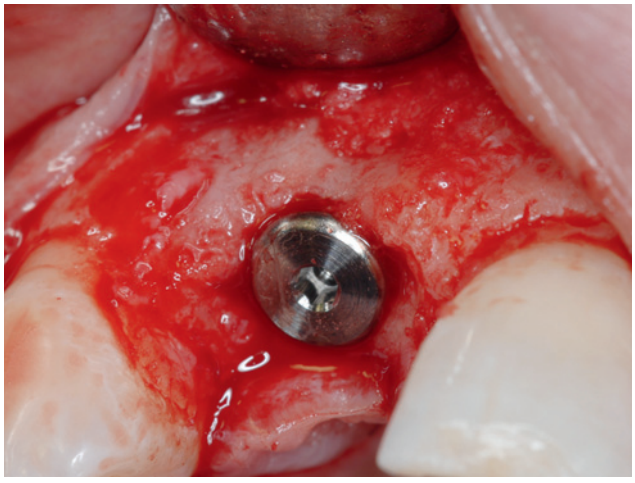


FIGURE 6-13 **E,** Bone collected from the implant preparation is placed into the labial defect.

crestal bone to prevent inadvertent fracture of the thin bone. The flap was elevated to expose the bony defect. Preoperative scanning revealed a site the appropriate size for an implant 4 mm in diameter. The site was degranulated, and an implant was placed; the emergence axis was kept palatal to the incisor edge. Bone was collected from the drills used to create the implant site. This autogenous bone was used to graft the labial defect. The crestal bone was preserved.

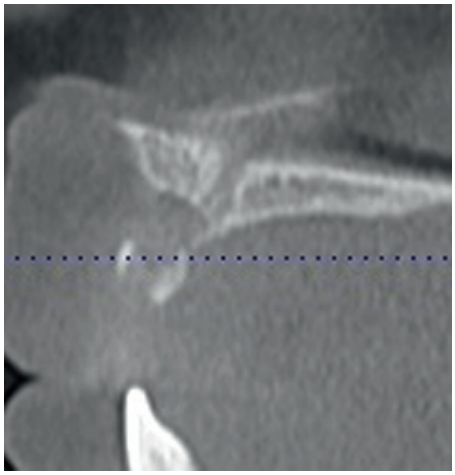


FIGURE 6-13 G, Cross-sectional image from a computed tomography (CT) cone beam scan shows small bridge of bone along the crest, with the apicoectomy bone defect superiorly. The bone defect is smaller than an implant 4 mm in diameter.

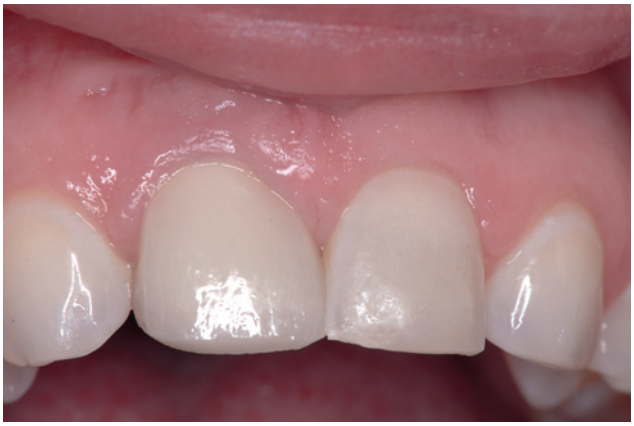


FIGURE 6-13 I, Final restoration. (Prosthetics by Dr. Jayne Sanchez.)

Moderate gingival thickness, ideal facial gingival margin position, fractured central incisor with thin but intact labial bone

This patient had a fractured right central incisor that required extraction and replacement. The tooth was ankylosed. The goal was to restore this site with excellent gingival margin position and a natural appearance (Figure 6-14, A-L).

Problem List:

Moderately thick gingiva over right central incisor

Facial margin 1 to 1.5 mm coronal to adjacent tooth (see Figure 6-14, A-B)

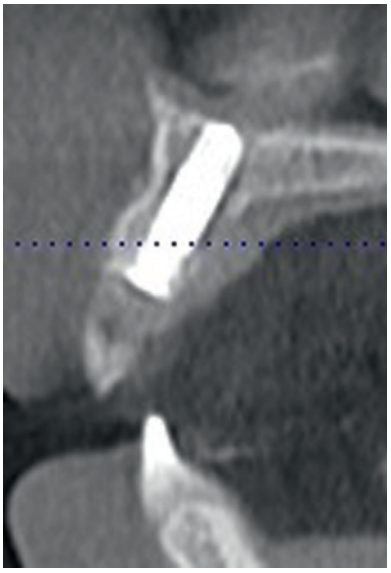


FIGURE 6-13 H, Cross-sectional image from a cone beam scan showing implant placed into the bone defect. The defects have been grafted with autogenous bone, which was collected from the drills used during implant site preparation. Note the preservation of the crestal bridge of bone.

Thin labial bone over retained central incisor root (see Figure 6-14, C)

Right central incisor slightly protrusive to adjacent tooth

High smile line, with gingiva showing on smile

Goals of Treatment:

Maintain moderately thick gingiva to limit gingival recession

Maintain labial bone form by grafting between implant and intact but thin labial bone at time of implant placement

Fabrication of implant-retained crown with correct proportions and function, with maintenance of gingival form over time

Treatment Sequence:

Fabricate removable temporary prosthesis using Essix-type retainer (DENTSPLY Raintree Essix Inc., Sarasota, Florida)

Extract tooth with sulcular incisions, place implant in ideal position, graft gap on labial aspect of implant with relatively nonresorbable xenograft, place healing abutment to guide gingival healing (see Figure 6-14, D-G)

After implant integration, fabricate esthetic temporary restoration (see Figure 6-14, H-J)

After final esthetics have been achieved with provisional restoration, fabricate final restoration (see Figure 6-14, K-L)

This patient required tooth removal with protection of the labial bulk and gingival position. A moderately thick gingiva was observed, based on its appearance, stippling, and

Placement of Implant in Compromised Central Incisor Site

DVD Video 6-2

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for the placement of implant in compromised central incisor site performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient has had loss of her right central incisor after multiple apicoectomies. The tooth had been extracted approximately 3 months prior to the surgical procedure depicted in this video. The surgical plan is to expose the thin bridge of bone on the labial aspect of the crest, remove the soft tissue in the previous tooth socket, and place an implant with autogenous bone grafting with bone harvested from the drills used to prepare the implant site.

After local anesthesia was administered, the surgeon made an incision in the sulcus of the adjacent teeth and on the crest. A small periosteal elevator is used to carefully elevate the gingiva, taking care to avoid trauma to the thin isthmus of bone on the labial aspect of the ridge. To avoid flap perforation from tearing and scar tissue, sharp dissection with the scalpel was used to aid in flap elevation. The periosteum over the labial aspect of the adjacent teeth is elevated to avoid tearing the keratinized gingival margins and to allow for access to the implant site. The palatal periosteum is also reflected to provide the surgeon with orientation for implant placement axis.

After the flap was reflected, the soft tissue was removed cautiously, with multiple small instruments, until the bone remained without soft tissue in the planned implant site.

A round bur was used to initiate the implant site on the palatal aspect of the now cleaned socket. A pilot bur, then graduating-sized drills, were used to prepare the site, with care taken to maintain the implant's emergence palatal to the incisive edge, with the labial aspect of the implant 2 mm palatal to the planned labial emergence of the crown. After each drill is removed from the bone, bone within the flutes of the drills is collected to be used to graft expected labial defects. A probe is used to confirm adequate bone presence prior to placement of the implant.

The implant is placed to be level with the labial crest of bone. The cover screw was placed and the labial defect was grafted with autogenous bone. The incisions were closed with vertical mattress suture with eversion of the papilla.

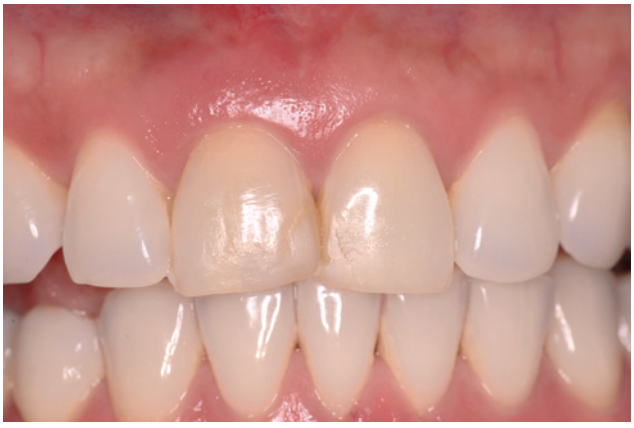


FIGURE 6-14 A, This 50-year-old woman had a fractured right central incisor. Note that the facial gingival margin is 1.5 mm coronal to the adjacent tooth and is moderately thick. The right central incisor is slightly protrusive, indicating a strong chance that the labial bone is thin.

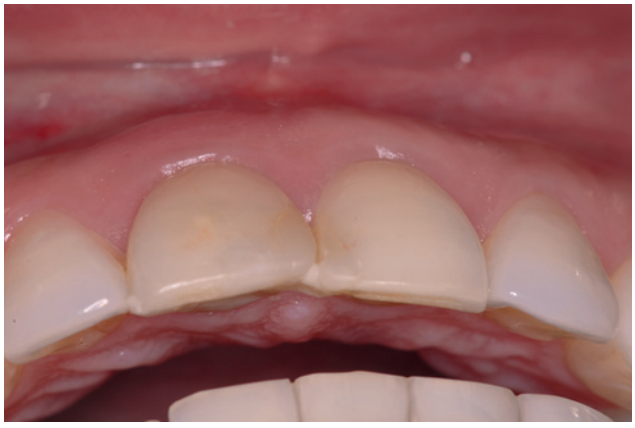
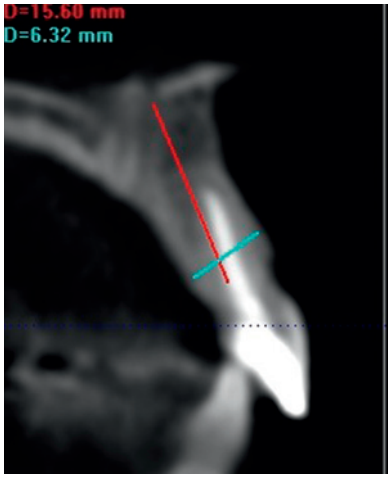
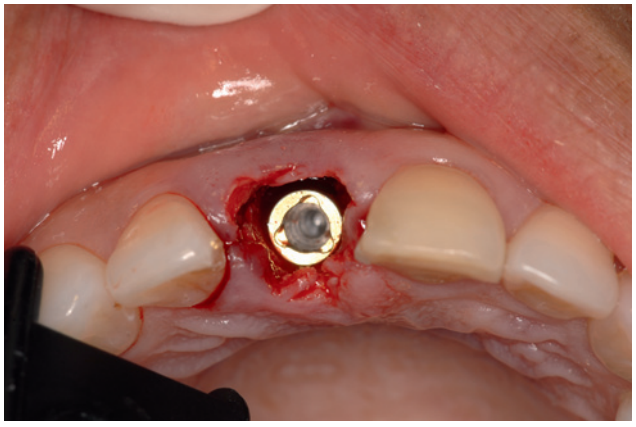


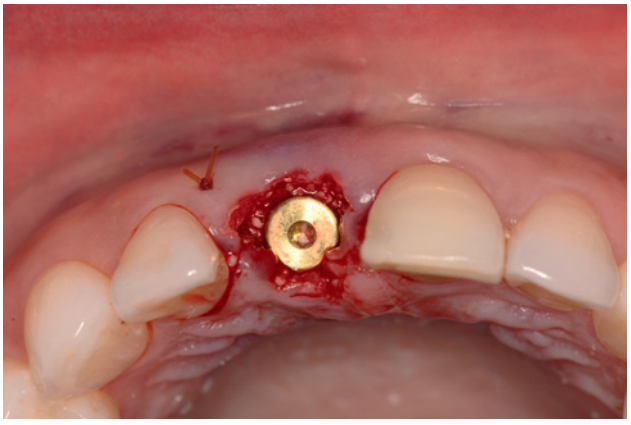
FIGURE 6-14 B, Occlusal view confirming the moderately thick gingiva and slight protrusion of the right central incisor.



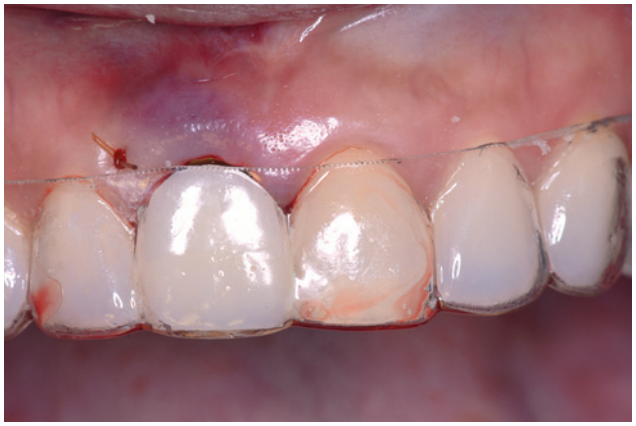
● **FIGURE 6-14 C,** Cross-sectional image of the tooth requiring extraction. Note the very thin labial bone and the intact bone on the palatal aspect, where the implant axis (red) is ideal. The width is adequate for implant placement, and a graft will be necessary to maintain the labial ridge form.



● **FIGURE 6-14 D,** Occlusal view of the implant placed 3 mm apical to the planned gingival margin, which was determined to be the level of the gingiva on the left central incisor. A gap exists between the labial surface of the implant and the intact but thin labial bone.



● **FIGURE 6-14 E,** Bovine particulate graft material is used to maintain the ridge form over time. In addition, a healing abutment 3 mm tall is placed with the graft caked firmly to the height of the abutment.



● **FIGURE 6-14 F,** Essix temporary is placed, and the replacement tooth is trimmed to prevent pressure on the healing abutment and the gingiva. Space is allowed for swelling without pressure.

similar color to the adjacent tooth. The crown form was not tall or oval. The procedure chosen involved removing the implant, with great care taken to preserve the thin labial bone; placing the implant into the palatal bone; placing a graft material in the gap between the implant and intact labial bone; and using a short (3 mm) healing abutment to maintain the form of the gingiva and promote its vertical position.

Surgical Procedure. A local anesthetic was infiltrated from the right lateral incisor to the left central incisor. A sulcular incision was made with a 15c scalpel. A thin periosteal elevator was used to reach the bone at the junction of the tooth root. A piezotome with a periotome-type extraction tip was used to separate the tooth root from the bone, with care taken to prevent loss of the thin but intact labial bone. The tooth root was elevated and removed with forceps. All of the labial bone was intact.

A round bur was used to engage the palatal slope of the socket. A series of drills was then used to prepare the implant site, and the implant was placed. After the implant

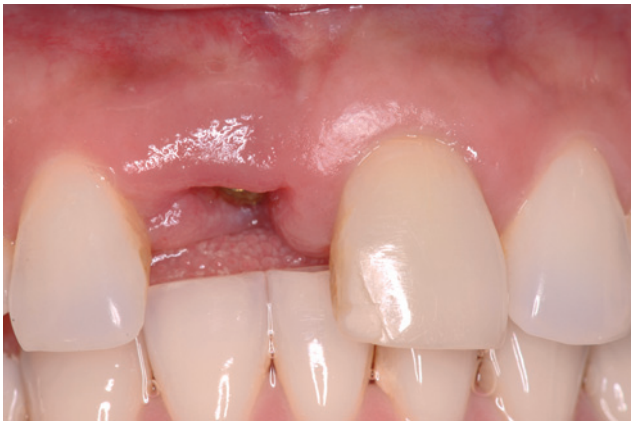


FIGURE 6-14 **G,** After 4 months of healing, the patient presents with an adequate facial gingival margin position approximately 2 mm coronal to the final. This allows the restorative dentist flexibility when fabricating the provisional and final restoration.

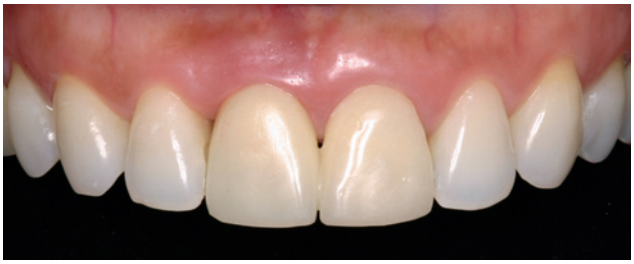


FIGURE 6-14 **I,** Provisional restoration results in excellent form and esthetics. Note that the facial gingival margin has moved superiorly to become equal with the adjacent tooth.

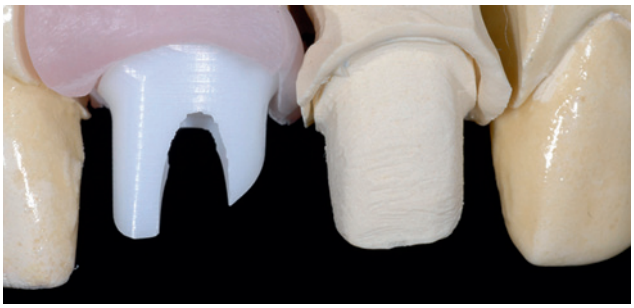


FIGURE 6-14 **K,** Ceramic abutment is used for the implant, and an all-ceramic crown is made for the adjacent tooth.

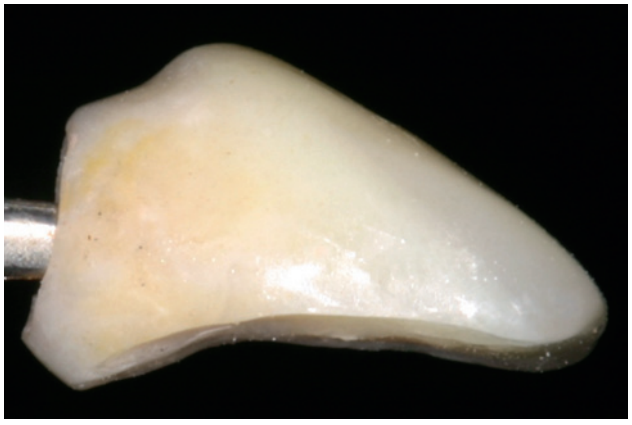


FIGURE 6-14 **H,** Provisional crown is fabricated with a concave labial sulcus to prevent displacement of the gingiva superiorly. This provisional is worn for several weeks until the soft tissue is stable.

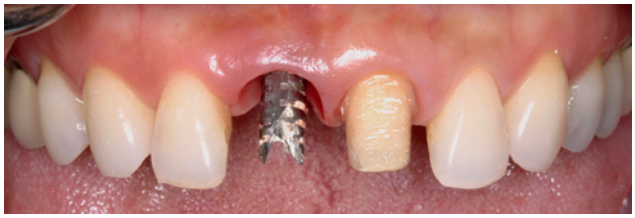


FIGURE 6-14 **J,** Provisional abutment in place with the gingival sulcus now defined by the provisional. A crown will be fabricated on the adjacent tooth to improve color and form.

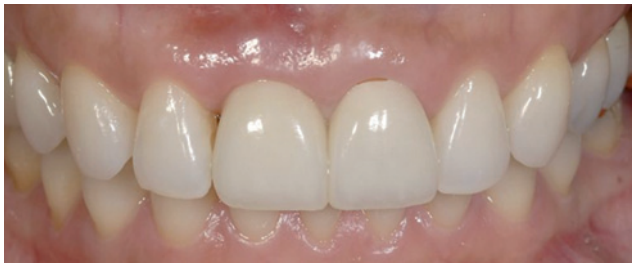


FIGURE 6-14 **L,** Final restoration has established function and esthetics. (Prosthetics by Dr. Paulino Castellon.)

had been secured, a 3-mm-tall healing abutment was screwed to the implant. A bovine xenograft (Endobon, Biomet 3i, Palm Beach Gardens, Florida) was firmly placed into the gap between the implant and the bone. One vertical mattress suture was placed to compress the gingiva slightly to the healing abutment. An Essix temporary was placed, avoiding contact between the pontic and the healing abutment and the adjacent soft tissue.

Prosthetic Phase. After 4 months had been allowed for integration, the ridge form was seen to be satisfactory without reduction. In addition, the gingival margin was 2 mm coronal to the adjacent tooth. Implant-level impressions were made, a temporary abutment was prepared, and a provisional crown was placed. Care was taken to prevent pressure on the facial gingiva through the creation of a concave subgingival labial form. After a satisfactory soft tissue form had been established by the temporary crown, a custom ceramic abutment was fabricated. A feldspathic coping was placed to mimic the light transmission of the adjacent tooth, and this was followed by fabrication of the all-ceramic final restorations (prosthetics by Dr. Paulino Castellon).

Thin bone, thin tissue

This patient had facial gingival migration as a result of lack of labial bone combined with thin facial gingiva, which was treated separately and delayed, potentially contributing to the final gingival position 1.5 mm apical to the desired position (Figure 6-15, A-K).

Problem List:

Thin gingiva over left central incisor
Facial margin level with adjacent tooth
Thin or lost labial bone over retained central incisor root
High smile line with gingiva showing on smile

Goals of Treatment:

Maintain gingival position to limit gingival recession
Maintain labial bone form by grafting extraction site at time of tooth removal
Fabrication of implant-retained crown with correct proportions and function, with maintenance of gingival form over time

Treatment Sequence:

Fabricate removable temporary prosthesis using removable appliance (see Figure 6-15, A-B)
Extract tooth with sulcular incisions, place graft in socket to reconstruct missing labial bone (see Figure 6-15, C-F)
After 4 months of healing, place implant in ideal position
Place connective tissue graft to convert thin gingiva to thick gingiva (see Figure 6-15, G-I)
After implant integration, fabricate esthetic temporary restoration
After final esthetics have been achieved with provisional restoration, fabricate final restoration (see Figure 6-15, J-K)

Extraction with Immediate Implant Placement

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for extraction with immediate implant placement performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient has a fractured central incisor that is not restorable. The surgical plan is to remove the tooth, preserve the labial bone, advance the gingiva against a healing abutment, and graft the expected gap between the implant and labial bone to preserve the convex ridge form.

After local anesthesic is infiltrated, an incision is made and the sulcular epithelium reflected to the junction of the tooth and crest with a Hirschfeld #20 periosteal elevator. The periotome tip of the piezotome was used to separate the bone from the tooth root. Care is taken to gently progress down the root to mobilize the tooth. A dental elevator is used to mobilize the tooth from the palatal aspect first. In this case, the crown is fractured and removed with forceps.

The piezotome is then used to continue separation of the tooth from the bone, and the root is mobilized with an elevator and then removed. The piezotome is used until the tooth root is freely mobile, which prevents fracture and the need for root tip retrieval.

After the tooth root is removed, a curette is used to confirm the presence of the labial bone. A round drill is attached to the drill extension, and the implant site is initiated with the round bur along the palatal slope of the root socket. This will allow proper placement of the implant palatal to the incisive edge of the planned crown.

The pilot drill is used to depth with consideration of placing the platform of the implant 3 mm apical to the facial gingival margin. A parallel pin is used multiple times to confirm proper orientation of the implant site.

The implant on the appropriate mount is started in the site with firm pressure from the surgeon. Because the implant will follow the path of least resistance, the surgeon must guide the implant placement to ensure proper angulation. After the implant is placed to proper depth, a healing abutment is placed to the level of the gingival margin. A graft is placed in the gap created between the implant and the labial plate. An Essix-type temporary is placed for immediate provisionalization with no contact on the healing abutment.

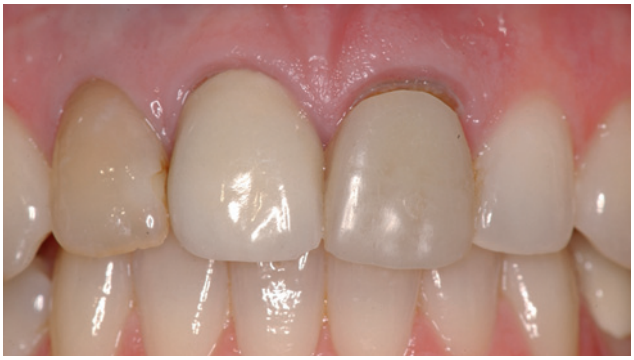


FIGURE 6-15 **A,** Preoperative view with temporary removable partial denture replacing the crown on the left central incisor. Note the thin gingiva and initial gingival margins approximately 0.5 mm apical to the adjacent natural tooth.

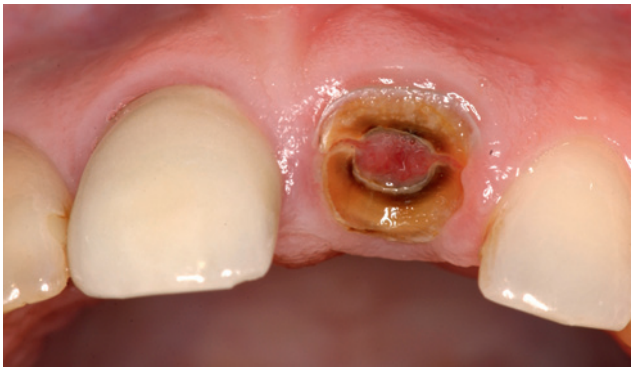


FIGURE 6-15 **B,** Pre-extraction occlusal view shows the slight tooth protrusion and thin gingiva; labial bone is likely to be thin.

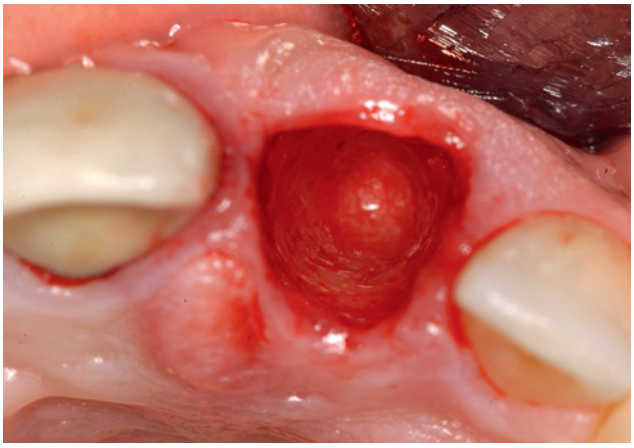


FIGURE 6-15 **C,** At the time of tooth removal, sulcular incisions were made around the tooth without touching the papilla. The tooth is removed atraumatically. A large labial dehiscence with approximately 4 mm of labial bone loss at the crest is found. The remaining labial bone is thin.

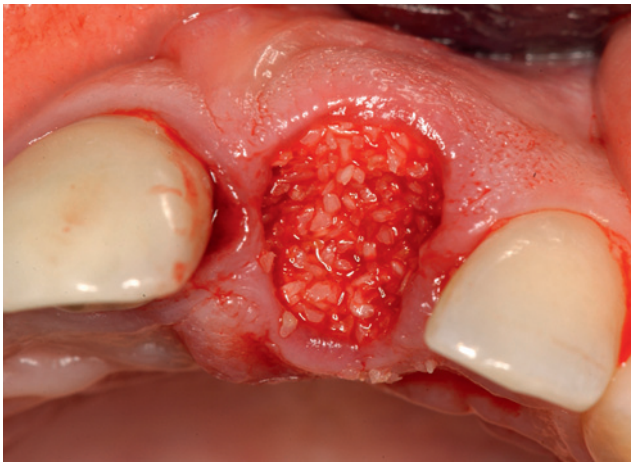


FIGURE 6-15 **D,** Socket is grafted with human mineralized cortical bone particles 350 to 500 μm in size. Approximately 0.5 ml of bone was firmly compacted into the socket.

This patient fractured her left central incisor. The tooth's position was slightly protrusive, with a thin overlying gingiva and very thin facial bone with labial defects. Prior to our understanding of early conversion of soft tissue to avoid recession, this patient was treated with extraction and grafting, followed by late connective tissue grafting. No advancement of the gingival margin was performed surgically, by either advancement of the gingiva over a healing abutment or orthodontic extrusion. The result was migration of the facial gingival margin 1.5 mm. This case is included in this text to illustrate the subtle need for accurate sequencing of procedures.

The preoperative evaluation revealed an excellent facial gingival margin level. The gingiva was thin, and the labial bone overlying the root of the central incisor was thin or nonexistent. The tooth root needed to be removed, the socket needed to be grafted to restore bone bulk for ideal implant placement, and the thin gingiva had to be managed. This case confirms the work of Kan et al.,[48] who demonstrated that gingival recession occurs when the bone is thin and the gingiva is not converted after removal of the tooth. The thin bone resorbs very quickly, and the gingiva recedes as the bone remodels.

The patient's tooth was removed, and the site was grafted. Approximately 4 months later, an implant was placed, and a further decrease in ridge width was noted clinically. Approximately 7 months after removal of the tooth, a connective tissue graft was placed to convert the thin tissue to thick tissue and to add a bulk of soft tissue to the ridge. By that

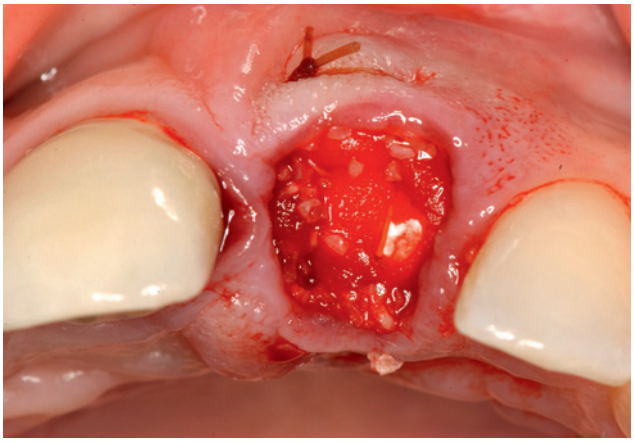


FIGURE 6-15 E, Piece of collagen hemostatic material (CollaPlug, Zimmer Dental, Carlsbad, California) was placed over the graft and held in position by 4-0 chromic horizontal mattress suture.

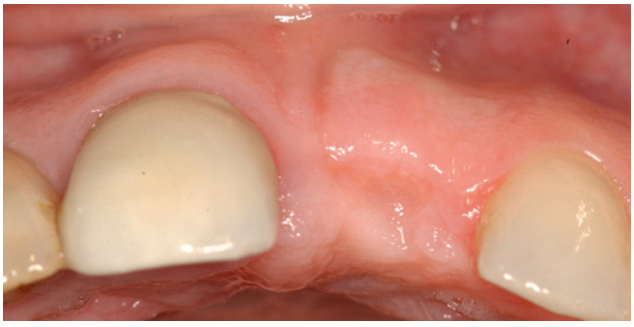


FIGURE 6-15 G, After 4 months of healing, the implant is placed. Three months later, a horizontal ridge deficiency is obvious.

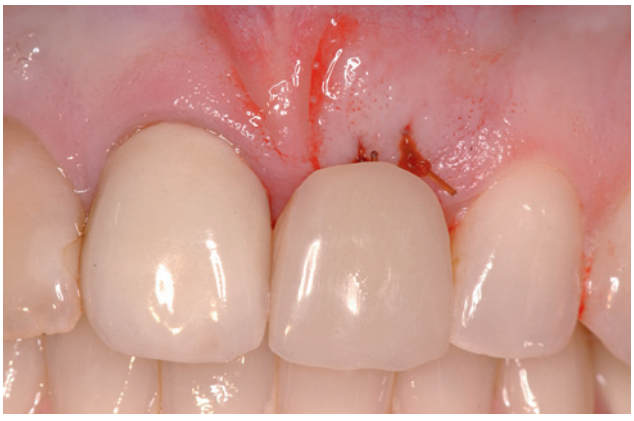


FIGURE 6-15 I, Removable prosthesis shows restoration of the gingival form prior to implant exposure and delivery of the final crown.

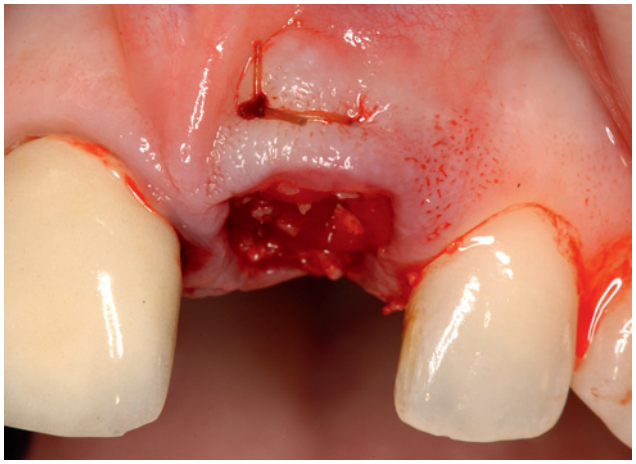


FIGURE 6-15 F, Eversion of the gingival margin to hold the facial margin as coronal as possible.

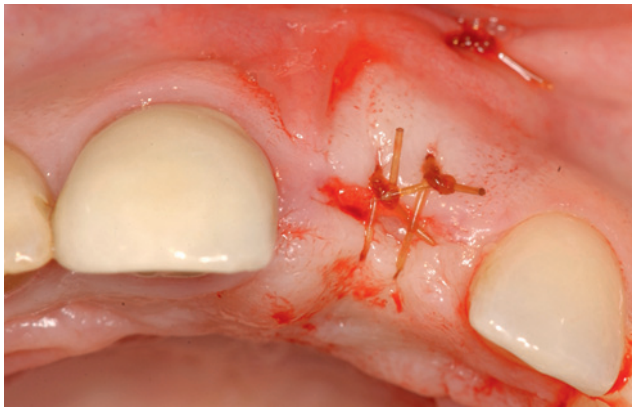
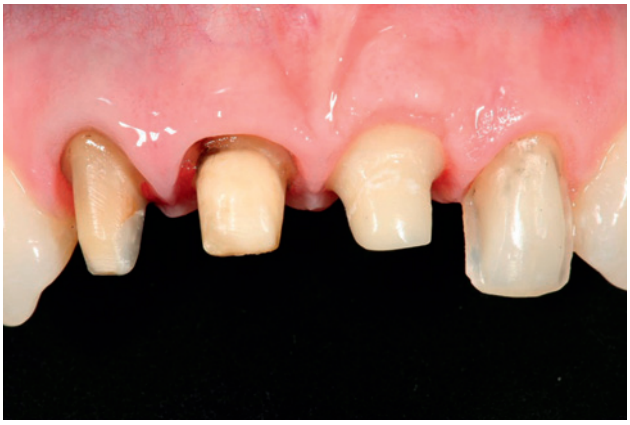


FIGURE 6-15 H, Connective tissue graft is placed at this time (7 months after extraction of the tooth) to augment the labial aspect of the ridge with thicker soft tissue available for the final prosthesis.

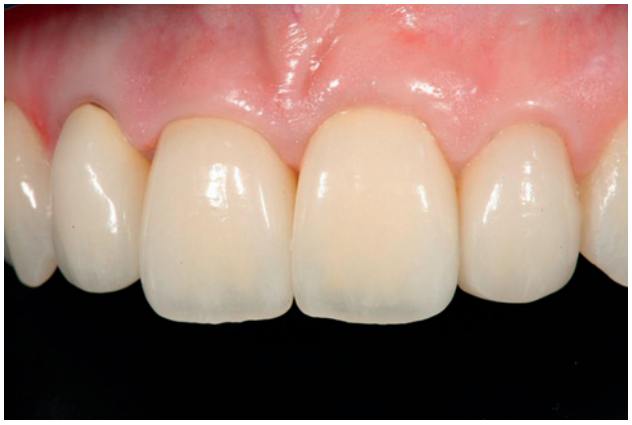
time, the damage had occurred, and ridge resorption affected the final result. A more ideal plan would have been to perform the tooth extraction, the socket graft, and the connective tissue grafting at the same time. The thickened gingival tissue should be more resistant to recession.

Thin facial gingiva, ideal facial gingival margin level, lack of labial bone

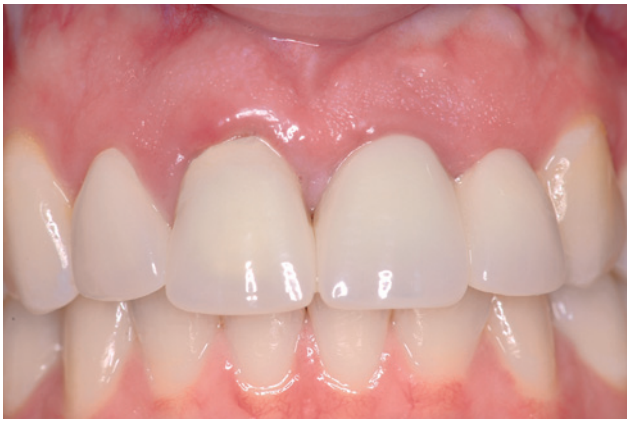
This patient presented with thin gingiva over the left central incisor (Figure 6-16, A). The facial gingival margin was level with the adjacent tooth, which was ideal in length and form. The gingiva was thin, with loss of papillation, and appeared red and glossy; the underlying crown margin could be seen through the thin overlying gingiva.



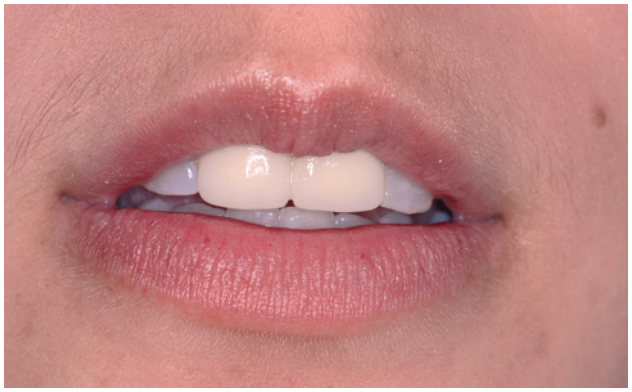
● **FIGURE 6-15 J,** Four incisors are prepared for crowns. Note that the facial gingival margin on the ceramic abutment of the left central incisor has migrated apically 1 mm.



● **FIGURE 6-15 K,** Final crowns have excellent esthetic form and have satisfied the patient; however, the facial gingival margin is 1 mm apical to the adjacent tooth. (Prosthetics by Dr. Markus Blatz.)



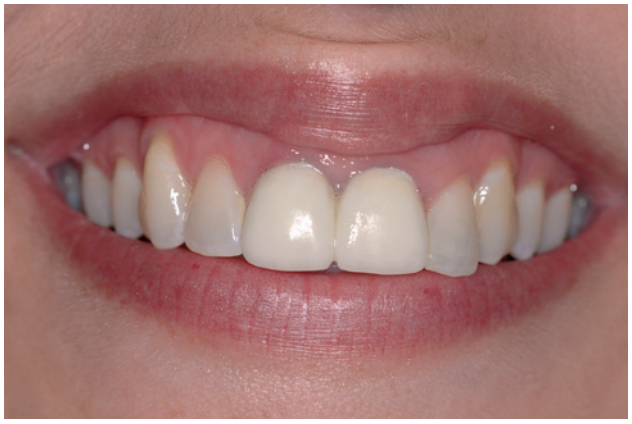
● **FIGURE 6-16 A,** Preoperative view showing anterior dentition. The patient will lose the left central and lateral incisors. The gingival margin is perfect with the incisor length ideal for her. The gingiva is thin.



● **FIGURE 6-16 B,** Tooth show at rest is ideal at 3.5 mm.

Problem List:
Thin gingiva over left central incisor
Facial margin level with adjacent tooth
Thin or lost labial bone over retained central incisor root
High smile line with gingiva showing on smile (Figure 6-16, B-C)

Goals of Treatment:
Convert thin gingiva to thick gingiva to limit gingival recession
Reconstruct lost labial bone bulk
Fabrication of an implant-retained crown with correct proportions and function, with maintenance of gingival form over time



● **FIGURE 6-16 C,** Smile line is high, and the gingival show is acceptable to the patient. The incisor edges of the maxillary teeth follow the lower lip contour.

Treatment Sequence:

Fabricate removable temporary prosthesis using Essix-type retainer

Extract teeth with sulcular incisions, place connective tissue graft to convert thin gingiva to thick gingiva, graft extraction sockets to reconstruct lost labial bone (Figure 6-16, D-K)

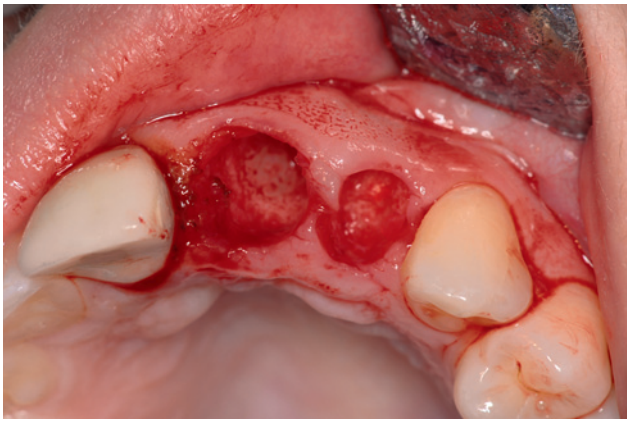
After healing (Figure 6-16, L-M), fabricate radiographic stent to create CT surgical guide stent for custom fabrication of healing abutment and placement of implant without incisions (Figure 6-16, N-T)

Fabricate custom healing abutment using CT surgical guide stent to guide placement of implant analog in master model (see Figure 6-16, P)

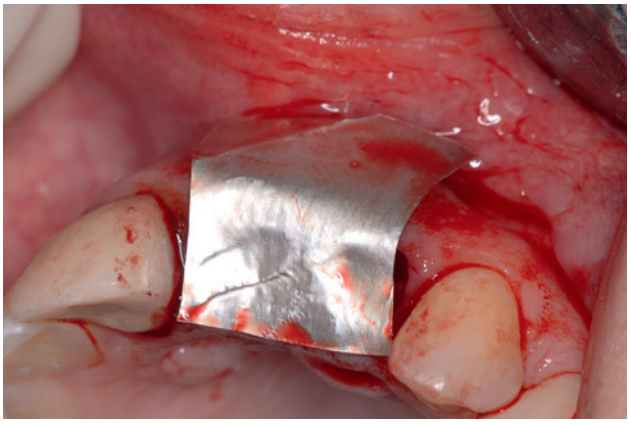
Surgically place implant and custom healing abutment to develop gingival profile

After implant integration, fabricate esthetic temporary restoration (Figure 6-16, U-X)

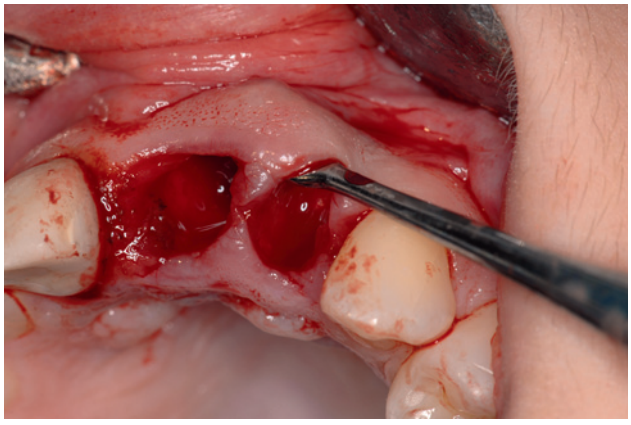
After final esthetics have been achieved with provisional restoration, fabricate final restoration



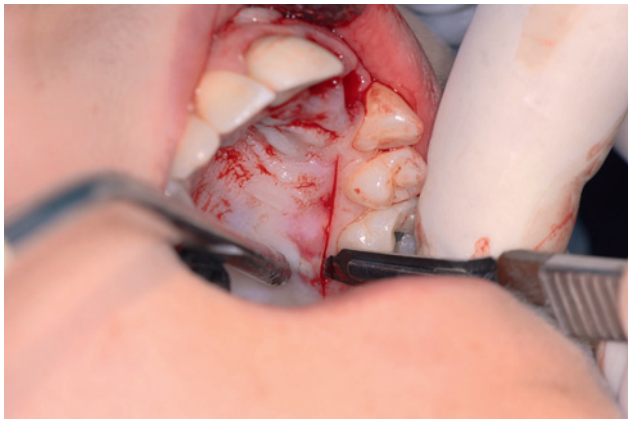
● **FIGURE 6-16** **D,** Sulcular incisions are made, and the teeth are extracted. Minimal labial bone is present.



● **FIGURE 6-16** **E,** Template is made from the suture pack foil to serve as a pattern for the required connective tissue graft.



● **FIGURE 6-16** **F,** Subperiosteal tunneling is performed to develop pockets under the labial gingiva for later placement of the connective tissue graft. Care is taken to avoid tearing the interdental gingiva.



● **FIGURE 6-16** **G,** Incision is made on the palate, and the scalpel blade is used to sharply develop a reflection of the palatal mucosa from the underlying connective tissue. The palatal tissue is kept thin to maximize the thickness of the planned subepithelial connective tissue graft.

1. Fabricate a removable temporary prosthesis using an Essix-type retainer. A model is made of the patient's maxilla and poured in stone. If the patient's current teeth will be used in the Essix temporary stent, the pre-extraction model can be used. If the patient's teeth are not planned for the provisional, the teeth to be extracted are removed from the case with a drill. Denture teeth can be used to replace the extracted teeth. The model with the denture teeth in place is duplicated in stone, and a vacuum form is made over the teeth and trimmed to cover all the maxillary teeth.

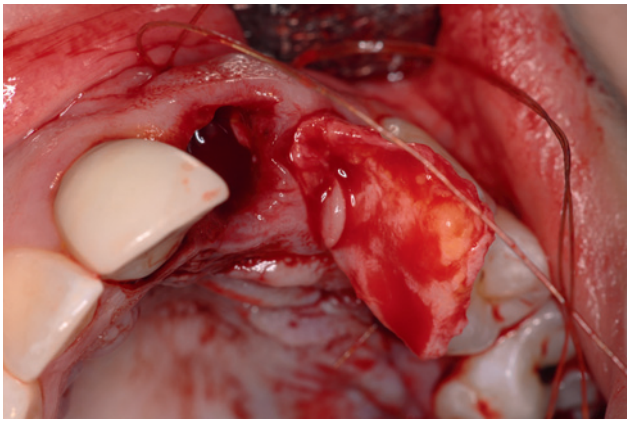


FIGURE 6-16 **H,** After harvesting of the graft, a suture is introduced from the vestibule through the labial tunnel, exiting in the extraction socket. The suture is passed through one corner of the connective tissue graft. An additional suture is placed on the left side through the vestibule, exiting from the extraction socket, and passing through the opposite corner of the graft.

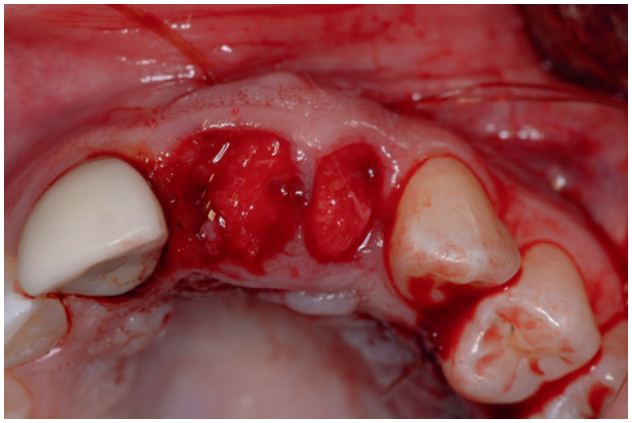


FIGURE 6-16 **I,** Graft is carefully and gently pulled and manipulated into the labial subperiosteal tunnel, under the labial gingiva. Part of the connective tissue graft extends over the extraction sites. The graft is incised to fit passively over each extraction site.

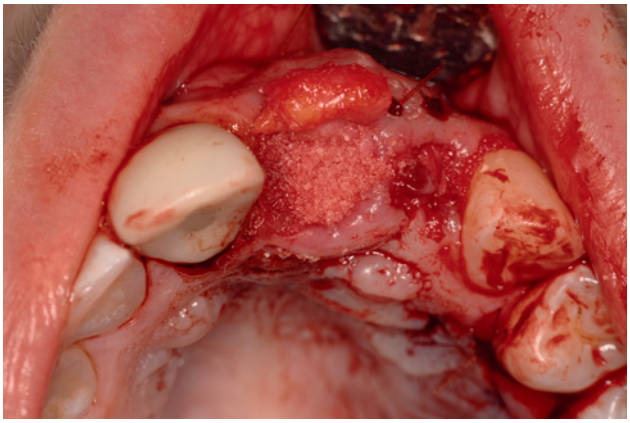


FIGURE 6-16 **J,** Connective tissue graft is rolled away from the extraction site, and the particulate human mineralized bone is firmly compacted into the site.

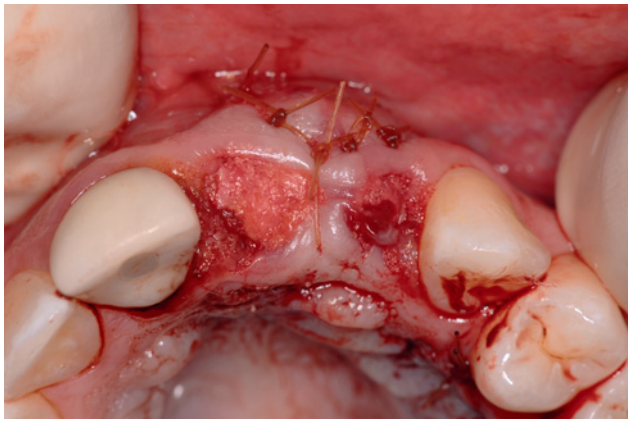


FIGURE 6-16 **K,** Sutures are placed to secure the connective tissue graft. Care is taken to avoid piercing the base of the graft on the labial aspect of the extraction sites. Vertical mattress and horizontal mattress sutures are used. A temporary Essix-type prosthesis is used during the healing period.

The CEJ of the replacement teeth in the Essix provisional should not quite reach the alveolar ridge to allow for soft tissue swelling after extractions and grafts. If necessary during surgery, the teeth in the provisional can be shortened after the provisional has been tried into the mouth. Pressure on the ridge after connective tissue grafting is not recommended until the connective tissue has healed and matured.

2. Extract teeth with sulcular incisions, place connective tissue graft to convert thin gingiva to thick gingiva, and graft extraction sockets to reconstruct lost labial bone. At the time of tooth extraction, a local anesthetic is administered in the vestibule and along the ridge, including the palatal mucosa. After a satisfactory plane of anesthesia has been reached, a small scalpel blade (15c) is used to make incisions around the neck of the teeth to be extracted. Care is taken to avoid sectioning the papilla.

After the tooth has been removed, a subperiosteal pocket is created superiorly and laterally through the sulcular incision. It may be very difficult to make this

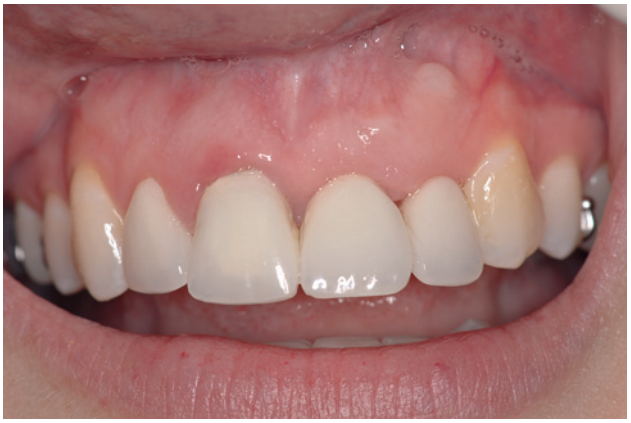


FIGURE 6-16 L, After 3 months, the soft tissue appearance over the left incisors has changed from thin to thick as planned. The ridge form has been re-established. The gingival margin now is coronal to the final planned location, which is at the level of the right central incisor.

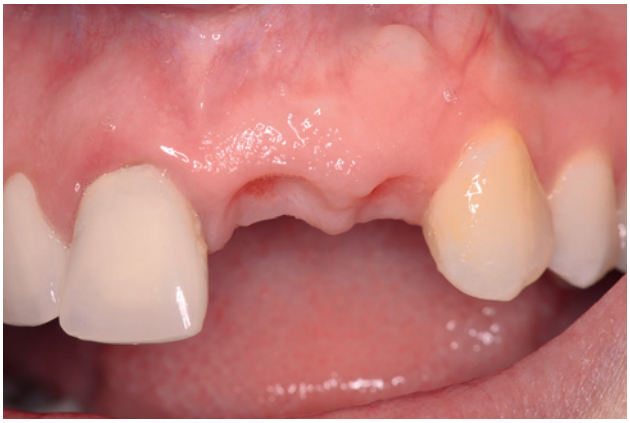


FIGURE 6-16 M, Close-up view of the soft tissue modeling under the Essix temporary. The esthetic of this site is now acceptable, and the prognosis is excellent for a stable final restoration.

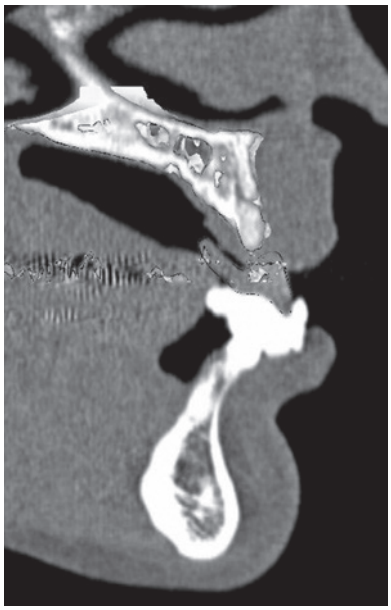


FIGURE 6-16 N, CT scan of an esthetic acrylic crown in place is taken using a dual-scan approach. This cross section shows excellent bone bulk from the graft placed 4 months previously.

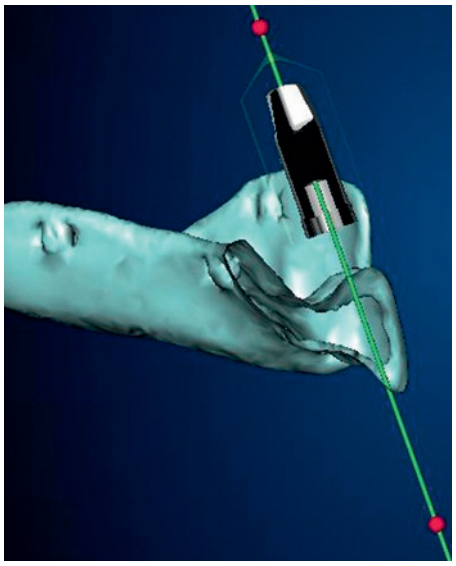


FIGURE 6-16 O, CT planning software is used to virtually place an implant in the ideal location. The implant emerges slightly palatal to the incisor edge; it is 4 mm apical to the planned gingival margin of the final crown, and its labial edge is palatal to the final crown's emergence from the gingiva.

dissection split thickness because of the thin gingiva. The pocket should extend superiorly at least 10 mm and laterally to the distal line angle of the adjacent teeth. The pocket should be confluent to allow one piece of connective tissue to be placed, which converts the thin gingiva to thick gingiva.

After the pocket has been formed, a piece of foil from the suture pack is cut to form a template for the needed connective tissue graft. The template is placed along the palatal mucosa, and an incision is made approximately 2 mm from the gingival margin of the maxillary posterior teeth. A thin palatal flap is raised from the horizontal

FIGURE 6-16 **P,** Model is made from the CT guide stent with a soft tissue mask. Prosthetic parts are placed, and a custom zirconium healing abutment is fabricated. This custom abutment will be placed at the time of implant placement to shape the gingiva during the implant integration period.

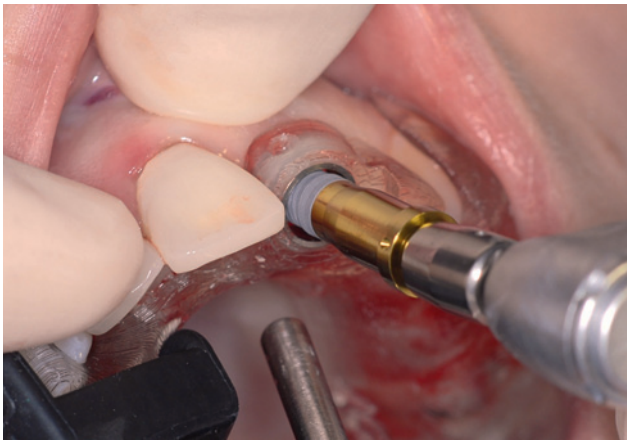


FIGURE 6-16 **Q,** Implant site is prepared, using a guide stent generated from the CT scan with the planned restoration duplicated in clear acrylic. The guided surgery allows implant placement with no incisions. The drills fit into sleeves, which are oriented by the master tubes of the guide stent for implant site preparation. Here, the implant is placed using the appropriate implant driver mount.

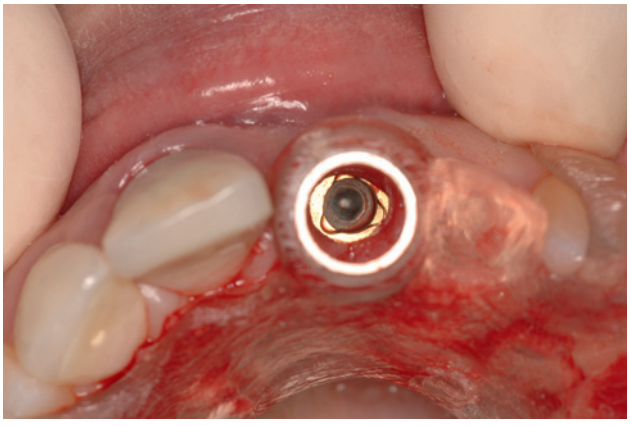


FIGURE 6-16 **R,** Implant as seen through the guide stent. Note that the orientation of the implant is specific, so as to match the orientation of the implant analog in the model during fabrication of the custom implant healing abutment.

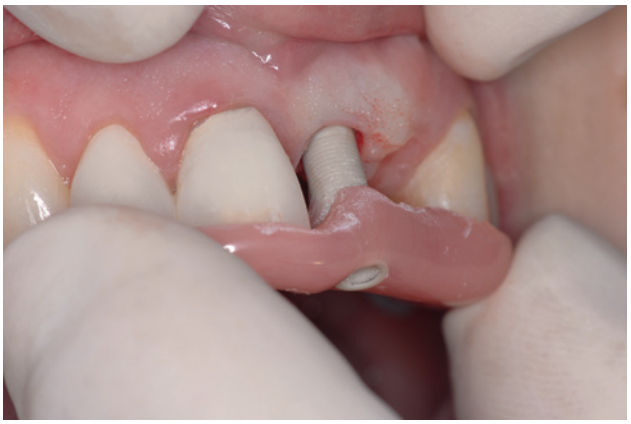


FIGURE 6-16 **S,** Implant waxing sleeve is used with an acrylic holder to confirm the rotational position of the implant after placement. The rotational orientation of the implant is confirmed if the device fits passively into the implant.

incision, leaving the underlying connective tissue as thick as possible. The scalpel then is turned perpendicular to the palatal mucosa, and the underlying connective tissue is outlined with a peripheral incision through the periosteum. The connective tissue is removed. Bleeding from within the palatal pocket is controlled with injection of a local anesthetic, placement of a hemostatic material (e.g., collagen), or if necessary, oversuturing of the bleeder with 3-0 chromic suture. Immediately after removal, the connective tissue graft is placed in a dampened sponge. The palatal incision is closed with a running chromic suture as necessary.

The graft is trimmed to match the template. Excessive fat is removed with scissors, resulting in a smooth graft approximately 1.5 to 2 mm thick. A 4-0 chromic suture is introduced from the unattached gingiva in the vestibule

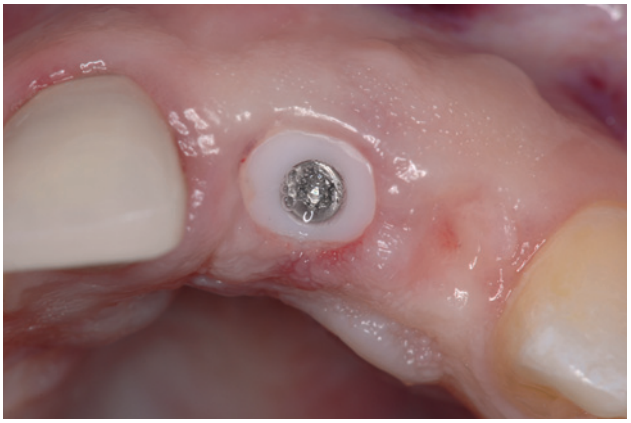


FIGURE 6-16 T, Custom healing abutment in position at the time of implant placement. Note the lack of tissue swelling and trauma because of the flapless, guided surgical approach.

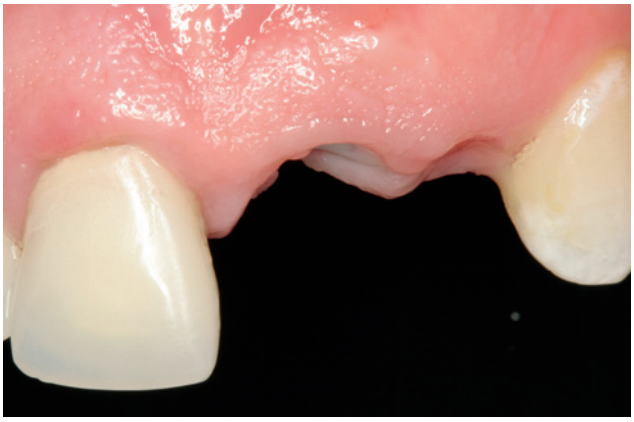


FIGURE 6-16 V, Three weeks later, the custom abutment is covered with soft tissue, indicating a very comfortable soft tissue response.

through the tunnel and into a corner of the graft. The suture is returned into the pocket, exiting close to the entry point laterally and superior from the pocket. A second suture is introduced from the distal aspect of the pocket and exiting through the extraction site to engage the opposite corner of the graft, then returning through the pocket and exiting near the entry site of the suture. The graft is carefully and gently introduced into the tunnel on the labial aspect to lie under the labial gingiva. Both vertical retention sutures are tightened and tied to locate the graft vertically. The graft may need to be incised to passively cross the extraction sites, acting as the cover to the socket graft.

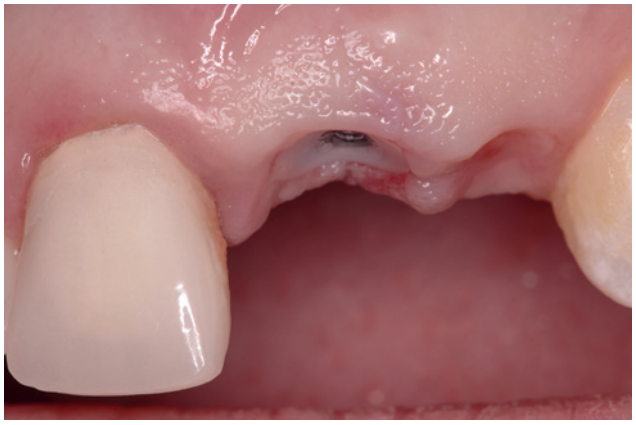


FIGURE 6-16 U, Frontal view shows the custom abutment in position after implant surgery. Note the lateral support of the papilla.

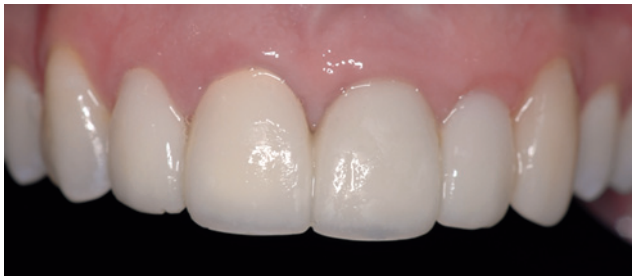


FIGURE 6-16 W, Provisionals have been fabricated and are ready for final restoration.

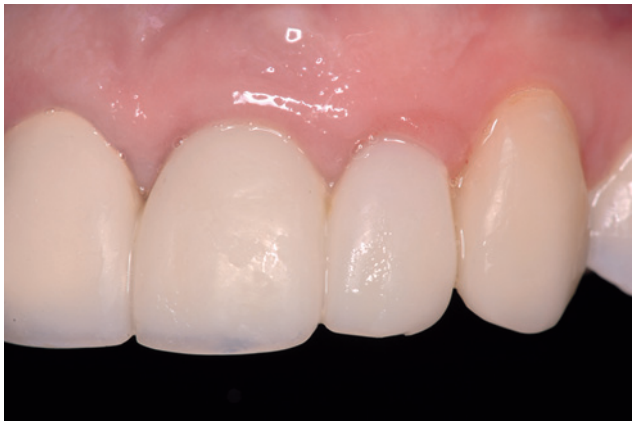


FIGURE 6-16 X, Note the excellent facial gingival margin position, the thick gingival tissue with esthetic stippling, and the healthy gingiva. (Prosthetics by Dr. Paul Child and Dr. Tyler Lasseigne.)

CT-Guided Surgery for Central Incisor with Custom Healing Abutment

DVD Video 6-4

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for CT-guided surgery for central incisor with custom healing abutment performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient will have a single implant placed using a CT-generated surgical guide stent and a custom-fabricated healing abutment placed to preserve facial gingiva and provide support to the papilla.

After local anesthesic is infiltrated, the guide stent is placed over the teeth. A tissue punch is used to remove the crestal gingiva. The countersink drill is used to initiate the osteotomy through the uneven bone crest. A drill sleeve is then used, and the pilot drill is used to depth as planned. After the pilot drill is used, the next-sized drill is used through a drill-diameter–specific sleeve to planned depth. Depending on the density of bone, the final-size drill is chosen to allow for implant seating with maximum thread fixation.

The implant is placed with the supplied drill mount, which will engage the inner surface of the master cylinder within the guide stent. This ensures that the implant will be placed close to the angulation as planned. After the implant is placed, the driver mount is removed and the custom healing abutment is seated and secured to the implant with a screw.

An Essix temporary restoration is placed for patient comfort and esthetics with the provisional modified to avoid pressure on the healing abutment that is flush with the gingiva. (Prosthetics by Dr. Paul Child.)

The soft tissue graft is reflected labially, and the socket is grafted with particulate graft material. After the mineralized graft material has been firmly consolidated, the soft tissue graft is returned to cover the sockets and is sutured in position. Sutures are passed through the gingiva over the gingival graft, covering the graft rather than entering it and preventing excessive suture damage to the connective tissue graft.

The provisional Essix restoration is modified as necessary to prevent pressure necrosis of the connective tissue graft. Swelling is expected; therefore, the intaglio surface of the provisional must be relieved. After the initial healing, pressure can be placed over the ridge to gently form a sulcus, anticipating the final desired gingival form.

3. After healing, fabricate radiographic stent to create CT surgical guide stent for custom fabrication of healing abutment and placement of implant without incisions. The extraction sites are allowed several weeks to months to mature, allowing for accurate development of the desired final restoration form. From the desired tooth form, a clear acrylic radiographic stent is made to delineate the specific implant position and to create a custom-fabricated healing abutment. The laboratory creates a clear acrylic stent with the following characteristics:

- The planned crown forms with ideal labial form, incisor edge position, and facial gingival margin location are present.
- Flanges are added to allow placement of radiographic markers (e.g., gutta percha) for use of a dual-scan technique.
- Full coverage of the dentition is provided to allow stability during implant placement.

The patient wears the radiographic stent during the scan, and the radiographic stent is scanned by itself in the same orientation as when the patient was scanned. The scan is taken according to the scanning parameters for the specific CT planning software used (in this case Nobel Guide, Nobel Biocare, Goteborg, Sweden).

4. Fabricate custom healing abutment using CT surgical guide stent to guide placement of implant analog in master model. Placement of a custom healing abutment at the time of implant placement can aid development of the planned sulcus during the time needed for implant integration. The anatomic form of the healing abutment provides support for the papilla, enables the labial gingiva to retain its form, and prevents retraction of the gingiva into the hole created by the flapless approach for guided implant placement. In addition, a healing abutment allows the gingiva to be tented over a portion of the abutment, which might result in a gain of soft tissue vertical height in the coronal direction.

The surgical guide stent has metal guide tubes that aid the surgeon in implant placement; drill sleeves and precise drill-sized holes ensure accurate placement. The metal tubes also can be used to fabricate healing abutments, provisional abutments and restorations, and for some clinicians, the final restoration. For this patient, a specific part is inserted into the metal tube and connected with an implant analog. The master cast has an appropriately sized preparation made to allow the analog to be placed within the diagnostic cast. The analog is secured in

position with stone or plaster. The guide stent is removed, and the analog is found to be in the exact location, rotation, and depth as the implant will be when placed by the surgeon.

The laboratory technician or restorative dentist forms the desired sulcus within the cast using drills. After the sulcus has been shaped, a custom abutment is formed with the aid of wax, computer-assisted design and manufacture (CAD CAM) scanning for milling, or fabrication using resin or acrylic. Zirconium has been found in a limited series to work very well by promoting soft tissue growth over the healing abutment when it is placed on the implant immediately upon implant placement.

The custom healing abutment should be at the level of the gingiva, with minimal supragingival prominence, to promote gingival overgrowth. It should laterally support but not compress the papillae to preserve their shape during the implant integration period. Over the period of implant integration, the gingiva heals with maturation of the collagen through cross-linking, which stabilizes the gingival form. As necessary, further sulcal shaping can be performed when the site is temporized.

5. Surgically place implant and custom healing abutment to develop gingival profile. At the time of surgery, specific items must be available, including the surgical guide stent, the surgical guide kit that matches the implant system to be used, the custom healing abutment with gold screw, and as determined by the team, a custom-fabricated jig for confirmation of the proper rotational orientation of the implant so that it matches the orientation of the custom healing abutment.

The area is prepared and anesthetized, including the nasal region, because the implant usually engages the nasal cortical bone. The surgical guide stent has been tried in place before the onset of anesthesia, preferably a few days prior to the actual implant surgery. The guide stent is placed, and the drilling sequence is followed. The gingival punch drill is used to remove a circular patch of gingiva. The series of twist drills are used at slow speeds to prevent burning of the bone; irrigation is difficult to deliver to the drill within the bone because of the tight constraints of the guide and sleeve and the high tolerances of the drill fit in the drill sleeve. The implant is placed as planned. It is oriented with the rotation of the internal connection verified by the insertion-orientation jig. The site is examined, and as necessary, soft tissue is cleaned from the implant with instruments or a water-cooled laser. The custom-fabricated abutment is placed and secured by its retaining screw. A radiograph is taken after the surgery to confirm seating of the abutment.

6. After final esthetics are achieved with provisional restoration, fabricate final restoration. After the implant has been allowed to integrate, an implant-level impression is taken, and a provisional restoration is made that mimics the initial esthetic setup. As necessary, it is modified to further sculpt the soft tissue and maintain the facial gingival margin position, support the papilla, and confirm stability before the procedure advances to the final restoration. The final restoration may be made using all-ceramic abutments, metallic abutments, all-ceramic crowns, or conventional porcelain-fused-to-metal crowns, as determined by the esthetic needs of the patient.

Ideal facial gingival margin level, thin or deficient labial bone secondary to previously placed and lost dental implant

This patient had lost the left central incisor when she was a child. A dental implant had been placed when she was 10 years old by a clinician in another state, not by this author. She had multiple problems, which resulted in removal of the dental implant 4 months before she presented for a new implant. She wanted a tooth that was esthetic and matched her natural right central incisor (Figure 6-17, A-O).

Problem List:

High smile line with gingiva showing on smile (see Figure 6-17, A)

Thin gingiva over left central incisor edentulous site

Facial margin level with adjacent tooth (see Figure 6-17, B)

Thin or lost labial bone over left central incisor location (see Figure 6-17, C-D)

Goals of Treatment:

Convert thin gingiva to thick gingiva to limit gingival recession

Reconstruct lost labial bone bulk

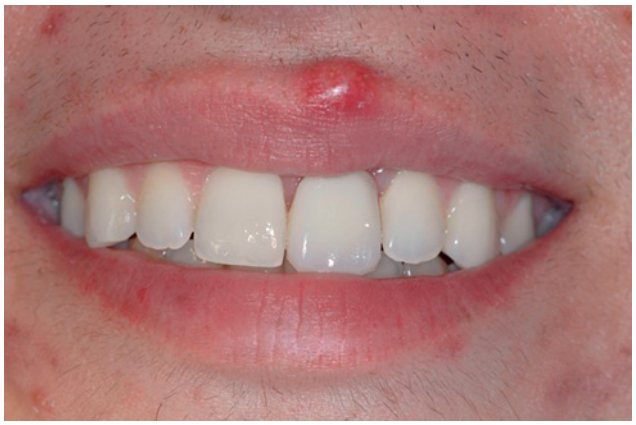


FIGURE 6-17 A, Initial presentation of a patient who needs an implant to replace the left central incisor. She has excellent show at rest and at smile, with the right central incisor at the ideal 10.5-mm length.

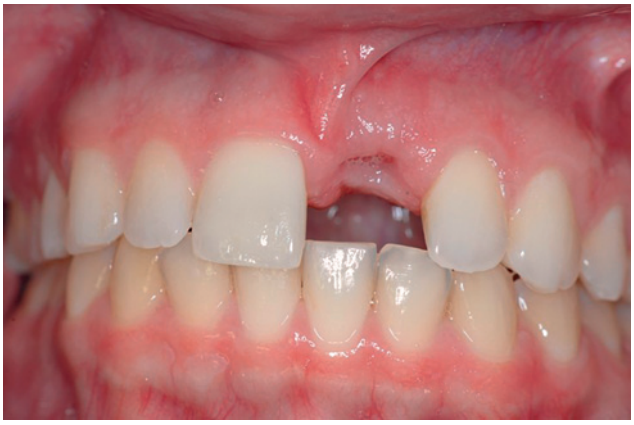


FIGURE 6-17 **B,** Site approximately 3 months after removal of a dental implant. The gingival margin is at the level of the adjacent tooth. The gingival thickness is relatively but not excessively thin.

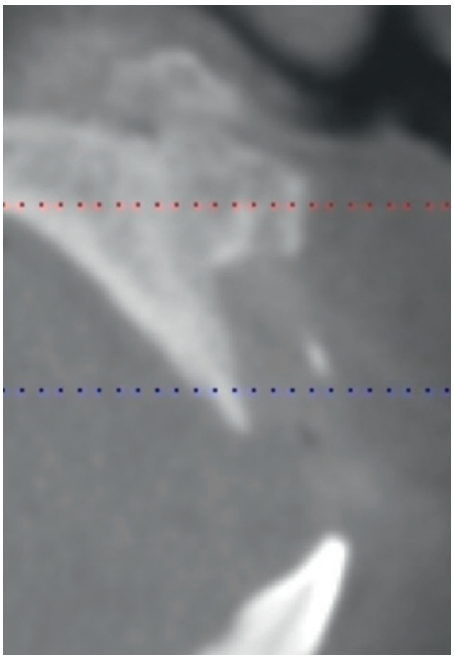


FIGURE 6-17 **D,** Cross section of the left central incisor site showing thin labial crestal bone with bone deficiency in the apical third of the previously placed implant. This is similar to extraction sites that have had a previous apicoectomy.

Fabrication of an implant-retained crown with correct proportions and function, with maintenance of gingival form over time

Maintain current position of facial gingiva without recession (see Figure 6-17, E)

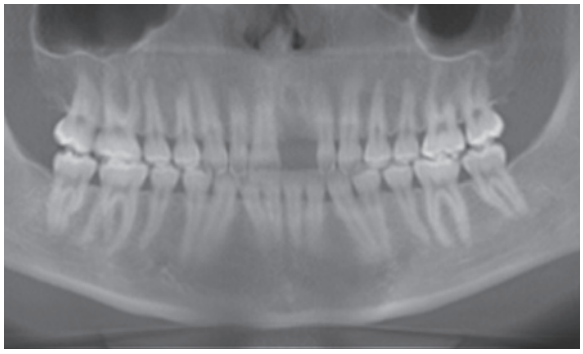


FIGURE 6-17 **C,** Panoramic image showing previous implant site with missing bone.

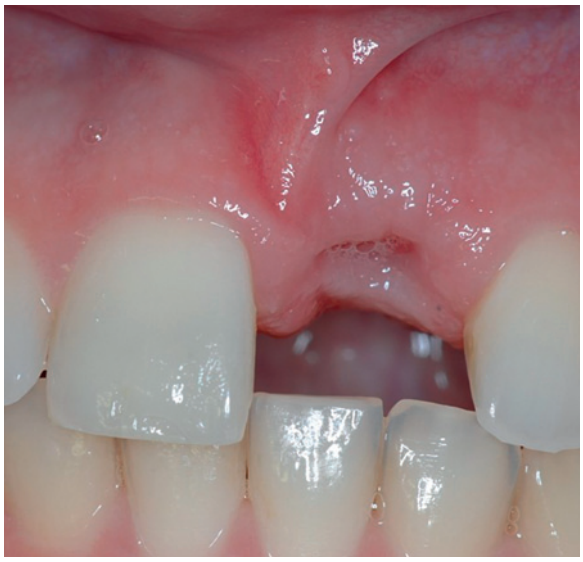


FIGURE 6-17 **E,** Close-up showing the frenum close to the interdental region and the facial gingival margin at the level of the adjacent tooth, which is ideal in length. Care must be taken to avoid gingival recession secondary to extremely thin or deficient labial bone.

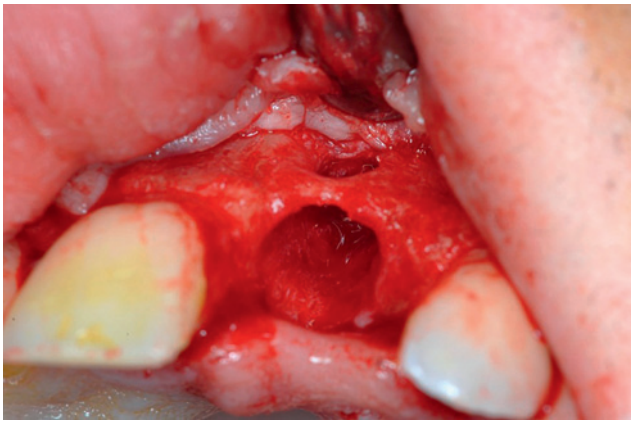
Treatment Sequence:

Current flipper provisional will be used during the surgical phases of treatment

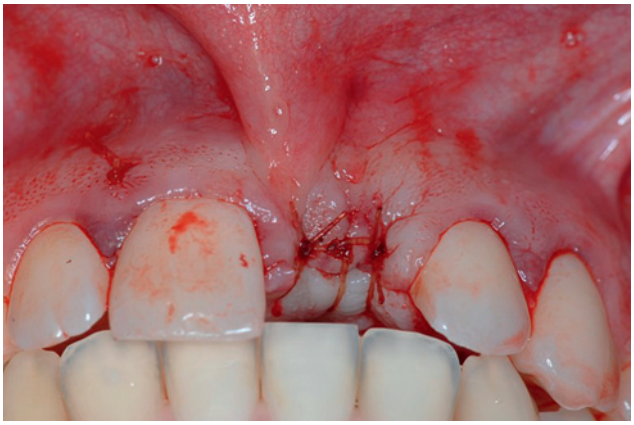
Crestal incision with implant placement, grafting of thin labial bone defect, and placement of healing abutment with advancement of facial gingiva to coronally reposition gingival margin (see Figure 6-17, F-I)

After healing (see Figure 6-17, J), placement of subepithelial connective tissue graft to augment gingiva and convert thin gingiva to thick gingiva (see Figure 6-17, K-L)

After 6 weeks for healing of connective tissue graft, exposure of the healing abutment with the aid of a Biolase laser (see Figure 6-17, M)



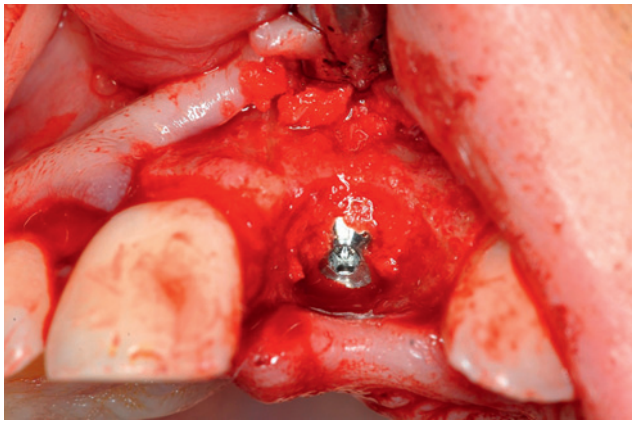
● **FIGURE 6-17** **F,** Surgical procedure uses a crestal incision with sulcular extension around the adjacent teeth. The flap is elevated with a small periosteal elevator (Hirschfeld #20). The reflection exposes the intact, thin labial bone. Granulation tissue is removed, and the site is cleaned to expose the remaining bone.



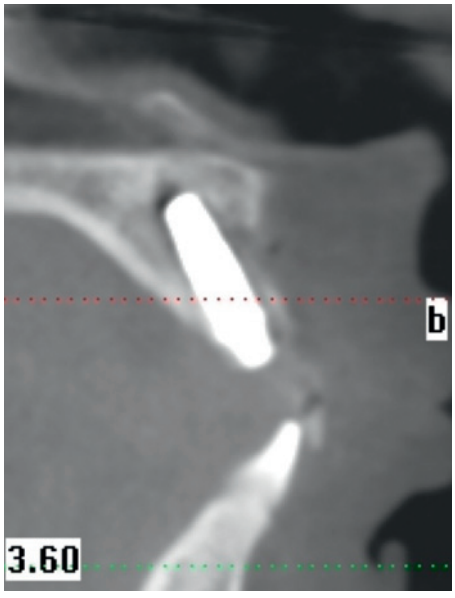
● **FIGURE 6-17** **H,** Periosteum in the superior aspect of the envelope flap is incised to allow tension-free closure over the healing abutment. This advanced the gingiva coronally, which combined with tenting should allow for thick gingival healing and less recession.

After final esthetics have been achieved with provisional restoration, the process of impressioning for final crowns is accomplished (see Figure 6-17, N-O)

This patient's surgical needs included implant placement, labial bone grafting to reconstruct the thin labial bone defects, advancement of the facial gingiva coronally 1 to 2 mm, and conversion of thin tissue to thick tissue. Because of the extent of the bone defect, the surgical treatment was divided into phases.



● **FIGURE 6-17** **G,** Implant is placed with proper emergence to the palatal and 3 mm apical to the planned gingival margin. The radiofrequency index is 75, indicating excellent implant stability. Bone from the drill is harvested and used to graft the bone defects. A straight emergence healing abutment 3 mm tall is placed.



● **FIGURE 6-17** **I,** Cross section shows the implant in position, the bone defects grafted, and the healing abutment in place.

First Procedure. Implant placement, bone grafting, and advancement of the facial gingiva constituted the first step. A local anesthetic was infiltrated, and a crestal incision was made combined with sulcular incisions. A full-thickness flap was enveloped to expose the thin labial bone and defects. The soft tissue within the bone defects was removed carefully. Sufficient bone was available in the desired

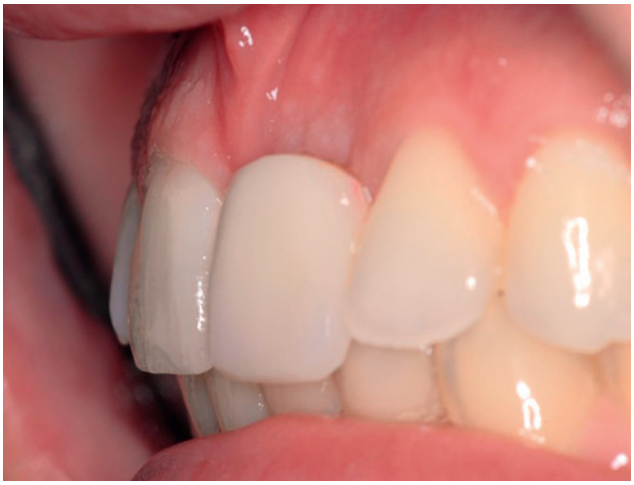


FIGURE 6-17 J, Three months later, the labial gingival position is deficient. Because of the preoperative presence of thin or absent labial bone combined with the relatively thin gingiva, this deficiency was expected. The patient is scheduled for connective tissue grafting to convert thin tissue to thick tissue and to provide horizontal ridge bulk for prosthetic reconstruction.

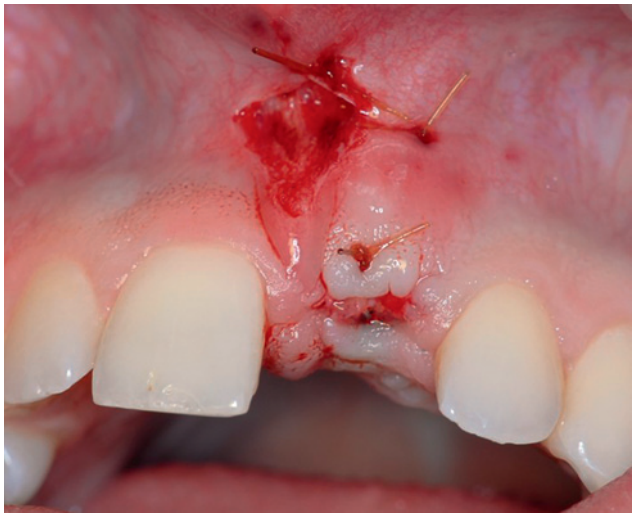


FIGURE 6-17 K, Incision is made over the healing abutment, and a pocket is created with a 15c blade. A subepithelial connective tissue graft is harvested from the palate and placed within the pocket. A frenectomy is performed with a Biolase laser.

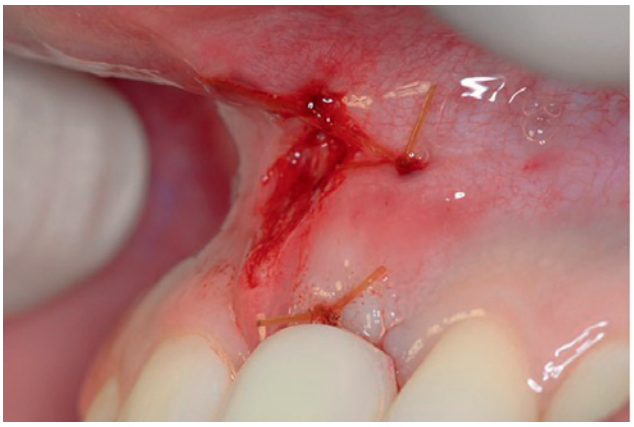


FIGURE 6-17 L, Immediate postoperative view shows obvious horizontal ridge augmentation.

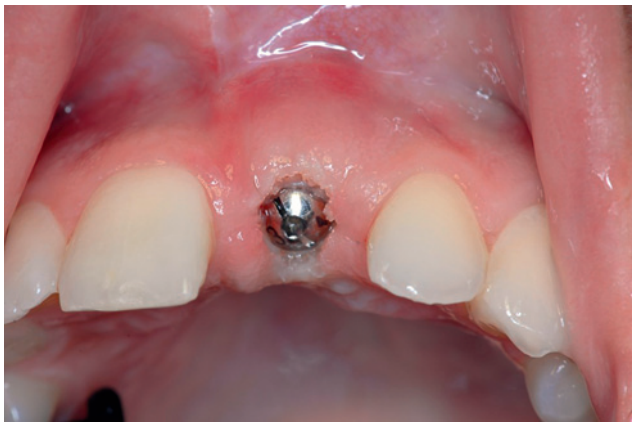


FIGURE 6-17 M, Six weeks after placement of the connective tissue graft, the patient is ready for exposure of the abutment. Note the restored ridge form. A laser is used to expose the healing abutment.

implant position, as predetermined from the cross-sectional CT image. The implant site was prepared, and the bone was harvested from the drills for later grafting. In addition, a sieve was placed within the suction line to collect all of the bone from the implant site. The implant was placed, and the radiofrequency index was 75, indicating excellent implant stability. A straight emergence healing abutment 3 mm tall was placed, and the autogenous bone from the drills was placed between the labial bone and implant and within the apicoectomy defect. A scalpel was used to release the periosteum within the depth of the flap to allow tension-free advancement of the gingiva. Primary closure over the healing abutment was achieved using 4-0 chromic suture on a tapered small half-circle (SH) needle.

Second Procedure. After healing, a horizontal ridge deficiency was observed, as expected, because of the thin

FIGURE 6-17 N, Crown was formed with a concave subgingival form to allow soft tissue formation without moving the gingiva superiorly.

bone and thin gingiva. However, the advancement of the gingiva over the healing abutment resulted in the facial gingival margin moving coronal to its original position. After infiltration of a local anesthetic, a 15c blade was used to create a subgingival pocket at the periosteal level extending 10 mm superiorly and to the line angles of the adjacent teeth. A subepithelial connective tissue graft was harvested from the left palate. A needle was used to enter the pocket superiorly through the unattached tissue in the vestibule. The suture was passed through the planned apical aspect of the connective tissue graft and re-entered the pocket from the crestal aspect, exiting into the unattached tissue in the vestibule adjacent to the entry site of the same suture. The suture was pulled, and the CT graft was placed within the pocket to augment the crest. The vestibular suture was tied and two interrupted sutures were used to close the crestal incision. In this patient, a frenectomy was performed using a water-cooled Biolase laser.

Exposure Procedure. Six weeks after placement of the connective tissue graft, a water-cooled Biolase laser was used to expose the healing abutment, which had become completely covered with soft tissue.

Prosthetic Procedure. An implant-level impression was taken, and a provisional restoration was made. The provisional abutment was contoured with a concave subgingival form to allow gingival positioning without excessive pressure. This maintains gingival position without apical migration (prosthetics by Dr. Paulino Castellon).

Thin gingiva with facial gingival margin apical to adjacent tooth

The patient required removal of one or more anterior teeth, and the initial facial gingival margin was apical to the ideal level. The general treatment flow was first to

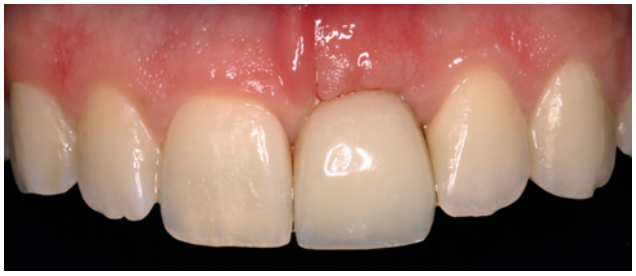


FIGURE 6-17 O, Crown in place, showing restoration of the missing tooth with maintenance of facial gingival position. (Prosthetics by Dr. Paulino Castellon.)

determine the ideal form and location of the final crowns, including the incisor edge position, the level of the facial gingival margin, the location of adjacent papillae, and the inclination of the labial surface of the tooth or teeth (Figure 6-18, A-DD). Vertical movement and correction of the apically positioned gingival margin should include consideration of orthodontic extrusion to move the facial gingival soft tissue coronally. If the tooth is extruded

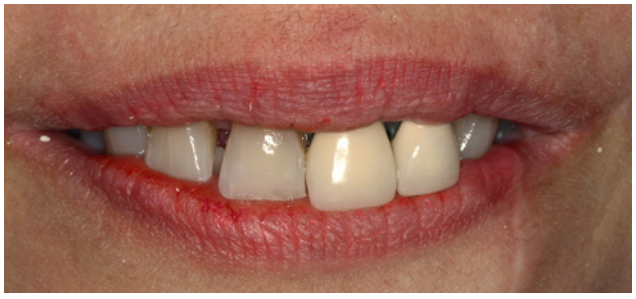


FIGURE 6-18 A, Preoperative view showing anterior teeth. Note that the incisor edges do not follow the lower lip contour; the patient has excessive incisor show at midsmile, and the alignment of the teeth is not esthetic.

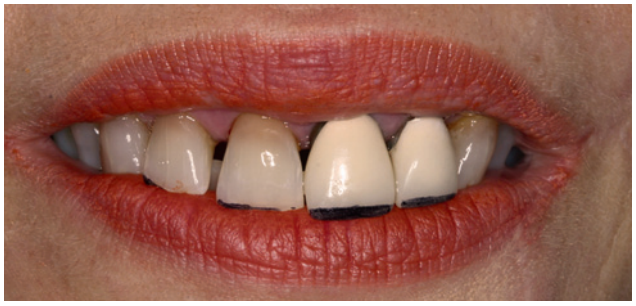


FIGURE 6-18 B, Marker is used on the teeth to show a better contour.

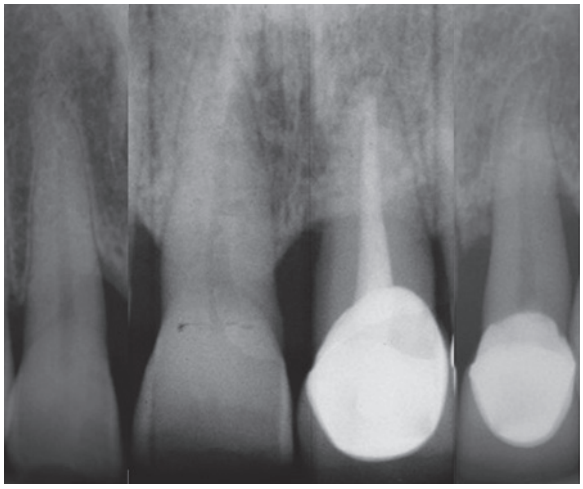


FIGURE 6-18 **C,** Periapical radiographs show excessive bone loss on the left central and lateral incisors.

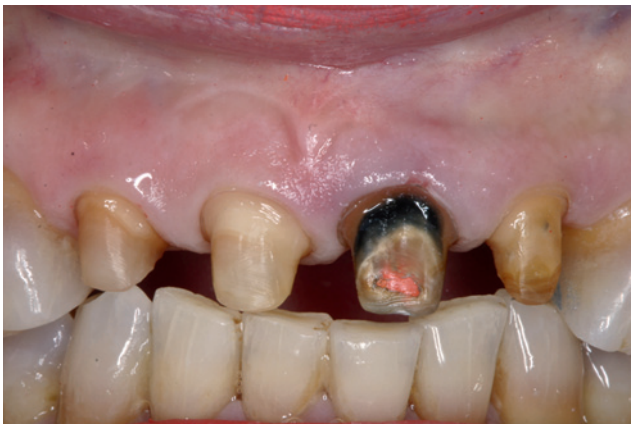


FIGURE 6-18 **E,** Old restorations are removed, exposing the teeth. The teeth are revised for fabrication of a new temporary, which is used for diagnosis.

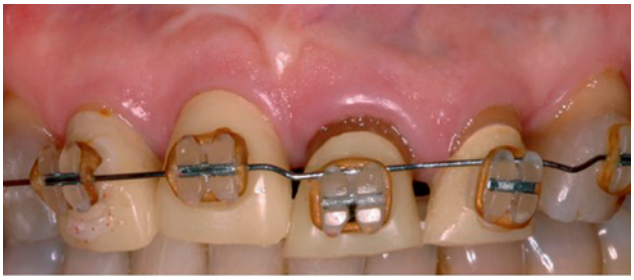


FIGURE 6-18 **G,** Teeth are extruded and overcorrected. They are left in retention until bone has filled the gaps created by the extrusion. Note that the facial gingival margin is overcorrected at least 2 mm.

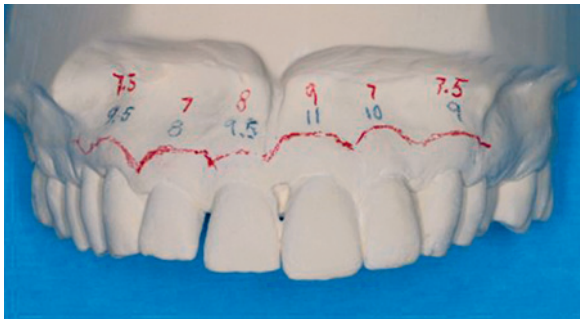


FIGURE 6-18 **D,** Diagnostic models are used to outline the vertical bone levels and then to create an esthetic waxup.

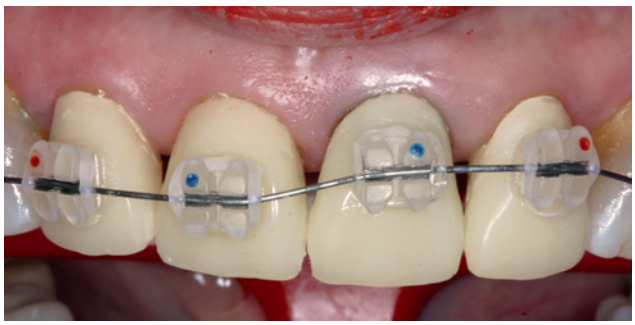


FIGURE 6-18 **F,** New temporary shows that the facial gingival margin is at least 3 mm apical to the planned restoration. The incisor edges in this temporary established the ideal incisor edge position. From this, the necessary facial gingival margin is determined. Orthodontic appliances are placed to extrude the left incisors and move the gingival margin coronally.

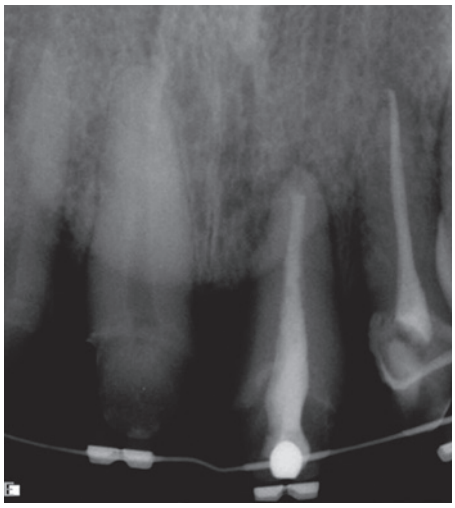


FIGURE 6-18 **H,** Extruded teeth have moved the bone coronally.

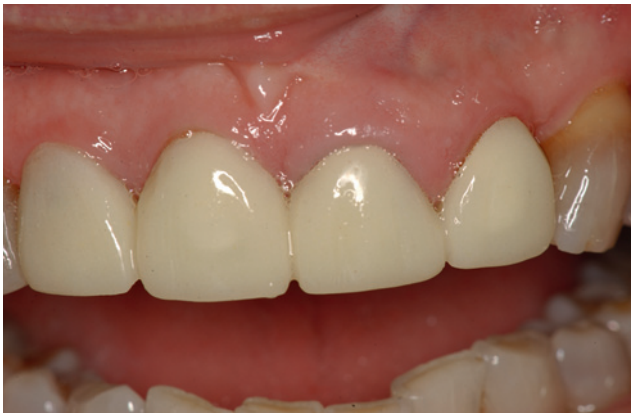


FIGURE 6-18 I, New four-unit provisional restoration is made, and the orthodontic appliances are removed.

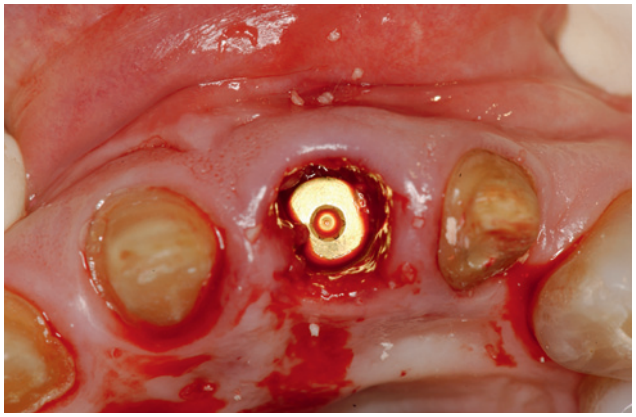


FIGURE 6-18 J, Provisional restoration is removed, as is the left central incisor. One implant is placed into the bone. No grafting is necessary, because the implant is completely within bone.

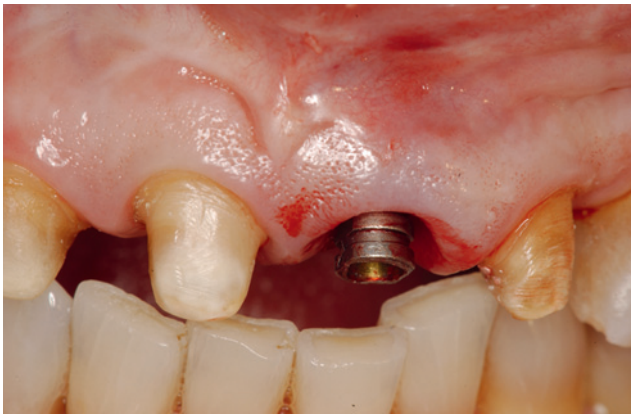


FIGURE 6-18 K, Provisional abutment is placed on the implant and modified to the correct height.

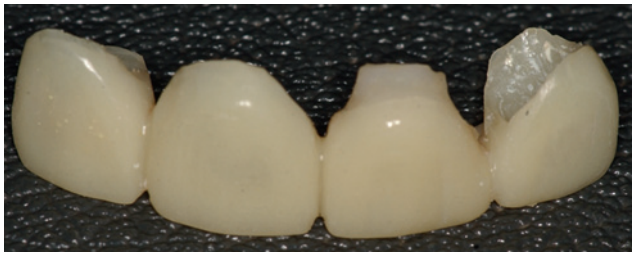


FIGURE 6-18 L, Provisional four-unit restoration is relined to cover the provisional abutment and then is recemented. The occlusion is lightened.

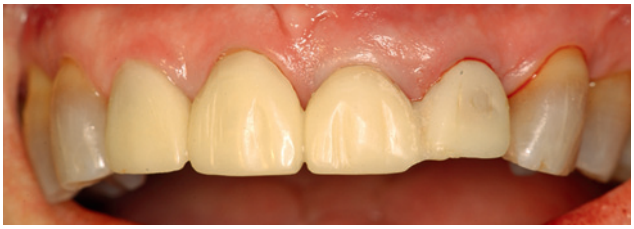


FIGURE 6-18 M, After 2 months, the patient is ready for the second implant. Note the tissue response to the orthodontic extrusion and implant placement.

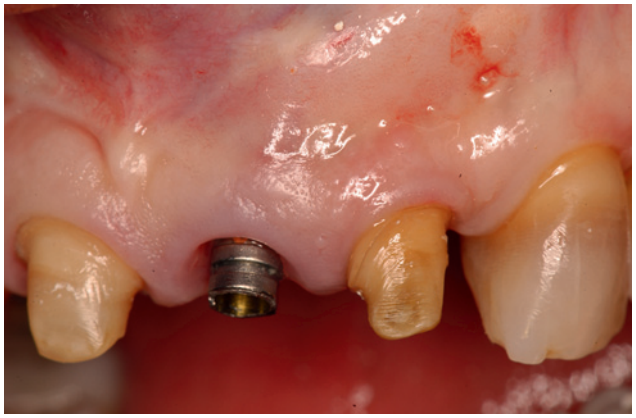


FIGURE 6-18 N, Provisional restoration is removed, and a local anesthetic is infiltrated. Note the healthy tissue response to the first implant.

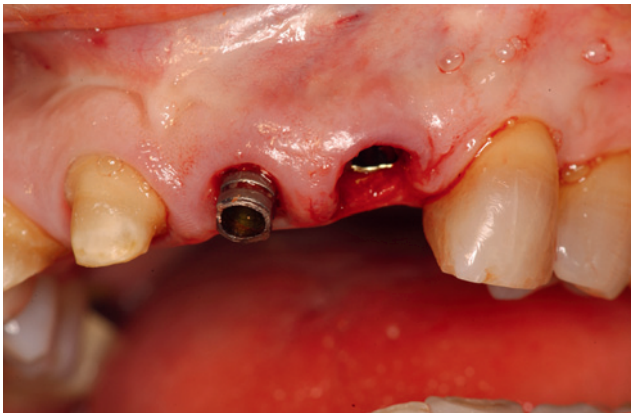


FIGURE 6-18 O, Lateral incisor is removed, and an implant is placed 3 mm apical to the gingival margin of the planned restoration.

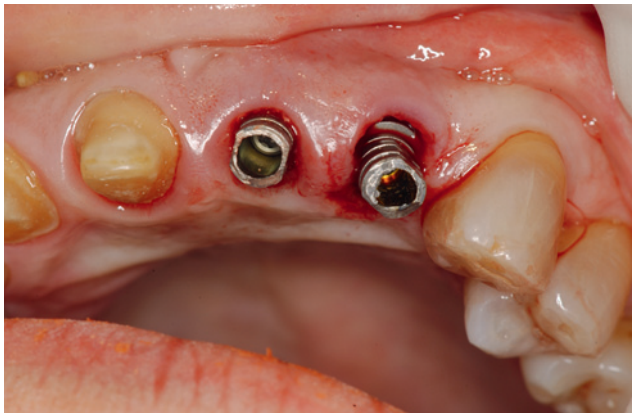


FIGURE 6-18 P, Provisional abutment is placed and modified for a second reline.

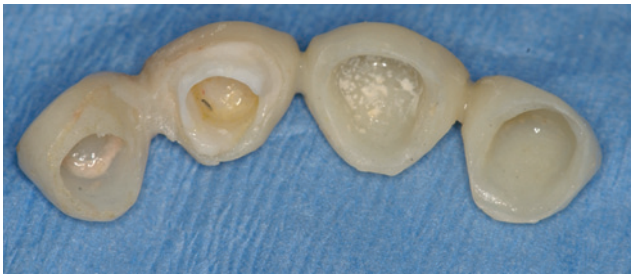


FIGURE 6-18 Q, Provisional four-unit restoration is relined over the second implant.

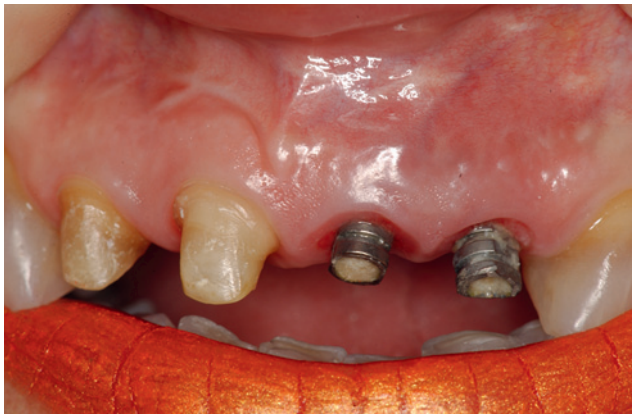


FIGURE 6-18 R, After 4 months, the provisional restoration is removed for fabrication of custom abutments and soft tissue sculpting.

FIGURE 6-18 S, Resin is applied to the provisional abutments to generate a sulcus that mimics the sulcus of a natural tooth.

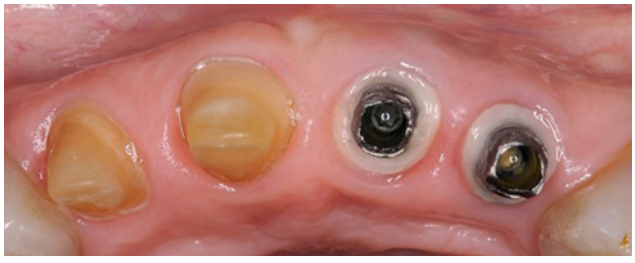


FIGURE 6-18 T, Customized provisional abutments are screwed to the implants, and the tissues begin to form a natural tooth morphology.

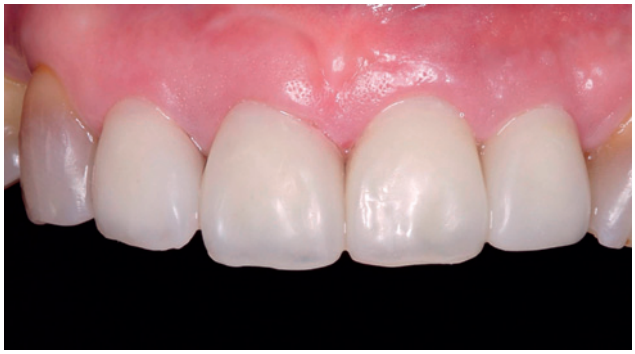


FIGURE 6-18 U, New temporary is made on the provisional abutments to further define and shape the soft tissue.

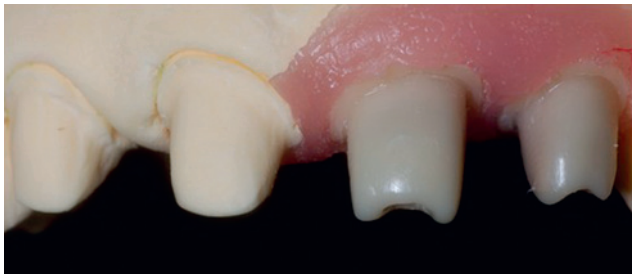


FIGURE 6-18 W, New abutments are waxed to ideal shape and proportions in the laboratory.

FIGURE 6-18 Y, Zirconium abutments are milled from scans of the waxed custom abutments.

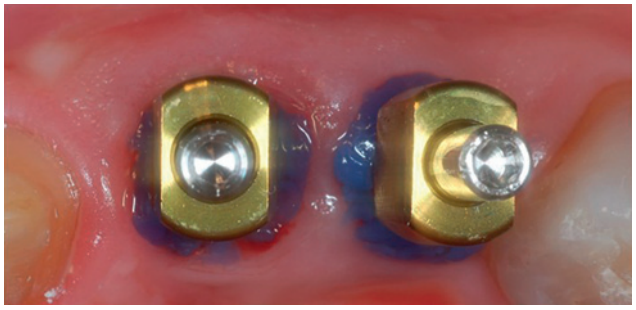


FIGURE 6-18 V, After the sulcular shape has matured, implant-level impressions are taken with light-cured resin to provide the technician with the anatomy of the subgingival sulcus.

FIGURE 6-18 X, Final abutments in wax, prior to scanning and computer-assisted design and manufacture (CAD CAM) milling of the final abutments.

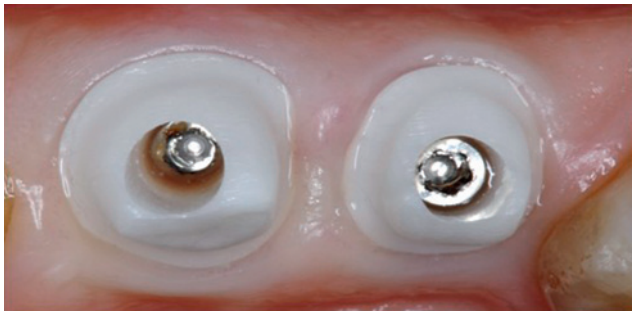


FIGURE 6-18 Z, Final abutments in place. Note the blanching of the tissue as lateral pressure is applied to promote papilla formation and idealization.

intentionally using orthodontics, the soft tissue usually moves with the extrusion, and when held in position, it matures and stabilizes in its new position. Depending on the angle of the alveolus and the vector of the extrusion, the labial bone may or may not be preserved. The soft tissue usually everts and appears thickened, preserving its new coronal location.

Establishing the Ideal Position of the Planned Restoration. To develop the best treatment plan, which the patient must approve, the restorative dentist must determine the ideal form for the final restoration. If a patient has teeth that are to be extracted, the dentist must obtain casts, develop a plan in wax, try in the plan, and confirm the position of the teeth in the patient's mouth. The dentist may develop a mock-up mask that fits over teeth or remove

FIGURE 6-18 **AA,** Final sulcular anatomy created by the custom abutments.

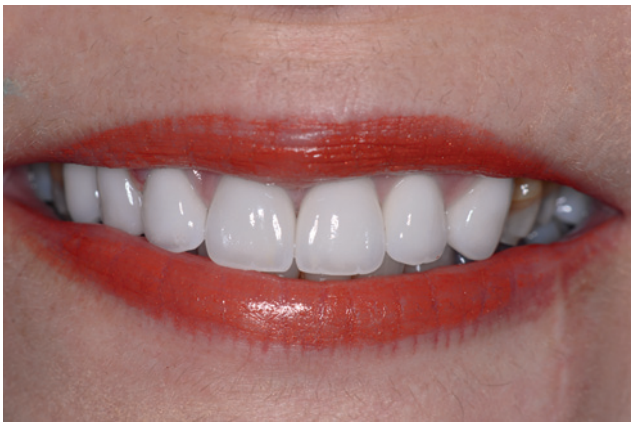


FIGURE 6-18 **CC,** Final restoration in place.

current restorations and make a temporary restoration that accomplishes the following:

1. Sets the vertical position of the incisor edge. Normal incisor exposure at rest is 2 to 4 mm, depending on the patient's age and lip form. The incisor edges of the anterior maxillary teeth usually follow the form of the lower lip.
2. Sets the length and width of the central incisor. Usually the central incisor is 10.5 to 11 mm long and 8 to 8.5 mm at its greatest width. The form of the incisor (e.g., square, oval, tapered) and the shape of cervical interdental region (concave or convex) contribute to the planned final restoration.
3. Sets the position of the facial gingival margin. The length of the central incisor can be used to generate a mask or mock-up that can then be used to determine the necessary procedures to mobilize the facial gingival margin in the coronal direction, resulting in the ideal esthetic restoration.

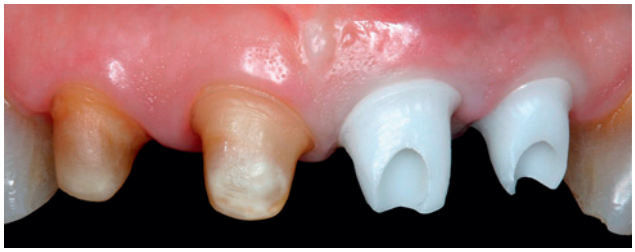


FIGURE 6-18 **BB,** Final abutments in place prior to final impressions.

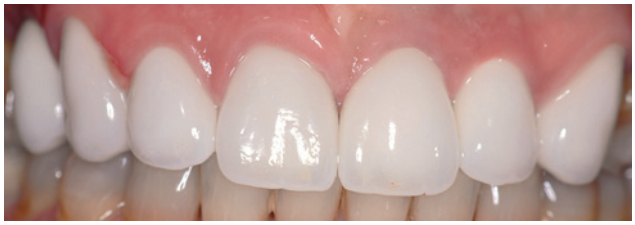


FIGURE 6-18 **DD,** Final restoration has re-established the esthetic appearance of the patient. (Prosthetics and orthodontics by Dr. Marco Brindis.)

Establishing the Ideal Position of the Facial Gingival Margin. The final restoration must ensure that the gingiva is stable over time. Stable gingival margins are associated with thick gingiva rather than thin gingiva, adequate bone on the labial surface of the implant, good bone levels on the adjacent teeth, a properly positioned implant 2 to 3 mm palatal to the labial emergence of the crown, and overcorrection of the gingival margin at the time of placement of the final restoration.

Thick gingiva reacts to vertical bone changes by forming pockets. Thin gingiva reacts to bone changes or resorption with recession. Therefore it is important to convert a thin gingiva to a thicker gingiva by placing a connective tissue graft to augment the soft tissue thickness on the facial aspect of the implant site.

Kan et al.[48] reported that after implants have been placed in sites with thin or lost labial bone, even in the face of grafting, the gingiva may recede over time. This author's experience is similar. Patients with thicker bone seem to have less gingival recession after final crown placement. Patients with thinner bone, in the face of thin gingiva, show recession of the gingiva. Recognition of thin bone should lead the surgical and restorative team to overcorrect the soft tissue profile, anticipating gingival recession. If the gingival margin is overcorrected, the expected recession likely will relocate the gingival margin to acceptable long-term levels.

If the adjacent teeth have bone loss in the interdental regions, then as the contact area exceeds 5 to 6 mm from the bone on the adjacent tooth, the papillae appear shortened. Peripheral support of the gingiva, including the papilla, can contribute to facial gingival margin discrepancy in isolated cases. It is important to identify this problem before treatment is started, either to correct it or to inform the patient of the potential for less-than-ideal final results.

Implant positioning has been discussed in different chapters in this book. For the single-tooth implant, the implant needs to be placed between the adjacent teeth, with equal distances from the implant's edge to the tooth surface. The labial surface of the implant platform should be palatal to the planned labial emergence of the crown. If the implant is placed close to the planned crown emergence, the subgingival form is limited, and a natural appearance of the final crown will be difficult to achieve. The implant angulation should result in its axis exiting slightly palatal to the planned incisor edge. If the implant is angled toward the labial, the gingiva may be pushed and respond by apical migration.

Our studies indicate that the facial gingival margin slowly moves apically up to 1 mm over the first 2 years after final crown placement. This may occur by natural collagen cross-linking and contracture of the connective tissue or by establishment of soft tissue attachments to the materials used, or it may represent final establishment of biologic width. Regardless of the mechanism, which has not been established by evidence-based trials, the clinician should anticipate a small amount of gingival settling over time.

Determining the Bone Levels on the Teeth to Be Removed. Before an implant can be placed, sufficient bone must be available for implant stability. In addition, the implant must be placed into bone that is in the correct position in relation to the planned restoration. If vertical bone loss is present, the implant can be placed mechanically; however, the vertical position makes it difficult to manage the overlying soft tissue because of apical loss of vertical dimension. The bone levels can be determined by periapical radiographs, CT imaging, or probing. The clinician may find it useful to superimpose the radiographs on the clinical photographs to visualize the bone-to-restoration relationship. The level of the bone also can be traced onto the diagnostic casts. If the bone level is apical to that needed to achieve the ideal restoration, correction is required; this may be done by onlay grafting, which can be very difficult to perform successfully; repositioning of the bone by osteotomy methods; or orthodontic extrusion.

Extruding the Teeth Using Orthodontics. Extrusion of teeth in the esthetic zone can result in dramatic changes in the eventual implant site. Even if the tooth to be extruded has minimal apical bone remaining (2 to 3 mm), slow tooth movement can result in soft tissue coronal movement, which can then be used to facilitate predictable hard tissue grafting and esthetic facial gingival margins.

The ideal facial gingival margin level has been determined by the esthetic workup. Orthodontic brackets are applied, and the appropriate mechanics are placed with memory-retaining wires to slowly move the tooth or teeth. Slow movement of the tooth (approximately 0.5 to 1.5 mm per month) can be continued over a relatively short period to overcorrect the facial gingival margin. It is recommended by our team that the soft tissue be overcorrected 2 mm, if possible. After the desired movement has been reached, the teeth need to be maintained in this position, with either retention of the orthodontics or a provisional restoration. Implants or grafting can be performed after the bone gaps have been filled with new bone formation, which may take a few months.

The extruded teeth require reduction of the incisive edge, possibly root canal therapy if not previously performed, and new bracket positioning as the tooth is moved.

Extracting an Extruded Tooth. If the tooth has been extruded in a vertical plane that is parallel to the labial bone, labial bone loss secondary to extrusion will be minimal. In this situation, labial bone likely will be present after removal of the tooth. If the soft tissue over the labial aspect is thick, an implant can be placed and provisionalized. If the gingiva is thin, placement of a connective tissue graft at the time of tooth removal is indicated.

If the extruded tooth has been moved in an axis protrusive to the labial alveolar bone, the labial bone will have been resorbed by orthodontic forces. In this situation, labial bone defects will be present. If labial bone defects are present at the time of tooth removal, reconstruction of the labial bone by grafting is necessary.

Placing an Implant with Immediate Provisionalization. In patients who require crowns on the teeth adjacent to the extruded tooth or teeth, the provisional multiunit restoration can be modified for immediate provisionalization. The temporary restoration is removed at the time of implant placement. The tooth is removed with sulcular incisions; vertical incisions are avoided. This maintains the vascular supply to the overlying labial bone. The implant is placed, and a temporary abutment is placed by the surgeon. The restorative dentist modifies the intaglio aspect of the provisional, and it is cemented with temporary cement. If desired, a screw-retained abutment can be picked up to allow for screw retention of the temporary prosthesis, although this requires more chairside manipulation of the implant site tissues. The surgeon and restorative dentist should avoid manipulation of the abutment and implant in the immediate postoperative period to allow successful initial healing without interruption of early tissue healing.

Prosthetic Management After Implant Integration. In these cases, the implants are allowed to integrate with the provisional restoration in place. When the provisional is removed, the restorative dentist must create a new provisional that will sculpt the soft tissue sulcus to mimic that with the teeth.

The temporary abutments are removed, and a new implant-level impression is taken. The temporary abutments then are replaced in the sites. In the laboratory, the stone model is modified to create ideal sulcal anatomy. New healing abutments are modified with resin in the subgingival region to push the tissue and form an anatomically correct sulcus. The provisional abutments are removed and replaced. The temporary bridge is adjusted as necessary to accommodate the new abutments.

After time has been allowed for maturation of the new sulcus, new impressions are taken and custom abutments are fabricated to mimic the form of prepared teeth and create an environment for ideal tooth-shaped crowns. New provisionals are made, and the interdental papillae are pushed to evert them and to complete the provisional to match the pretreatment plan. After the provisionals have been in position with stability of form, function, and hygiene, the final restoration is fabricated.

Thin gingiva with adequate bone for implant placement

These patients present with either an edentulous site or a site that has a tooth in need of extraction (Figure 6-19, A). The bone levels are adequate, but the gingiva is either at the correct level or slightly apical to the ideal position. Adequate bone is available for implant placement in the correct position (Figure 6-19, B). Soft tissue grafting is needed to convert thin gingiva to thick gingiva, and the gingiva must be advanced coronally to account for the expected recession after final restoration.

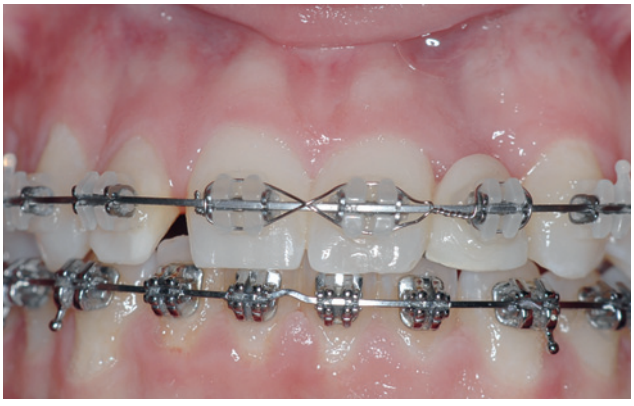


FIGURE 6-19 **A,** Preoperative view showing thin, horizontally deficient gingiva over the left lateral incisor.

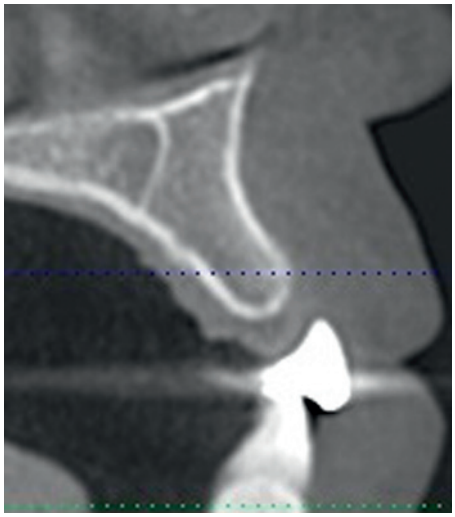


FIGURE 6-19 **B,** Cross section from a cone beam scan shows adequate bone for implant placement, although augmentation is required for horizontal projection. Because of the thin gingiva, a soft tissue graft is chosen rather than a particulate hard tissue graft, which might show through the thin gingiva.

Problem List:
High smile line with gingiva showing on smile
Thin gingiva over left lateral incisor edentulous site
Facial margin level with adjacent tooth
Adequate bone over left lateral incisor location

Goals of Treatment:
Convert thin gingiva to thick gingiva to limit gingival recession
Fabrication of an implant-retained crown with correct proportions and function, with maintenance of gingival form over time

Treatment Sequence:
Use of the orthodontic provisional during the surgical phases of treatment
Crestal incision with implant placement combined with simultaneous placement of subepithelial connective tissue graft to convert thin gingiva to thick gingiva (Figure 6-19, C-D)
After 4 months, fabrication of a provisional restoration and fine-tuning of tooth position with postimplant provisional orthodontics, followed by final restoration after completion of orthodontics (Figure 6-19, E)

Treatment Plan. The final restoration must be established on a diagnostic cast, and a guide stent must be made to identify the planned incisor edge and the planned ideal gingival margin position. The case example is a patient with a missing lateral incisor. The patient is a 17-year-old

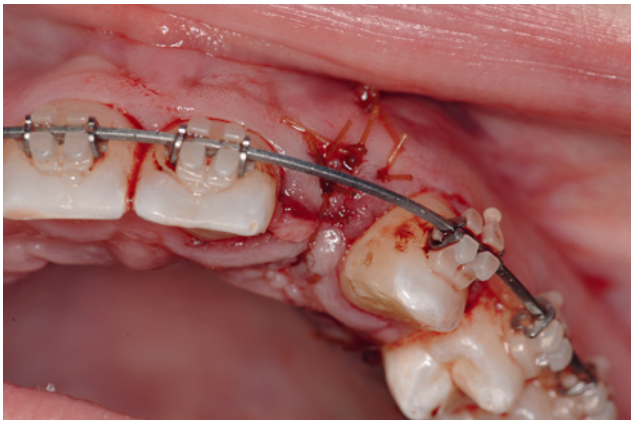


FIGURE 6-19 **C,** Crestal incision is made combined with sulcular incisions. A flap is raised without the use of vertical incisions. The implant is placed. The periosteum is incised to allow advancement. A subepithelial connective tissue graft is harvested from the left palate and placed over the labial bone. A healing abutment is placed. The incision is closed tension free. The orthodontic pontic then is replaced.

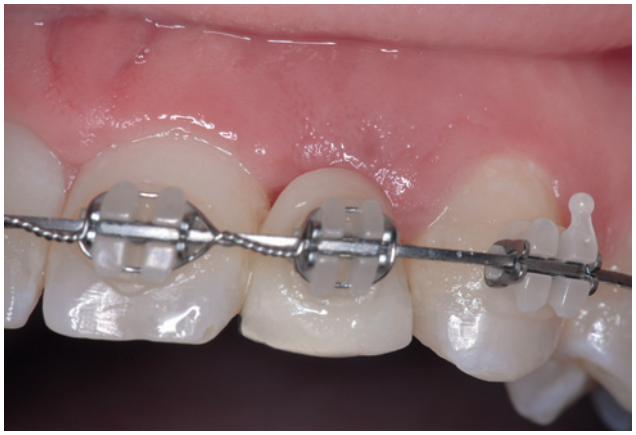


FIGURE 6-19 **D,** Note the change in gingival appearance approximately 8 weeks after placement of the implant and the connective tissue graft surgery.

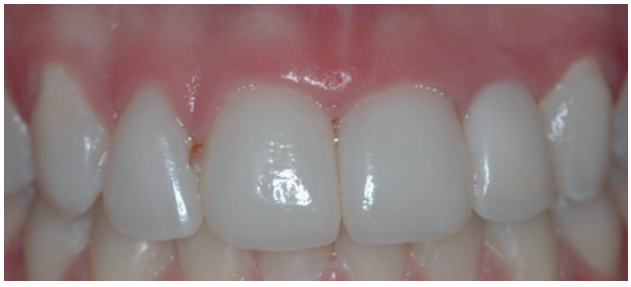


FIGURE 6-19 **E,** Final restoration. Note excellent soft tissue appearance on left lateral incisor. (Prosthetics by Dr. Paulino Castellon.)

young woman with a high smile line and high esthetic concerns. She has adequate bone for correct implant positioning. She has thin gingiva with the potential for gingival recession after final restoration because of flat crestal bone rather than convex crestal bone. The treatment plan is to place the implant, place a subepithelial connective tissue graft, and advance the gingiva over a 3-mm-tall healing abutment to enhance the vertical position of the crestal gingiva. Preoperative orthodontics has been used to create ideal space for the left lateral incisor, with 6 mm of crestal space between the CEJ of the central incisor and the canine teeth. The implant chosen has a platform 3.25 mm in diameter and is 13 mm long. Preoperative radiographs confirm that adequate bone is available for the implant.

After infiltration of a local anesthetic to the left lateral incisor site and the adjacent two teeth on each side of the planned implant site, additional anesthetic is gently administered to the left palate for the connective tissue graft. In general, this author prefers to take the subepithelial connective tissue graft on the same side as the implant to minimize patient morbidity.

A crestal incision is combined with incisions around the adjacent teeth and the adjacent papillae. A small periosteal elevator is used to meticulously raise the gingiva full thickness to expose the labial and palatal aspects of the ridge. It usually is necessary to raise the papillae between the central incisors and between the canine and first premolar to allow gingival elevation without tearing of the thin, fragile facial gingiva on the adjacent teeth. The implant then is placed, with care taken to position it in the ideal location; that is, in the middle of the crest between the teeth, emerging palatal to the planned incisor edge, and with the labial surface of the implant's platform 2 mm palatal to the planned emergence of the final crown.

After the implant has been placed, a 3-mm straight emergence healing abutment is placed into the implant. This author does not use a flared abutment in this specific circumstance to allow for easier primary tension-free closure after the connective tissue graft has been placed and the gingiva has been advanced over the healing abutment.

The periosteum is released at the base of the envelope flap. This release is performed with either small scissors or a scalpel, with care taken to avoid perforation of the labial gingiva. It is important to have passive closure and excellent hemostasis. After the periosteum has been released, a small piece of gauze may be placed for pressure to prevent hematoma formation during the postoperative healing period. A piece of foil from the suture package is used to create a template for the soft tissue graft. This

template is placed on the palatal tissue to mark the harvest site.

A subepithelial tissue graft is then harvested. It should be at least 1.5 mm thick and smooth. A piece of collagen sponge can be placed into the pocket of the donor site for hemostasis, and the harvest site is closed with 4-0 chromic suture. A 4-0 chromic suture on an SH tapered needle is introduced from the vestibule into the pocket, emerging adjacent to the implant. A suture is placed in the apical end of the graft and then reintroduced into the subperiosteal pocket, emerging in the loose, unattached gingiva in the vestibule. The suture is pulled to place the graft in its planned position over the labial portion of the implant, approximately at the coronal level of the healing abutment. Interrupted sutures then are placed to close the incision. If necessary, the graft can be sutured, but it usually is not mobile and fits passively in the site. After the incisions have been closed, the temporary tooth is generously relieved to prevent pressure immediately after the surgery and in anticipation of swelling. Pressure is kept off the soft tissue for the entire 4-month healing period.

In a patient with thick tissue but a gingiva prone to be too apical in location, the healing abutment can be placed and the gingiva advanced passively without the need for a connective tissue graft. This situation can occur in an adult who has long-standing bone loss from periodontal disease with gingival recession. Some patients do not want orthodontic extrusion and have other teeth compromised esthetically, with a relatively low smile line; therefore, a more practical, less expensive approach can work for these patients.

Treatment of the trauma patient: avulsion of anterior teeth

Clinical Situation. The patient comes to the dentist within hours to a week after traumatic avulsion of anterior maxillary teeth (Box 6-2). The patient may have lip swelling and facial bruising and may want restoration of the lost teeth in a timely manner. The patient also may want to avoid having to use removable prostheses, as well as crown preparation of the adjacent teeth. These patients want the lost teeth replaced as they were prior to the accident. Typically, the implants are placed within 1 or 2 weeks after the trauma if the bone and soft tissues are in appropriate health.

Evaluation. Physical examination should include evaluation of the patient for complicating injuries involving the facial skeleton, including the cranial, orbital, midfacial, and mandibular regions. If other fractures are present, the surgeon may decide to delay implant placement until the other facial injuries have healed. In the patient whose primary injury is loss of teeth, the status of the bone and soft tissues adjacent to the avulsion site determine the treatment plan. A patient with a thin gingiva biotype may have excessive gingival recession after implant placement; therefore, in these cases, implant placement should be delayed until the thin gingiva can be converted to thick gingiva. Typically 2 to 3 months are allowed for healing from the trauma, after which placement of implants with simultaneous connective tissue grafting is performed to minimize gingival recession.

BOX 6-2 Indications for Implant Placement within 1 to 2 Weeks after Tooth Avulsion

1. Labial and palatal bone is intact. Fractured bone must be allowed to heal prior to implant placement because bone remodeling may be significant.
2. Apical bone is available for initial implant stability.
3. Gingiva at the implant site is healthy and without tears, ecchymosis, or obvious vascular compromise.
4. Surrounding soft tissues of the lips and palate are not compromised, ensuring adequate peripheral blood supply to the bone and soft tissues at the proposed implant site.
5. Temporary prosthesis is available that will not put pressure on the soft tissues. Use of an Essix-type provisional or carefully designed removable appliance is adequate, but it may need to be fabricated after the swelling from the trauma has resolved.

The most significant advantage of placement of the implant soon after tooth avulsion is more rapid reconstruction and potential preservation of the ridge form. However, as the level of the trauma increases, the reaction of the hard and soft tissue with regard to shrinkage and resorption also increases. The clinician must assess each patient on a case-by-case basis.

In trauma cases, the surgeon should make sure proper radiographs are used to confirm the presence or absence of root tips in the extraction sites and intact labial bone without evidence of fracture or displacement. Small flaps may be necessary to remove root tips or other debris, but the surgeon should avoid periosteal stripping of the bone to preserve the fragile blood supply to thin labial bone. This author may use flapless or palatal flap approaches to preserve all the blood supply to the labial bone.

Case Example. This 75-year-old man fell while taking a walk. He suffered significant facial edema and fractures of

his right and left central incisors and the left lateral incisor (Figure 6-20, A-H). His dentist referred him for implant placement. Radiographs showed excellent bone presence without fractures or displacement. His gingiva was thick and healthy. The facial gingival margin was at an appropriate level. He also had a low smile line with no gingival show at smile.

After consultation with his dentist, the treatment plan was designed to include placement of three implants to restore the three teeth with single-tooth implant restorations.

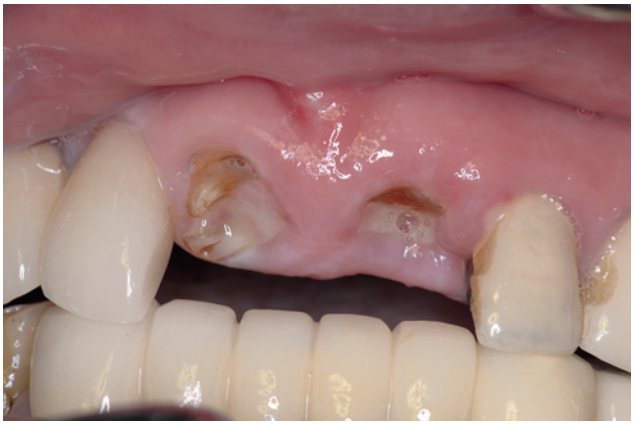


FIGURE 6-20 A, Initial presentation, approximately 3 days after this patient had fallen, fracturing the right and left central incisors and left lateral incisor. Note that the soft tissues have a relatively normal form and color.

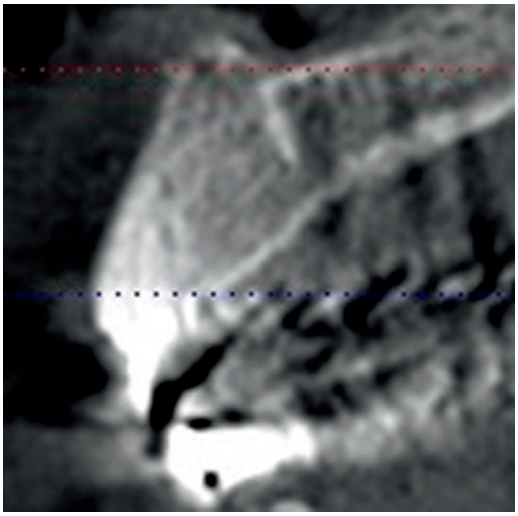


FIGURE 6-20 B, Cross-sectional image from a cone beam scan shows the retained root with excellent palatal bone available for implant placement. No obvious fractures of the alveolar bone have been seen in any of the cross-sectional images.

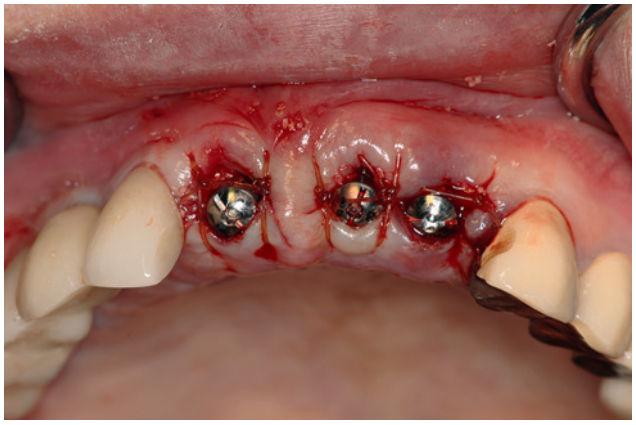


FIGURE 6-20 C, Immediate postsurgical view. The root tips have been removed with minimal flap reflection. The implants have been placed to engage the palatal slope of each extraction socket. The radiofrequency indices are in the mid-70s for each implant. Short healing abutments have been placed to preserve soft tissue form and prevent collapse. Mineralized bone has been placed in the gaps between the implant and intact labial bone.

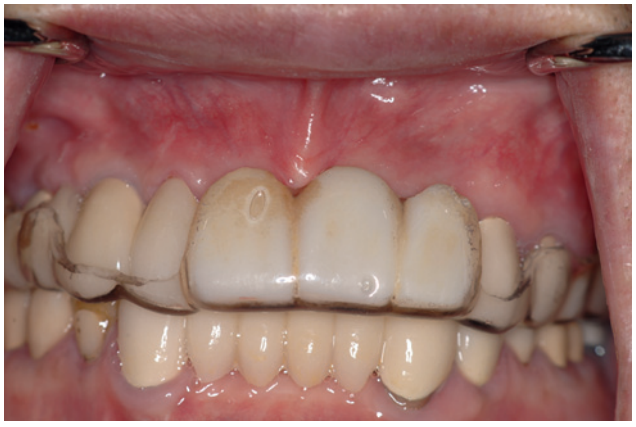


FIGURE 6-20 D, Provisional appliance is fabricated to fit over the teeth with no contact with the healing abutments.

A small incision was made to allow removal of the root of the lateral incisor, which had been impacted into the alveolar bone. The roots were removed with the aid of a piezotome to preserve labial bone. Three implants were placed, with care taken to orient the implants vertically by starting the implant entry site along the palatal slope of the extraction socket. The implants were placed with excellent primary stability, as demonstrated by implant stability quotient (ISQ) values between 75 and 79. The gap between the implants and the intact labial bone was grafted with

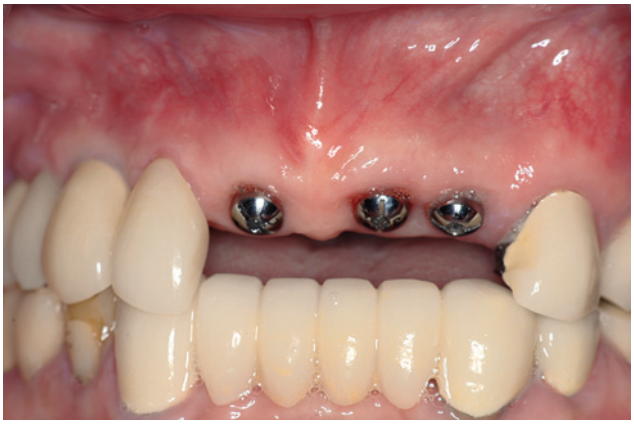


FIGURE 6-20 **E,** After 4 months for implant integration, the healing abutments appear to be surrounded by healthy gingiva. The healing abutments are removed, and the implant stability quotient (ISQ) values are 78 for each implant, indicating excellent bone-implant integration.

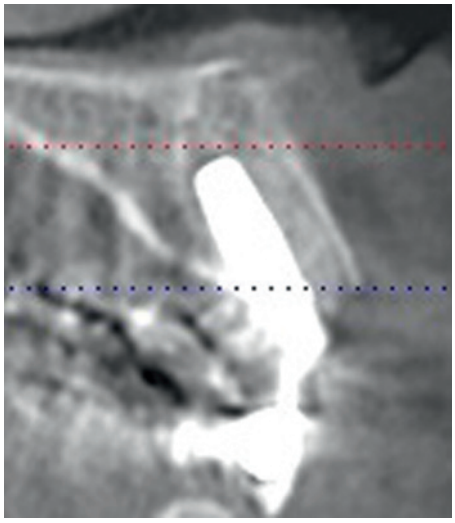


FIGURE 6-20 **F,** Cross-sectional image after implant placement shows the implants' position and graft placement maintaining the horizontal ridge projection.

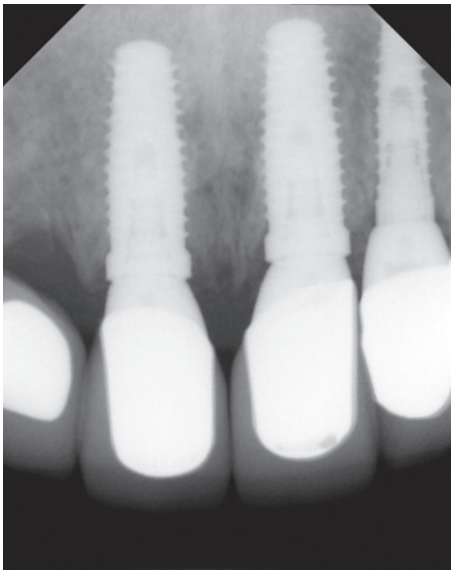


FIGURE 6-20 **G,** Periapical radiographs taken after final restoration show bone maintenance between the implants and within 0.5 mm of the implant platform. These implants (Prevail, Biomet 3i) use medialization of the implant-abutment interface to minimize crestal bone resorption.

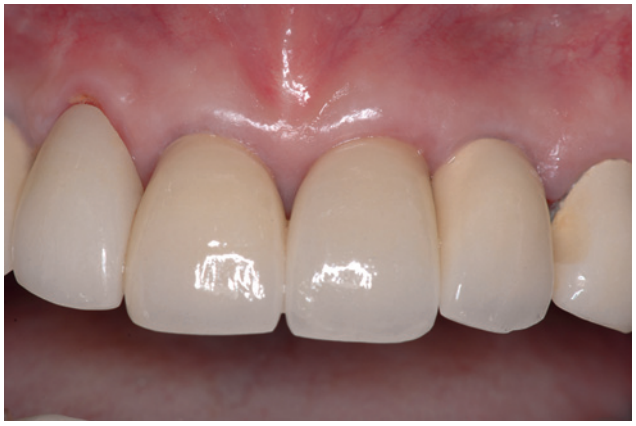


FIGURE 6-20 **H,** Final restoration, showing excellent soft tissue response to the treatment regimen. (Prosthetics by Dr. Kevin Schellhaus.)

allograft-mineralized cortical bone particles 350 to 500 μm in diameter. A small periosteal elevator was used to compact the bone firmly into the depths of the gap. Healing abutments were placed to help preserve the sulcular dimensions. The healing abutments were 3 mm tall to match the facial gingival margin levels. Straight emergence healing abutments were used to minimize stretching of the soft tissues, with less vascular blanching. A tooth-borne (rather than tissue-borne) removable prosthesis was placed so as not to exert pressure on the healing abutments. Four months later, after the implants had integrated, a final prosthesis was fabricated.

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Chapter 7

Immediate Provisionalization of Implant Restorations

Chapter Outline

Patients who receive implants may be candidates for immediate provisionalization at the time of implant placement. Patients want replacement of their missing teeth or tooth as efficiently as possible. Immediate provisionalization of an implant with a toothlike restoration, even though out of occlusion, is well accepted by patients. Patients do not like removable temporary restorations. Patient-driven implant care demands that clinicians consider immediate provisionalization as often as possible.

Methods for Immediate Provisionalization of Single-Tooth Implant Restorations

The provisional prosthesis provides a reliable method for developing the soft tissue site of single-tooth restorations and facilitates efficient fabrication of the final restoration. The restorative dentist can fabricate the provisional restoration at chairside, before implant placement, or in

the laboratory. Methods discussed here include the following:

- *Preoperative laboratory preparation of abutment and provisional crown.* This technique minimizes chairside time for the restorative dentist. From simple impressions, an implant analog is placed into the model, an abutment is prepared, and a provisional crown is made in the laboratory. At the time of implant placement, the abutment and the provisional crown are placed. Contacts and occlusion may need to be adjusted at chairside (see Figure 7-1 and DVD Figure 7-1).
- *Chairside abutment preparation and fabrication of a provisional crown.* This technique requires the abutment or supragingival portion of a one-piece implant to be minimally prepared at implant placement. This requires the surgeon to perform the adjustment, which can be refined by the restorative dentist. The provisional crown is fabricated by relining a hollow shell. The patient will need to see the implant team and have closely coordinated appointments (see Figure 7-2).
- *Transfer impression ("indexing") of implant or abutment for laboratory fabrication of provisional prosthesis, with placement in patient's mouth within hours or days.* At implant placement, the final abutment can be placed. These abutments are designed to eliminate the need for preparation; they use snap-on transfers, thus eliminating many of the transfer parts and copings. The impression can be given to the restorative dentist or laboratory for fabrication of the provisional crown, which is placed as soon as it is completed by the laboratory (see Figure 7-3 and DVD Figure 7-2).

General Considerations

Careful patient and site selection result in successful implant integration and decreased failure. Literature review indicates that single-tooth restorations with a delayed approach, which allows integration of the implant before the final restoration is placed, have a success rate of 94% to 100%, depending on specific implant protocols and the nature of the implant site.[1-4]

Criteria associated with success using immediate provisionalization include the following:

1. Sufficient bone height, width, and density for stability of the implant at placement. The choice of implant length and width involves considerations similar to those used for implants in a two-stage method. An implant insertion torque of 20 N-Cm or a radiofrequency index greater than 60 are the deciding factors that indicate that implant stability is sufficient for immediate provisionalization.
2. Sufficient mesial-distal, buccal-lingual, and interocclusal space for placement of an anatomic restoration. If the opposing occlusion interferes with the provisional restoration, a two-stage technique is used rather than the immediate provisionalization method.
3. Sufficient vertical dimension stability with occlusal stops to prevent occlusal loading of the provisional restoration.
4. The patient should agree to limit chewing to only the softest of foods, preferably liquids, for up to 8 weeks. Patients with excessive parafunctional habits are not provisionally reconstructed.

Preoperative Laboratory Preparation of Abutment and Provisional Crown

After the patient has been confirmed as a candidate for immediate provisionalization, a preoperative phase precedes implant placement. Mandibular and maxillary impressions are made, and a periapical radiograph is obtained at the implant site. The preoperative laboratory phase is completed, and the patient is scheduled for surgery. At the time of implant placement surgery, the surgeon should have the abutment, retaining screw, provisional crown, and models with the analog in place (Figure 7-1, A-P; and DVD Figure 7-1, A-L).

DVD Images 7-1, A-L

Laboratory technique

The technique is similar for any single-tooth restoration, incisor or molar. The preoperative evaluation of esthetics should follow the same details as for a two-stage procedure. The following technique can be used for immediate extraction sites as well as sites that are edentulous:

1. Impressions are made of the maxilla and mandible, and stone casts are poured.
2. For a site planned for tooth extraction, the tooth is removed from the cast after a model has been poured. The need for a waxup is determined by the need for esthetic

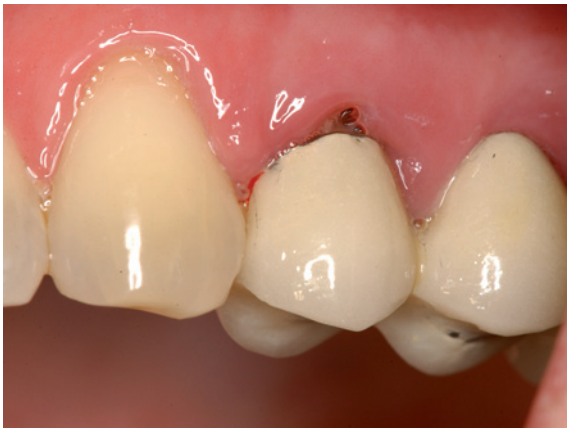


FIGURE 7-1 **A,** This first premolar requires extraction because of root fracture.

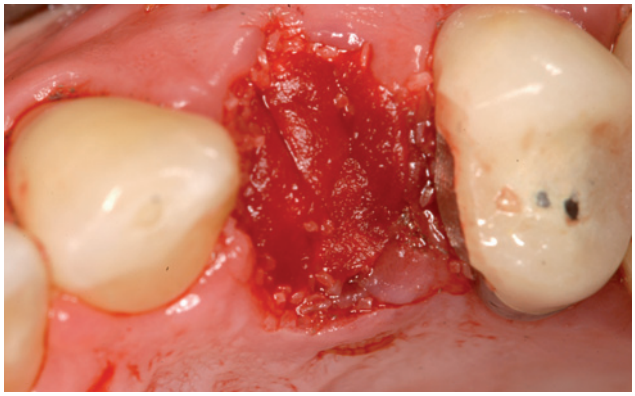


FIGURE 7-1 B, Tooth has been removed and the extraction site grafted with human mineralized bone. A collagen resorbable membrane (CollaPlug, Zimmer Dental, Carlsbad, California) is used to hold the graft in position.

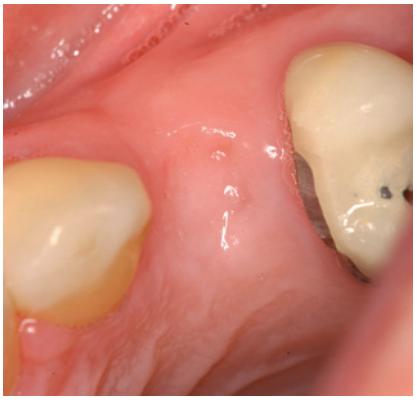


FIGURE 7-1 C, Four months after the tooth extraction, the ridge has excellent width. A flapless or minimal flap procedure can be performed at the time of implant placement.

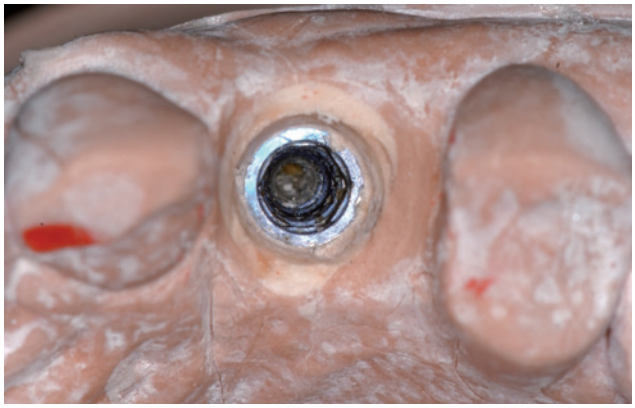


FIGURE 7-1 D, Models are made, and an implant analog is positioned with the labial surface of the implant approximately 2 mm palatal to a line drawn from the labial surface of the adjacent teeth. The internal flat surface of the hex is placed directly labial.

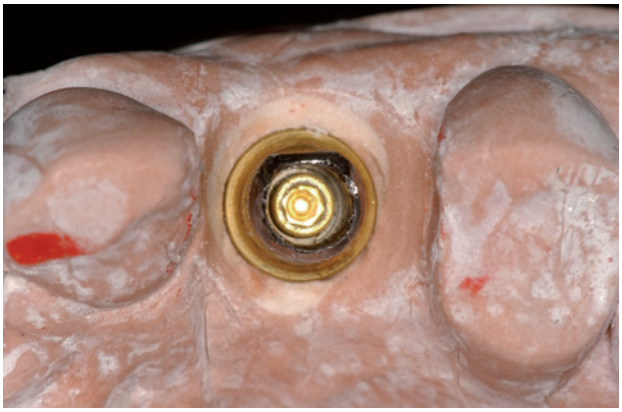


FIGURE 7-1 E, Abutment chosen has a gingival collar height of approximately 2 to 3 mm. The abutment is prepared vertically with minimal change in the wall parallelism to ensure retention of the provisional crown.

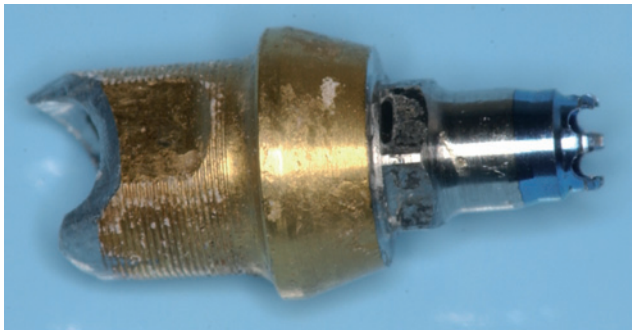


FIGURE 7-1 F, Modified fixed abutment. Note that the flat surface has not been removed so as to improve provisional crown retention. The parallel walls also provide excellent retention of the provisional crown.

FIGURE 7-1 G, Provisional crown on the abutment. Note how the margins are finished to promote gingival health.

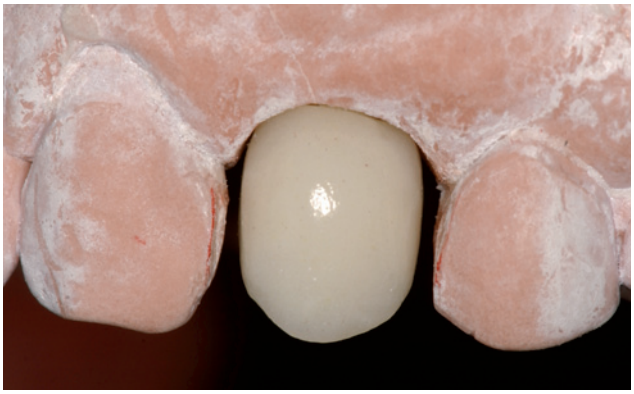


FIGURE 7-1 **H,** Provisional crown on the model. Note 0.5-mm gap between the mesial and distal contact points to allow surgical flexibility and passive seating of the crown. The gingival margin has been prepared to match the gingival margin of the tooth before extraction.

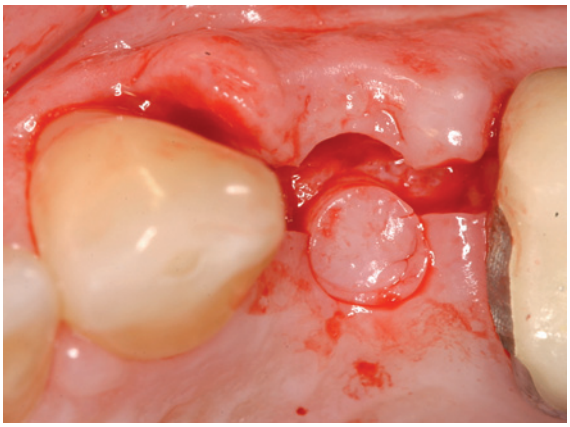


FIGURE 7-1 **J,** After the tissue punch has been used, a small incision is made across the crest and around the adjacent teeth within the gingival sulcus with a small, 15c scalpel blade. Elevation of the periosteum is limited to the superior aspect of the crest. Depending on the contour of the ridge, more elevation can be performed to confirm placement of the implant within bone. Vertical incisions are not recommended.

implant positioning. For many situations, a surgical guide stent is not necessary. The position of the implant to be placed is marked, and a pilot hole is drilled in the stone cast. The stone coronal to the analog is shaped to allow an emergence profile for the provisional restoration.

3. The proposed vertical position of the implant analog is marked on the cast, anticipating approximately 3 mm of gingival thickness. A periapical radiograph can be used to approximate the position of the bone on the crest. The vertical position of the analog in the model should result in an ideal implant position.

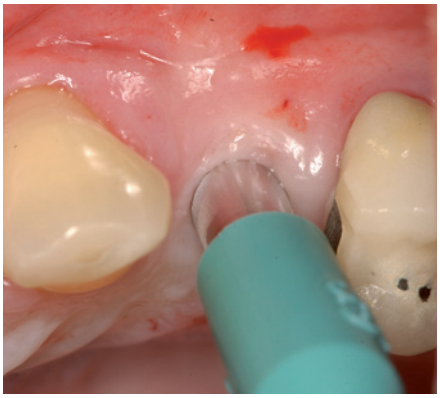


FIGURE 7-1 **I,** After administration of a local anesthetic, a tissue punch is used in the exact location where the crown will emerge.

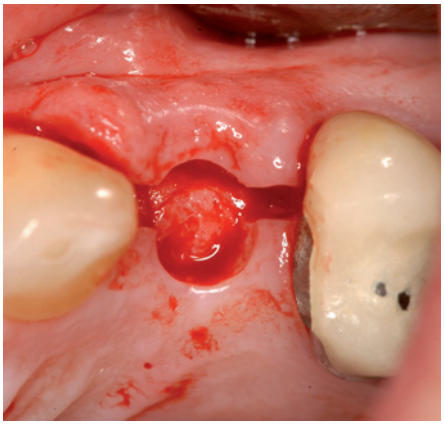
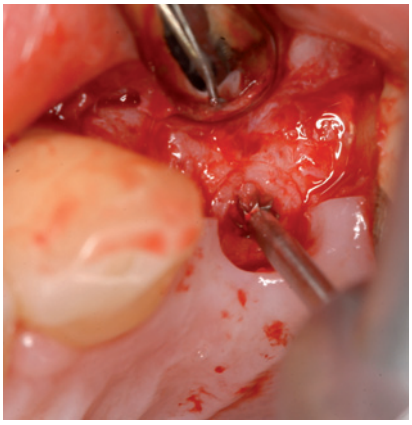
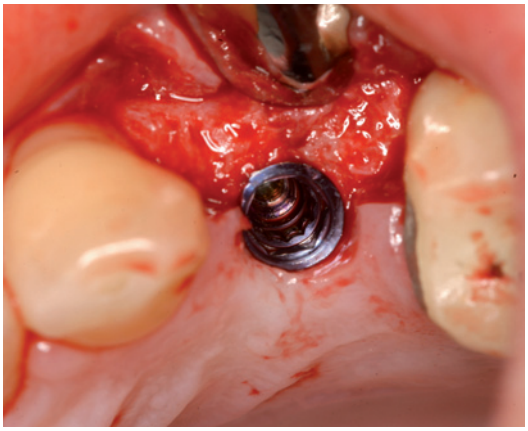


FIGURE 7-1 **K,** Circle of tissue created with the tissue punch is removed. The ridge is further examined before implant placement.

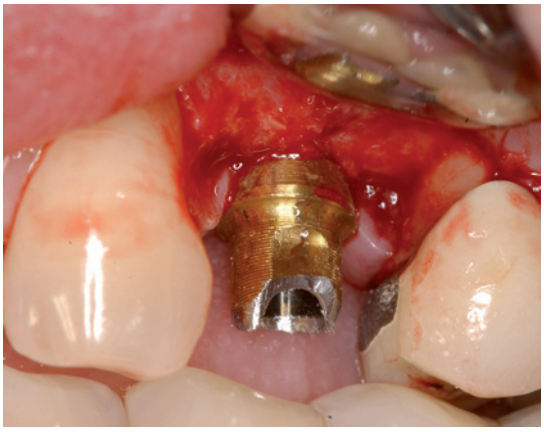
4. A hole is drilled in the model for placement of the analog. The hole must be large enough for passive placement of the analog. The analog is tried in place to confirm proper alignment. Its vertical position should place the top of the implant at the anticipated level of the bone, or 3 mm from the planned gingival margin. The analog is secured in the hole with cyanoacrylate glue, stone, or plaster. The analog should be consistently positioned with an internal or external retentive feature, such as the flat surface of a hex, facing labially. When the implant team maintains consistent orientation of the analog, the result is less variability of implant orientation, better positioning of the prepared abutment and temporary crown, and better communication among members of the implant team.
5. A "prepable" abutment is placed in the analog and prepared in the laboratory to allow placement of a



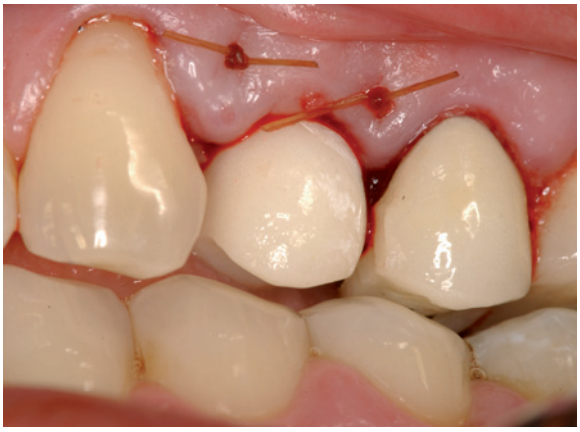
● **FIGURE 7-1 L,** Round bur is used to create the entry hole for the first drill. The round bur sets the position of the implant between the teeth, in the middle of the crest, and in the appropriate buccal-palatal direction.



● **FIGURE 7-1 M,** Implant is properly positioned according to the prescription from the model. Note that the internal flat surface of the hex is directly labial. Also note the excellent bone contour over the area.



● **FIGURE 7-1 N,** Abutment previously prepared in the laboratory is passively seated and secured with a screw. After cotton has been placed, the provisional crown is tried-in.



● **FIGURE 7-1 O,** Provisional crown is placed in position, and after occlusal clearance has been confirmed, it is cemented in position with temporary cement. Vertical mattress sutures are used to place the gingival margin back in the correct position.

provisional crown. Many dentists or laboratory technicians prepare the abutment in a manner similar to a tooth preparation. However, many fixed abutments have flat surfaces and small retentive grooves incorporated into their structure. The preparation of the abutment, therefore, should take into consideration the vertical clearance and modification of the labial or lingual surfaces while retaining much of the retentive aspects of the abutment. An abutment preparation that looks like a tooth prep is not recommended.

6. The abutment margins should be at the level of the gingiva to avoid deep subgingival margins and to allow ease of cleaning after the implant and provisional crown have been placed. Some feature should identify the labial surface of the prepared abutment, such as the flat surface of the abutment or a dot or groove placed into the abutment's surface. This allows accurate orientation of the abutment at surgery. The prepared fixed abutment should be left with a rough surface to allow retention of the abutment to the provisional crown with temporary cement. The abutment preparation may result in a shorter abutment than the final abutment so as to allow 1 to 2 mm of interocclusal space between the provisional crown and the opposing restoration. These crowns are provisional and are not placed in occlusion. Typically, 3 mm of interocclusal space is required.

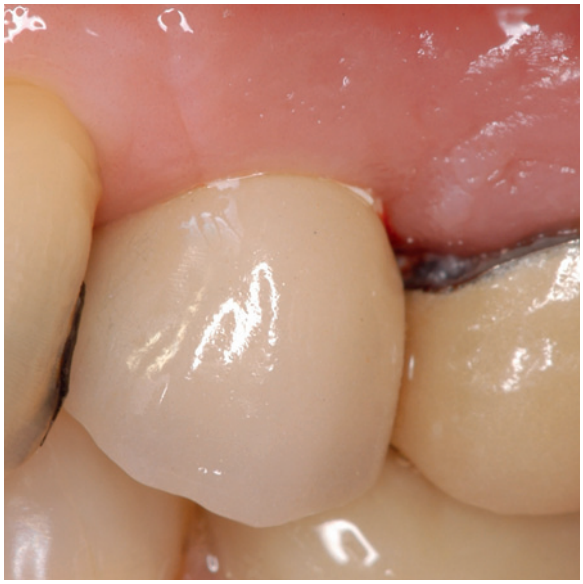


FIGURE 7-1 **P,** Final restoration at 2-year follow-up.

7. After the abutment has been prepared, either a hollow denture tooth or a hollow-shell crown is relined over the abutment using the opposing model. The provisional crown is adjusted to prevent occlusion. It is useful to leave 0.5 mm of space at the mesial and distal marginal ridges to allow surgical flexibility at the time of the placement and to prevent micromotion on the implant caused by movement of the adjacent teeth. The provisional crown margins are smoothed and polished to optimize the soft tissue response.
8. A hole can be made in the occlusal aspect of the provisional crown to allow access to the retaining screw that secures the abutment to the implant and to allow excess cement to vent. In addition, this gives the restorative dentist the option of taking an impression of the provisional crown to avoid the use of transfer copings. The abutment retaining screw is removed, and the abutment and provisional crown are removed as one piece. The abutment and crown are placed as one unit onto an analog of the appropriate implant system. This is then placed in the impression, which is poured in stone. The transfer of the implant and the subgingival sulcus is very accurate and eliminates the need for a transfer coping and placement of resin into the gingival sulcus.

Surgical procedure

At the time of implant placement, the surgeon will have the prepared provisional abutment, the provisional crown, and the screw to retain the abutment into the implant. It is useful for the surgeon also to have the model of the analog in place to help guide implant placement and orientation.

Incisions. The incision design takes into consideration the need for keratinized gingiva (KG) on the surfaces of the implant restoration. Single-tooth sites in the maxilla often have an adequate amount of attached KG to allow the use of a tissue punch or a flapless or minimal flap protocol. If teeth are present, sulcular incisions are made only around the tooth. Vertical incisions in the esthetic zone are avoided. Mandibular sites typically require transposition of the attached, thin band of KG; therefore, a crestal incision is used.

Extraction and Immediate Provisionalization of a Central Incisor. Extraction and immediate provisionalization of a central incisor are performed when the patient has a central incisor or other esthetic maxillary tooth that requires removal. The patient also must have intact labial bone, no active drainage, and an occlusion that will allow the provisional crown to be made out of occlusion. If the occlusion is tight or deep anteriorly, the provisional crown must be shortened, which results in poor, unacceptable esthetics.

This patient (Figure 7-2, A-M) has an excellent prognosis for success, because she has intact, thick labial bone; relatively thick gingivae; square teeth, so that the contact is close to the bone crest; and an occlusion that allows 1 mm shortening of the provisional without esthetic compromise. The expected success rate is similar to that for placing implants into edentulous bone.

Incisions are limited to around the tooth with no vertical incisions and no periosteal reflection. The tooth is separated from the bone using periotome instruments or a piezotome with a periotome tip. After the tooth has been removed, the implant site is prepared. The procedure starts with the round bur on the palatal slope of the extraction site; the site then is developed using the normal sequence of drills. The implant site can be tapped to form threads in dense bone if necessary. The implant is placed with careful

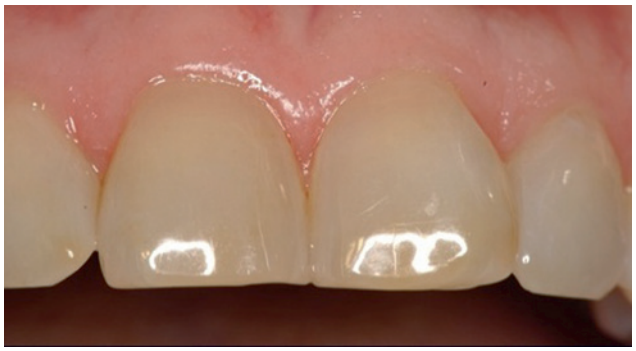


FIGURE 7-2 **A,** Preoperative view. Note the square tooth and thick gingiva, indicating an excellent candidate for immediate provisionalization after tooth removal, because the expected gingival recession should be minimal.

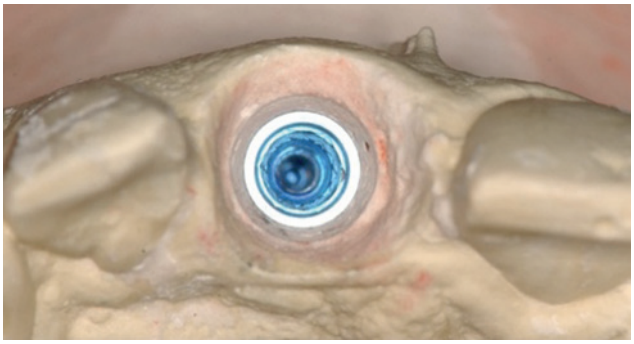


FIGURE 7-2 B, Models are taken, and the implant analog is placed. The analog's labial platform edge is 2 to 3 mm palatal to the planned crown emergence. The platform is countersunk 3 mm apical to the planned gingival margin.

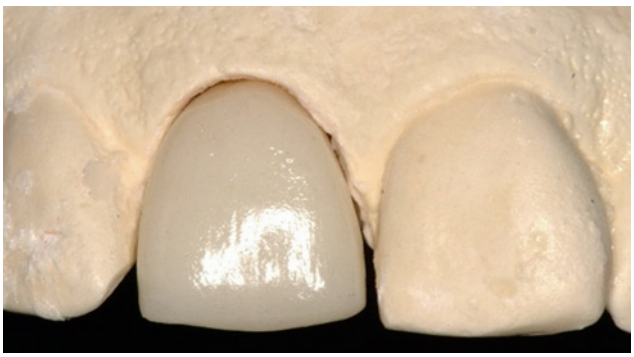


FIGURE 7-2 D, Provisional crown is fabricated in the laboratory. Note that it is 1 mm shorter than the adjacent tooth to keep it out of occlusion. Also note the very light contacts to facilitate placement and to avoid small movements from the adjacent teeth.

FIGURE 7-2 F, Provisional crown on the abutment. Note the polished margins, which promote gingival health.

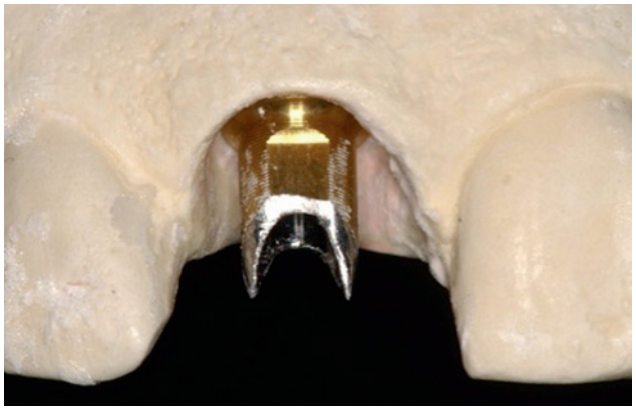


FIGURE 7-2 C, Metal abutment is placed and modified as necessary to allow fabrication of the provisional crown. Care is taken to leave the surface rough for cement retention and to leave straight surfaces for crown retention.

FIGURE 7-2 E, Provisional abutment has been prepared lightly and will be placed at the time of implant placement.

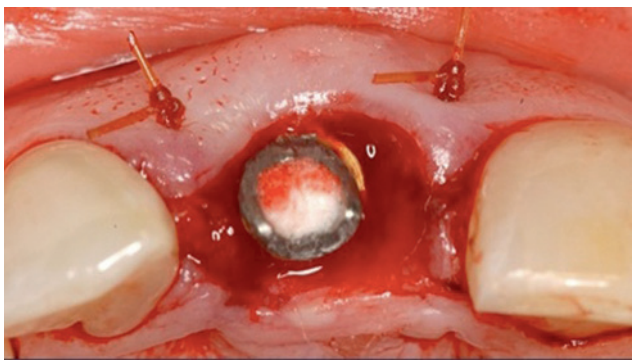


FIGURE 7-2 G, At the time of surgery, incisions are made around the sulcus of the tooth. The periosteum is not reflected. The tooth is removed with the aid of a periotome or piezotome. The round bur is used to initiate the osteotomy on the palatal slope of the extraction socket. The drills are used according to the manufacturer's instructions, with care taken to maintain emergence slightly palatal to the incisor edge of the adjacent teeth. After the implant has been placed and its stability has been confirmed with a radiofrequency index, the abutment is placed and screw retained to the implant. Cotton is placed in the screw access hole.

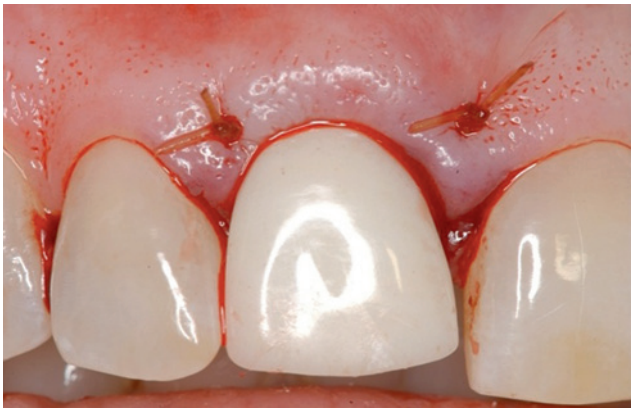


FIGURE 7-2 **H,** Provisional crown is placed, and occlusal adjustment is made as necessary. Small vertical mattress sutures can be placed to apply gentle pressure to the gingiva for conformation to the provisional crown.

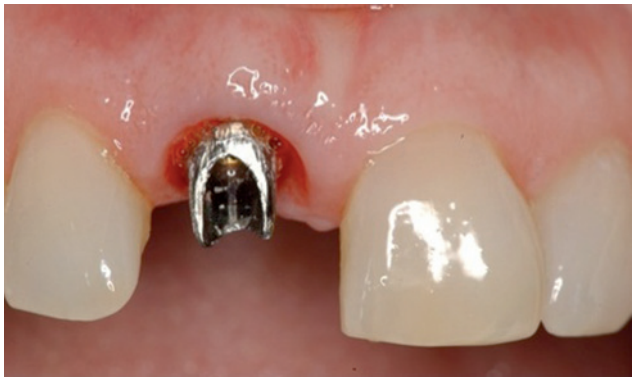


FIGURE 7-2 **I,** Four months later, the crown is removed and the abutment evaluated. Commonly, a new abutment is needed for final esthetics. Note the excellent sulcular definition from the provisional crown.

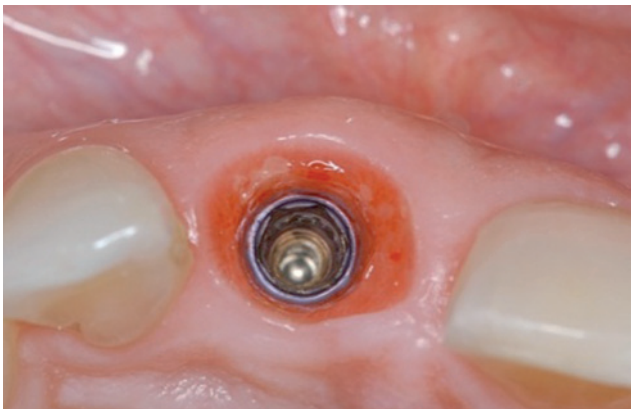


FIGURE 7-2 **J,** Provisional abutment has been removed, allowing an implant-level impression to be made. Note the shape of the sulcus, which allows efficient fabrication of the final crown.

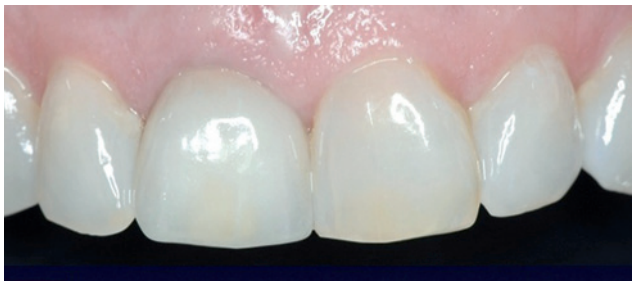


FIGURE 7-2 **K,** Restoration at 2-year follow-up.

guidance to prevent malalignment. The rotation is adjusted to match the analog on the model, and the abutment is placed. The abutment is screw retained, and the provisional crown then is placed and adjusted.

Tissue Punch Technique. A topical anesthetic ointment is applied before infiltration of the local anesthetic. The local anesthetic is administered to the labial and lingual surfaces to anesthetize the periosteum. A 30-gauge needle is used to sound the bone through the labial and palatal/lingual gingiva to visualize the bone without flapping the tissue. After a satisfactory time has elapsed, a tissue punch 3.5 mm in diameter is used to remove a circle of gingiva exactly where the implant is to be positioned.

The labial surface of the implant should be approximately 2 mm palatal to a line drawn from the labial surfaces of the adjacent teeth. The 2-mm distance allows development of the proper emergence of the final crown from the gingiva. If the implant is placed too far labially, the gingiva migrates superiorly and eliminates the possibility of an esthetic final restoration. Location of the tissue punch starts the accurate positioning of the implant.

If the surgeon is certain that sufficient bone width is available for implant placement, the implant site can be prepared through the gingival hole made with the tissue punch, without elevation of a flap (Figure 7-3, A-M). The implant site is prepared using the standard series of drills for implant placement. Attention must be paid to positioning the implant vertically 3 mm apical to the planned gingival margin. The implant should be rotated to place the flat side of the retentive aspect to match the analog in the model. When a flapless approach is used, through a hole made with a tissue punch, the implant driver mount is used

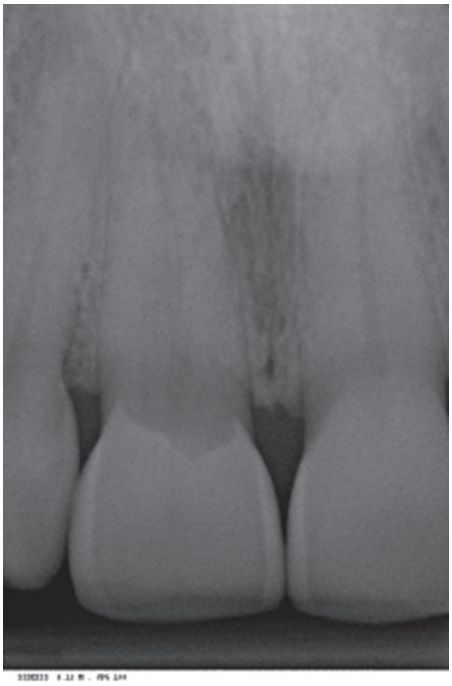


FIGURE 7-2 L, Radiograph taken prior to tooth removal, which was required because of external resorption.

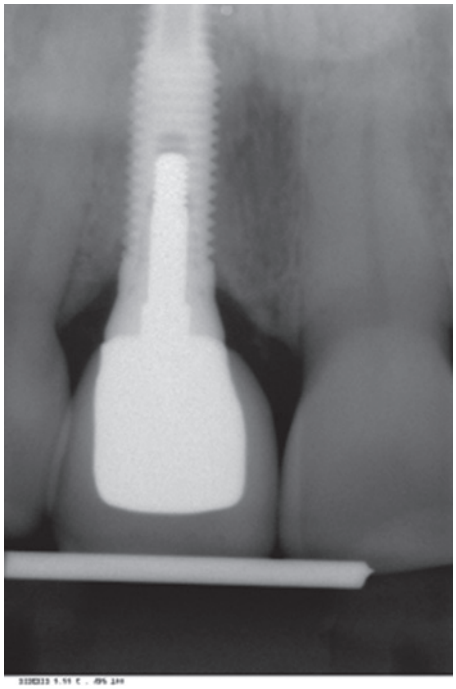


FIGURE 7-2 M, Radiograph at 2-year follow-up shows excellent crestal bone maintenance and healthy bone levels on the adjacent teeth.

to place the implant at the correct depth and to orient it correctly.

A minimal tissue flap can be made to allow visualization of the bony crest. A 15c scalpel blade is used, and the incision is taken from the circle of the tissue punch to the adjacent tooth, then labially and lingually within the sulcus of the adjacent tooth, avoiding incision of the papilla on the distal aspect of the adjacent teeth. A small periosteal elevator (e.g., Hirschfeld #2 or #20) is used to raise a full-thickness flap carefully halfway around the adjacent teeth, without tearing the gingiva on the margin of the adjacent teeth. No vertical incisions are necessary. The implant site is exposed, and if necessary, the small periosteal elevator can be slid under the periosteum over the labial bone to confirm its inclination and the presence of undercuts.

In molar sites and sites with previous surgical loss of KG, the incision is made across the crest, combined with anterior and posterior releasing incisions to transpose the KG and preserve it. A full-thickness mucoperiosteal reflection is made.

After the bone has been exposed, a round bur is used to mark the site for the implant. This marking must be made perfectly, because all drills follow its location. In single-tooth sites, the implant is placed in the middle of the

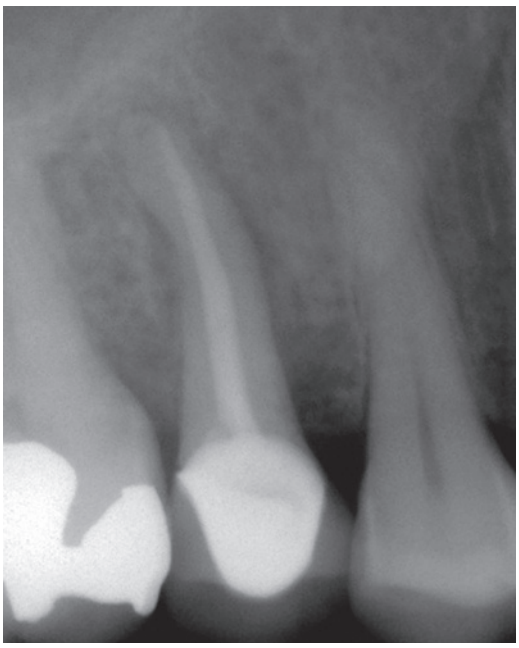


FIGURE 7-3 A, Preoperative radiograph of maxillary right second premolar with mobility and purulent drainage. This condition was refractory to endodontic therapy.

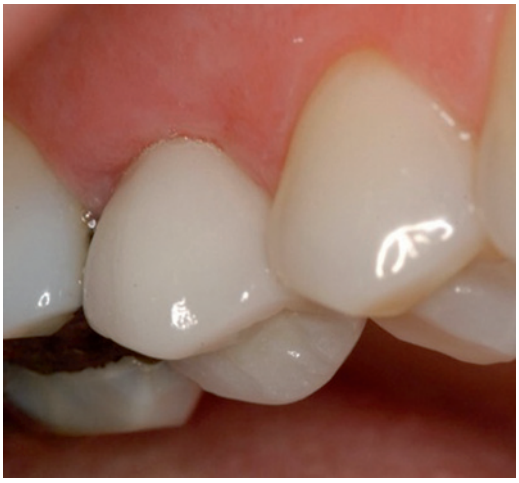


FIGURE 7-3 **B,** Lateral view of tooth prior to extraction. The tooth was removed and the site grafted with human mineralized bone. Four months were allowed for healing before implant placement using a tissue punch and immediate provisionalization.

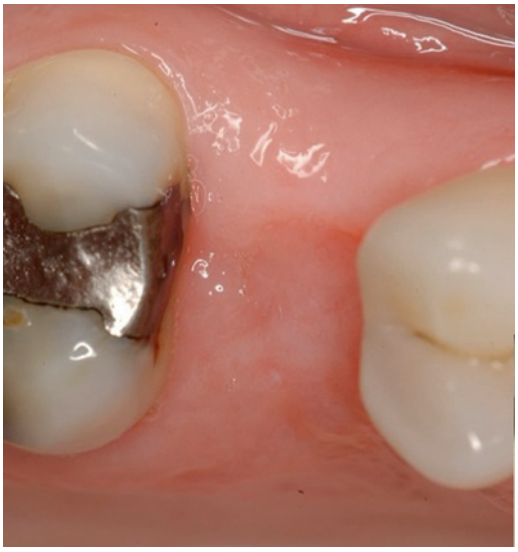


FIGURE 7-3 **C,** Edentulous site had excellent bone width, which was confirmed by palpation and probing.

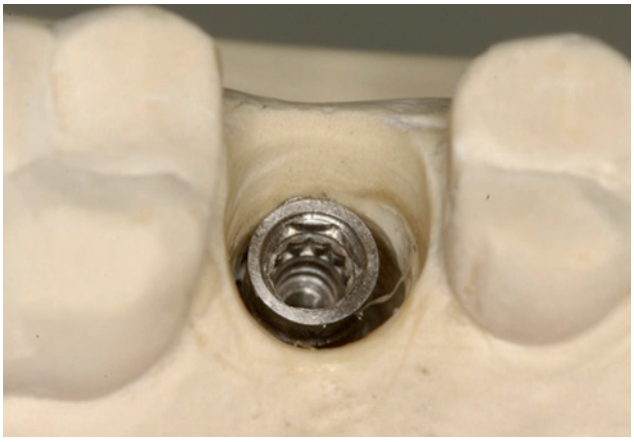


FIGURE 7-3 **D,** Models were made, and an implant analog was positioned in the premolar edentulous site. The implant was countersunk 3 mm from the gingival margin, in the central region between the adjacent teeth, with its labial surface 2 mm palatal to the planned crown emergence.

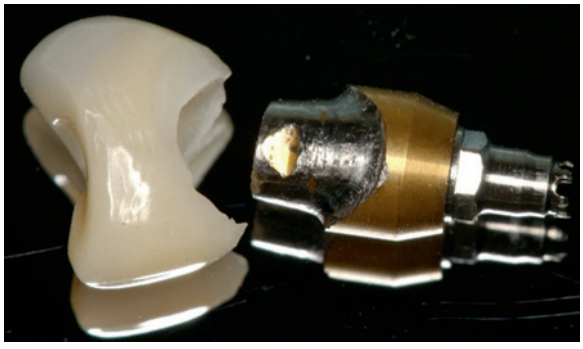


FIGURE 7-3 **E,** Metal abutment was prepared slightly with margins for the crown 0.5 mm subgingival. The surface of the provisional abutment was left rough for cement engagement. The crown was made with polished margins to promote gingival health.

edentulous site, equidistant from the adjacent teeth. The center of the implant site should take into account the implant's final diameter to place the implant definitively, avoiding labial malpositioning. For molars, the center of the implant should allow it to be positioned under the working cusp or within the central fossa of the planned restoration. Similar to anterior cases, the labial surface of the implant should be 2 mm lingual or palatal to the eventual position of the labial surface of the restoration to allow for emergence of the crown and ideal contours.

After the round bur mark has been made, the drilling sequence is followed. Guide pins are placed after the first drilling to make sure the implant is properly positioned and angled. Modifications are easily made, using the round bur again, by redrilling the pilot hole if necessary.

The implant preparation is completed. When the consecutive series of drills is used, guide pins should be placed to confirm perfect implant placement. The surgeon should orient the eyes to be able to confirm that the

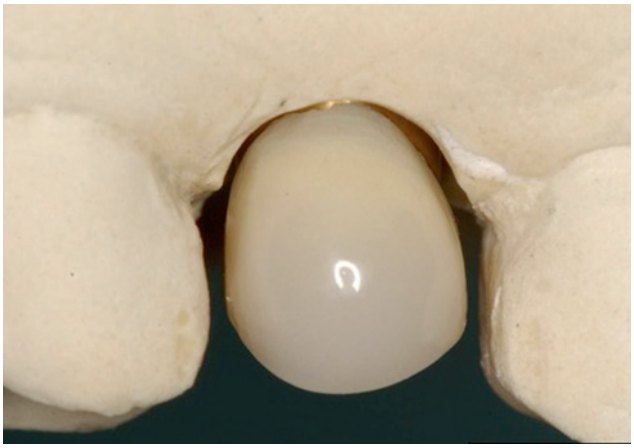


FIGURE 7-3 **F,** Provisional crown on the model prior to surgery. The contacts are left open 0.25 mm to allow surgical flexibility and to avoid small movement from the adjacent teeth.

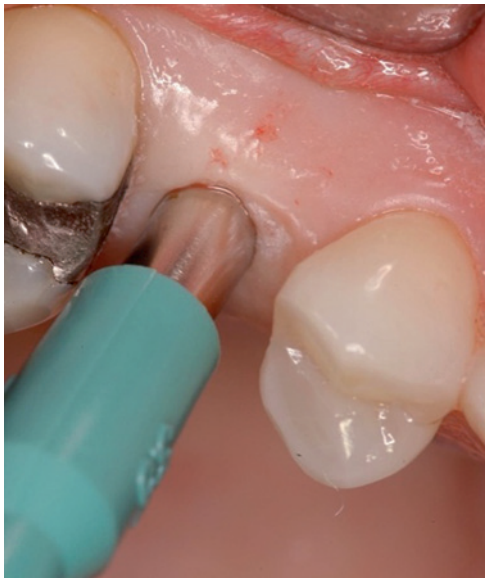


FIGURE 7-3 **G,** After infiltration of a local anesthetic, a tissue punch 4 mm in diameter is used to create a gingivectomy on the crest. This patient had a band of keratinized gingiva (KG) 10 mm wide. After the tissue punch has removed the gingiva to bone, the drilling sequence is followed.

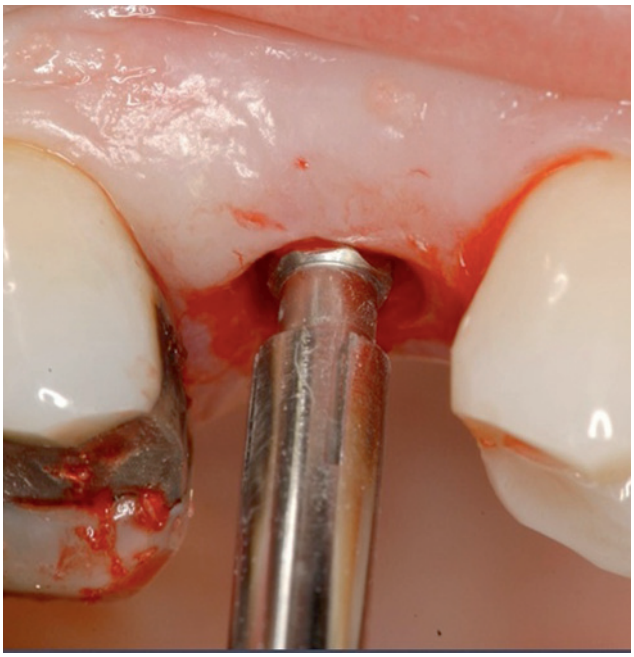


FIGURE 7-3 **H,** It is important to orient the implant rotationally to match the analog, generally keeping the internal flat of the hex to the labial. The implant's depth is determined by the markings on the implant driver mount.

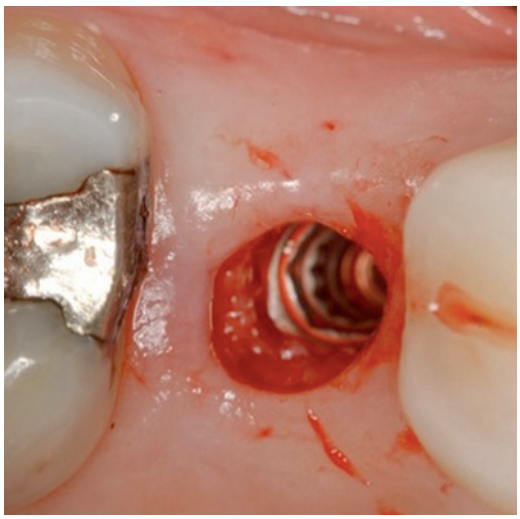


FIGURE 7-3 **I,** After the implant has been placed, the driver mount is removed, and the implant's position, rotation, and depth are confirmed. Note the lack of bleeding and lack of tissue trauma at the surgical site.

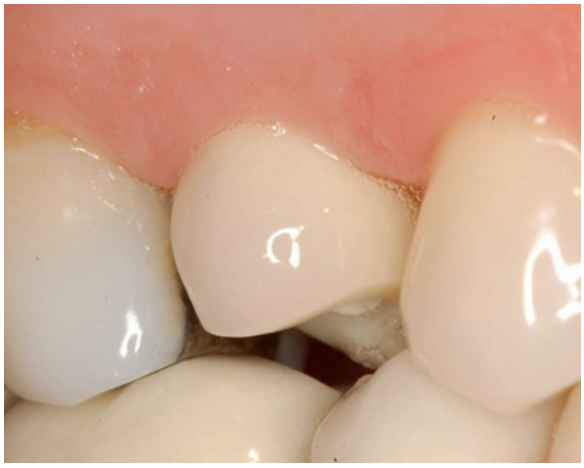


FIGURE 7-3 **J,** Abutment is secured to the implant with its gold screw, and the provisional crown is placed out of occlusion. Note the excellent soft tissue response at this 1-week follow-up.

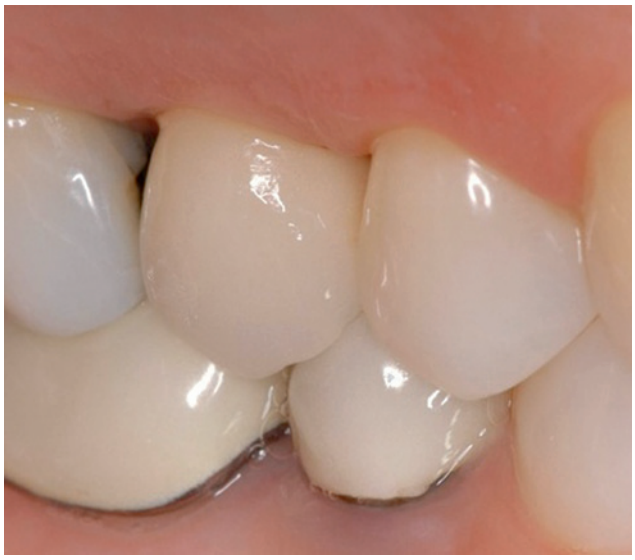


FIGURE 7-3 **L,** Final crown in place.

implant has been placed midway between the teeth and angled perfectly. If necessary, the countersinking drills are used to avoid bone and soft tissue interference when the implant is seated to its correct depth. These interferences also need to be removed sufficiently to allow placement of the abutments, which may flare according to the restorative plan.

The implant is placed with the orientation of the internal or external retentive features matching the orientation of the analog in the model. The implant should be flush with the bone or subcrestal aspect, depending on the

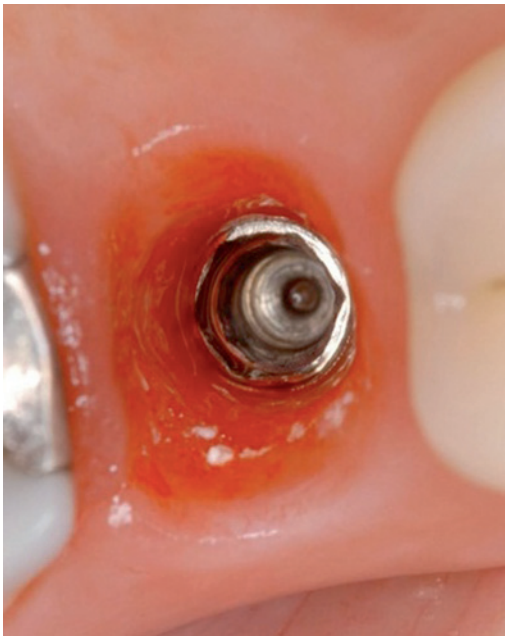


FIGURE 7-3 **K,** Four months later, the abutment is removed. Note the formation of an anatomically correct sulcus because of the immediate provisional.

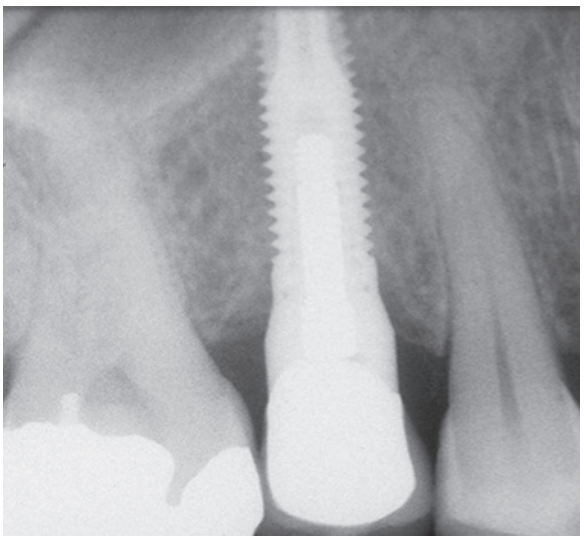


FIGURE 7-3 **M,** Final periapical radiograph 2 years after implant placement.

esthetic plan. A radiofrequency reading confirms that the implant has been placed with an index of at least 60. If the index is less than 60, the implant may be installed in a two-stage procedure rather than provisionally restored.

During preparation of the implant site, the prosthetic parts should be soaking in a sterilizing solution. The abutment, provisional crown, and abutment retaining screw are placed in a bowl of povidone-iodine (Betadine) solution. When the implant has been placed, the parts are removed from the solution and rinsed with sterile saline.

The abutment should be placed passively, without interferences from soft or hard tissue. Any bony interferences must be removed to allow passive placement of the abutment into the implant. If the abutment is not placed passively, excessive pressure can be transferred to the threads, increasing the chance of implant failure. The interocclusal distance is confirmed at this time. If the abutment has not been shortened sufficiently on the model or if the implant is placed more superficially than planned, the abutment may have to be adjusted with a high-speed drill out of the mouth, and the corresponding provisional crown may need relining at the time of insertion. With accurate model preparation, the incidence of abutment modification is less than 5%.

The abutment screw is hand-tightened rather than torqued, because it is difficult to place countertorque pressure on the abutments while a torque procedure is performed. The provisional crown is tried in position. The contacts are adjusted as necessary, and occlusal clearance in all jaw movements is confirmed. The crown is cemented after a small piece of retrievable material (e.g., cotton, gutta percha, other soft material) has been placed into the abutment to protect the screw from becoming clogged with temporary cement. After the provisional crown has been cemented and the cement has been cleaned from the margins, the gingiva is sutured if necessary. The KG tissue previously on the crest should be repositioned on the labial surface of the provisional crown.

Chairside Abutment Preparation and Fabrication of a Provisional Crown

With the use of new high-speed drills and gentle technique, abutments can be adjusted in the mouth. This reduces implant dentistry to conventional dentistry, without the need for transfer copings and other parts. The surgeon places the implant and the abutment or a one-piece implant with the abutment incorporated into its body. The surgeon or restorative dentist performs a simple reduction in height and labial or lingual contouring as necessary, and then a hollow shell is relined (DVD Figure 7-2, A-G).

7-2, A-G

The use of high-speed, new diamond or carbide burs with copious irrigation and gentle pressures does not transmit excessive heat to the implant and surrounding bone. Thus, preparation of the abutment or supragingival portion of a one-piece implant is acceptable if properly performed. The advantage is simple, routine dentistry techniques similar to crown preparations; however, the disadvantage is the need for careful coordination of the appointments for both offices and gentle technique for abutment modification.

Preoperative considerations

This protocol requires minimal preoperative preparation. The abutment is selected before implant placement, taking into consideration the estimated thickness of the gingival margin and the interocclusal distance. If the abutment is carefully selected, minimal modification is necessary. Chairside preparation of the abutment portion of an implant is also routine with one-piece implants. The provisional crown must be chosen before implant placement, taking into consideration the shade of the adjacent teeth.

The surgical technique for placing the implant is similar to that described earlier. When a one-piece implant is used, careful attention to inclination is critical, because angle correction is not possible beyond a few degrees.

Provisionalization method

After the implant has been placed, the abutment is placed and torqued to 20 N-Cm. A high-speed drill is used with new burs to remove the excessive vertical component of the abutment and to modify the labial or lingual as necessary. The gingival margin can be adjusted at the time of implant placement if absolutely necessary. If the gingival margin is adequate, final adjustments are better made after the gingiva has healed and matured. The provisional crown is relined, and the margins are smoothed to promote gingival health. The occlusion is cleared to prevent trauma from occlusion.

Indexing the Abutment for Laboratory Fabrication of a Provisional Crown, with Placement in the Patient's Mouth within Hours or Days

The concept in this approach is for the surgeon to place the implant and then the final abutment. The final abutment requires a snap-on transfer coping and a conventional closed-tray impression. The impression is given to the restorative dentist or laboratory for fabrication of the provisional crown. This reduces the number of implant parts required for purchase by the restorative dentist and reduces chair time for both the patient and the dentist (Figure 7-4, A-M; and DVD Figure 7-3, A-S).

7-3, A-S

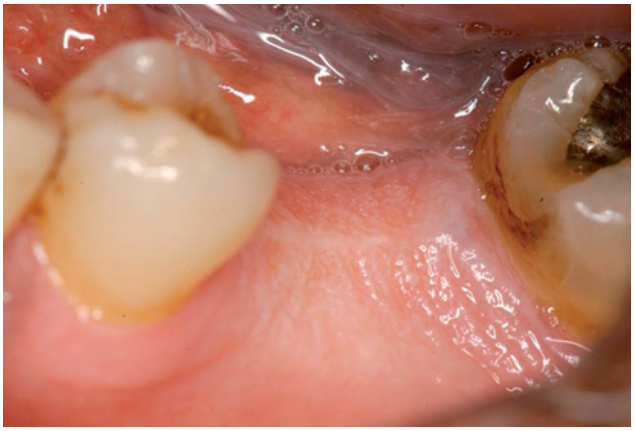


FIGURE 7-4 **A,** Treatment plan for this patient calls for the placement of one implant in the first molar location with immediate placement of a final, "nonprepable" abutment. Before surgery, the gingival collar height is chosen to match the 2-mm gingival thickness; the interocclusal space allowed an abutment 5 mm tall.

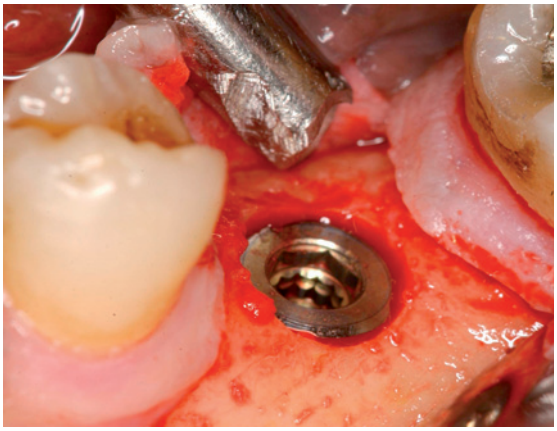


FIGURE 7-4 **C,** Implant is placed level with the crestal bone. A radiofrequency index of 75 indicates excellent implant stability.

Preoperative considerations

Bone quantity is required for this technique, as with any immediate provisionalization method. Before surgery, the edentulous site must be evaluated for tissue thickness and interocclusal distance. The interocclusal clearance can be determined by evaluating models or measuring directly in the patient when in occlusion. Two measurements are necessary. The first is an estimate of the thickness of the gingiva. In the posterior regions, the clinician usually chooses a gingival collar 3 mm tall. The second measurement is the abutment height. With the mouth closed, the distance from

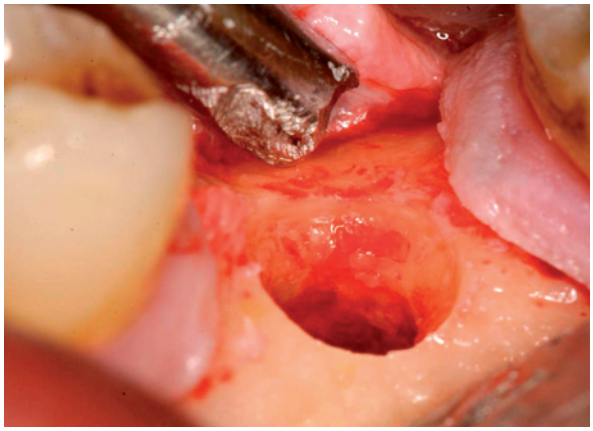


FIGURE 7-4 **B,** Implant site is prepared for an expanded platform type of implant (Prevail, Implant Innovations, Palm Beach Gardens, Florida).

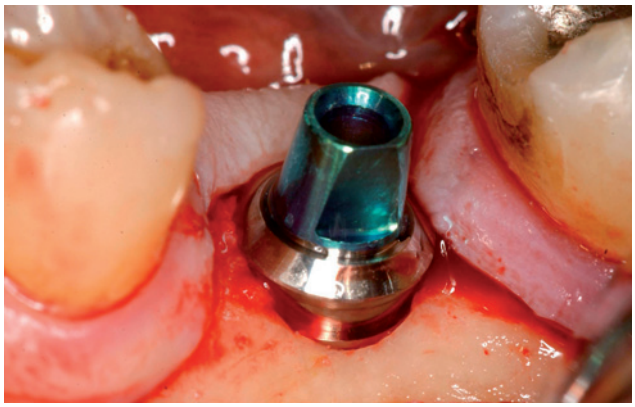


FIGURE 7-4 **D,** Abutment is placed and secured with a gold screw. The margins of the Provide abutment (Implant Innovations) are predetermined, which allows the transfer to snap into place.

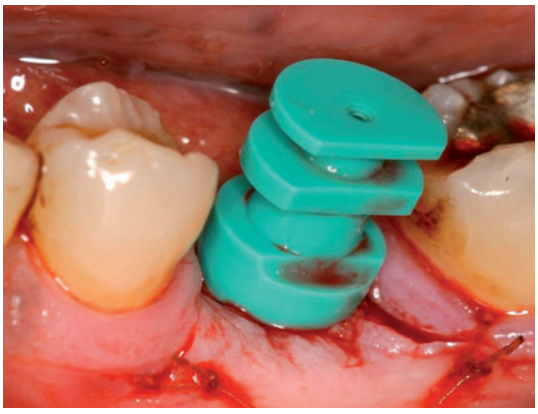


FIGURE 7-4 **E,** Transfer coping is snapped over the margins of the abutment.

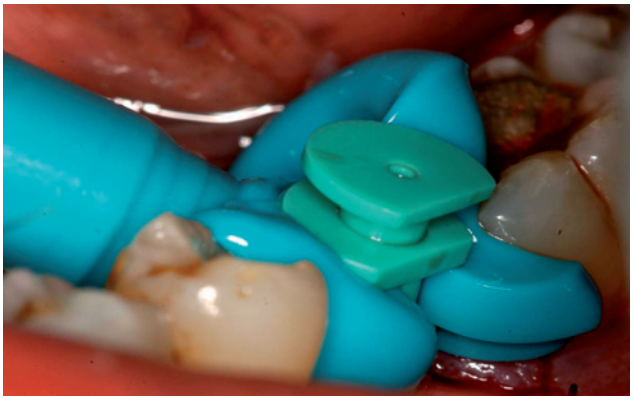


FIGURE 7-4 F, Impression is taken by first placing the less viscous material around the transfer coping (Aquasil, Dentsply/Caulk, Milford, Delaware).

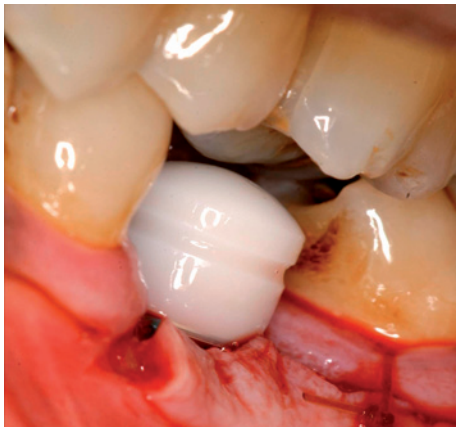


FIGURE 7-4 H, After removal of the impression from the mouth, a protection cap is placed over the abutment to prevent trauma to the patient's tongue.

FIGURE 7-4 J, Abutment analog is snapped into the transfer coping in the impression.

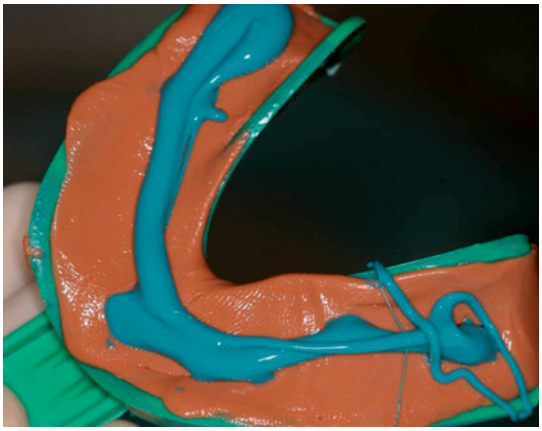


FIGURE 7-4 G, Rim of impression material is placed over the putty, which has been mixed and placed in an impression tray.

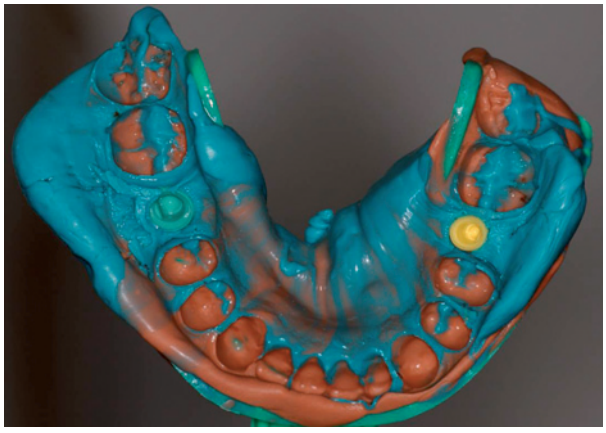
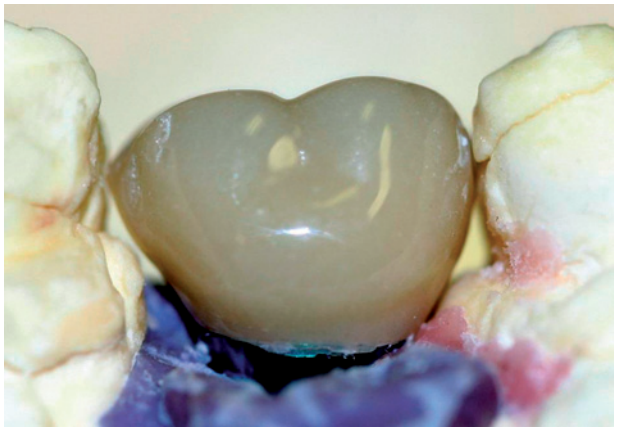
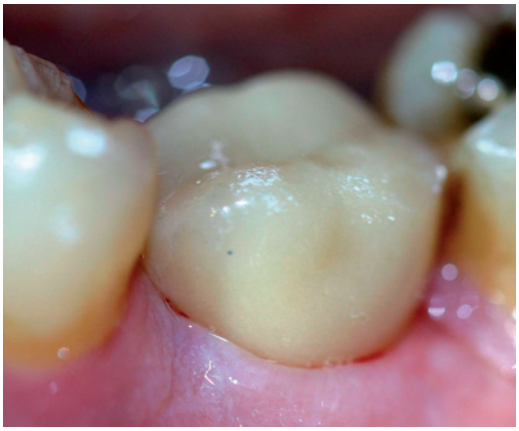


FIGURE 7-4 I, Impression with the transfer copings in place. This patient had bilateral implants placed.

FIGURE 7-4 K, Impression with the analog in place is poured in the laboratory.



● **FIGURE 7-4** **L,** Provisional crown can be made using a hollowed denture tooth or a hollow-shell crown.



● **FIGURE 7-4** **M,** Provisional restoration out of occlusion is positioned within days of implant placement.

the ridge to the opposing working cusp is recorded. The abutment chosen typically is 2 to 3 mm shorter than the occlusal clearance to allow at least 1.5 mm for the thickness of a full porcelain restoration.

Specific materials are required for the impression.

A "nonprepable" abutment must be available on the day of surgery. These abutments typically require specific gingival collar and the abutment heights. Based on the specific abutment ordered, the matching transfer coping, protection cap, and implant analog also must be available on the day of implant placement.

Surgical and impression techniques

The surgical procedure for implant placement is the same as for any other single implant. After the implant has been placed and its stability confirmed, the abutment is placed into the implant and secured with a retaining screw. The retaining screw is hand-tightened.

The next step is to make the transfer impression. If the gingival margin of the abutment is supragingival, the incisions can be closed before transfer coping placement. If the margin of the abutment is subgingival and if the incisions are closed tightly, the transfer coping may be difficult to seat properly. If a subgingival margin is present, the surgeon sutures one side of the incision, takes the impression, and then sutures the second side.

The transfer coping is placed and snapped over the margins of the abutment as recommended by the manufacturer. An impression tray is tried in place. Putty is placed into the tray, and a rim of less viscous impression material (e.g., Aquasil, Dentsply/Caulk, Milford, Delaware) is placed over the putty to ensure accurate seating of the impression over all the teeth. The thin, viscous material is syringed over the transfer coping, and an impression is made. After the required time for setting of the impression material, the impression is pulled from the mouth with the transfer coping retained in the impression tray. The analog is placed into the transfer coping, and the impression is poured in the laboratory. Before the patient is dismissed, a cap is placed over the abutment to prevent trauma to the tongue and cheek from the sharp edges of the abutment.

In the laboratory, a provisional crown is fabricated using a denture tooth or hollow-shell crown. The margins are smoothed to promote gingival health. The occlusion is checked to make sure there is no occlusion in all jaw movements. The crown is delivered within hours or days, depending on laboratory support and scheduling (see DVD Figure 7-2).

An alternative technique is for the surgeon to "index" the implant after its placement. The *index* is an impression of the abutment or implant to allow for transfer of the implant to a model. The model can be used to generate a provisional restoration. The index can be made with a transfer coping screwed into the implant or a snap-on coping snapped onto an abutment. Usually a tray is used to make an accurate impression, but bite registration material or resin also can be used. The index impression has an analog placed within the transfer coping. The master model has a hole made in the implant site, and the analog is luted to the model using stone or fast-setting glue. If a tray is used to take a full-arch or half-arch impression, routine model pouring is done to generate a separate model. To make the provisional prosthesis, a bite may be needed, an opposing model is necessary, and a shade is necessary to fabricate an esthetic device. The index allows the laboratory to fabricate a provisional restoration.

If an immediate provisional restoration is planned but an index is not performed, the case needs to be handled

carefully. If the implant has a healing abutment placed to provide access for indexing at a later date, the removal of the temporary healing abutment cannot result in reversing the implant from its initial placement. In this situation, a two-piece healing abutment is recommended. The two-piece healing abutment (Encode, Implant Innovations) has one piece that is seated into the internal hex of the implant and is secured to the implant by a retaining screw. When removed, the screw is removed with counterforce holding the abutment, preventing counterclockwise movement of the implant. After the screw has been removed from the two-piece abutment, the abutment piece is pulled straight out, without rotational forces on the implant.

Postoperative Management

Patients are instructed to avoid chewing solid, textured food for 8 weeks. They are advised to chew on the opposite side of the mouth and to avoid loading the implant restoration. Postoperative antibiotics and pain medication are prescribed. Diluted chlorhexidine solution is started 1 week after implant placement.

The gingiva heals quickly and facilitates the efficient restoration of the patient. After an appropriate time for integration of the implant, the final impression is taken using either the provisional crown or the transfer coping method. The final abutment is prepared to place the final crown margins to within 1 to 0.5 mm of the gingival margin. At this point, the final crown is fabricated and cemented.

Potential Complications

1. **The implant is placed with a different angulation than planned because of variations in bone morphology.** If the implant is positioned in a different angulation or a different position than planned on the model, the crown must be adjusted, including modification of the gingival contour to prevent apical migration of the gingiva. If the cervical region is too bulky, the gingiva recedes. It is better to undercontour the cervical region of the esthetic restoration to have the gingival margin in a better position as planned.
2. **The abutment is too close to the opposing occlusion, requiring adjustment of the abutment.** This occurs if the implant analog is placed too deep into the model, then placed flush with the bone, resulting in the abutment needing adjustment. The abutment is removed from the implant, and its height is reduced using a drill. The occlusal clearance is verified, typically 2 to 3 mm from the opposing teeth. The provisional crown must be relined to ensure adequate retention.
3. **The provisional crown needs occlusal adjustment to keep it out of occlusion.** This is common, because many laboratories do not allow sufficient space. The occlusal clearance must be at least 0.5 mm, preferably 1 mm. The surgeon should examine the model with the abutment and crown to evaluate interocclusal clearance. If necessary, the surgeon can reduce the occlusal table to achieve 0.5-mm clearance before performing the surgery. This reduces chair time during the surgical procedure, because no additional adjustment is necessary.
4. **The provisional crown needs removal of a contact to allow for passive placement.** If the temporary crown was made with tight contacts in the laboratory, these contacts must be removed so that the crown fits passively. If it is placed with tight contacts, forces are transmitted to the implant-bone interface, which may cause bone resorption rather than integration.
5. **The provisional crown becomes loose and requires recementation.** This occurs because of the lack of ideal retentive form of the abutment, which often is short and its surface polished. By placing a labial groove and leaving the abutment surface rough, cement retention is improved.
6. **Failures result from inappropriate loading of the implant.** The implant restoration must be kept out of occlusion. The patient cannot chew a hard-textured diet. Infection is rare and is similar to that with two-stage implants.

Discussion

The decision for immediate provisionalization of a dental implant involves excellent cooperation of the surgeon and restorative dentist. Using the described technique, the team should have good communication to ensure proper patient selection, correct placement of the analog in the model, and delivery of a modified abutment and provisional crown that can be efficiently placed by the surgeon.

When working as a team, ideally the members have equal experience. A team member who has experience with a procedure may need to lead the other members. The surgeon may need to drill the hole into the diagnostic model until the team becomes familiar with the method. If the implant is placed at the wrong depth, interferences with the opposing occlusion can occur, or the implant restoration may be extremely short. If the provisional restoration is too short and is an esthetic problem, it must be relined at the time of abutment insertion.

The restorative dentist or laboratory technician may provide a refined, "ideal" type of preparation. However, the ideal abutment preparation, especially if highly polished, limits flexibility if the implant is angled slightly differently from the planned angulation. The surgeon may make angulation alterations to prevent exposure of the implant through bony undercuts or unknown angulations of the cortical plates. To prevent the problem of lack of flexibility, this author's team suggests that the abutment be slightly overprepared

with labial grooves and that the surface of the abutment be left in a roughened state. The grooves and roughened surface enhance retention of the provisional crown.

If the implant's angulation results in an unesthetic situation, the provisional crown may need to be adjusted by the restorative dentist through selective grinding, polishing, and in rare cases, relining of the restoration. To anticipate the need for access to the margins of the abutment, the margins of the provisional crown should be within 0.5 mm of the gingival margin, avoiding deep margins.

The surgeon should be prepared to adjust the mesial-distal contact of the provisional crown, if necessary, to prevent direct contact and inadvertent loading of the implant from the adjacent teeth. The surgeon should always check the occlusion of the restoration and, as necessary, reduce the occlusal surface to keep the provisional restoration free of occlusal loading from the opposing dentition.

One advantage of using a provisional restoration technique is that the restoration shapes the gingival sulcus; therefore, there is less need for the restorative dentist to manipulate the implant site's soft tissue morphology. Maturation of the soft tissue allows immediate placement of the final restoration after the implant has integrated. The soft tissues have appeared stable in form after they have healed after implant surgery.

Methods for Immediate Provisionalization of Multiunit Implant Restorations

Immediate provisionalization of multiunit segments is beneficial for the patient, because a toothlike restoration is in place, and the provisional prosthesis aids the development of the soft tissue contours, eliminates the need for removable temporary prostheses, and reduces the need for second-stage surgeries, because the implants are exposed and have an abutment in place. The disadvantages mainly involve the dentists, who must spend additional time preoperatively and immediately after implant placement to position and refine the provisional prosthesis.[5-17]

The term *immediate provisionalization* is used to describe implants that receive a temporary restoration within hours to 14 days after the implants have been placed. These implant restorations are not placed into occlusion, because the implants are isolated to one arch, ranging from two to five units. No cross-arch stabilization is used; therefore, the occlusal forces are not distributed in a similar manner, as in full-arch, cross-arch–stabilized prostheses.

Literature Review: Case Reports

Malo et al.[8] reported on 94 self-tapping machined implants (Mark II, Nobel Biocare AB, Goteborg, Sweden) supporting 54 fixed prostheses in 49 patients. The implants were placed from first premolar to first premolar in either jaw; 94% were placed in type II bone. Of the prostheses, 23 were bridges, with 14 in maxillas and 9 in mandibles, and 31 were single crowns, with 22 in maxillas and 9 in mandibles. Provisional implant-supported restorations were delivered at surgery with no occlusal contacts. Final restorations with appropriate occlusion were delivered 5 months later. The cumulative survival rate was 96% at 1- and 2-year follow-up examinations; 43% of the implants were evaluated after 2 years. Four failures occurred in fresh extraction sites. No differentiation resulted between the partial edentulous and the single-tooth groups. The authors concluded that the restoration of threaded, rough-surfaced implants with immediate, nonfunctional, fixed provisional restorations used in the esthetic zone of both jaws might be a viable concept.

Jaffin et al.[9] reported on 149 implants; 122 sandblasted or acid-etched and 27 machined titanium implants in partially and fully edentulous jaws. The exact number of implants placed in each group of patients was not detailed. Provisional restorations were delivered within 72 hours of implant placement. The type of occlusal contacts in the partially edentulous patients was not specified. After 12 weeks, the success rates were 95%, similar to those in delayed-loading cases. The implant surface was reported to be a key factor, because the success rate of immediately loaded, relatively smooth, machined implants was significantly lower (83%) than that of the TPS/SLA implants (99%). More detailed information is needed to apply these findings to the partially edentulous patient, because most patients in this case series seemed to be totally edentulous.

Testori et al.[10] placed 101 implants (Osseotite, Implant Innovations) in 32 partially edentulous patients. At least two implants were placed to restore each partially edentulous space in different locations with different bone quality. Fifty-two implants in 14 patients were loaded immediately, within 24 hours of surgery, with no occlusal contacts. In this group, 27 implants were inserted in the maxilla and 22 in the mandible. The cumulative survival rate for the two groups was similar: 96.15% for the immediately loaded group and 97.96% for the early loaded group. These authors concluded that implant-supported, fixed partial prostheses can be immediately nonocclusally loaded and restored with a predictability similar to that of early loaded implants. Several factors were suggested as success predictors for the immediate, nonfunctional loading protocol: (1) good bone quality, (2) adequate implant primary stability, (3) ideal implant position, (4) one implant per missing tooth with at least two splinted implants for each restoration, (5) the presence of adjacent teeth to provide occlusal support, and (6) the absence of parafunctional habits.

Degidi and Piattelli[11] compared implants that were subjected to immediate functional and immediate nonfunctional loading. A total of 646 implants from six different

systems were placed in 152 patients. The protocol was changed after the first year of the study, and both totally and partially edentulous patients were treated with immediate loading. The change resulted from multiple failures in the partially edentulous group. Of 422 implants placed, 187 were in postextraction sites and 235 in healed sites. Immediate nonfunctional loading was performed on 224 implants in 116 patients; 58 were multitooth spans, and 58 were single teeth. In the immediate functional loading group, six implants failed (1.4%), and in the immediate nonfunctional loading group, two implants failed (0.9%). For the partially edentulous patients, the authors suggested (1) the implants should be restored with immediate nonfunctional loading, and (2) the ratio of prosthetic units to the number of implants should be as close as possible to 1 to prevent bending and flexure of the provisional restoration, which might cause implant micromovement and fibrous encapsulation.

Rocci et al.[12] compared TiUnite (Nobel Biocare AB) and machined-surface Branemark System implants when applying immediate loading to partial fixed bridges in the posterior mandible. Twenty-two patients received 66 TiUnite surface implants supporting 24 fixed partial bridges, all of which were connected on the day of implant insertion. Twenty-two patients received 55 machined-surface implants supporting 22 fixed partial bridges, which also were connected on the day of implant insertion. All restorations were two- to four-unit bridges. Three TiUnite and eight machined-surface implants failed during the first 7 weeks of loading, resulting in a cumulative success rate of 95.5% after 1 year in the posterior mandible. The corresponding cumulative success rate for machined-surface implants was 85.5%. This study demonstrated a 10% higher success rate after immediate loading of partial fixed bridges in the posterior mandible supported by TiUnite surface implants than with relatively smooth, machined-surface implants.

Glauser et al.[13] evaluated 102 threaded, rough-surfaced implants (Branemark System Mark IV TiUnite, Nobel Biocare AB) placed in 38 immediately loaded patients, supporting 20 single-tooth restorations, 30 fixed partial dentures, and one complete fixed mandibular restoration. Most of the implants (88%) were placed in posterior regions and mainly in soft bone (76%). No differentiation was mentioned between the patient groups, and all 51 prosthetic restorations were placed immediately in full occlusal contact with maximal intercuspation. The cumulative implant survival rate was 97.1% after 1 year of loading.

In 2004, Nikellis et al.[14] placed 190 implants in 40 patients; 12 implants were placed in five partially edentulous patients missing two or more adjacent teeth. Although all implants were loaded within 72 hours of placement with provisional restorations, the specific occlusal scheme for the partially edentulous patients was not detailed. The authors' criterion for loading was clinical judgment of primary stability above 32 N-Cm. After 1 to 2 years, all 12 implants had survived and were considered 100% successful.

Nordin et al.[15] placed 59 SLA-surfaced implants (ITI, Straumann, Waldenburg, Switzerland) in 19 partially edentulous patients in the posterior maxilla and 53 in 15 partially edentulous patients in the posterior mandible. Definitive fixed prostheses were delivered after a mean delay of 9 days after implant placement. One implant was lost in the maxilla. The authors concluded that the immediate-loading protocol can be applied with predictable results using rough-surfaced implants for rehabilitation of the posterior partially edentulous maxilla and mandible.

The implant must be mechanically stabile after placement. A radiofrequency index greater than 60 is associated with success for immediate provisionalization. Another measure is to use an insertion torque greater than 30 N-Cm as the limiting factor. However, well-controlled studies verifying these measures are lacking.

The immediate provisional restoration should be designed to eliminate micromotion. Pillar et al.[16] demonstrated that micromovement up to 150 μm is associated with fibrous rather than bony integration. Brunski[17] agreed, suggesting that micromotion greater than 100 μm causes the wound to undergo fibrous repair rather than osseous apposition (Table 7-1).

General Principles

The patient is seen by the implant team members. After the prosthetic goals have been established, which include an implant-supported fixed restoration, diagnostic models are mounted and a setup is performed. The setup is used to evaluate available bone and to generate the necessary models for fabrication of the surgical guide stent and temporary prosthesis.

The techniques described in the following cases use analogs placed into the model. Abutments are prepared, or abutments for screw retention are placed. The provisional prosthesis is then made. Use of a computed tomography (CT) scan allows the surgical guide stent to be fabricated from virtual implant placement surgery. The CT-generated stent is used to place analogs in the model. At surgery, because the CT scan is accurate, a flapless approach can be used, which is advantageous for the patient with regard to postsurgical morbidity.

Posterior Maxillary Case

This patient previously had the maxillary first premolar and first molar extracted, and the sockets had been grafted with human mineralized bone. The patient presented with a unilateral edentulous segment (Figure 7-5, A), and she wanted to avoid having to wear a removable prosthesis.

TABLE 7-1 Key Factors in the Success of Immediate-Loaded Implants in Partially Edentulous Patients

Factor	Rationale
Bone quality and quantity sufficient to provide primary stability of implants	Elimination of micromotion and bicortical engagement of the implant increases the likelihood of successful osseointegration.
Roughened implant surface	Literature indicates that implants with a roughened surface have been more successful than machined implants.
No immediate direct functional load for 2 to 3 months	Literature implies that a nonfunctional provisional restoration is crucial to prevent occlusal overload.
Implant number	Literature review implies that "an implant per missing tooth" scheme should be used. Data are not available on fixed partial denture with pontics over immediate-loaded implants.
Prevention of excessive occlusal forces and minimization of horizontal forces on implants	Bruxers and splint implants should be avoided.

Her smile is wide and exposes the edentulous sites. Four months after the grafting, the patient has satisfactory bone for the placement of implants (Figure 7-5, B).

To fabricate a fixed temporary prosthesis, diagnostic models are made and a setup is done in the laboratory. Two implant analogs are placed into the model in the locations determined from the setup (Figure 7-5, C). The shoulders of the implants are placed 3 mm apical to the planned gingival margins of the restoration, with the screw access in the fossae of the planned restoration.

Fixed abutments are placed into the analogs and prepared according to the planned restoration (Figure 7-5, D). For the temporary restoration, the gingival margins are kept slightly supragingival. Approximately 3 mm is allowed between the abutments and the opposing occlusion.

The model with the setup is duplicated in stone, and a vacuum form (vacuform) made. Acrylic is used to process a fixed temporary prosthesis on the prepared analogs. The margins are adapted. The three-unit temporary restoration is prepared to allow for minimal relining, as necessary (Figure 7-5, E-H).

Occlusal screws are placed into the implant analogs, and metal tubes are placed over the screws. A vacuform is placed, with holes allowing the tubes to fit passively within the vacuform. Acrylic is used to lute the tubes to the vacuform. This will be the surgical stent, providing the surgeon with an accurate prescription for implant placement (Figure 7-5, I). The inner diameter of the tubes is 2.5 mm, because the pilot drill of the implant system used is 2.3 mm.

At surgery, the surgical stent is placed. The pilot drills are used to mark the implant sites in the gingiva (Figure 7-5, J). After removal of the stent, a tissue punch 3.5 mm in diameter is used to remove the gingiva (Figure 7-5, K).

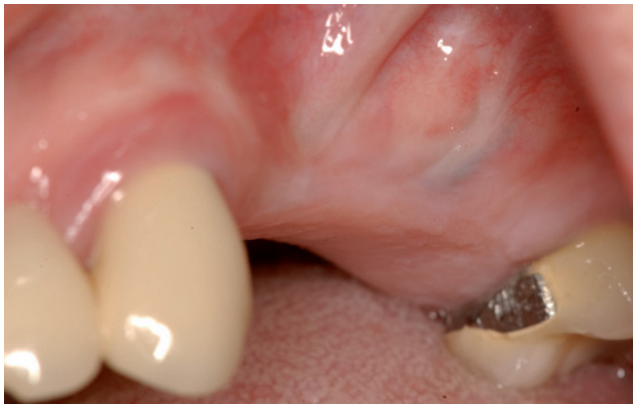


FIGURE 7-5 A, Preoperative view of the left maxillary quadrant.

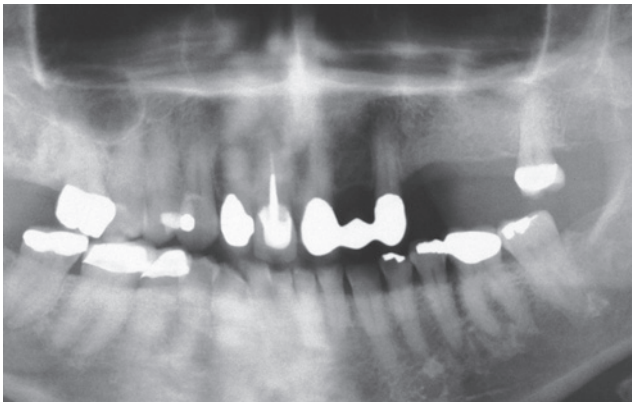


FIGURE 7-5 B, Preoperative panoramic radiograph showing adequate bone for implant placement.

FIGURE 7-5 **C,** Implant analogs placed in the appropriate position, as dictated by the planned setup.

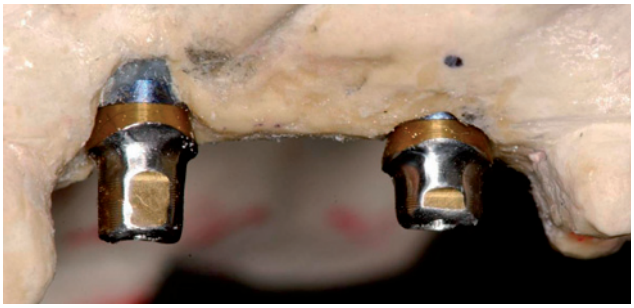


FIGURE 7-5 **D,** Implant abutments are placed and prepared, leaving the retentive aspects and supragingival margins.

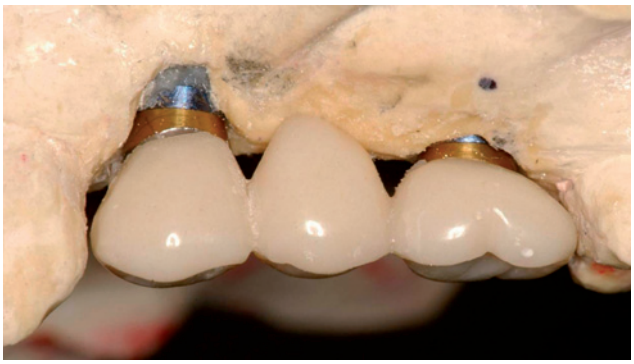


FIGURE 7-5 **E,** Fixed temporary restoration is fabricated.

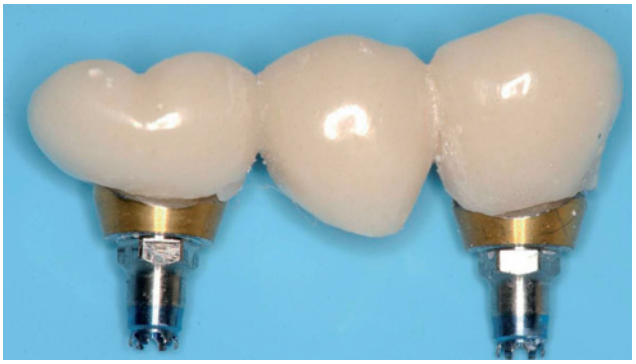


FIGURE 7-5 **F,** Margins are finished to promote gingival health.

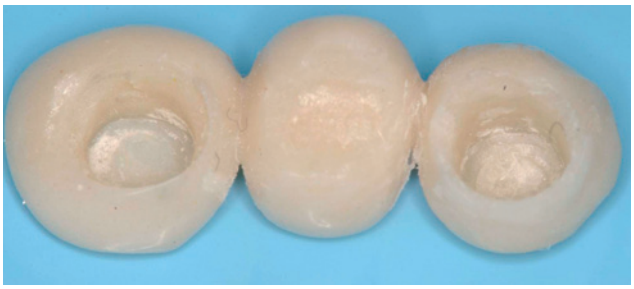


FIGURE 7-5 **G,** Intaglio surface of the temporary restoration.

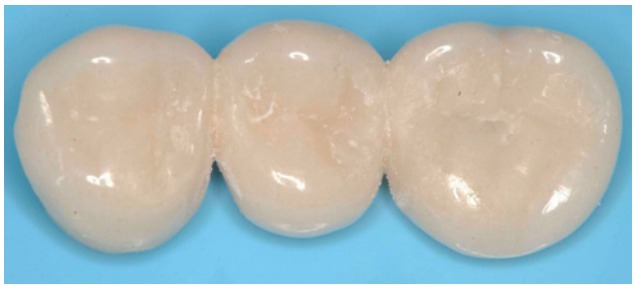


FIGURE 7-5 **H,** Occlusal surface of the restoration.

The anterior implant site is exposed with a small flap because of a palpable undercut in the ridge. For this site, a crestal incision is carried anteriorly using a sulcular incision halfway around the canine tooth. A vertical release incision is made in the region of the second premolar, keeping the vertical component away from the esthetic zone. The surgical stent is placed, and the pilot drill is used to prepare the anterior site (Figure 7-5, L). The stent is removed, and the remaining sequence of drills is used to finalize the implant site. Care is taken to maintain the orientation of the implant site (Figure 7-5, M).

The stent is used to guide the pilot drill for the posterior site. Because of the bulk of bone present in the molar site, no flaps are used. The drills are used in sequence through the hole made from the tissue punch. Use of an implant mount that allows the surgeon to determine the depth and orientation of the implant is critical for this method (Figure 7-5, N).

The abutments are placed and the anterior site sutured (Figure 7-5, O). This particular implant uses *platform switching,* otherwise known as a "medialized interface,"

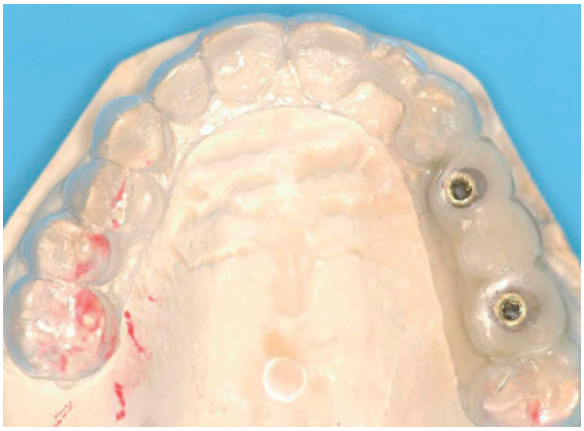


FIGURE 7-5 **I,** Surgical stent on the model. The stent is a vacuum form filled with acrylic, with metal tubes positioned by the analogs.

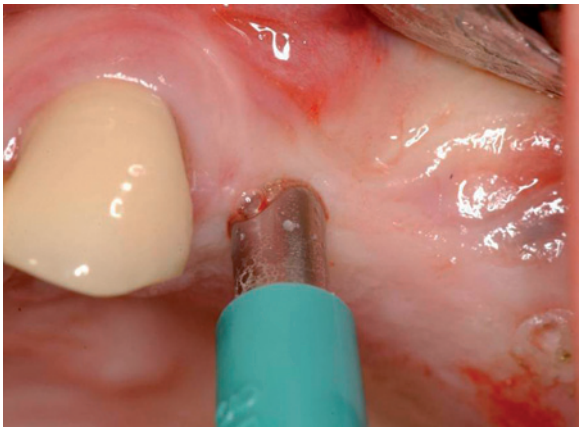


FIGURE 7-5 **K,** Tissue punch is used to remove gingiva before implant site preparation.

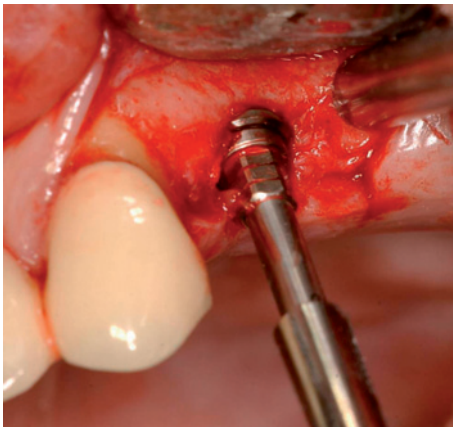


FIGURE 7-5 **M,** Implant is positioned to the appropriate depth and orientation.

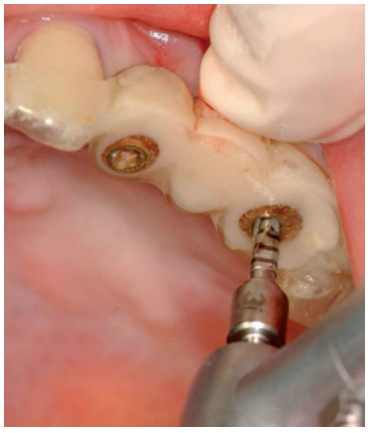


FIGURE 7-5 **J,** Stent in place. The pilot drill is used to mark the implant site.

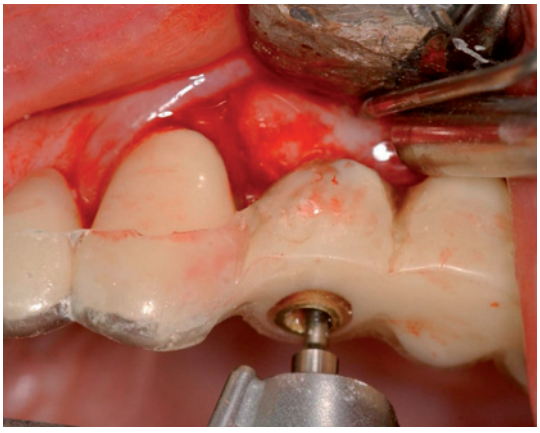


FIGURE 7-5 **L,** Stent is used to guide the pilot drill.

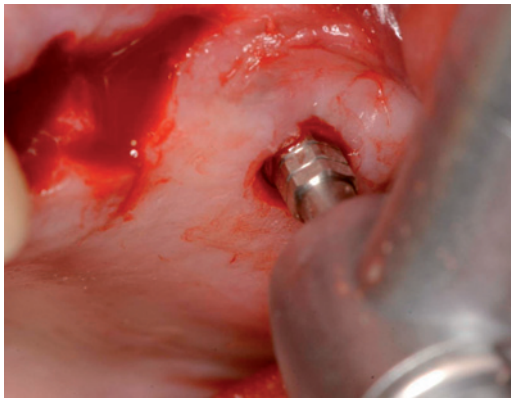


FIGURE 7-5 **N,** In molar position, the implant is placed. Note that the implant drive has flat surfaces that correspond to the internal aspect of the implant, and the lines on the driver mount allow the surgeon accuracy of depth placement (Biomet 3i, Palm Beach Gardens, Florida).

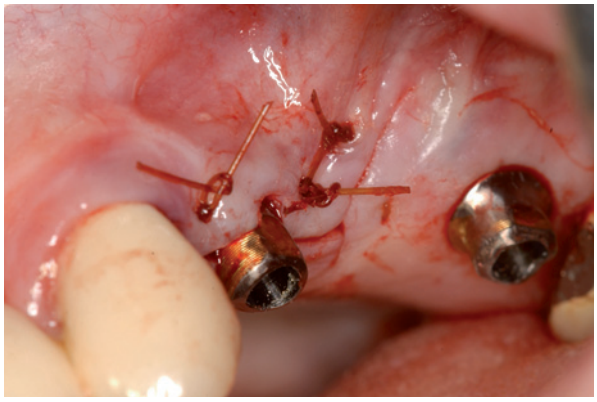


FIGURE 7-5 O, Abutments are placed, and the anterior incision is sutured. Note the lack of trauma to the flapless posterior site compared with the minimal flap involved with the anterior implant.

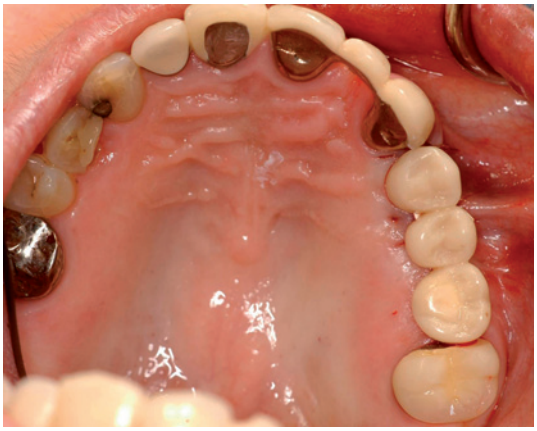


FIGURE 7-5 P, Temporary restoration in place. Note the appropriate contour of the restoration to the arch of the maxilla.

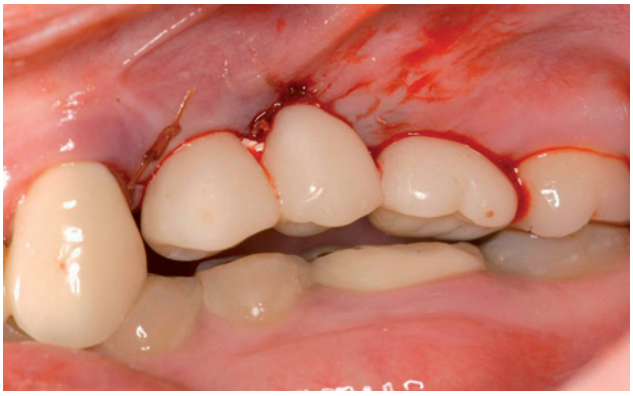


FIGURE 7-5 Q, Lateral view showing the occlusal freedom.

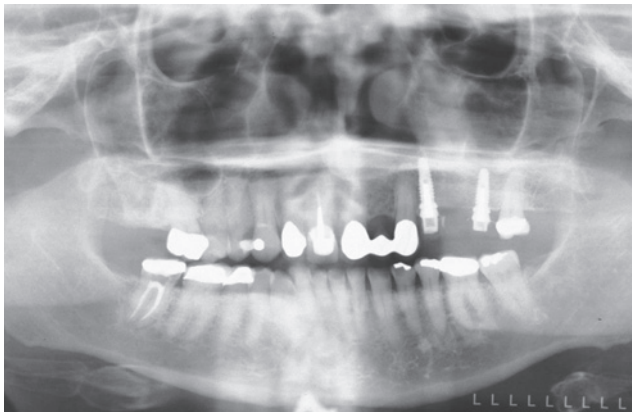


FIGURE 7-5 R, Postoperative panoramic radiograph.

which allows ease of abutment placement because of less restriction from emergence of the abutments.

The temporary fixed restoration is placed with a small reline of resin. The restoration is kept out of occlusion (Figure 7-5, P-R).

Anterior Maxillary Case with Cement Retention

DVD Images 7-4, A-R

This patient presented with three missing anterior teeth: the right lateral and central incisors and the left central incisor (DVD Figure 7-4, A-B). Palpation indicated sufficient bone for implant placement in the central incisor positions. A significant undercut was noted in the lateral incisor position.

Preoperative evaluation starts with an esthetic analysis. Using the patient's lower lip line as the guide, a new incisor edge is established (DVD Figure 7-4, C). From the setup, implant analogs are placed into the model (DVD Figure 7-4, D). The shoulders of the implant analogs are placed 3 mm apical to the planned gingival margin of the restoration. The fixed abutments are prepared to allow passive placement of the provisional restoration (DVD Figure 7-4, E).

The model with the diagnostic setup is duplicated in stone, and a vacuform is made. The vacuform has holes made in the planned implant locations (DVD Figure 7-4, F). Screws and tubes are placed into the model with the analogs in position, and the tubes are then ligated to the vacuform using acrylic (DVD Figure 7-4, G). This is now the surgical guide stent. The temporary restoration is finished and smoothed (DVD Figure 7-4, H).

At surgery, a crestal incision is made with sulcular incisions extending around two teeth distally, and the gingiva is raised in an envelope-type flap. No vertical incisions are

made. The surgical guide stent is placed, and the pilot drill is used to position the implants. A sequence of drilling is completed, marked by careful placement of guide pins and adjustment of the implant angulation, as necessary, to ensure accurate placement of the implants (DVD Figure 7-4, I-K).

The surgical guide is placed after the flap has been raised, and the bone is inspected to confirm thickness. A round bur with the extension is used to mark the sites for the implants. The surgical stent is removed, and the round bur is used again to define the entry point into the crest. Often this is necessary without the stent because the round bur is smaller in diameter than the metal tubes.

The surgical stent is replaced, and the pilot drill is used to prepare the sites. Guide pins are placed, and the sites are carefully evaluated for correct angulation. As can be seen in DVD Figure 7-4, I, the distal implant site needs to be angled more palatally to place the guide exactly in the prescribed position. The remaining drills are carefully used, with constant checking for accurate angulation using the drill guide (DVD Figure 7-4, J). The implants then are placed and the abutments secured. The implant may need to be rotated slightly a few degrees to achieve perfect positioning (DVD Figure 7-4, K).

After the abutments have been secured to the implants with screws (DVD Figure 7-4, L), the temporary restoration is tried in place, and a small amount of resin is used to achieve accurate margins and seating of the restoration. Incisions then are closed with resorbable suture and vertical mattress–type suturing. Occlusal clearance is confirmed.

The temporary restoration is cemented into position (DVD Figure 7-4, M). For this patient, the crestal incision and placement of the temporary restoration allowed gingival healing around the necks of the temporary prosthesis, without the need for sulcus development by pressure and blanching. The advantage of this method using an incision is that minimal pressure is exerted on the implants by the restoration through the abutments. Soft tissue can mature and form around the abutments, and after implant integration, the tissues can be shaped with pressure from the temporary device (DVD Figure 7-4, N-O). For this patient, implant-level impressions are made, and zirconium abutments are prepared in the laboratory (DVD Figure 7-4, P-Q). The new temporary prepares the patient for her final prosthesis (DVD Figure 7-4, R).

Anterior Maxillary Case with Computer-Generated Surgical Stent and Screw Retention of Provisional Prosthesis

This case involves the replacement of five anterior teeth. The patient initially presented with nonrestorable teeth (Figure 7-6, A). The teeth were extracted, and the sites were grafted with human mineralized bone, as described throughout this text (Figure 7-6, B). A removable temporary prosthesis was placed.

After 12 weeks for healing, diagnostic models are used to create an esthetic setup. This setup is duplicated in clear acrylic in the laboratory (Figure 7-6, C). To overlay the

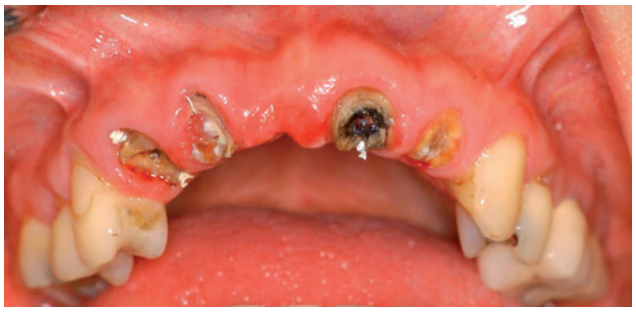


FIGURE 7-6 **A,** Preoperative view of anterior teeth before extraction.

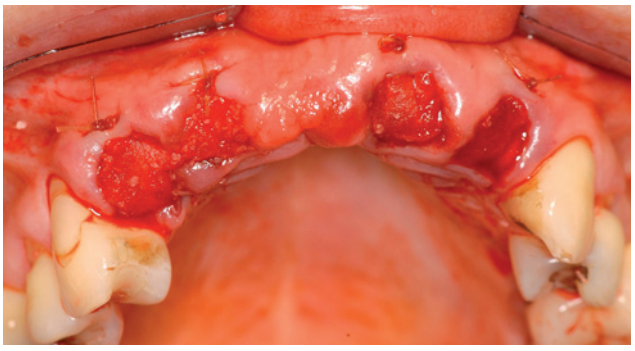


FIGURE 7-6 **B,** After the teeth have been extracted, the sockets are grafted with human mineralized bone.

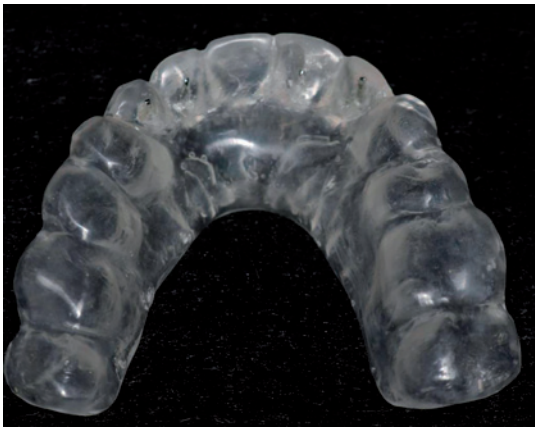


FIGURE 7-6 **C,** Clear acrylic duplicate of the esthetic setup is made in the laboratory.

radiographic stent on the patient's bone, six small lead-ball markers were placed below the level of the dental restorations (Figure 7-6, D). The patient then has a CT scan.

The CT scan must follow the protocol for the specific software used to create the surgical guide stent. Most scans use a 0 gantry angle, which places the beam parallel to the occlusal plane. The scan thickness will be 0.7 to 1 mm; other specific parameters are used for each software program. For the CT scan, the radiographic stent, with markers embedded, is placed in the patient's mouth, and the scan is exposed. A second scan with the radiographic stent by itself is then made. The data from each CT scan are placed on a CD in DICOM format. The patient then goes home and returns for the surgery when the guide stent and provisional prosthesis are ready.

Depending on the software program chosen, the CD is placed into a computer, and the data are combined for each scan. A "spline" is created around the arch of the jaw, and then perpendicular planes to the spline are created. Panoramic views are created by the software (Figure 7-6, E). Implants are placed into the cross-sectional images (Figure 7-6, F-G). The implant manufacturer is chosen, and the implant's diameter, length, and shape are chosen by using an implant library included with the software (IDENT, Tel Aviv, Israel). The computer

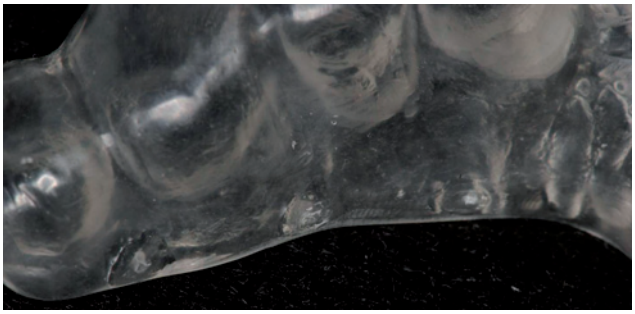


FIGURE 7-6 D, Small radiopaque markers are placed into the duplicated setup, beyond the occlusal plane. The markers should be placed in a plane that will not compete with scatter from dental restorations, thus the placement in the flange or palatal aspect of the duplicated setup.

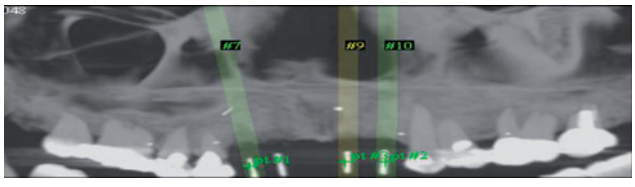


FIGURE 7-6 E, CT scan data are used to generate a panoramic image. The implants are placed using virtual surgery.

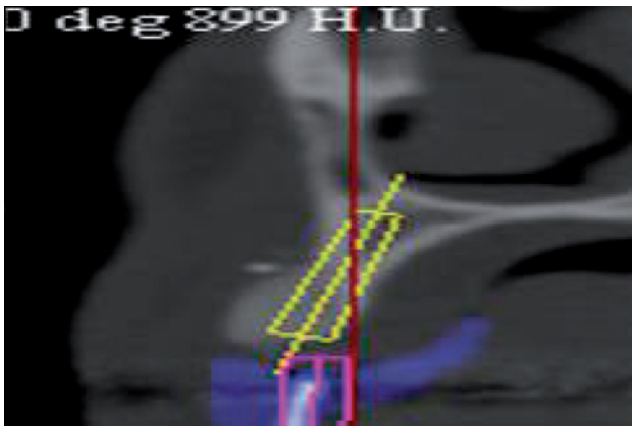


FIGURE 7-6 F, Cross-sectional images of the planned implants; the diameter, length, and shape depend on the specific implant chosen for each anatomic site. The yellow represents the implant, and the blue is the virtual image of the surgical guide stent.

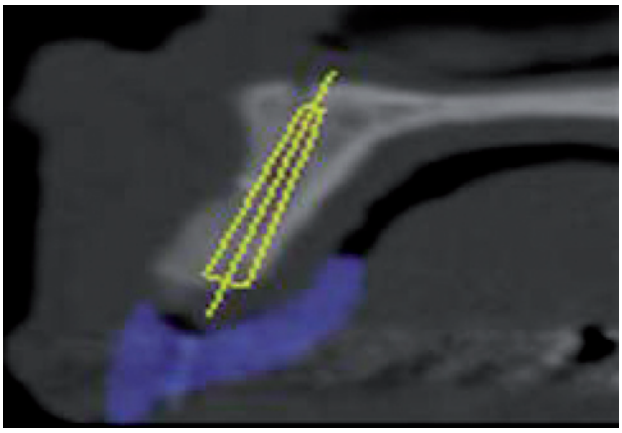


FIGURE 7-6 G, Cross section in the left central incisor location, within the planned surgical guide stent designed by the computer.

then designs the surgical guide stent. The final design is electronically uploaded to the manufacturer. The surgical guide stent is rapidly prototyped, and metal tubes are placed to allow accurate implant placement (Figure 7-6, H-I). The surgical stent will fit over the teeth to achieve accurate positioning for implant placement.

After receiving the surgical guide stent, the team initiates the laboratory procedure for provisional prosthesis fabrication. The guide stent is placed over the master model, and the pilot drill is used to create holes in the model. A drill press and an adjustable table are

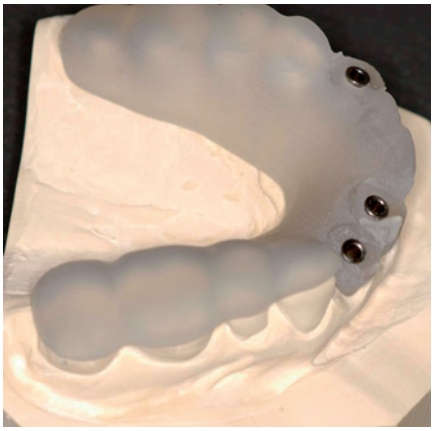


FIGURE 7-6 H, Surgical guide stent is fabricated after electronic transmission of the information designed by the virtual surgery.

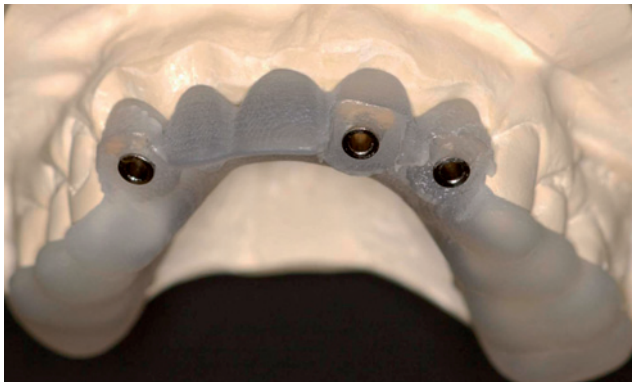


FIGURE 7-6 I, Surgical guide stent fits on the remaining dentition. The metal tubes are chosen to allow accurate orientation of the implants.

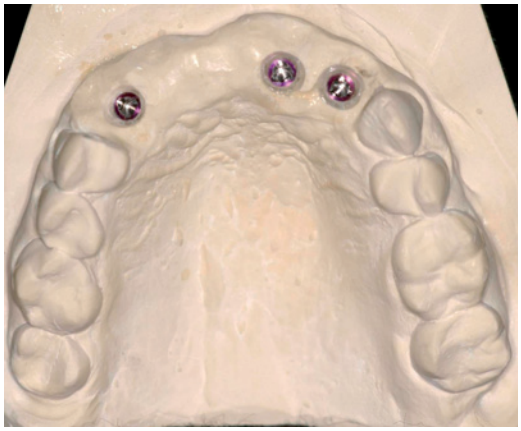


FIGURE 7-6 J, Surgical guide stent is placed over the master model, and the implant analogs are placed using the stent as a guide.

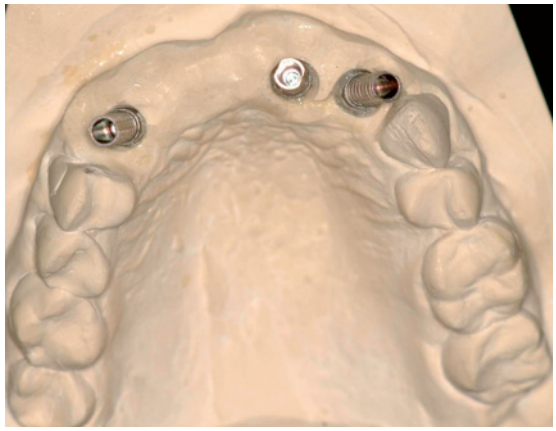


FIGURE 7-6 K, Fixed abutments are placed into the analogs and prepared as necessary.

recommended so that parallelism can be maintained with the larger drills needed to place the analogs in the model. The holes are made, and the analogs are placed at the depth decided by the computer, using the guide stent as the reference (Figure 7-6, J). For this case, screw-retained abutments are placed into the analogs and then prepared as necessary (Figure 7-6, K).

The provisional restoration is made using the diagnostic esthetic setup as a reference (Figure 7-6, L). The lingual aspects of this temporary restoration are left open so that it can be luted to the screw-retained abutments at surgery. Another option is to make the definitive provisional restoration, but small variations may be necessary at surgery.

The patient is seated and anesthetized. The surgical sites are confirmed (Figure 7-6, M). The stent is placed, and the pilot drills are used to mark the sites. A tissue punch is used to remove the gingiva. The implant sites are prepared with the guidance of the surgical stent (Figure 7-6, N). The abutments are then placed (Figure 7-6, O). The seating of the abutments is confirmed if necessary (Figure 7-6, P). The provisional prosthesis is then seated over the abutments, and resin is applied to lute them together. In the laboratory, additional acrylic is applied, then smoothed and contoured to achieve gradual emergence from the implants (Figure 7-6, Q). The prosthesis is seated with screws, which are tightened to achieve slight blanching; after the blanching disappears, the screws are tightened again until final seating is achieved (Figure 7-6, R).

The patient has an excellent esthetic result within hours (Figure 7-6, S). The screw retention of the prosthesis allows for removal anytime after surgery to refine the provisional restoration as necessary (Figure 7-6, T). Another advantage with screw retention is the pressure exerted on the soft tissues by the prosthesis and the retaining screws.

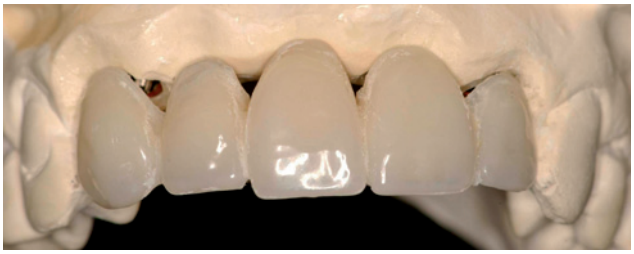


FIGURE 7-6 L, Provisional restoration is fabricated, mimicking the esthetic diagnostic setup. The lingual aspect is left open to allow luting of the provisional prosthesis to the abutments for screw retention.

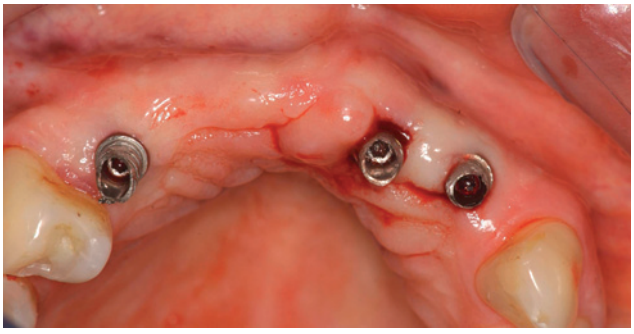


FIGURE 7-6 N, Three implants are placed using the surgical guide stent.

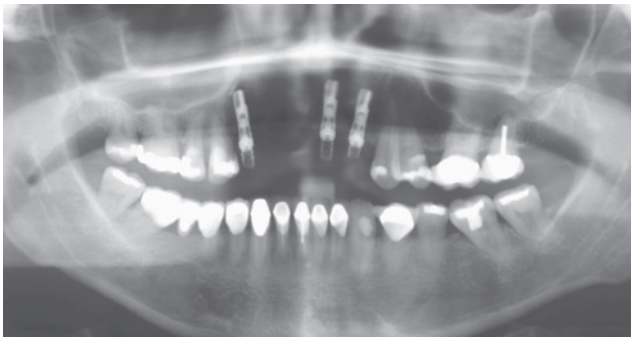


FIGURE 7-6 P, Panoramic radiograph showing the implants and abutments in correct position.

The disadvantage is that this method can transmit significant forces to the implants. If care is not taken, the implants can be overloaded and may not integrate. This method is used with generous release of the soft tissues by a large gingivectomy with the tissue punch, scalpel, or laser to help form the sulcus and prevent pressure-induced implant failure.

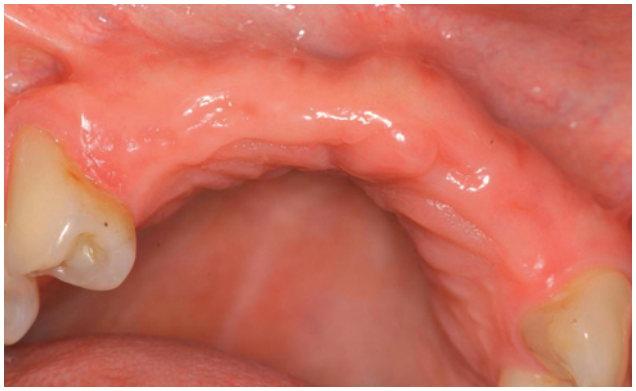


FIGURE 7-6 M, At surgery, the occlusal view demonstrates adequate width for implant placement.

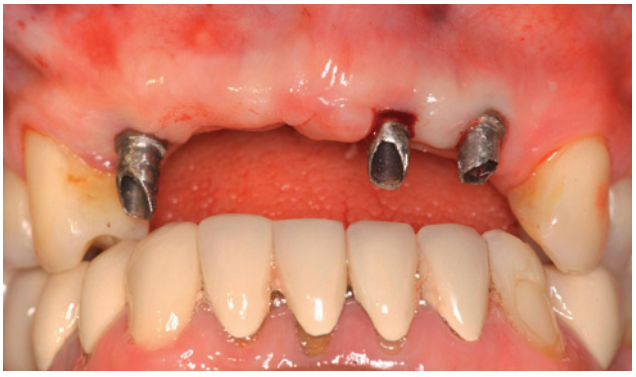


FIGURE 7-6 O, Abutments are placed.

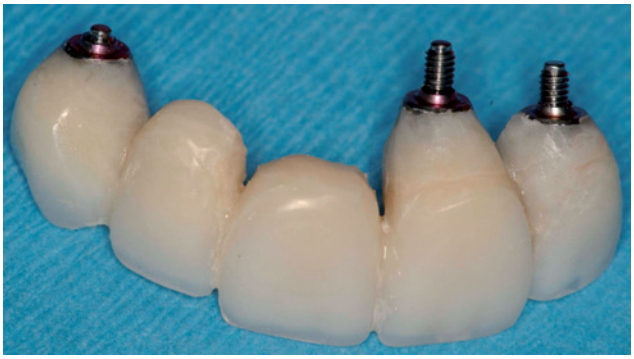


FIGURE 7-6 Q, Temporary restoration is placed, and the abutments are luted to it with resin. In the laboratory, more acrylic is placed and smoothed to promote gingival shaping.

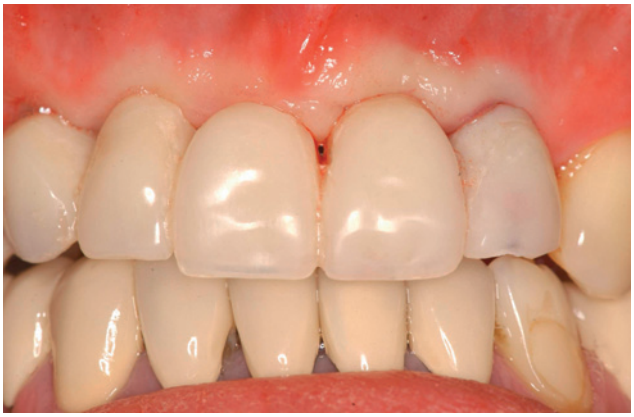


FIGURE 7-6 R, Provisional restoration is placed and secured to the implants by the retaining screws. Note the blanching of the gingiva after gentle screw tension has been achieved.

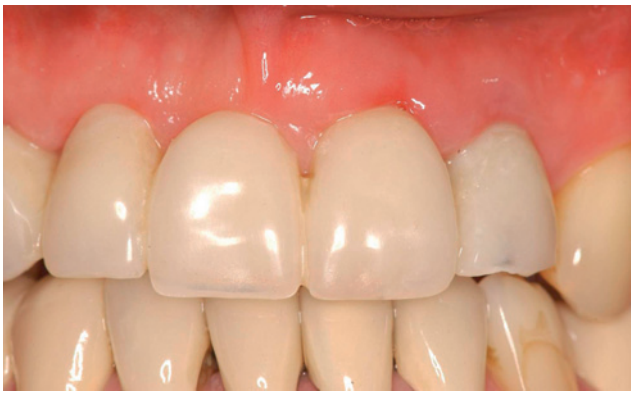


FIGURE 7-6 S, Two-day follow-up view. Note the excellent gingival form. (Prosthetics by Dr. Tyler Laseigne and Dr. Paulino Castellon.)

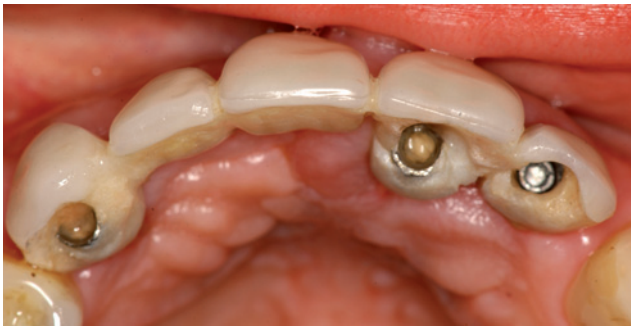


FIGURE 7-6 T, Occlusal view showing screw retention of the prosthesis.

Immediate Provisionalization Using CT Guidance

Replacement of the anterior maxillary dentition

Patients with fixed prostheses retained by natural teeth may develop recurrent caries and require removal and replacement. These patients will have teeth that are restorable and teeth that require removal. The implant planning process should start as early as possible for these patients. Coordination of tooth removal, grafting of the extraction site, and prosthetic planning for implant-supported teeth replacement improves the prognosis for the final therapy.

The patient with a long-span restoration with recurrent decay requires removal of the current prosthesis and assessment of the dentition. The restorative dentist must determine which teeth are restorable and which are not. Provisionalization of the removed bridge is required to allow team coordination (Figure 7-7, A). The surgeon then removes the selected teeth, grafts the sockets as needed, and perhaps performs ridge augmentation if horizontal problems will compromise the eventual esthetic restoration (Figure 7-7, B-D). After the sites have healed for 3 months, the provisional prosthesis is duplicated in radiopaque material for CT scanning and planning (Figure 7-7, E). The scan is taken, and the DICOM data are entered into the CT planning software.

In this patient, four teeth must be replaced, including the right and left central incisors, the left lateral incisor, and the left canine. Because of space limitations and the patient's high smile line, it is decided to replace these four teeth with three implants. The size of the central incisors allows implant spacing of at least 3 mm. The implant platform size is 4 mm. The implant lengths are chosen to engage the nasal floor. The angulation of the implants is designed so that the implant orientation axis emerges lingual to the incisive edge. The labial surface of the implant is 2 mm palatal to the emergence of the planned crown. The plan provided by the CT software (Simplant Pro, Materialise, Brussels, Belgium) is approved by all members of the team (Figure 7-7, F-I).

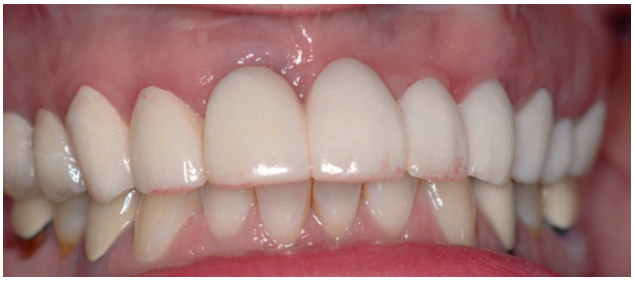


FIGURE 7-7 A, This patient is to have her old long-span fixed restoration removed and a provisional fabricated and cemented with temporary cement.

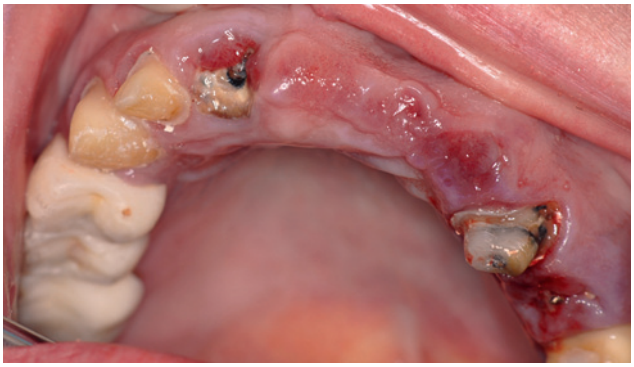


FIGURE 7-7 B, Provisional prosthesis is removed, revealing that tooth 8 is necrotic and the root tips of teeth 11 and 13 are covered with granulation tissue.

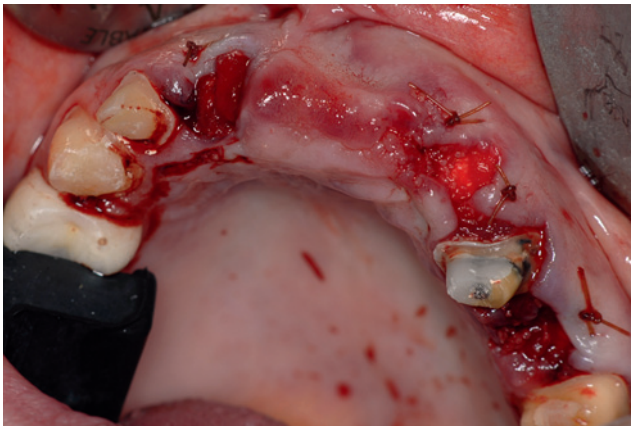


FIGURE 7-7 D, Sites are sutured, and the extraction sites are covered with a short-term collagen dressing (CollaPlug, Zimmer Dental). This preserves the location and symmetry of the attached gingiva.

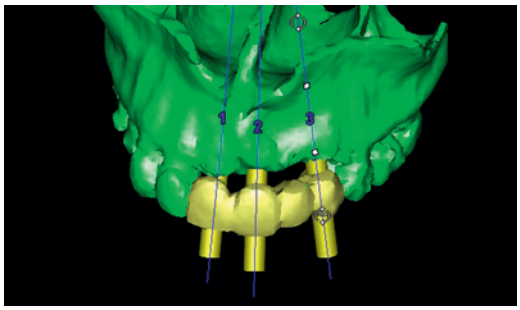


FIGURE 7-7 F, CT scan DICOM data are entered into a computer, and planning is accomplished. In this case, three implants are virtually placed. This three-dimensional image shows the implants spaced and located in positions that will result in an implant-supported restoration.

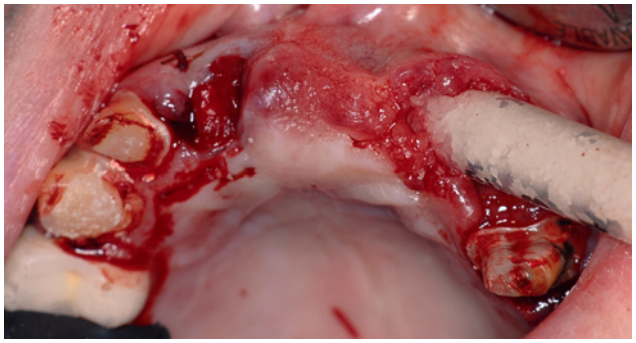


FIGURE 7-7 C, Teeth are removed with minimal tissue reflection. A subperiosteal tunnel is used to graft the thin alveolus from the left central incisor, lateral incisor, and left canine locations.

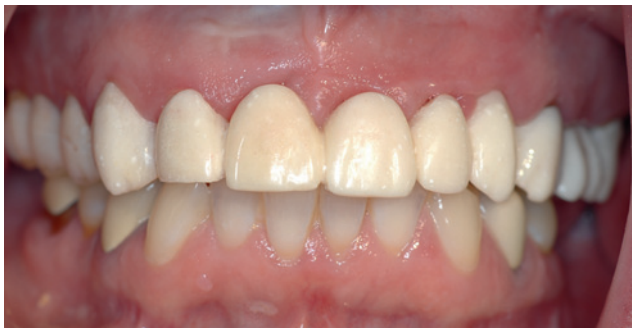


FIGURE 7-7 E, Provisional restoration has been duplicated in a radiopaque material. In this case, acrylic impregnated with barium sulfate (15% by volume) was used. Other materials, such as a radiopaque resin, also can be used.

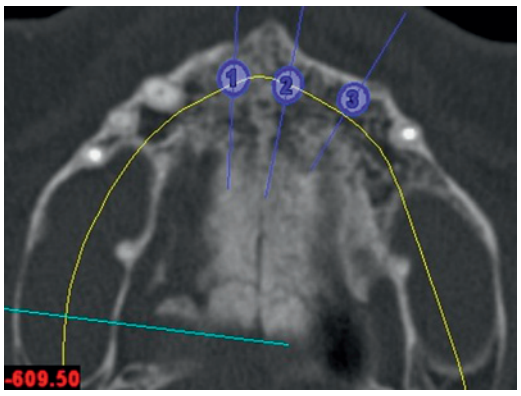


FIGURE 7-7 G, Axial view shows the planned positions of the implants within the confines of the cortical bone.

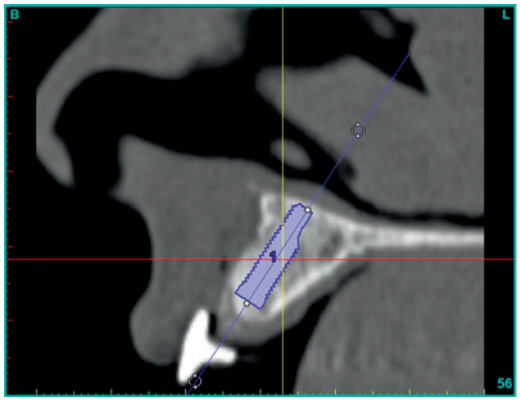


FIGURE 7-7 H, Cross-sectional image of the plan for one of the implants shows the angulation and depth, which will result in a distance of 3 mm from the planned gingival margin to the implant platform, with emergence of the implant palatal to the incisor edge.

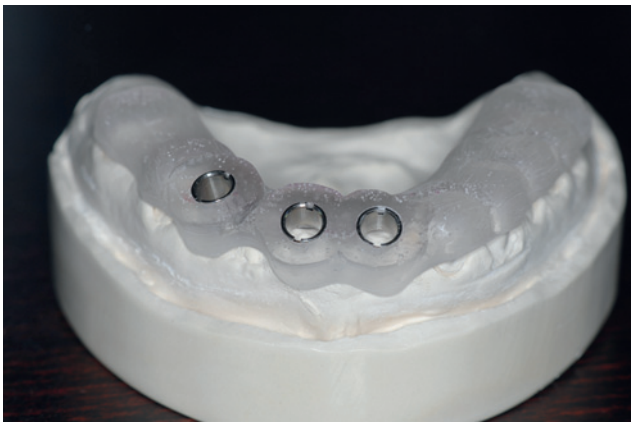


FIGURE 7-7 J, Guide stent is rapid prototyped to the model of the preparations. It is tooth borne and covers all the teeth in the maxillary arch. No fixation screws are ordered because of the stable status of the remaining occlusion.

The plan is electronically transmitted to the manufacturer for guide stent fabrication. A model of the patient with preparations also is sent. This model is scanned for stent fabrication. The guide stent with three tubes is manufactured (Figure 7-7, J). Because the patient's occlusion is balanced and stable, it is decided to place a provisional restoration immediately without occlusal contacts.

Implant analogs are attached to system- and implant-specific prosthetic parts. Care is taken to confirm that these parts engage the grooves within the master cylinders of the surgical guide stent (Figure 7-7, K). The next phase is fabrication of the provisional, which will be placed immediately after implant insertion. The provisional abutments

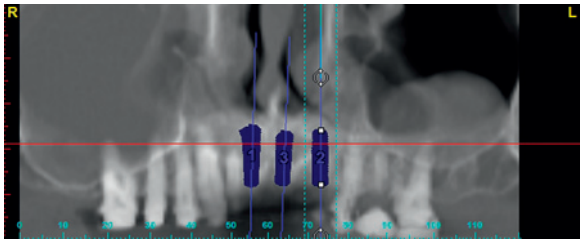
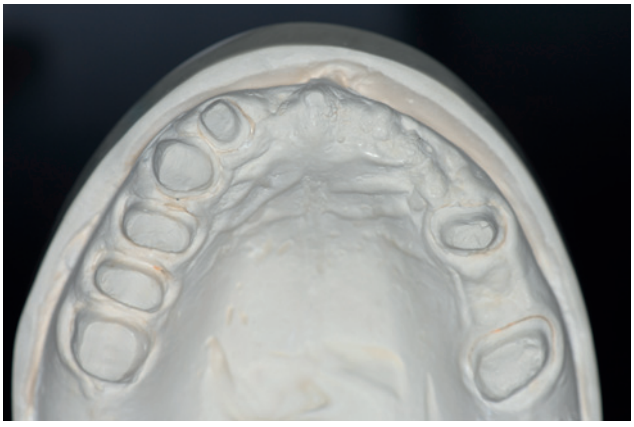


FIGURE 7-7 I, CT planning software can create panoramic image with the implants in position as planned. This image is useful for confirming that the implants will not be too close to or impinge on the adjacent teeth.

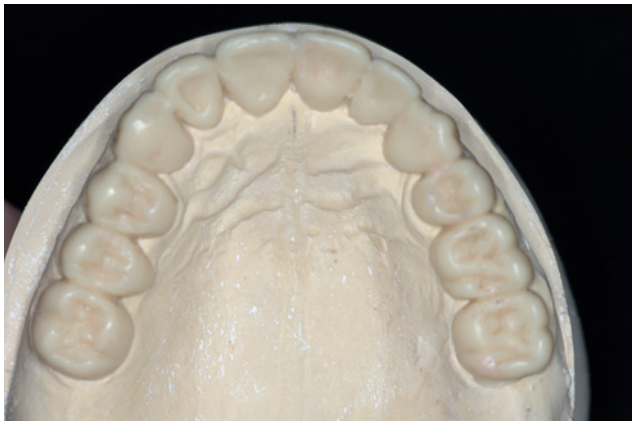
FIGURE 7-7 K, Implant analogs are connected to specific prosthetic connectors, which fit into the master cylinders. These are placed into the master tubes on the guide stent, where they engage small grooves within the cylinders. This identifies and matches the rotation of the internal antirotational aspects of the implants.

will be prepared, and a four-unit fixed temporary restoration will be fabricated.

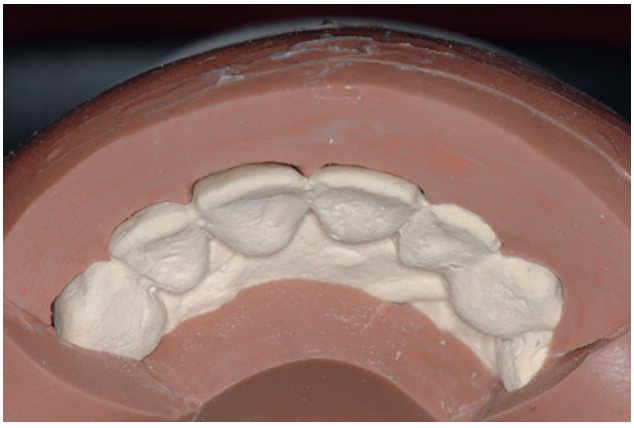
To create such a provisional with the final esthetics, the restorative dentist must have established the position of the teeth using diagnostic casts. A master cast is made of the patient's preparations (Figure 7-7, L). A waxup of the planned final restoration is created and confirmed by trying it in the patient (Figure 7-7, M). This waxup then is duplicated in stone. A silicone matrix is made of the planned final restoration to create the provisional (Figure 7-7, N). The surgical guide stent with the implant analogs in place is used to locate the analogs accurately in the master cast. The implant sites are marked, and holes are made in the case. The stent is positioned on the model, and the analogs are secured with stone. The stent then is removed, leaving the implant analogs in the model similar to an implant-level transfer impression and



● **FIGURE 7-7 L,** Prior to stent fabrication, a model of the patient's tooth preparations is made to allow for a diagnostic, esthetic waxup.



● **FIGURE 7-7 M,** Waxup was completed and tried in the mouth. The patient approved the esthetics and the plan for restoration of all the maxillary teeth. The waxup was duplicated in stone.



● **FIGURE 7-7 N,** Silicone matrix is made to outline the planned form of the anterior teeth. This is used in the fabrication of the provisional and final restorations.

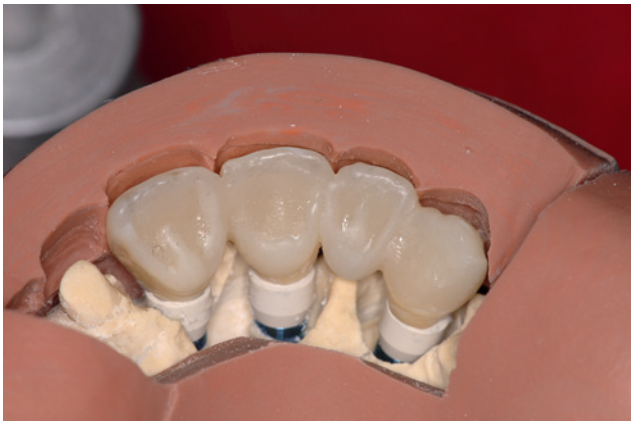
● **FIGURE 7-7 O,** After the analogs are connected to the surgical guide stent, holes are made in the master cast. The analogs are passively positioned within the master cast and secured in place with stone. The prosthetic connectors are removed. Provisional abutments then are placed into the analogs and conservatively prepared to fit within the matrix.

cast. The provisional abutments are placed onto the analogs and prepared to fit within the confines of the previously created matrix (Figure 7-7, O). The provisional four-unit restoration is then made to fit onto the provisional abutments with margins polished (Figure 7-7, P). The matrix is removed, showing the restoration on the abutments, prior to actual implant placement in the patient (Figure 7-7, Q-R).

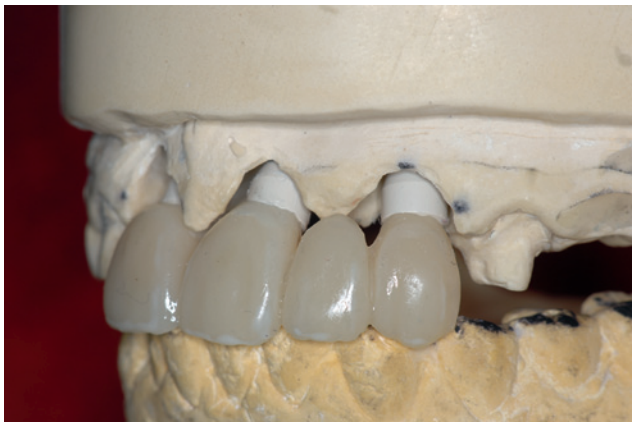
Surgical procedure

On the day of surgery, the team is present in one operatory. The patient's face is prepared with povidone-iodine (Betadine) solution. The patient had rinsed with an antibacterial liquid for 3 days prior to implant surgery to reduce the bacterial load. A local anesthetic is infiltrated, and the provisionals are removed to allow placement of the guide stent on the tooth preparations and access to the edentulous ridge. The surgical guide stent is placed over the teeth and held in position by the retention to the teeth and finger pressure (Figure 7-7, S).

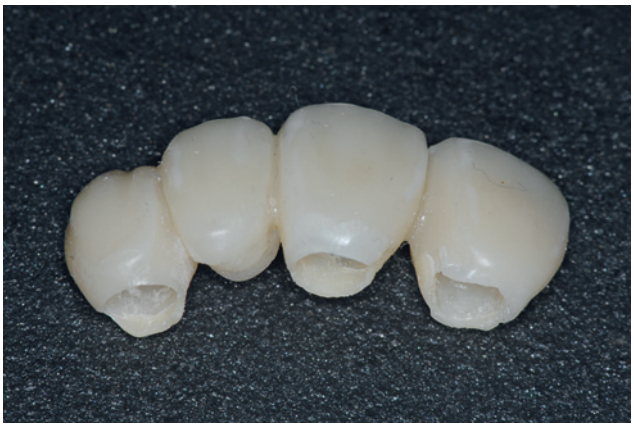
The surgical sequence begins with removal of a small circle of gingiva using the tissue punches. After removal of the gingiva, a countersinking burr is used to initiate the osteotomy. This is especially important when the ridge is not flat. After this is used, the drill sleeves are used in graduating sizes, and one implant is placed and positioned flush with the master tube in the correct orientation of the grooves. The remaining two implants are then placed. The



● **FIGURE 7-7** **P,** Provisional four-unit, fixed restoration is fabricated to fit onto the provisional abutments. This is done using the matrix of the diagnostic waxup as a guide.



● **FIGURE 7-7** **Q,** Provisional restoration on the provisional abutments on the master cast. The surgical guide stent was used to position the implant analogs.



● **FIGURE 7-7** **R,** Provisional restoration is removed and sterilized with Betadine before it is placed in the mouth.

● **FIGURE 7-7** **S,** At the time of surgery, the surgical guide stent is sterilized by soaking in a Betadine solution. Small grooves are made to identify the very small grooves that are used to align the implants with the plan. A marking pen is used to outline the grooves. After infiltration of a local anesthetic, the stent is placed and held in position, with excellent stability.

surgeon confirms that the grooves align to ensure that the abutments and prosthesis will fit as planned (Figure 7-7, T). After the final implant has been placed, the implant driver mounts are unscrewed and removed. The guide stent then is removed, the implant sites are inspected and irrigated, and the soft tissue is trimmed if necessary (Figure 7-7, U). The bone profiler may be needed if the implants were countersunk and to conform with the flare of the provisional abutments. The abutments are placed exactly as oriented on the model. They are secured with screws, which are hand-tightened (Figure 7-7, V). The provisional restorations are placed. Small adjustments may be needed on the provisional restoration because of very small differences between the model and the patient. After the restoration has been seated and the occlusal clearance confirmed, the restoration is cemented with temporary cement (Figure 7-7, W).

Antibiotics and pain medication are prescribed as necessary. Oral hygiene instructions are given and reinforced at the follow-up visits. Within a few weeks, these patients have a very acceptable esthetic appearance (Figure 7-7, X). The postoperative radiograph shows the implants in position as planned. The final restoration is made 4 months after implant placement (Figure 7-7, Y-Z).

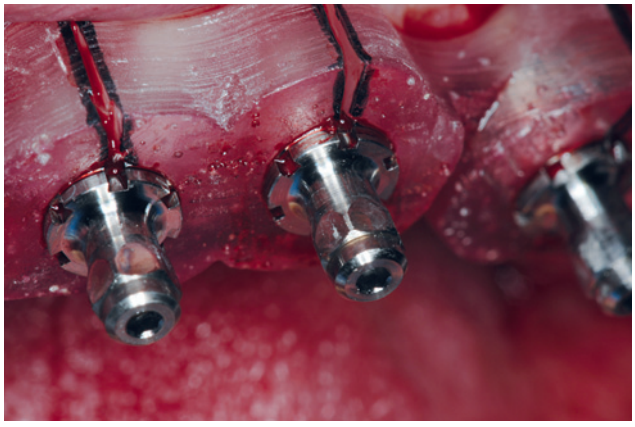


FIGURE 7-7 **T,** Drills in graduating sizes are used first to place one implant and then the remaining two. Each driver mount must be rotated to line up the groove in the driver mount with the groove in the master cylinder. This allows for accurate rotational alignment of the provisional abutment as planned on the master cast.

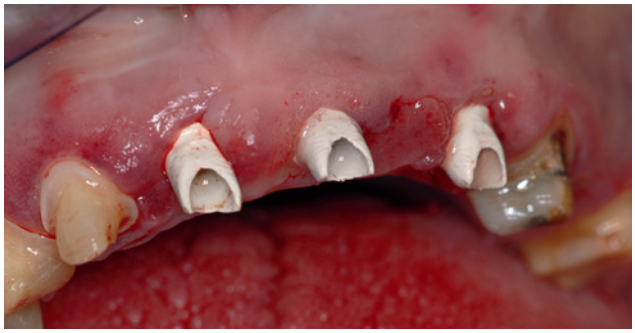


FIGURE 7-7 **V,** Abutments are secured into the implants, maintaining their position as recognized on the master cast. Seating of the abutments is confirmed by direct vision, palpation, and radiographs as necessary.

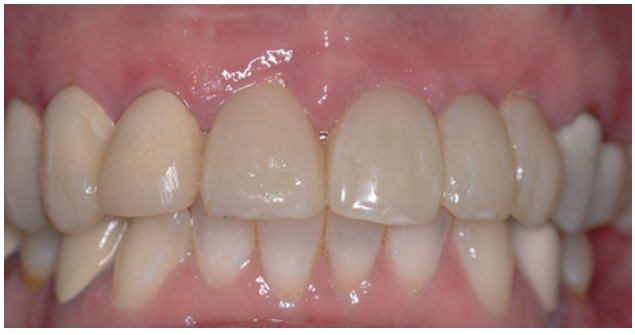


FIGURE 7-7 **X,** One month after implant surgery. Note that the soft tissue is healing nicely.

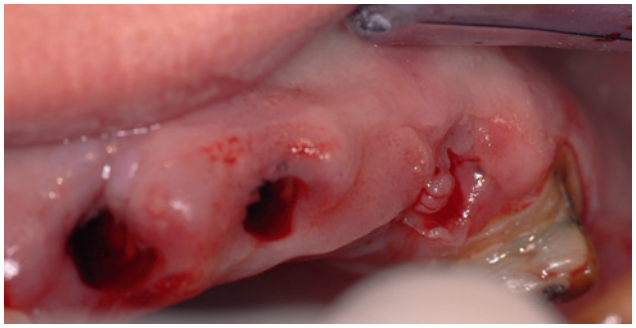


FIGURE 7-7 **U,** After the implants have been placed and aligned, the driver mounts are removed, and the stent then is removed. The implant sites are irrigated and cleaned of bone debris and soft tissue tags.

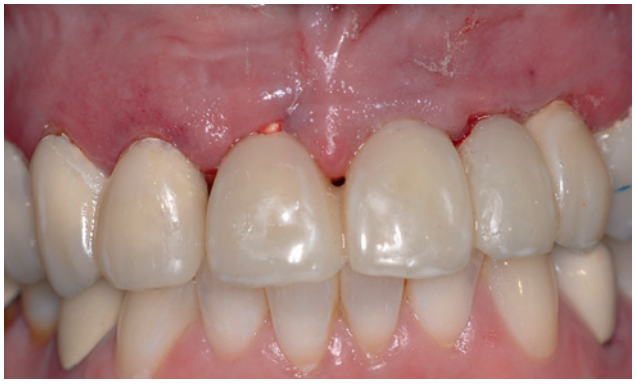


FIGURE 7-7 **W,** Provisional restoration is tried in place. For this patient, a small adjustment is necessary in the distal aspect of the posterior implant in the temporary. After the provisional has been seated and occlusal clearance confirmed, the provisional is cemented with temporary cement.

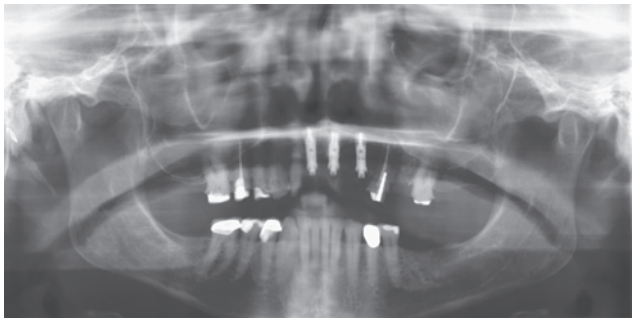


FIGURE 7-7 **Y,** Postoperative panoramic radiograph.

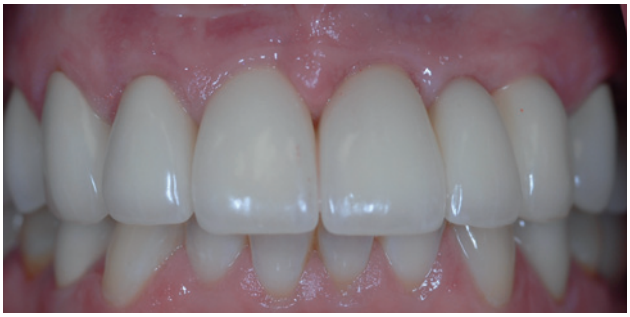


FIGURE 7-7 **Z,** Final restoration. All ceramic crowns on implant abutments with ceramic cores. (Prosthetics by Dr. Ace Jovanoski.)

Posterior Maxillary Case with Transfer after Implant Placement

The previous methods involve extensive preoperative planning and time in the laboratory. This method involves accurate placement of the implants with an intraoperative transfer using snap-on transfer copings. The impression is sent to the laboratory, and within days a multiunit provisional can be placed. This method is extremely versatile, as described earlier for single-tooth immediate provisional restorations.

This case involves a woman who has a fractured first premolar in need of extraction (Figure 7-8, A). The premolar is the anterior abutment for a long-span bridge abutting the second molar. She wants an implant-borne restoration of the missing teeth. Her treatment plan calls for sectioning the bridge and extracting the tooth, with implants placed posterior to the extraction site. After 4 months, the posterior two implants would be exposed and a third implant placed in the premolar site, with immediate provisionalization of the quadrant.

At the time of tooth extraction, an incision is made around the sulcus of the premolar, with posterior extension on the crest and vertical release at the molar tooth. The first premolar is fractured (Figure 7-8, B). The tooth is extracted, and two implants are placed posteriorly (Figure 7-8, C). The extraction site has no labial bone, but it does have palatal,

CT-Guided Anterior Maxillary Surgery with Immediate Provisionalization

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for CT-guided anterior maxillary surgery with immediate provisionalization performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient's treatment plan calls for removal of the provisional restoration and placement of three implants using a CT-generated surgical guide stent, placement of three provisional abutments, and cementation of a four-unit fixed temporary bridge.

The bridge is removed, and a local anesthetic is infiltrated. The surgical guide stent is fitted in place over the teeth, and its stability is confirmed. The tissue punch drill is used first and then a countersink drill, which initiates the osteotomy sites in the uneven crestal bone.

The first implant site is prepared through implant placement. A drill sleeve corresponding to the 2-mm-diameter drill is used to the appropriate depth. The next-sized drill sleeve is placed into the master cylinder, and the next-sized drill is used. After the final drill size has been used, the implant is placed.

The implant is removed from its packaging, and a length-specific driver mount is secured to it. The implant is placed until the driver mount is flush with the master cylinder. Note that constant pressure is placed to make sure the guide stent is perfectly positioned on the teeth during all facets of the implant preparation procedure.

After the first implant is placed, the next two implants are placed using a similar operating procedure. Care is taken to prepare each site with slow drill speeds to limit bone trauma from heating of the burs. After the last implant has been placed, the hand ratchet is used to turn the implants to align the driver mount with the slots in the master cylinders. The driver mounts are loosened and removed one by one, and the guide stent then is removed. The implant sites are irrigated, and loose tissue ends are trimmed as necessary. The abutments are placed in the exact orientation in which they were placed in the model. After the abutments have been screw retained, their seating is confirmed by careful inspection, often aided by a dental explorer. The temporary bridge is tried in place and, when necessary, modified to seat perfectly on the abutments. Cotton is placed in the screw holes on the abutments. The occlusion is adjusted, and the provisional is cemented with temporary cement. The provisional is not in contact with the opposing dentition, yet it provides the patient with an esthetic, comfortable restoration.

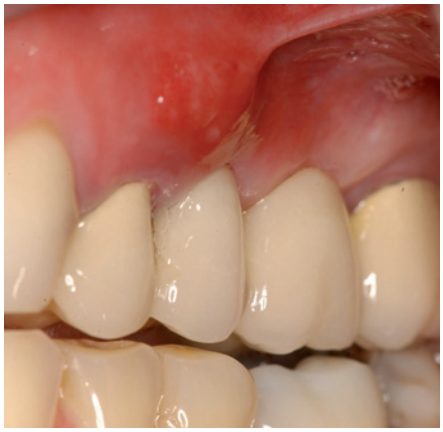


FIGURE 7-8 A, Patient presents with a fractured first premolar, which is the anterior abutment for a long-span bridge to the second molar.

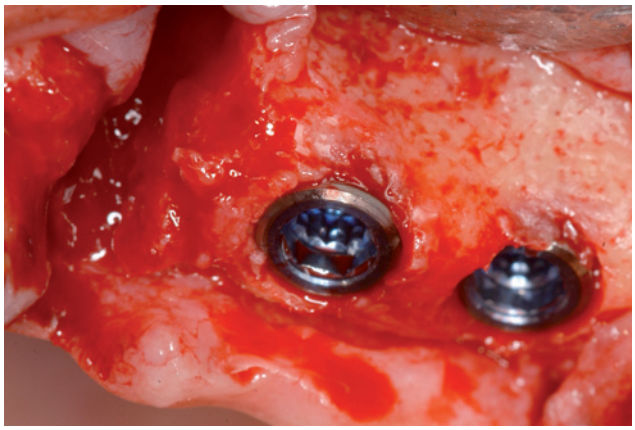


FIGURE 7-8 C, Tooth is removed easily. The site is gently curetted to remove gross granulation tissue. In the second premolar and first molar locations, two Prevail implants (Implant Innovations) are placed; each is 4 mm in diameter and 11.5 mm long, with a 4.8-mm platform.

mesial, and distal bone, forming a three-wall defect. Human mineralized bone allograft is placed (Figure 7-8, D). The periosteum is released, and a primary closure is achieved.

Four months later, the patient returns for placement of the first premolar implant and immediate provisionalization (Figure 7-8, E-F). Preoperative measurements of the gingiva and interocclusal space indicate that the abutments should have 2-mm gingival collars and 5 mm in abutment height. This would leave at least 2 mm of space to the opposing occlusion. The parts ordered before surgery, to be present at surgery, include the following:

- Three abutments
- Three gold screws to retain the abutments to the implants
- Three transfer copings matching the abutments

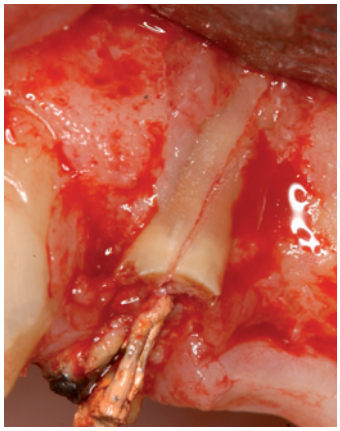


FIGURE 7-8 B, Incision around the neck of the first premolar is combined with a posterior crestal incision to the second molar. A vertical release incision is made just anterior to the second molar. The premolar tooth is obviously fractured.

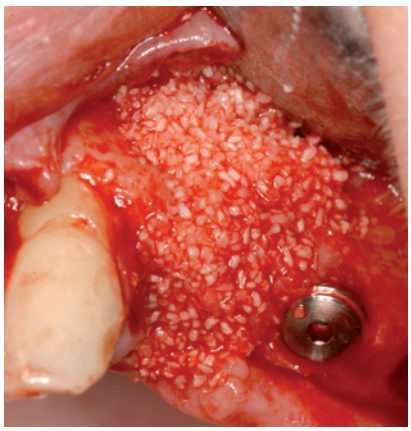


FIGURE 7-8 D, Tooth extraction site is irrigated and grafted with 0.5 ml of human mineralized bone. The periosteum at the extraction site is released, and tension-free closure achieved. No prosthesis is placed to avoid pressure on the surgical sites.

- Three plastic protection caps, which are placed to prevent trauma between surgery and prosthesis delivery
- Three analogs of the abutments

After a local anesthetic has been infiltrated, a tissue punch is used to expose the posterior two implants, and the abutments are placed. This allows accurate positioning of the third implant, using the implants already placed as guides. Because an abutment will be placed after the implant has been seated, a tissue punch is used to create the gingival contour. An incision then is made connecting the sulcus of the adjacent tooth and the adjacent implants (Figure 7-8, G). No vertical incisions are used.

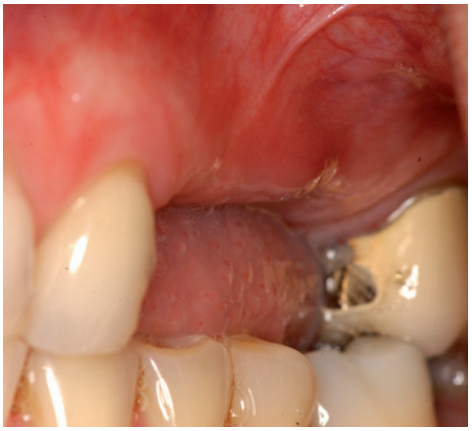


FIGURE 7-8 E, After 4 months, the patient returns for implant placement into the grafted site and immediate provisionalization.

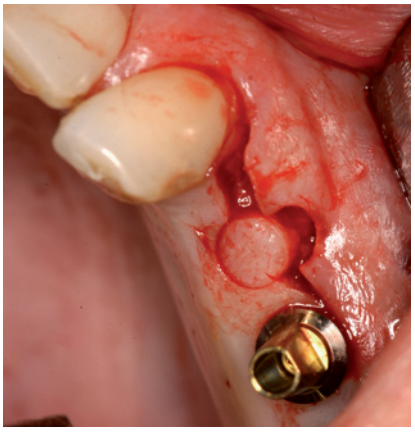


FIGURE 7-8 G, Tissue punch is used to remove a circular patch of tissue to allow for passive closure around the abutment, which will be placed after implant placement. A conservative incision is made halfway around the anterior canine and around the implant, allowing direct visualization of the bone graft.

The bone from the graft is excellent and allows placement of an implant 4 mm in diameter with a 4.8-mm expanded platform. A guide pin is placed after the pilot drill has been used to confirm accurate positioning (Figure 7-8, H). The implant is placed 3 mm apical to the planned gingival margin, which is slightly more apical than the adjacent implants. The radiofrequency index is 76 after implant placement. The "nonprepable" abutment (Provide, Implant Innovations) is placed and secured with the gold screw (Figure 7-8, I). The incisions are closed with 4-0 chromic suture in a vertical mattress fashion to evert and coronally reposition the gingiva.

The transfer copings are snapped onto the abutments (Figure 7-8, J), and an impression is made using a closed-tray

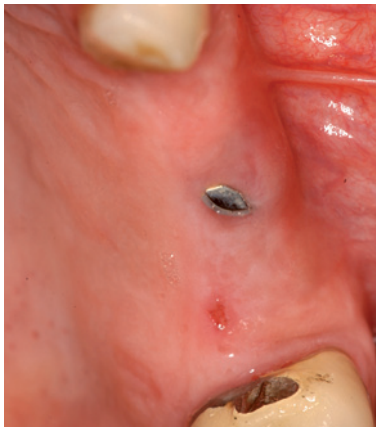


FIGURE 7-8 F, Occlusal view showing a small exposure of the implant placed into the second premolar site.

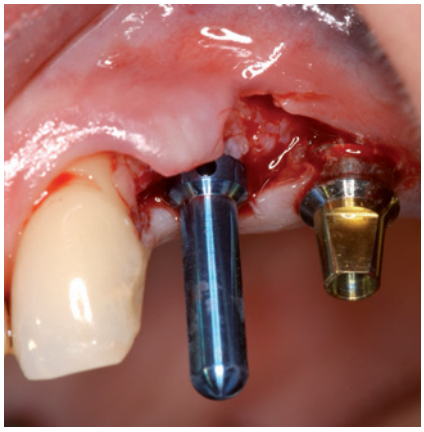


FIGURE 7-8 H, Bone graft works well, and the implant site is prepared. The abutments are placed before implant site preparation to guide the implant placement. A guide pin is used to confirm accurate orientation.

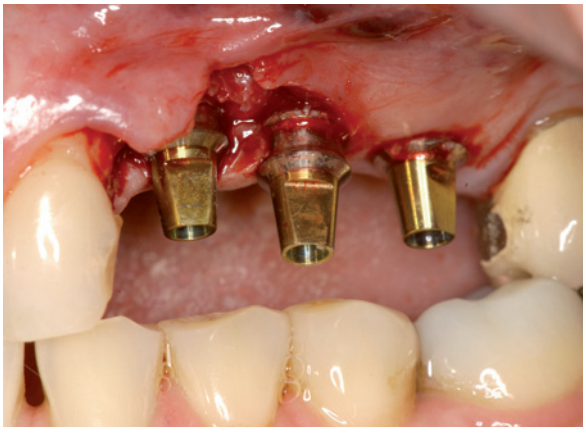


FIGURE 7-8 I, Implant is placed and the abutment positioned. Sufficient space exists for the restoration. The small incisions are closed with two vertical mattress sutures.

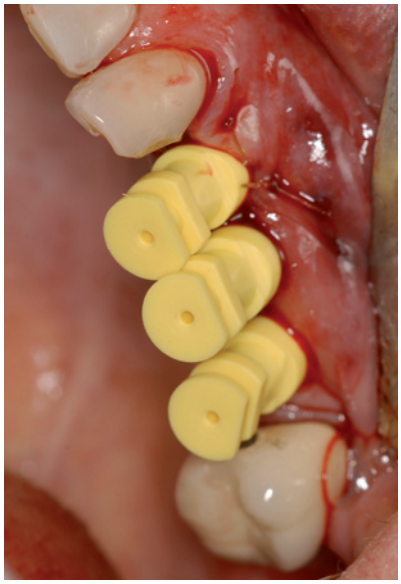


FIGURE 7-8 J, Snap-on transfer copings are placed in 1 minute. This is a simple, efficient method for transfer.

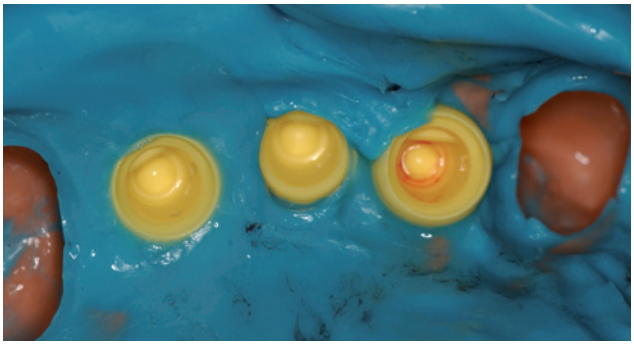


FIGURE 7-8 K, Closed-tray impression is taken, and the transfer copings are removed within the impression.

technique. After the appropriate time for setting of the impression material, the tray with transfer copings is removed (Figure 7-8, K). The analogs are snapped into the transfer copings within the impression (Figure 7-8, L). The protection caps are snapped onto the abutments in the patient's mouth (Figure 7-8, M).

The impression is delivered to the laboratory, along with an opposing model and an example of the shade of the teeth. The model is poured, and a fixed provisional prosthesis is fabricated out of occlusion. The provisional restoration is seated within 7 days of implant placement (Figure 7-8, N-S).

Chair time for this technique consists of the surgery time to place the implants, insert the abutments and secure them with screws, snap on the transfer copings, take the impression, and then place the protection caps. No chairside

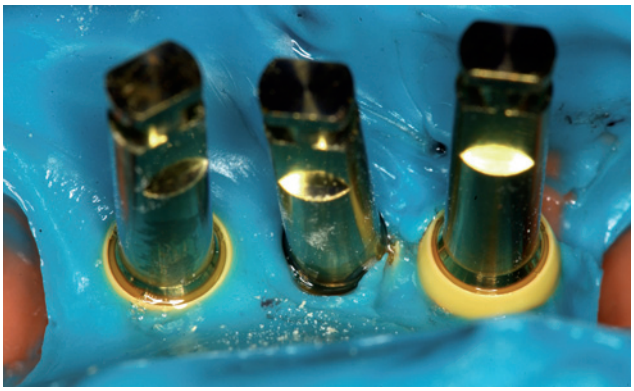


FIGURE 7-8 L, Analogs are snapped into the copings. The impression then is sent to the laboratory for fabrication of the provisional prosthesis. Depending on laboratory support, the provisional prosthesis, out of occlusion, can be delivered within hours or days. (Prosthetics by Dr. Paulino Castellon.)

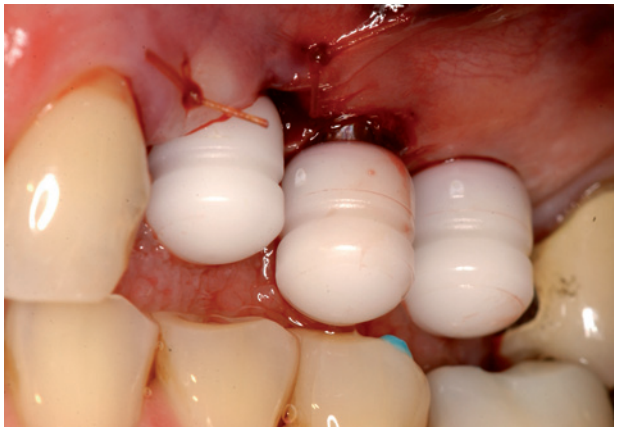


FIGURE 7-8 M, Plastic protection caps are snapped onto the abutments to prevent trauma to the adjacent soft tissues from the sharp edges of the abutments.

adjustments are necessary. The impression tray is a conventional tray used for alginate impressions. The impression involves the use of thick putty and a wash of Aquasil, which does not require mixing. The technique for placing the temporary involves removal of the protection caps, which takes less than 1 minute, and then snapping on the three units. The occlusion is checked and adjusted if necessary, but because of the accuracy of the transfer impression, minimal adjustments are needed. The provisional bridge can be cemented if patient compliance with a soft diet is questionable.

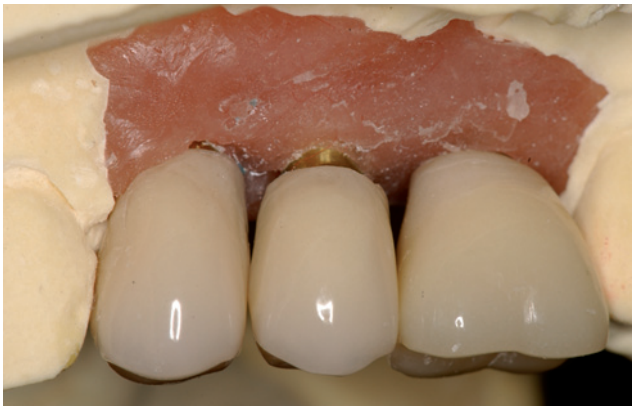


FIGURE 7-8 **N,** After the model has been poured, a temporary three-unit provisional restoration is fabricated.

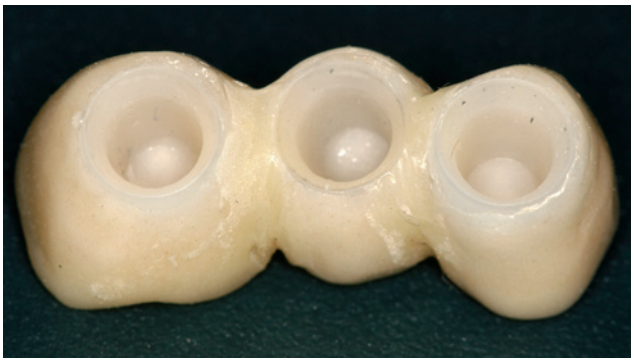


FIGURE 7-8 **P,** Inside of the bridge shows the snap-on wax copings used to fabricate the temporary prosthesis.

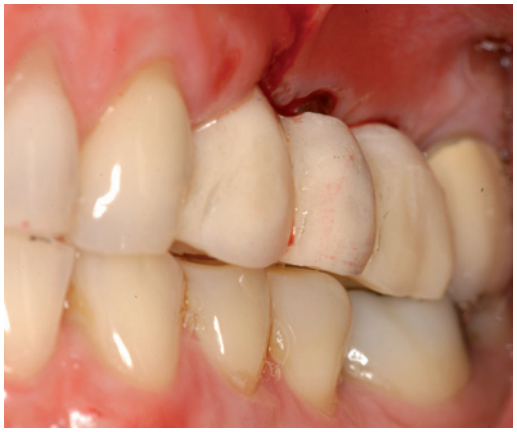


FIGURE 7-8 **R,** Lateral view showing supragingival margins for the provisional prosthesis. Light occlusal contact is present only on the posterior implant, which is integrated.

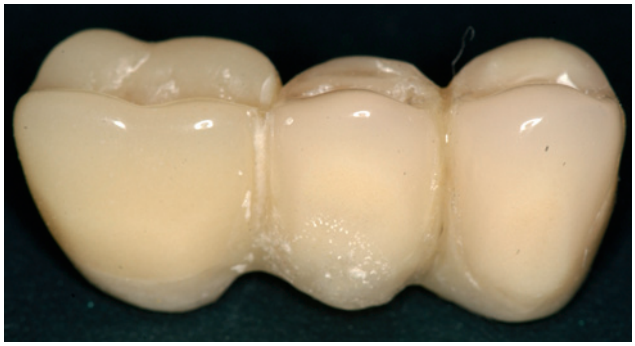


FIGURE 7-8 **O,** Three units are splinted together and trimmed to promote gingival maintenance.

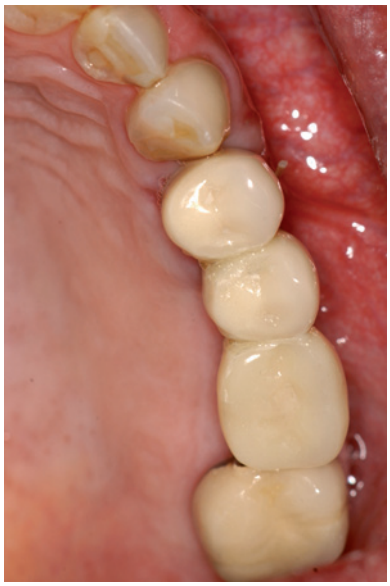


FIGURE 7-8 **Q,** Restoration is snapped onto the abutments. This occlusal view shows restoration of the arch form.

Posterior Units with Immediate Temporary Prosthesis with Splinted Implants

This case demonstrates the use of individual temporary crowns, which are relined and luted together with resin at the time of implant placement to form a splinted fixed provisional restoration. The advantage with this technique is the flexibility that allows for small discrepancies between implant placement and preoperative planning. This technique uses conventional models and conventional laboratory procedures rather than more complex and expensive CT-generated models.

Preoperative planning indicates that this patient has sufficient bone for implant placement. She also requires

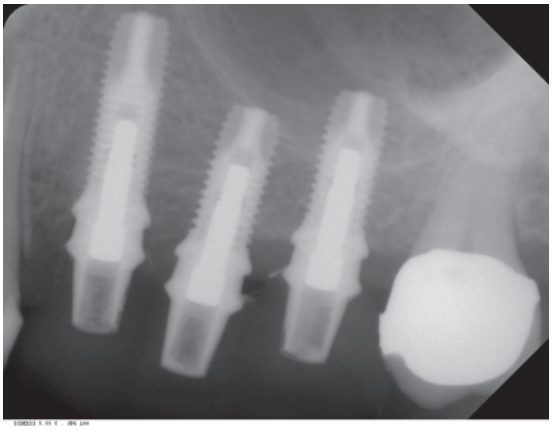


FIGURE 7-8 S, Follow-up periapical radiograph showing the implants in position with adequate bone levels.

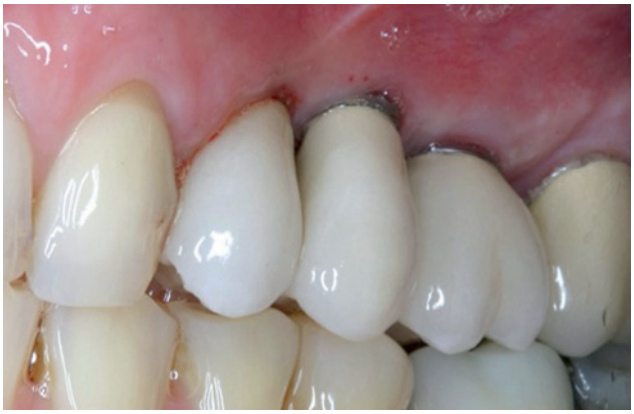


FIGURE 7-8 T, Final restoration on three snap-type abutments.

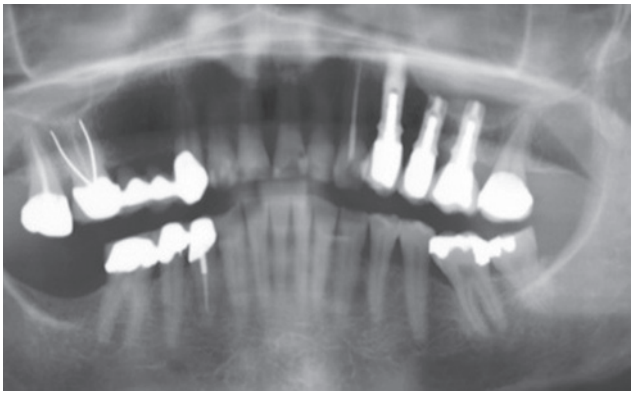


FIGURE 7-8 U, Final radiograph showing maintenance of crestal bone.

extraction of the fractured maxillary left canine (Figure 7-9, A-B). The treatment plan includes the following:

1. Diagnostic models and setup to fabricate provisional crowns before implant placement
2. Fabrication of a surgical guide stent
3. At surgery:
   - Crestal incisions with sulcular extension anteriorly and vertical release posteriorly
   - Extraction of maxillary left canine
   - Placement of four implants to replace four maxillary teeth
   - Abutment placement immediately after implant placement
   - Placement of four provisional single crowns, adjustment as necessary to prevent occlusion, and splinting of the crowns together with resin
   - Temporary cementation of the provisional restoration
4. After 4 months, fabrication of final four single crowns

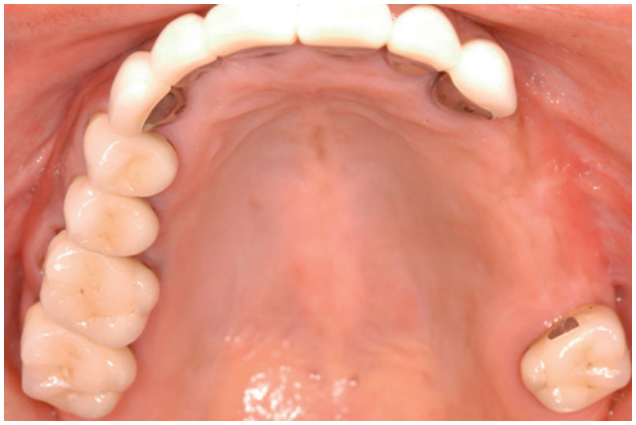


FIGURE 7-9 A, Occlusal view at presentation. A second molar will provide a posterior vertical stop for the occlusal table. The left canine requires extraction, with the remaining anterior dentition providing the anterior vertical stop.

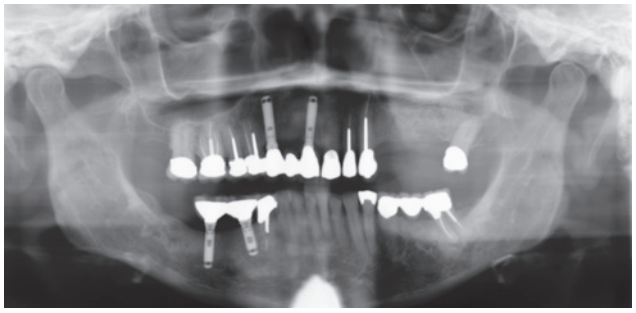


FIGURE 7-9 B, Panoramic radiograph showing adequate bone for placement of the implants.

Before surgery, implant analogs are placed into diagnostic models. From this model, abutments are placed and prepared, single provisional crowns are prepared, and a surgical guide stent is fabricated (Figure 7-9, C-F). The occlusion is protected vertically by the anterior dentition and a remaining second molar.

At the time of implant placement surgery, a local anesthetic is infiltrated. An incision is made around the sulcus of the maxillary left canine, with sulcular incisions made anteriorly, avoiding vertical incisions in the anterior maxilla. The incision is extended posteriorly on the crest, maintaining at least 3 mm of KG to cover the labial portion of the abutments. A posterior vertical releasing incision is also made. The tooth is extracted, keeping the labial bone intact. Four implants are placed (Figure 7-9, G). The implant in the canine position is angled labially and vertically positioned approximately 4 mm apical to the planned gingival margin of the canine.

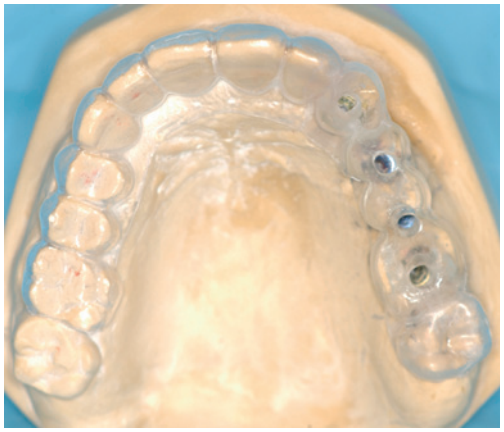


FIGURE 7-9 C, In the laboratory, four implant analogs are placed, and a surgical guide stent is fabricated. The diagnostic setup is duplicated in acrylic, and holes are marked and drilled through the acrylic resin. The surgical guide stent is tooth borne and rigid.

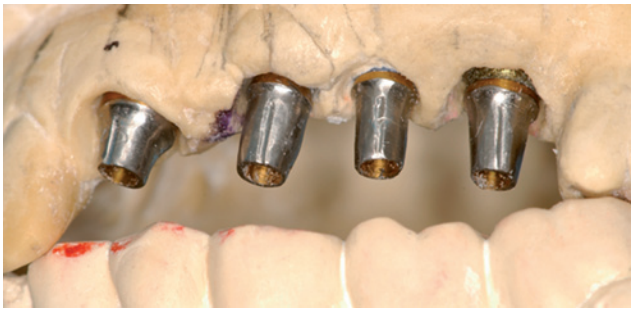


FIGURE 7-9 E, Fixed abutments are placed and prepared in the laboratory. The margins are kept supragingival.

Abutments are placed and secured to the implants with gold screws. The incisions are closed with 4-0 chromic suture before the temporary crowns are placed.

After the incisions have been closed, a long-acting local anesthetic is infiltrated into the left maxilla to provide patient comfort during the prosthetic phase of the treatment.

The single crowns are placed over the abutments. The occlusion is adjusted, and the contour of the temporary crowns is modified, especially for the angled canine implant. Resin then is applied in the mouth to splint the restoration. The splinted restoration is removed, then finished and smoothed to allow gingival health (Figure 7-9, H-J). The occlusion is adjusted to prevent occlusal loading (Figure 7-9, H).

After 4 months for healing, final impressions are taken, and final abutments are prepared. As necessary, angled abutments are used to achieve a balanced occlusion and appropriate contour (Figure 7-9, K-P).

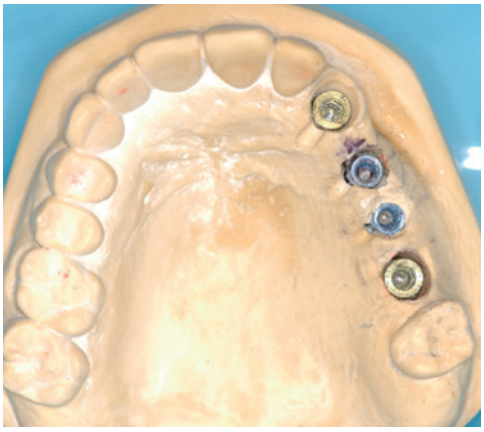


FIGURE 7-9 D, Implant analogs are placed into the master cast to mark the ideal location of the implants. The canine and molar implants are 5 mm in diameter, and the two premolar implants are 4 mm in diameter.

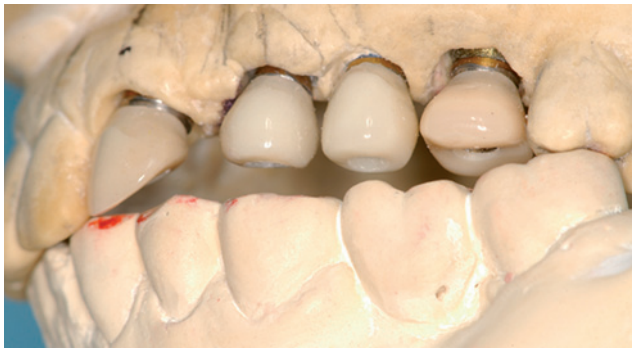


FIGURE 7-9 F, Four individual crowns are fabricated, leaving sufficient space for ease of placement at surgery. The margins are finished to enhance gingival health.

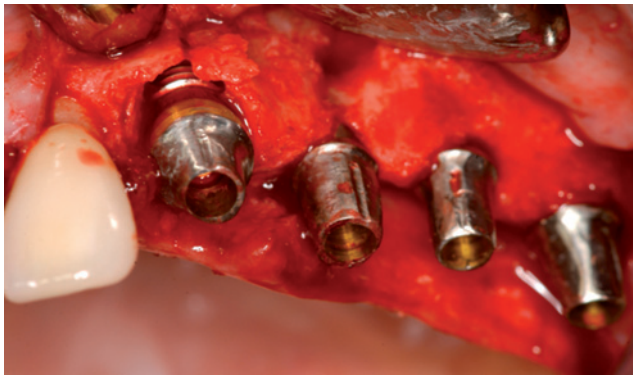


FIGURE 7-9 G, At surgery, an incision is made around the necks of the teeth anteriorly and on the crest posteriorly. The crestal incision allows at least 3 mm of KG to be transposed labial to the abutments. The implants are placed. The canine implant is angled because of the vertical slope of the palatal aspect of the alveolar bone. Abutments are placed and secured with gold screws.

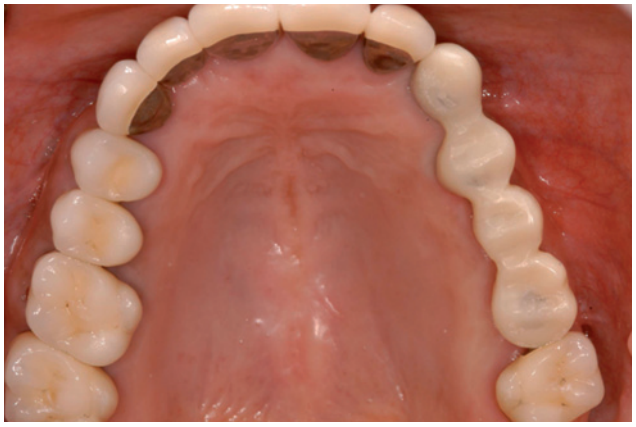


FIGURE 7-9 I, Occlusal photograph showing the restoration of maxillary form by the temporary restoration.

Partial Mandibular Restoration Using a Removable Partial Denture as a Provisional Hybrid-Style Prosthesis

Many patients present needing implants and requesting a fixed provisional restoration. If the patient has a current removable partial denture (RPD), it can be modified into a fixed prosthesis using simple chairside techniques similar to those discussed in Chapter 1. The key to implant survival is to stabilize the implants with a cross-arch, place implants of sufficient length to support the prosthesis, and maintain a fixed restoration without mobility during the implant integration period.

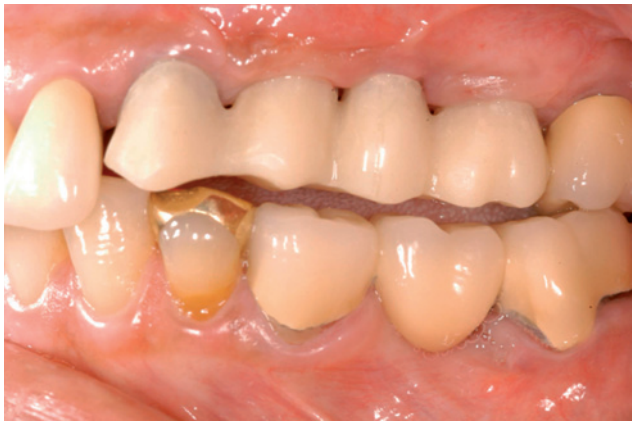


FIGURE 7-9 H, Individual crowns are placed and splinted with resin. After the resin has hardened, the splinted, four-unit restoration is removed and finished chairside. The four-unit restoration is adjusted to prevent occlusal loading.

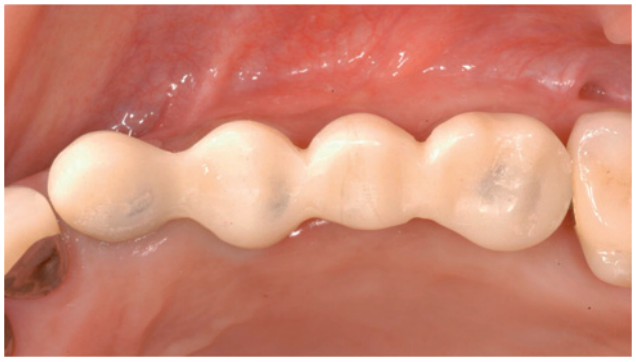


FIGURE 7-9 J, Temporary restoration is splinted with relatively wide contacts to provide strength.

This patient presented with one mandibular tooth that needed extraction. She and her restorative dentist wanted to retain her remaining mandibular dentition, because it was in adequate condition (DVD Figure 7-5, A-B).

DVD Images 7-5, A-J

The patient's problem list was simple: one tooth in need of extraction; the desire to have a fixed, nonremovable prosthesis during the implant integration period; and use of a cost-effective method. The panoramic radiograph demonstrates the surgical plan to the patient (DVD Figure 7-5, C). Before surgery, the implants are ordered, as are the abutments, gold screws, and telescoping copings. For the day of surgery, the patient's schedule is coordinated so that she sees the surgeon first, and then the restorative dentist immediately converts the RPD to an implant-borne provisional prosthesis over approximately 3 hours.

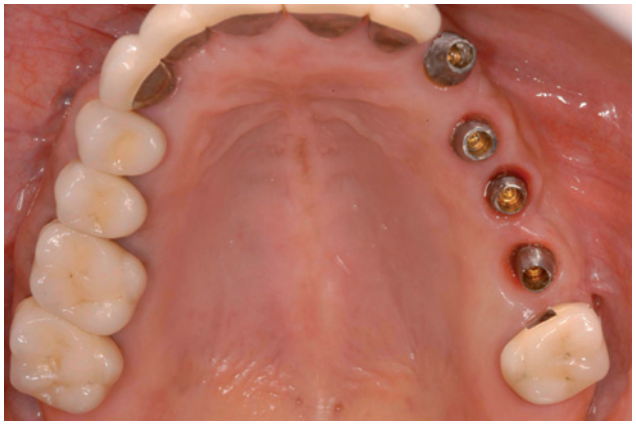


FIGURE 7-9 K, After 4 months, the soft tissue has healed well. After final impressions, new abutments are prepared, compensating for small angulation discrepancies.

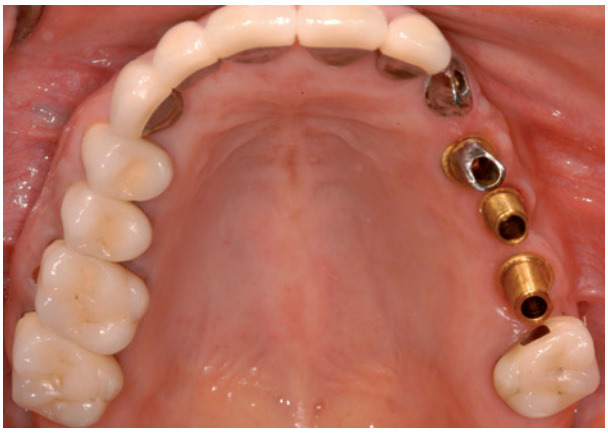


FIGURE 7-9 M, Final abutments in the mouth.

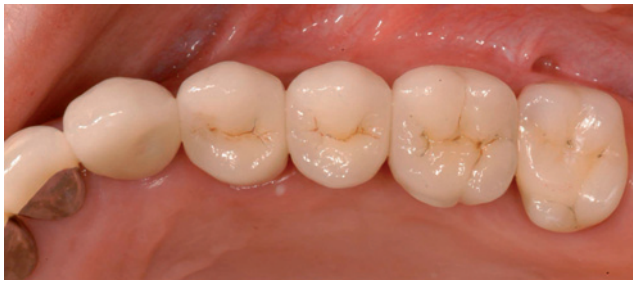


FIGURE 7-9 O, Final restoration in place, restoring maxillary arch form and function.

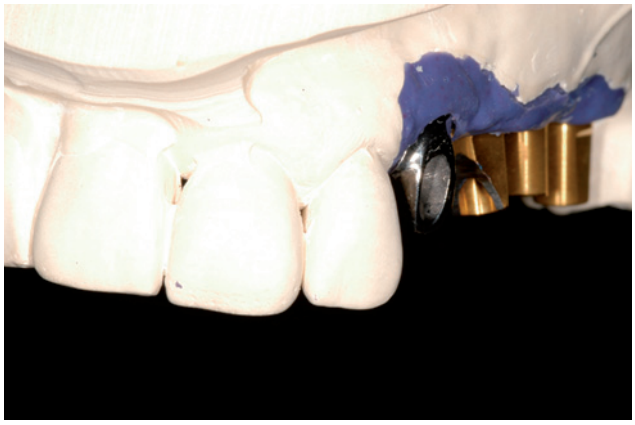


FIGURE 7-9 L, View on the model showing the angle corrections.

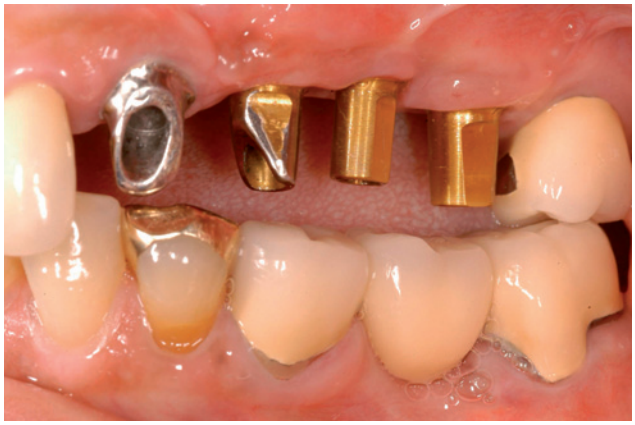


FIGURE 7-9 N, Lateral view showing the final abutments, which are modified or custom-cast (canine) to eliminate excessive labial contour.

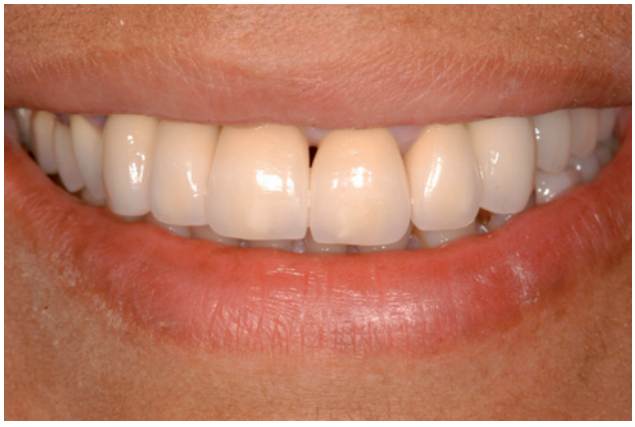


FIGURE 7-9 P, Smile demonstrates excellent esthetics for this restoration extending from canine to molar. (Prosthetics by Dr. Marianna Pasciuta, Dr. Yoav Grossman, and Dr. Israel Finger.)

At surgery, a local anesthetic is infiltrated to the ridge. A crestal incision is made to access the edentulous crest. Anterior vertical releasing incisions are made just anterior to the teeth on the left arch; sulcular incisions are used around the tooth to be extracted; and a crestal incision is extended posteriorly, bisecting the KG, with a lateral vertical release incision. A full-thickness mucoperiosteal flap is elevated on the labial and lingual aspects of the mandible. The mental foramen is exposed to prevent damage to the nerve. The right premolar tooth is extracted, and the extraction socket is cleaned of granulation tissue with a round spoon curette.

A bone-collecting sieve is placed into the suction line. The implant sites are identified first by use of a round bur, which is followed by the routine drilling sequence. An implant 10 mm tall is placed posteriorly because of the proximity of the nerve. The remaining three implants are 13 mm tall. After the implants have been positioned, abutments are placed and torqued into position with 20 N-Cm (DVD Figure 7-5, D). The abutments do not engage the antirotational aspect of the implants. The height of the collar is 4 mm, to place the margins supragingivally. The gingiva is sutured with 4-0 chromic suture using interrupted and horizontal mattress suture technique (DVD Figure 7-5, E). A long-acting local anesthetic is injected into the surgical region to provide patient comfort during the next 3 hours of restorative treatment.

At the restorative dentist's office, acrylic is added to the patient's previous RPD. The implant sites are marked, and holes are made through the RPD. Telescopic copings are placed and connected to the original RPD with denture resin. After the resin hardens in the mouth, the restoration is removed, additional resin is applied, the intaglio surface is smoothed, the flanges are removed, and the provisional prosthesis is polished and then screw-retained to the abutments (DVD Figure 7-5, F-G).

After 4 months, the prosthesis and abutments are removed, and implant-level impressions are made (DVD Figure 7-5, H). The final prosthesis is fabricated using fixed abutments and porcelain fused to metal (DVD Figure 7-5, I-J).

From the time the implants were placed, the patient never wore a removable prosthesis and expressed her delight in the comfortable method of her therapy.

Posterior Mandibular Immediate Provisional Crowns with CAD CAM Abutments

This case demonstrates the use of single units for immediate temporization of two adjacent implants rather than use of a multiunit, splinted provisional prosthesis. The patient previously had the first molar extracted and the socket and adjacent ridge augmented with particulate mineralized bone. The ridge had satisfactory width and height for implants (Figure 7-10, A-B).

Models are used to fabricate the two provisional crowns. A drill is used to create a hole in the desired location for the implants, and analogs are positioned into the model. An implant 5 mm in diameter is used for the molar site, and one 4 mm in diameter is used for the second premolar site. The analogs are positioned with the flat surface of the internal hex to the labial aspect (Figure 7-10, C). Abutments are placed and prepared (Figure 7-10, D). Denture teeth are hollowed and relined over the abutments (Figure 7-10, E). Space is intentionally left between the provisional crowns to allow ease of insertion. The margins of the provisional restorations are smoothed (Figure 7-10, F).

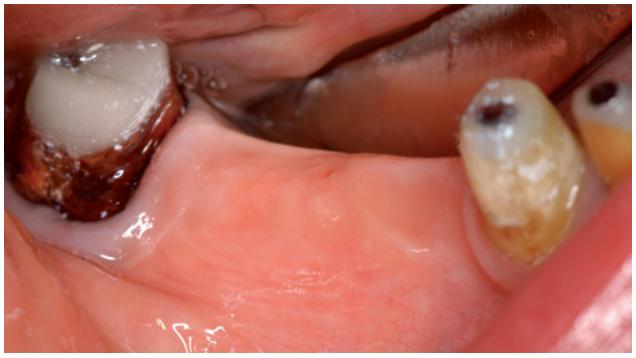


FIGURE 7-10 A, Preoperative view of the mandibular right arch, with missing first molar and second premolar. Approximately 5 months before implant placement, the molar had been extracted, the socket had been grafted with mineralized bone, and horizontal ridge augmentation with particulate bone had been performed using a tunneling approach.

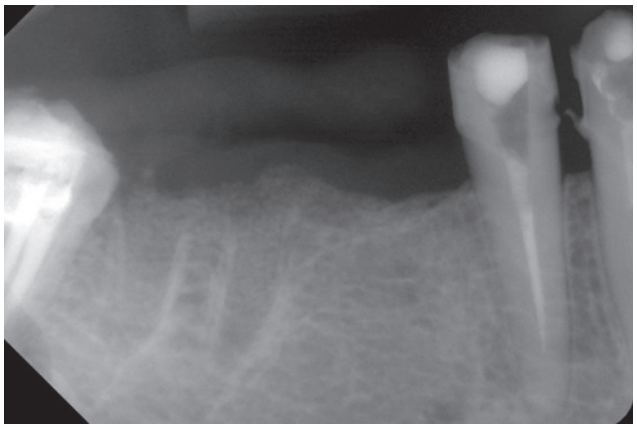


FIGURE 7-10 B, Radiograph showing excellent bone height for implants.

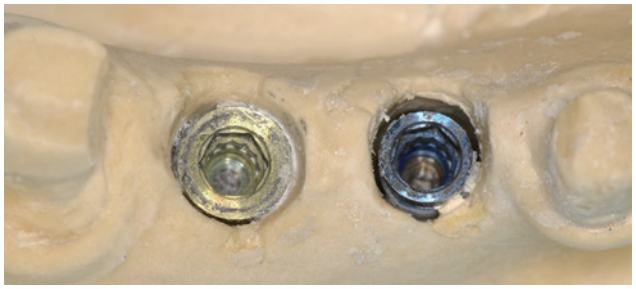


FIGURE 7-10 C, Models are used to place analogs for preoperative provisional fabrication. A round bur is used to mark the implant sites. A small-diameter twist drill then is used to make a small hole, followed by a larger-diameter drill similar in size to the analog. An analog 5 mm in diameter is used for the molar, and an analog 4 mm in diameter is used for the premolar. The analogs are glued in position with fast-setting cement. The flat surface of the internal hex is positioned to face the labial aspect.

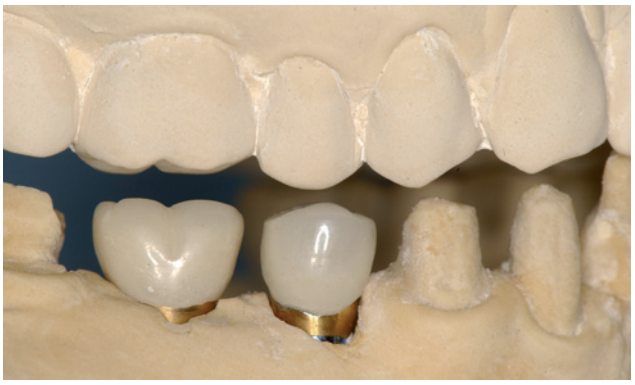


FIGURE 7-10 E, Provisional crowns are made on each abutment. Interproximal space is left for surgical flexibility and ease of placement. These individual crowns are fabricated out of occlusion.

At the time of implant placement, a surgical guide stent is used for the pilot drill only. The implants are placed, and the abutments are secured to the implants with gold screws (Figure 7-10, G). The provisional crowns are placed passively, the occlusion does not need to be relieved, and the crowns are cemented with temporary cement (Figure 7-10, H). After 4 months for healing, the patient returns for final impressions (Figure 7-10, I).

At the time of final impressions, it is noted that the anterior implant is 1 mm distal to the ideal location, and the molar implant is 1.25 mm labially positioned. To correct these small discrepancies, the restorative dentist uses computer-assisted design and manufacture (CAD CAM) abutments. The temporary crowns and abutments are

FIGURE 7-10 D, Fixed abutments are placed and prepared to allow at least 3 mm of interocclusal space to the opposing dentition. The labial surfaces are marked to allow proper orientation at surgery.

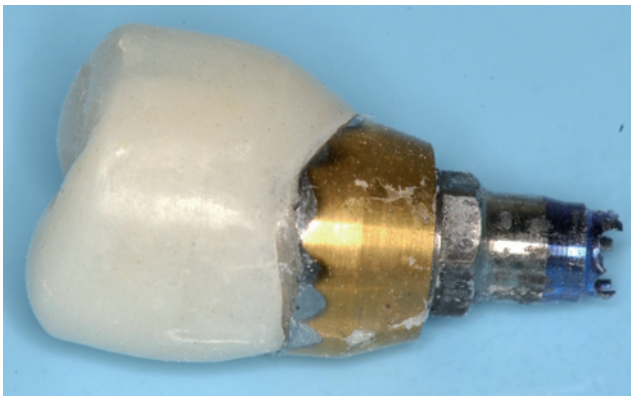


FIGURE 7-10 F, Margins of the crowns are smoothed to promote optimal gingival health.

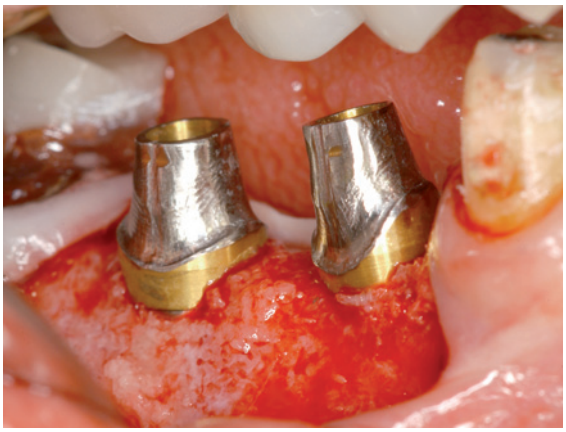


FIGURE 7-10 G, At surgery, a crestal incision is made to transpose the attached KG to the labial surface of the abutments. The implants are placed, with a surgical guide stent used for the pilot hole. At surgery, the anterior implant is placed 1 mm more distal to the adjacent first premolar than planned, and the posterior implant is placed 1.25 mm labial to the planned position.

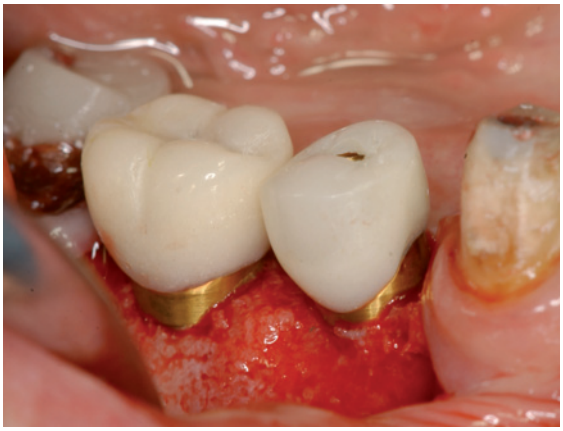


FIGURE 7-10 H, Provisional crowns are placed and cemented with temporary cement.

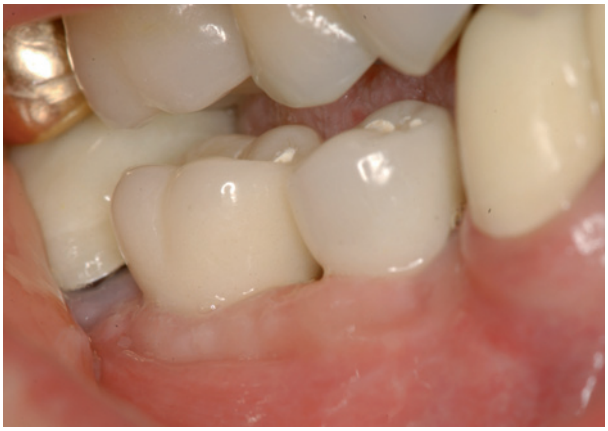


FIGURE 7-10 I, After 4 months, the patient returns for final impressions.

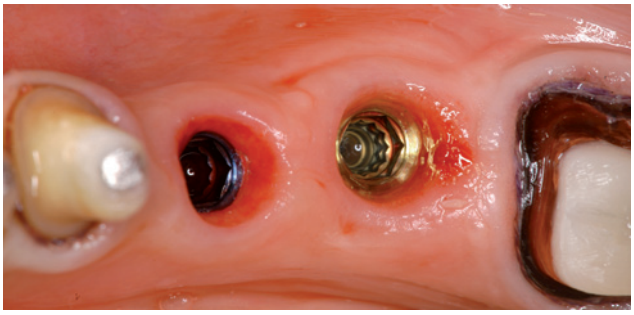


FIGURE 7-10 J, Abutments are removed, revealing excellent sulcular health.

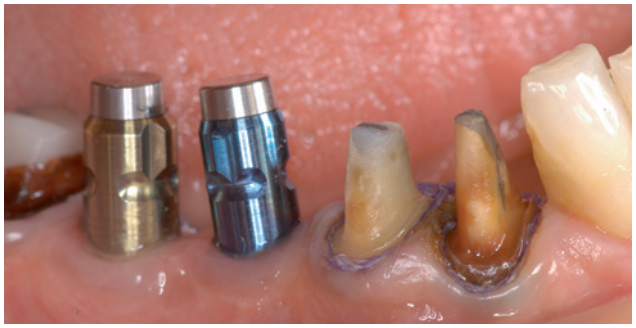


FIGURE 7-10 K, Transfer copings are placed to index the implant position in relation to the adjacent teeth.

removed, revealing a well-healed sulcus (Figure 7-10, J). Transfer copings are placed to make a final index (Figure 7-10, K). Encode (Implant Innovations) healing abutments are positioned, and an impression is made of these two-piece abutments (Figure 7-10, L). Perfect seating of these abutments is confirmed by radiographs (Figure 7-10, M). These implants have specific grooves on their surfaces that are transferred to the stone model (Figure 7-10, N). The final model is poured in rigid stone specified by the manufacturer (Figure 7-10, O). The stone model is mounted on a specific articulator and scanned in the laboratory. The grooves in the healing abutment transfer information on the depth and orientation of the implant. In the laboratory, a CAD CAM computer system is used to design custom abutments for this patient.

The molar abutment is made to compensate for the 1.25-mm labial malposition in this patient. The anterior abutment is moved toward the adjacent tooth to allow ideal emergence and avoid the embrasure space. The CAD CAM

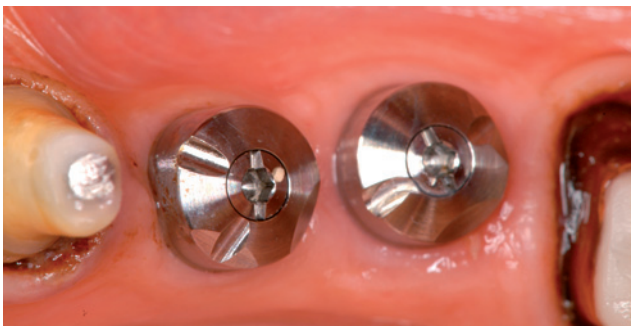


FIGURE 7-10 L, Because custom abutments are needed, CAD CAM technology is used. Encode abutments (Biomet 3i, Palm Beach Gardens, Florida) are placed. The grooves of this two-piece healing abutment are transferred through a stone model and scanned, providing a computer design of the abutments.

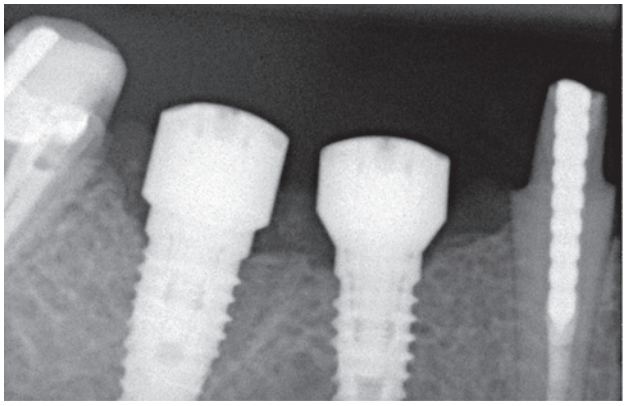


FIGURE 7-10 M, Radiograph is used to verify seating of the abutments.

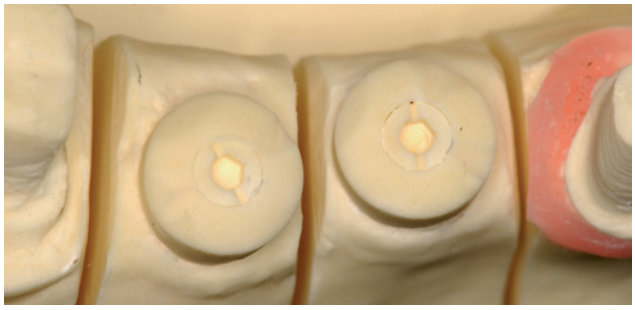


FIGURE 7-10 N, Accurate impression of the CAD CAM healing abutments is made and poured in hard yellow stone, as recommended by the manufacturer. The grooves of the healing abutments are included in the stone model.

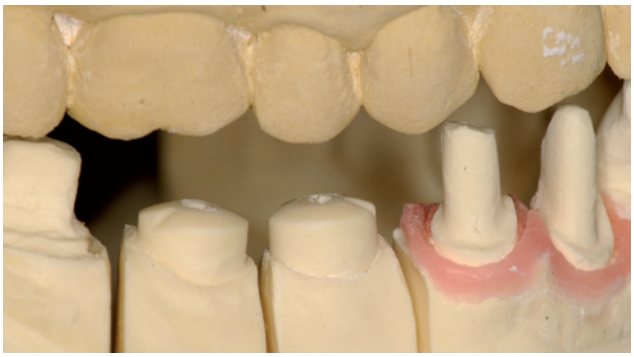


FIGURE 7-10 O, Model is articulated for scanning. Based on the scan of the grooved healing abutments and the opposing teeth, the virtual design will result in an ideal abutment, which creates an ideal emergence and retention.

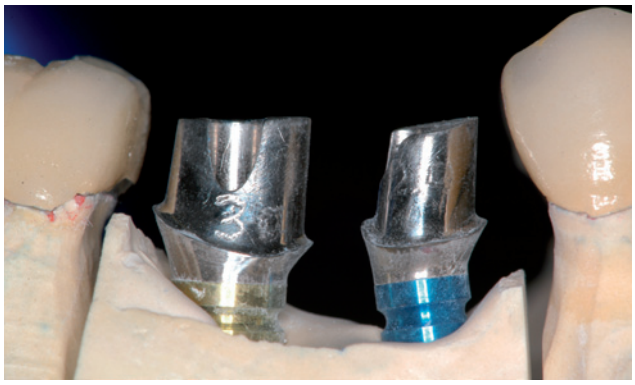


FIGURE 7-10 P, Abutments are milled and fit the indexed model. The final ceramic restorations are fabricated from this model.

abutments are designed to mimic the natural emergence and form of a natural tooth (Figure 7-10, P-Q). They are delivered into the abutments passively and secured to the implants with gold screws torqued to 20 N-Cm (Figure 7-10, R-S). The intraoral evaluation revealed excellent compensation for the small surgical discrepancy from ideal (Figure 7-10, T). The final crowns are cemented after minor customary final adjustments, restoring the arch's form and function (Figure 7-10, U-W).

This case demonstrates two key features. The first is the use of individual provisional crowns rather than a splinted multiunit bridge. This allows for simple, efficient crown placement without relining. As long as complete control of the occlusion is maintained with both anterior and posterior vertical stops of the occlusion, individual provisional

FIGURE 7-10 Q, Occlusal view showing how the posterior abutment corrects for the 1.25-mm labial-positioned implant, and how the anterior abutment creates a better relationship to the embrasures.

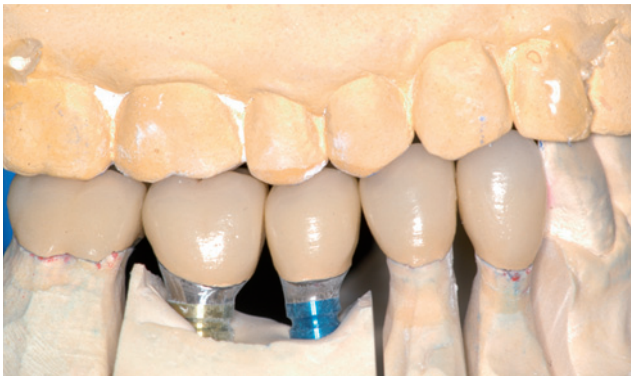


FIGURE 7-10 R, Final restorations on the models. Note the natural, toothlike emergence from the implant to the crowns.

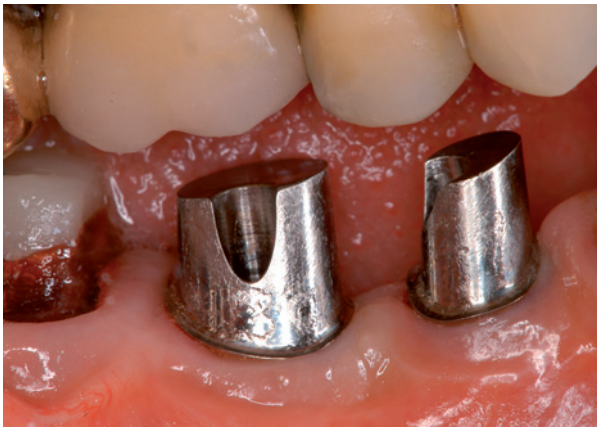


FIGURE 7-10 S, CAD CAM abutments in the mouth. Because the impressions were taken after the gingiva had healed around the provisional crowns, accurate gingival margin position is achieved.

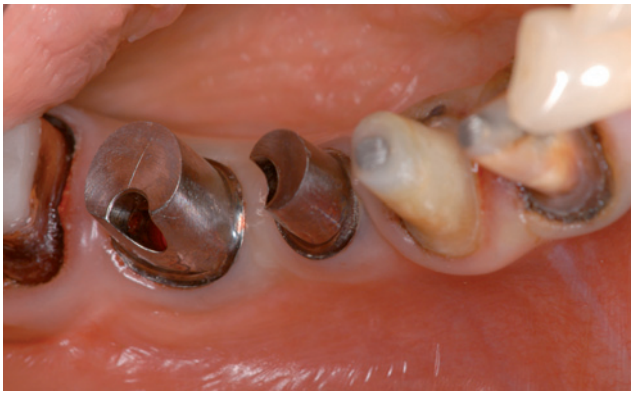


FIGURE 7-10 T, View before seating of the final restorations.

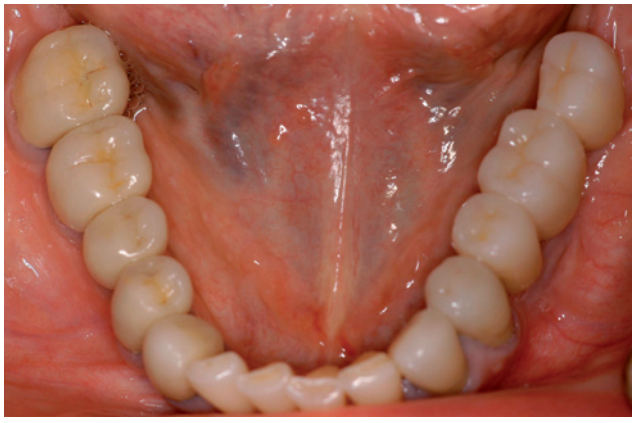


FIGURE 7-10 U, Occlusal view of the single crowns on the implants and teeth. Note the natural arch form achieved.

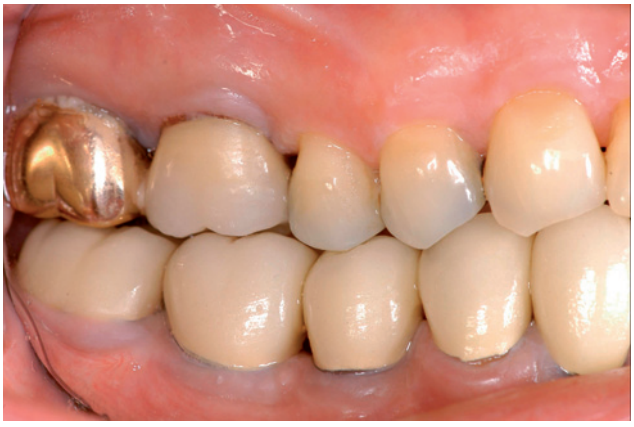


FIGURE 7-10 V, Lateral view of the final restoration. (Prosthetics by Dr. Marianna Pasciuta and Dr. Israel Finger.)

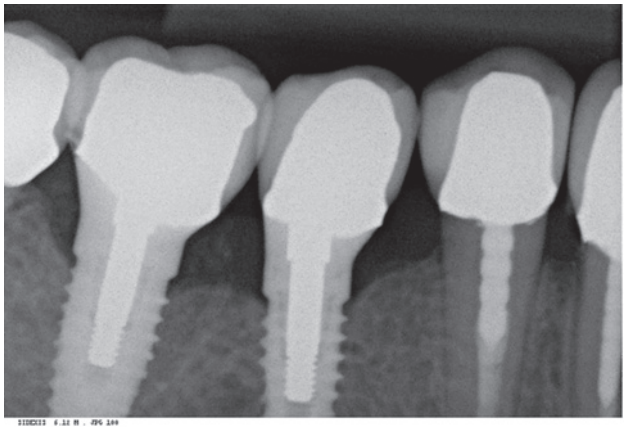


FIGURE 7-10 W, Two-year postrestoration radiographs.

crowns can be used. The second key feature is the use of CAD CAM technology to make custom abutments that have optimal retention and form while correcting small implant position discrepancies. Because these abutments are milled, no casting error is involved, and the fit into the implants is machined based and not cast based.

Acknowledgments

Part of the literature review for this chapter was contributed by Dr. Yoav Grossmann and Dr. Marianna Pasciuta, both former residents in the Department of Prosthodontics, Louisiana State University School of Dentistry, New Orleans.

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Chapter 8

Esthetic Anterior Implant Restorations: Surgical Techniques for Optimal Results

Chapter Outline

Esthetic implant restorations represent a challenge to reproduce normal-appearing restorations with normal-appearing soft tissue bulk and form. For the patient, the "normal" appearance of the restoration means that the restored tooth looks like a natural tooth.[1,2] An ideal implant site with complete preservation of bone and the overlying soft tissue is infrequently seen. Most esthetic-requiring implant sites have deficiencies in the ideal bone and overlying soft tissue and must be enhanced with a variety of surgical techniques. This chapter provides surgical guidelines for handling the esthetic implant site that has hard tissue compromise. Chapter 9 discusses the reconstruction of soft tissue deficiencies for esthetic implant restorations.

A tooth may be missing because of lack of tooth development, caries, external or internal resorption of teeth after trauma, root canal complications, bone loss from periodontal disease, or recent dentoalveolar trauma. Each of these causes has secondary effects on the proposed implant site. A deficiency in labial bone with loss of the previous root eminence form of the ridge is common. In addition, the overlying soft tissue at the level of the alveolar crest may be thin, resulting in lack of stippling, variations in gingival color, and increased translucency, causing parts of the implant and abutment to show through the gingiva.

Critical Factors for Esthetic Central Incisor Implant Restorations

Clinicians must understand the critical factors to achieve an esthetic implant restoration. These principles can be demonstrated using the central incisor tooth as the example, with applications to other teeth.

The central incisor is the dominant tooth in the smile (Figure 8-1). Gingival problems, such as recession of the facial gingival margin, clefts, scars from vertical incisions, lack of papilla, discontinuous bands of keratinized gingiva (KG), and changes in gingival thickness all have a major effect on the final esthetic restoration. These problems must be prevented or compensated for to provide the patient with an esthetic tooth, rather than simply a crown on an implant.

Six related areas must be considered for implant restoration of the single central incisor, as follows (Figure 8-2):

1. *Bone.* The bone requires assessment of ridge width and height, as well as ridge and root prominence contour.
2. *Soft tissue.* Assessment includes the pre-extraction levels of the gingival margin, the quality and biotype of the gingiva, and the presence or absence of papilla.

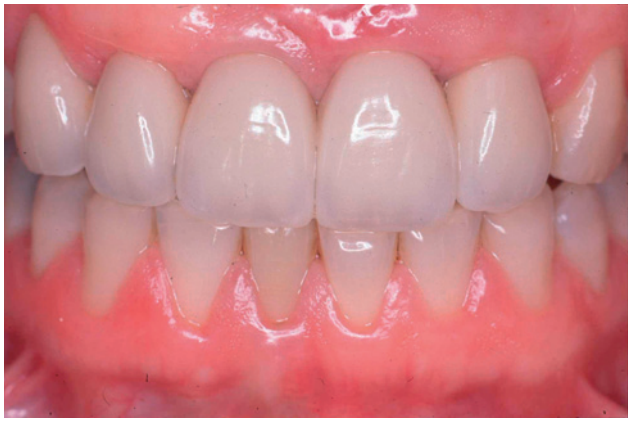


FIGURE 8-1 This patient shows symmetry of the teeth and gingiva. The size of the teeth results in prominent central incisors, with the gingival margins of the lateral incisors in an appropriate vertical location. Implants are in locations 7 and 8, with a pontic for tooth 10 and a three-unit fixed restoration from 9 to 11.

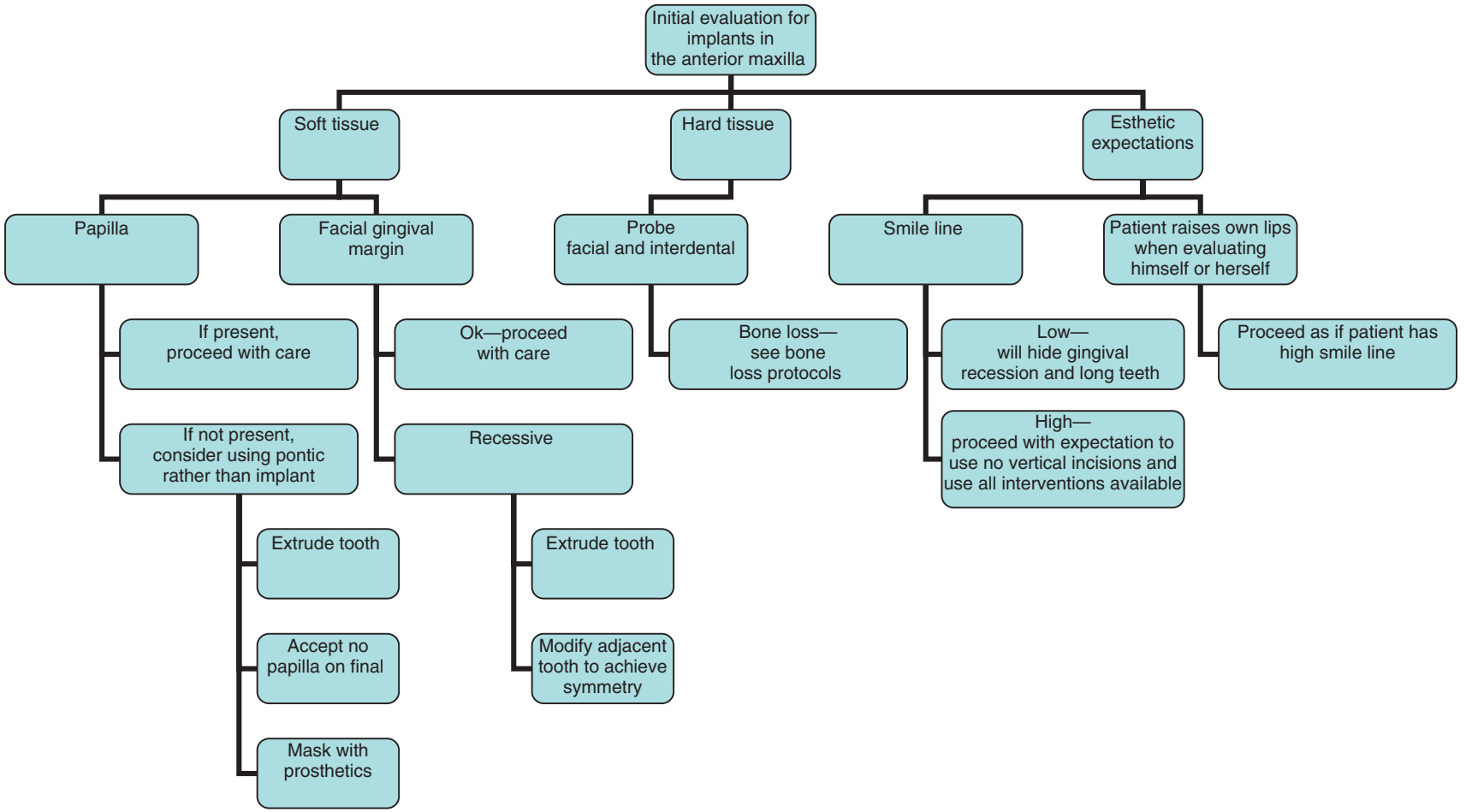
3. *Smile line.* The level and contour of the smile may mask gingival problems, as well as highlight small discrepancies.
4. *Color of the teeth.* Some teeth are perfectly white and homogenous, whereas others are yellow with staining patterns.
5. *Symmetry.* The presence of symmetric anterior dentition can have a beautifying effect on the esthetic outcome, and lack of symmetry brings nonesthetic attention to the restoration.
6. *Position of the implant.* If the implant is too far labial, an esthetic outcome is not possible. Accurate placement of the implant, avoiding excessive cervical contouring of the crown, is critical to achieve an esthetic restoration.

Bone and Soft Tissue

Four walls of bone surround the implant. Palatal bone is often present and minimally prone to resorption after tooth extraction. If lost from caries, palatally located external tooth resorption below the alveolar crest, or trauma, the vertical height of bone must be reconstructed with onlay or interpositional grafting.

If the mesial or distal interproximal bone has been lost on the adjacent tooth, loss of papilla results from loss of bone support. To correct this problem, the adjacent tooth may need to be extruded orthodontically.

A periapical radiograph can be used to assess the crestal level of bone on the adjacent teeth. If the bone is at the level or within 1 mm of the cementoenamel junction (CEJ) of the adjacent teeth, papilla support is expected. Ryser et al.[3]



● **FIGURE 8-2** Algorithm for initial evaluation for implants in the anterior maxilla.

found that the most critical factor for predicting papilla in the final restoration was the distance of bone from the contact point of the teeth to the level of bone on the adjacent teeth. Thus a periapical radiograph combined with the observation of adequate papilla before tooth extraction is often the basis for predicting the esthetic quality of the final restoration (Figures 8-3 and 8-4).

Loss of bone occurs most often on the labial surface (Figures 8-5 and 8-6). If labial bone loss is limited to 3 mm from the planned gingival margin, the implant can be placed at the level of the remaining bone with minimal esthetic compromise, as long as the original position (before tooth extraction) of the facial gingival margin is appropriate. If gingival recession is present, extrusion of the tooth is necessary to reposition the facial gingiva.

Loss of greater than 3 mm of bone or of all the labial bone requires grafting to reconstruct the missing labial bone and place the implant in the correct position. At the time of tooth extraction, a particulate graft can be placed, or if delayed, an onlay bone graft can be placed.

Loss of labial bone can result from caries, tooth fracture, or periodontal disease. The patient with thick gingivae may have significant labial bone loss without gingival recession. The facial gingival margin is ideal, even though labial bone loss exists. These patients often have an excellent result. If labial bone loss from chronic disease is present in a patient with a thin gingival biotype and if gingival recession is present, the result is compromised with a "long" tooth. Adjunctive procedures on the adjacent tooth (e.g., crown lengthening) may be necessary.

8-1, A-E

Labial orientation of the implant results in gingival recession because of the labial position of the implant (Figure 8-7, A-B, and DVD Figure 8-1, A-E). When a crown is placed on a labially positioned implant in the esthetic zone, excessive gingival contour results in apical migration of the gingiva. This situation often requires removal of the malposed implant to gain a final esthetic result.

Placement of Implants into Extraction Sockets Immediately after Tooth Extraction

A periapical radiograph shows the crestal level of the bone. If the bone is within 3 mm of the planned gingival margin, placement of an implant may be considered immediately after tooth extraction. At tooth extraction, labial bone is confirmed, and the implant is placed into the palatal aspect of the socket to appropriately position the labial surface of the implant 2 mm palatal to a line from the labial surfaces of the adjacent teeth.

If a central incisor is to be extracted and is surrounded by loss of bone that also involves the adjacent tooth, the loss of interdental bone most likely will result in loss of papilla, even if grafting is performed when the tooth is extracted. When a flap is elevated, if the bone is not present on the CEJ area of the adjacent tooth, the patient must be informed about the guarded prognosis of the papilla.

Smile Line

Men typically do not show the gingival margins, especially as they age. The smile line of the upper lip should expose a generous portion of the central incisor. The incisal plane of the upper teeth should follow the curvature of the lower lip (DVD Figure 8-2).

8-2

In the patient with a low smile line, the height of the centrals and apical migration of the gingival margin may mask an otherwise poor esthetic result.

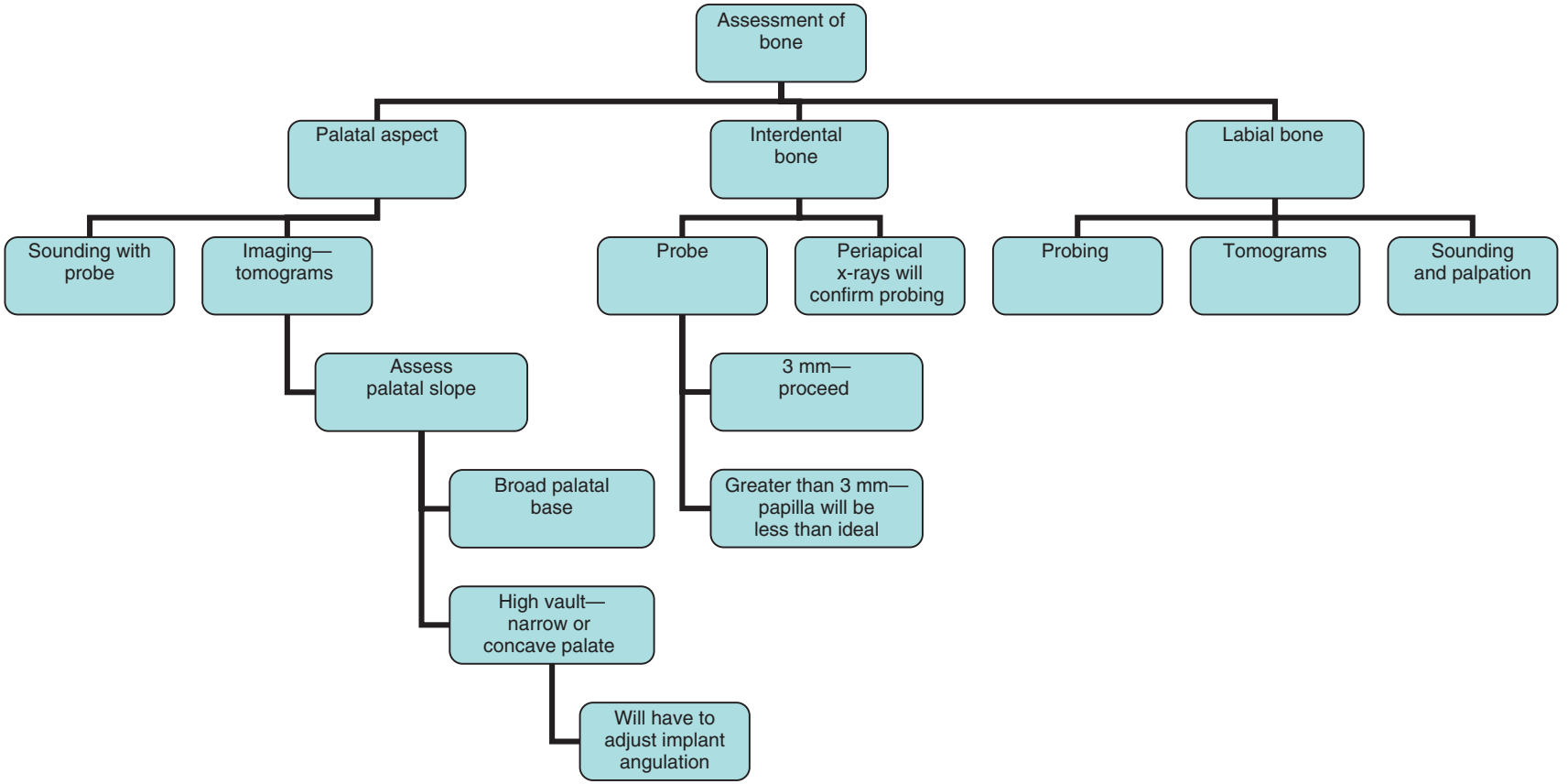
Women tend to show more of the gingiva, often with 2 to 3 mm of gingiva on smiling. In the female patient, "gingival show" is a youthful factor. In these patients, symmetry of the centrals may be more important than their individual dimension. That is, if the gingival margin on the implant is slightly apical, a crown-lengthening procedure to achieve symmetry of these two centrals may be sufficient to achieve the desired esthetics.

Patients may show excessive gingiva for two reasons. One reason may be skeletal dysmorphism, with vertical maxillary excess present in the anterior maxilla. These patients' teeth most likely are normal in length, with the central incisor approximately 11 mm tall. To correct vertical maxillary excess as a skeletal problem, an osteotomy is required to reposition the maxilla superiorly. Lip lengthening may be used to reduce gingival show only if the lip is short. The deficient lip may be short in the length of the skin above the wet line, or the bulk of the upper lip may be deficient. Lip augmentation may be an appropriate procedure rather than, or combined with, skeletal surgery.[4]

A second common reason for excessive gingival show on smiling is short teeth caused by passive altered eruption. These teeth are normal in length structurally, but they are covered with gingiva along their cervical region because of passive eruption. Treatment of this problem, which is dental in origin, is crown lengthening.[5] In these patients, implant crown planning must include crown lengthening. It may be advisable to have the crowns lengthened before implant placement to know exactly where to place the implant vertically, which should be 3 mm apical to the planned facial gingival margin. The workup should include photographs with computer-generated adjustment of the teeth and gingiva to find the optimal gingival show. At the time of crown lengthening, a surgical stent is made available to reposition the gingiva accurately within 0.5 mm.

Color of Adjacent Teeth

In older patients with staining on their teeth, a new implant crown will be more acceptable if the staining and other discoloration or tooth length are incorporated into the



● **FIGURE 8-3** Assessment of bone for implants in the maxilla.

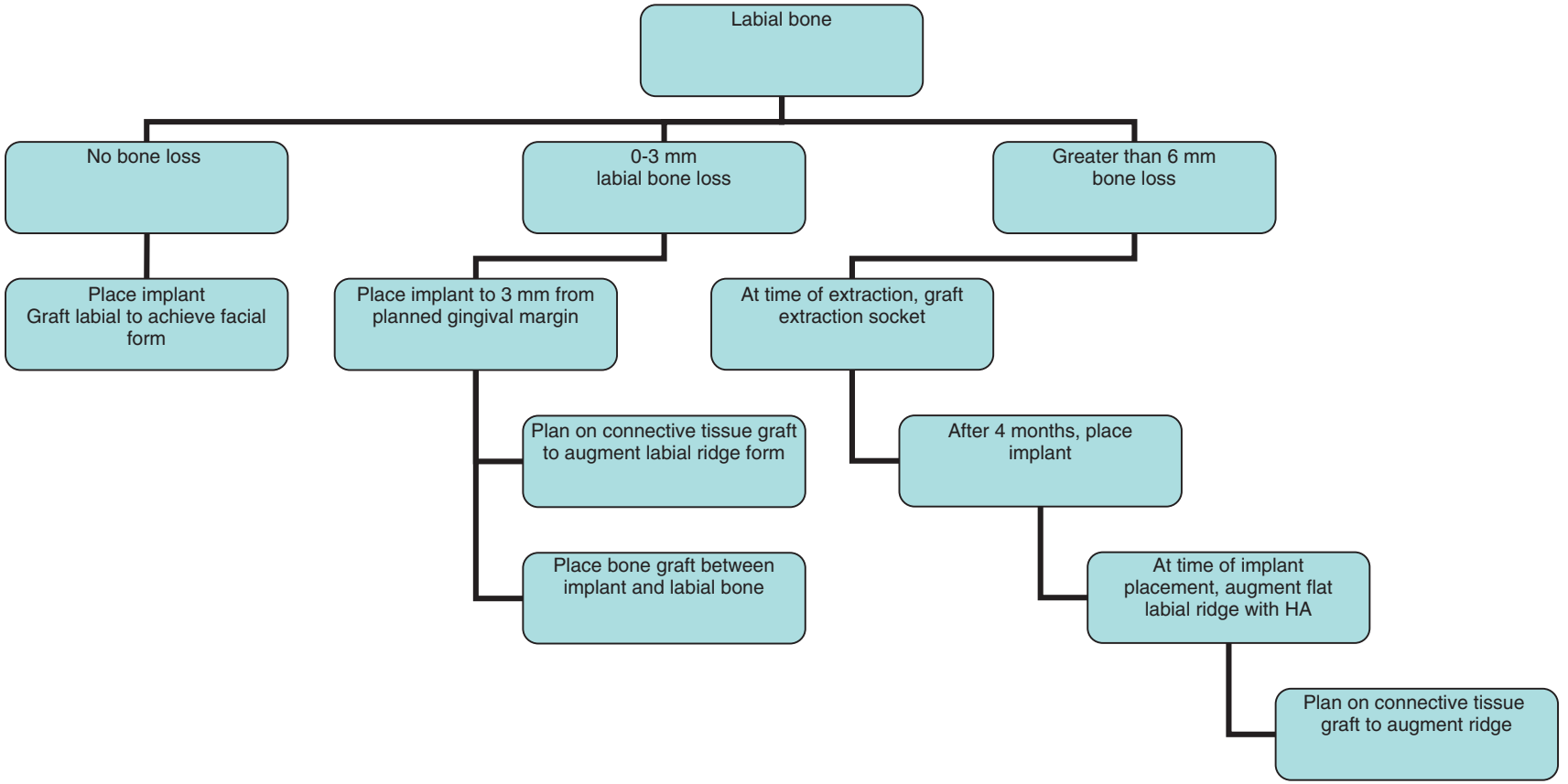
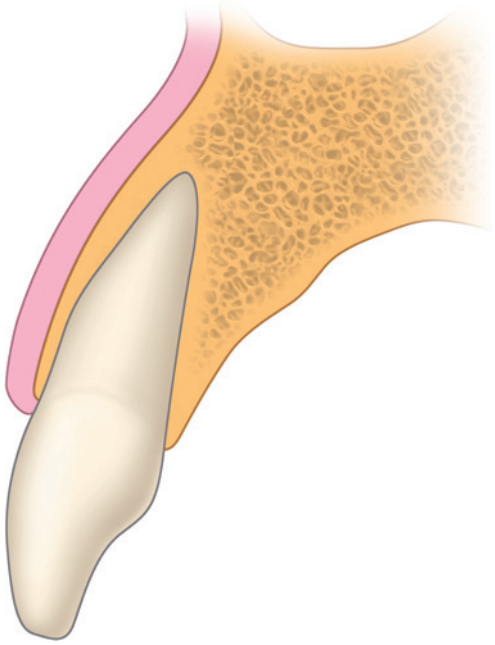
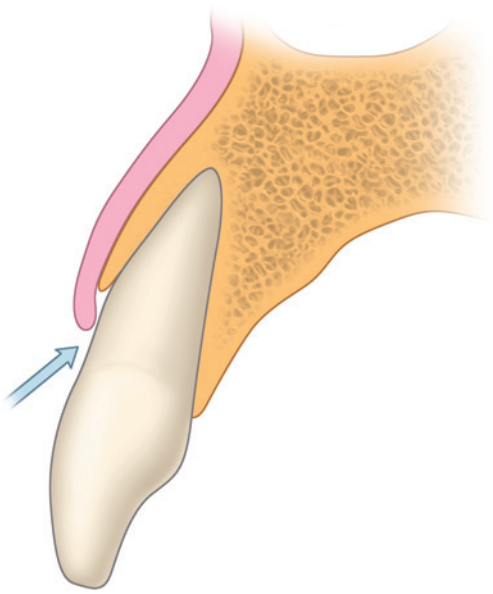


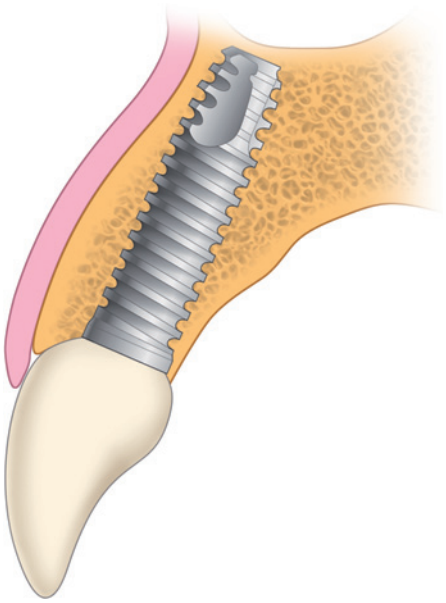
FIGURE 8-4 Strategy after evaluation of labial bone. *HA*, Hydroxylapatite.



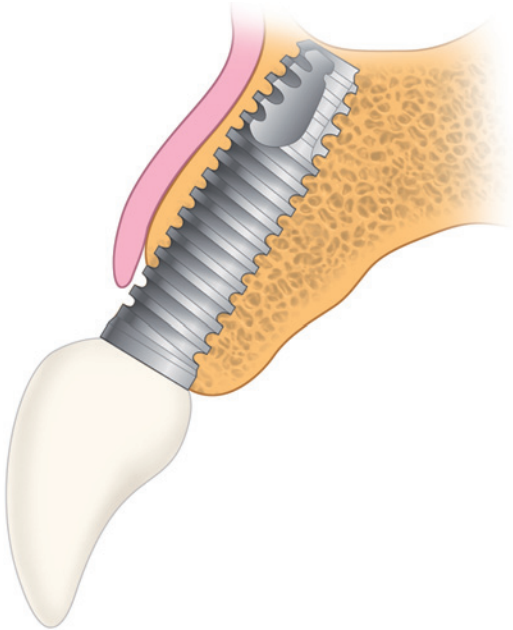
● **FIGURE 8-5** Normal relationships among the gingiva, labial bone, and tooth.



● **FIGURE 8-6** Gingival recession secondary to loss of labial bone.



● **FIGURE 8-7** **A,** Ideal location of the implant 2 mm palatal to the emergence of the planned restoration; this allows for a natural, esthetic gingival margin position.



● **FIGURE 8-7** **B,** If the implant is placed labially, the labial bone resorbs and the gingival margin migrates apically, resulting in an unesthetic restoration.

8-3, A-B

implant crown to keep the anterior teeth natural in appearance (DVD Figure 8-3, A-B). The presence of a diastema may be acceptable in the patient. If gingival recession is present on adjacent teeth, creative ceramics, including dentin and pink porcelain, may be appropriate. Thus, for each patient, consideration should be given to matching the other teeth.

Symmetry of Anterior Dentition

The anterior teeth should have symmetry from left to right, with no single tooth different from the matching tooth on the opposite arch. The color, shape, translucency, height, width, and contour of the teeth should match. In addition, the levels of the gingival margin should match left to right. Even when the teeth have gingival recession or less-than-ideal contours, as long as the right side matches the left side, the presence of symmetry allows deviations from ideal to be acceptable to the patient.

If a single-tooth implant results in gingival margin discrepancy with the matching tooth on the opposite side of the anterior maxilla, an adjunctive procedure can be performed to correct the discrepancy. The most common problem is gingival margin location. Crown lengthening can create symmetry and can be acceptable. Color discrepancy may require the use of a master technician or a laminate on the adjacent tooth. Contour problems may be the result of excessive prosthetic fabrication or a labially positioned implant. The implant that is not placed properly may require removal and grafting with replacement to correct an implant malposition etiology.

Position of Implant

For a single-tooth implant, the implant should be placed equidistant from each adjacent tooth. This assumes that the width of the tooth to be replaced is the same as the space that exists. If diastemas are present, the specific position of the implant is determined by an esthetic setup. Orthodontic therapy may be indicated to correct space issues, or new restorations may be needed on the adjacent teeth.

The implant's labial surface should be placed approximately 2 mm palatal to the labial emergence surface of the planned restoration. The center of the implant will be more palatal to allow for the 2 mm of space beyond the labial surface. The labial surface of the implant cannot be placed labially. The abutment and crown need sufficient distance to develop an emergence profile. If the implant is placed too far to the labial, the thickness of the abutment and the crown will exceed the physiologic borders of the gingiva, and the gingiva will recede and migrate apically (see Figure 8-8, C). Apical migration of the facial gingival margin cannot be fixed without major compromise. If the implant is placed too far labially, with the gingival margin receding, the implant should be removed, the site grafted, and the implant replaced in the correct position. At the other extreme, if the implant is placed greater than 2 mm palatal, adjustment of the prostheses often can mask this problem without major esthetic compromise.

Prognostic Factors

Factors to consider in determining whether a single-implant restoration will be esthetic include the gingival margin, loss of labial bone, and implant positioning.

Gingival margin of the tooth before extraction or after healing

8-4, A-D
8-5, A-C

A key clinical sign used to predict the final esthetic result is the position of the facial gingival margin as it appears before extraction of the tooth (DVD Figure 8-4, A-D). If the gingiva is not healthy or appears hyperemic, with evidence of granulation tissue, the gingival levels after implantation appear apical to the ideal location (DVD Figure 8-5, A-C). In this clinical situation the tooth to be extracted should be treated prophylactically to allow the gingiva to heal and achieve health, if possible. A healthy gingiva can be used to predict the final position of the facial gingival margin at the conclusion of the implant restoration.

If the gingival position is 1 to 2 mm apical to the adjacent tooth, the final gingival position will be no better than 1 to 2 mm apical to the gingiva on the adjacent tooth. To correct this problem, the tooth to be extracted may need to be orthodontically extruded or the tooth and bone moved coronally by an osteotomy. These procedures move the facial bone coronally and bring the gingiva with it. However, many patients do not want orthodontic therapy because of the cost, esthetics, and time factors. Patients also may choose to avoid interpositional osteotomies because of the extent of the surgery. Most patients would rather adjust the adjacent tooth by using a simple and predictable crown-lengthening procedure, with or without a prosthetic procedure (e.g., laminate).

The observation that pre-extraction gingival levels are predictors of the final gingival position holds true even with extensive labial bone loss in the presence of a thick gingival biotype. As long as (1) the surgical procedures are performed with minimal trauma and avoid excessive tension on closure, (2) the restorations—temporary and final—are not overcontoured at the cervical margin, and (3) the implant is positioned 2 mm palatal to the labial emergence of the restoration, an esthetic restoration can be achieved. In contrast, if the surgery traumatizes the gingival margin by laceration, excessive tension on closure, the use of too many sutures, the use of numerous simultaneous procedures, overcontouring of the implant, or malpositioning of the implant, a poor esthetic result occurs.

Loss of labial bone

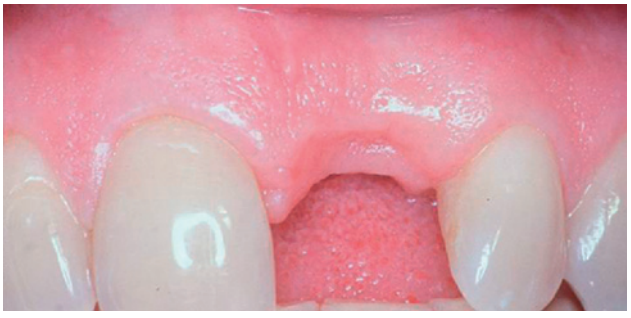
At the extraction of a tooth, a labial bone defect may exist. A graft can be placed immediately at the time of extraction or can be delayed. The final dimension of the grafted ridge

may be less than ideal, regardless of whether the graft was particulate or solid in form. In the ideal graft, a ridge has a convex profile that simulates an underlying tooth root, such as the root prominence. The long-term result of onlay grafts (particulate or solid) is unknown with regard to maintenance of the initial bone ridge bulk and the root prominence. As the labial bone defect increases, the final bone graft bulk may result in a flat, rather than a convex, root prominence. Therefore, soft tissue augmentation or further hard tissue augmentation with a nonresorbable material may be needed. If the ridge crest is exposed and found to be sufficient for implant placement but establishment of a root prominence is essential because of the smile line, nonresorbable hydroxylapatite (HA) can be placed over the ridge to "plump" the ridge form, establishing a root prominence (Figure 8-8, A-F).

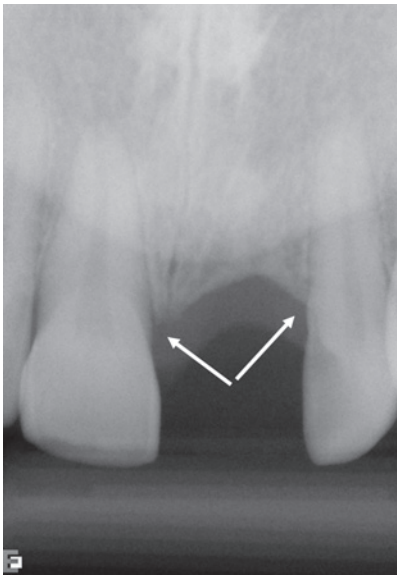
When the single-tooth edentulous site in the central incisor region is examined, four surfaces of bone need to be evaluated. The mesial and distal interproximal crestal bone surfaces on the adjacent teeth determine the bone support for the papilla. The interproximal bone level on the adjacent tooth is the most critical bone determinant of papilla support[3] (Figure 8-9, A-B).

The level of the palatal bone is important in predicting success in restoring the horizontal width of the ridge. If the palatal bone height is compromised, the resultant vertical height deficiency may be difficult to restore. In this situation, options include routine crown and bridge restorations with soft tissue grafts to form the ridge under a pontic, placement of an onlay graft, or an interpositional osteotomy with either immediate or distraction osteogenesis to achieve vertical ridge augmentation.

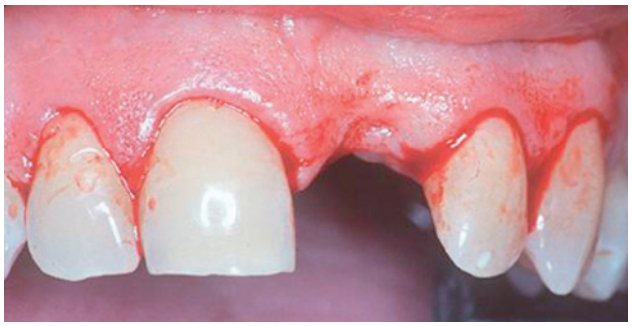
The labial bone that supports the facial gingival margin of the tooth must be restored to provide bone support for the final restoration. Labial bone loss is common, because the labial bone thickness over an anterior tooth is very thin. This thin bone is lost secondary to periodontal disease, caries, fracture of the tooth, and recession by attrition. If the



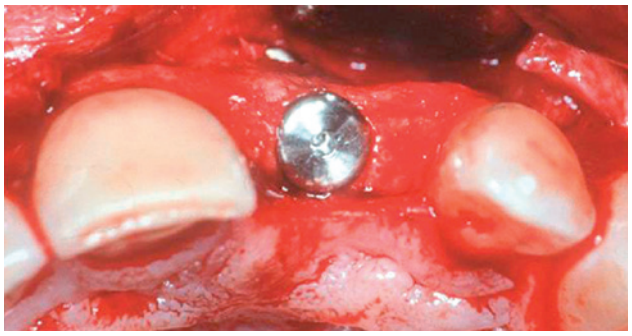
● **FIGURE 8-8** **A,** This 55-year-old patient lost his central incisor 2 years earlier secondary to fracture. The patient currently wears a "flipper." Thick gingiva is predominant.



● **FIGURE 8-8** **B,** Periapical radiograph showing crestal bone at the level of the cementoenamel junction (CEJ) on the adjacent teeth.



● **FIGURE 8-8** **C,** After administration of a local anesthetic, sulcular incisions are made to access the underlying bone. The sulcular incision is extended to the premolars bilaterally.



● **FIGURE 8-8** **D,** Implant is placed in the proper position, with the labial surface 2 mm palatal to the labial emergence line planned from the labial surfaces of the adjacent teeth. Note the flat ridge form.

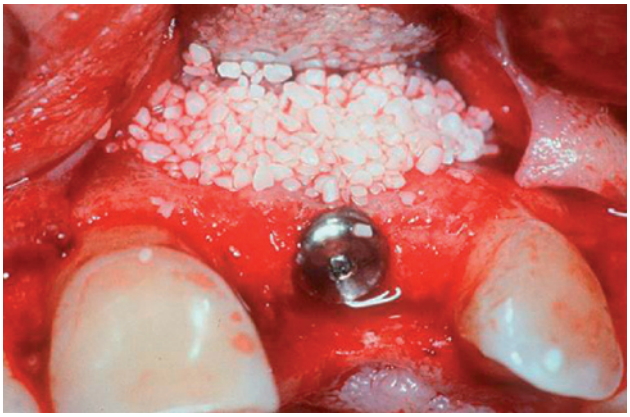


FIGURE 8-8 **E,** To form a root prominence for better esthetics, nonresorbable hydroxylapatite (HA) is placed on the flat labial bone.

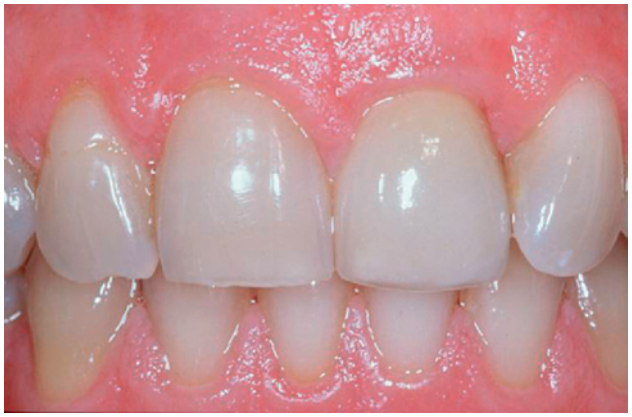


FIGURE 8-8 **F,** Final restoration shows excellent gingival margin levels and symmetry of the root prominence. (Prosthetics by Dr. Avishai Sadan.)

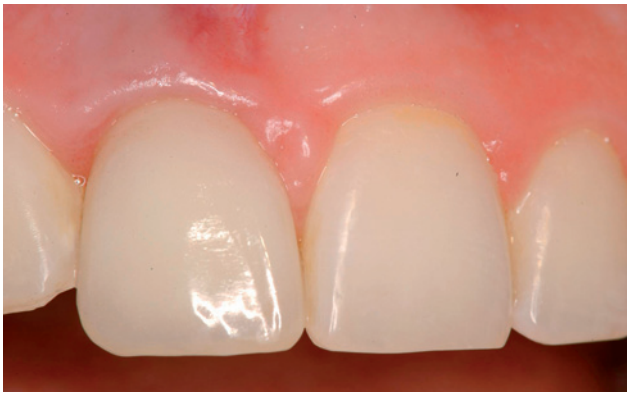


FIGURE 8-9 **A,** Five-year postrestoration follow-up on a young woman who had the right central incisor extracted 7 years earlier secondary to external resorption. The implant was placed and the labial ridge augmented with bone and a membrane.

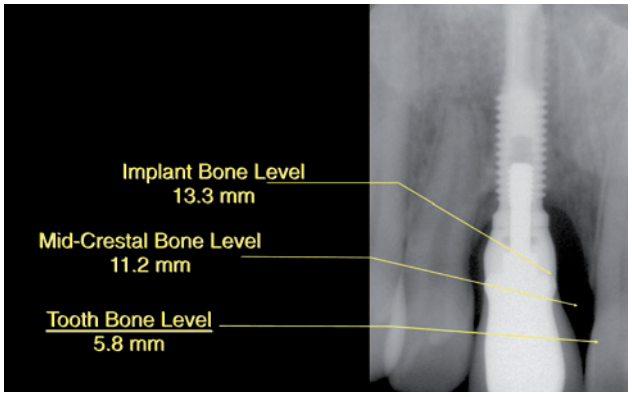


FIGURE 8-9 **B,** Five-year periapical radiograph showing excessive distance from the contact point of the restoration to the bone levels on the implant and the midcrestal regions. However, because the distance from the contact point to the bone on the adjacent tooth is 5.8 mm, papillae are supported and are esthetic.

tooth is extracted and the site is not grafted, labial bone resorption results in a less-than-ideal ridge width.

Bone can be restored to the width of the bone at the mesial or distal surfaces facing the adjacent teeth. It is difficult to establish long-term maintenance of the convex ridge profile once this bone has been lost. Restored bone width is less than ideal in the middle of the facial aspect of the tooth to be replaced. This is seen in cases presented throughout this chapter and in other chapters. Ridge contour can be restored by adding interpositional soft tissue grafts after graft consolidation. In the thick gingival biotype, this is less of a problem (Figure 8-10, A-H). In the thin biotype, however, it is a more significant problem. The lip line must be assessed. Often the problem can be solved by using carefully designed crown contours. The use of temporary prostheses is critical in these patients to develop optimal gingival architecture.

Orthodontic extrusion of a tooth before its extraction can move the gingival margin from an unesthetic apical position to an ideal position. When the tooth is extruded, if the tooth movement is directed labially, labial bone loss occurs. At the time of tooth extraction, the facial gingival margin will be excellent, but a labial defect will be present and will require grafting. Because the gingival margin has been corrected, the case has a very good esthetic prognosis, because when the gingival margin is at an ideal location

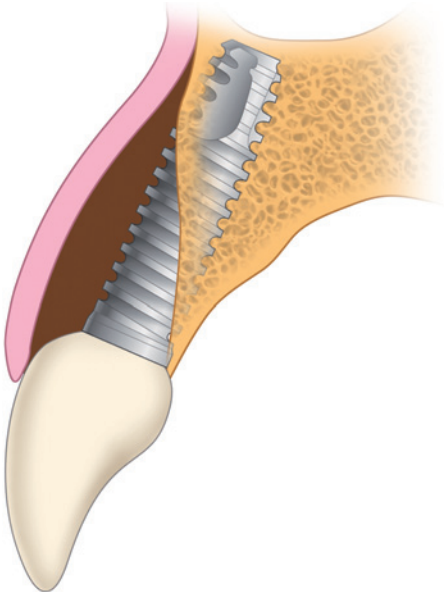


FIGURE 8-10 A, Diagram of an implant in a site that lacks labial bone. This site must be grafted before implant placement so that the implant can be placed in the ideal position.

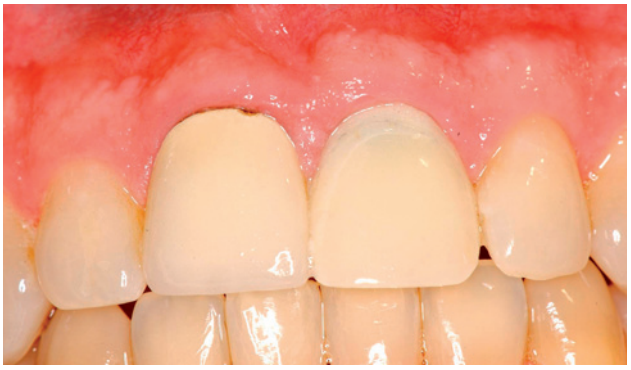


FIGURE 8-10 C, This 33-year-old patient needs extraction of the right central incisor because of external and internal resorption. The tooth has fractures, and the crown is slightly mobile. No bone is present along the labial surface of the tooth. Positive prognostic criteria include ideal gingival margin position before tooth extraction and adequate bone levels on the adjacent teeth.

before extraction, the implant restoration has an excellent prognosis to achieve excellent esthetics.

Crestal bone remodeling around an implant may result in apical migration of the facial gingival margin. When an implant with a flush abutment-implant interface and a smooth collar is used, bone remodels to approximately 2 mm from

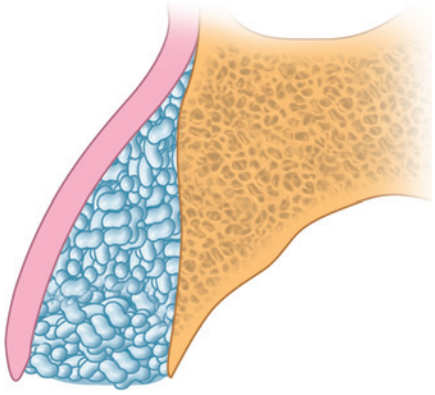


FIGURE 8-10 B, Diagram of the location of the graft to restore ridge width and labial gingival shape. The graft can be placed immediately after tooth extraction.

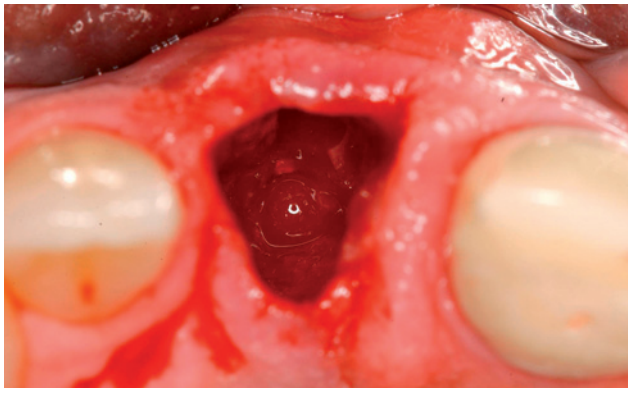


FIGURE 8-10 D, Incision is made around the tooth, avoiding the papilla. The tooth is extracted with the aid of osteotomes. After extraction, no bone is present on the labial surface of the socket, similar to the diagrams.

the interface. Gingival migration may occur, with movement of the facial gingival margin up to 2 mm. Implant designs that medialize the abutment implant interface and use a rough surface at the location of the crestal bone are purported to preserve crestal bone, with less chance of gingival margin migration because facial bone is preserved.

Implant positioning

For a single-tooth replacement, two considerations are important when positioning the implant. First, the implant should be placed equidistant from the adjacent teeth. This allows for symmetry of the final restoration. If the space is excessive, a diagnostic setup determines the specific location of the implant.

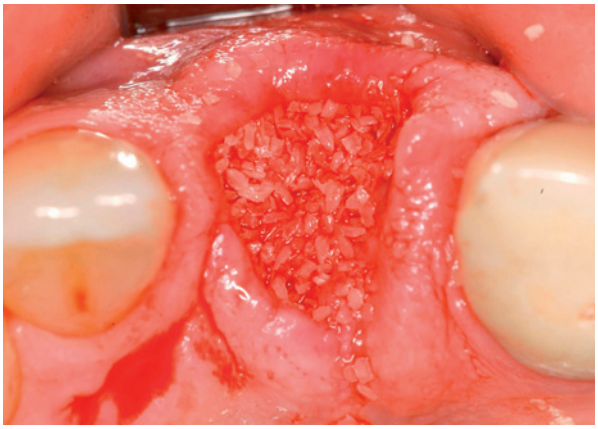


FIGURE 8-10 E, Socket is immediately grafted with human particulate mineralized bone, 350 to 500 μm in diameter. Approximately 0.5 ml of graft is packed into the socket. A piece of collagen is placed over the site to maintain the graft, and an Essix-type temporary prosthesis is placed.

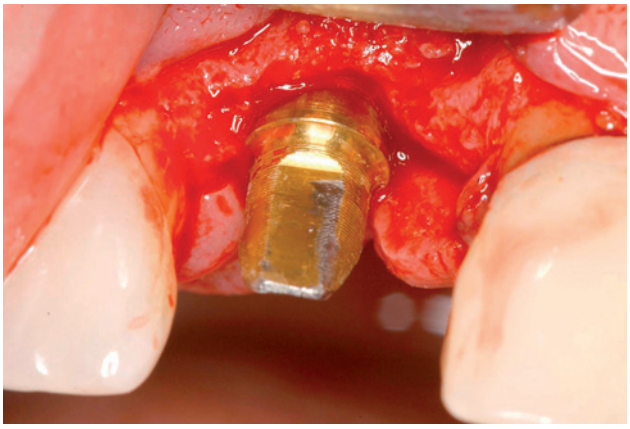


FIGURE 8-10 G, Implant is properly positioned into the ridge with torque to place the implant exceeding 30 N-Cm. The abutment is placed.

DVD Images 8-6, A-B

Second, the position of the implant labial to palatal is critical to achieve an ideal restoration (DVD Figure 8-6, A-B). If the implant is labially positioned, the gingival margin around the restoration will be apical to the planned restoration. A labially positioned implant also is prone to labial bone loss or bone dehiscence. From the implant's shoulder, the abutment emerges labially, and the crown also emerges labially. The implant's labial edge needs to be positioned approximately 2 mm palatal to the labial edge of the planned restoration. If the clinician draws a line connecting the labial surfaces of the adjacent teeth, the labial edge of the implant can be placed 2 mm palatal to this line.

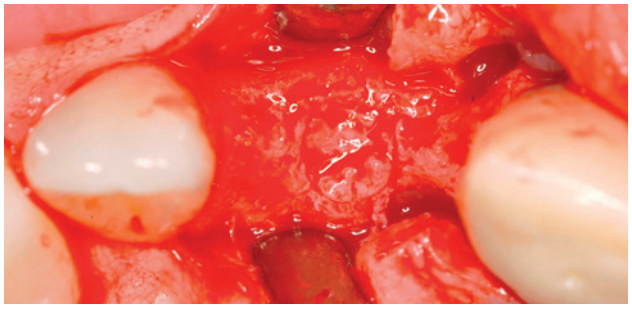


FIGURE 8-10 F, After 4 months, a crestal incision is combined with sulcular incisions halfway around the adjacent teeth to access the ridge. The graft is firm and has restored 75% of the ridge width. In most of these grafts, the resultant ridge is flat and confined by the width of the ridge created by the adjacent teeth. A prominent root prominence occasionally is seen, but the flat ridge form is most common.

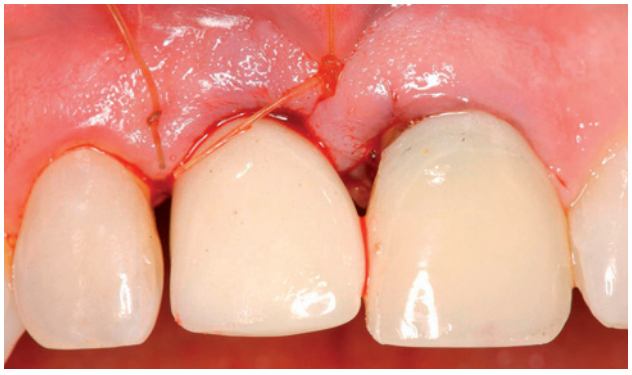


FIGURE 8-10 H, Gingiva is reapproximated to the provisional crown. Note the excellent gingival levels.

Diagnosis, Treatment Planning, and Surgical Techniques

To establish the treatment plan, the surgeon and restorative dentist initiate a diagnostic phase at the patient's first visit. Articulated models are used to create an esthetic diagnostic tooth setup using wax or denture teeth to determine the extent of missing hard and soft tissues. The planned restoration is used to determine the need for hard and soft tissue grafting.[6-12]

In a series of 100 consecutive cases of single anterior maxillary implants treated with a traditional two-stage technique, fewer than 20% of patients had adequate bone and soft tissue with no need for hard or soft tissue grafts. Another 20% of the single anterior maxillary implant sites

appeared to have adequate bone, but soft tissue thickness was deficient, requiring only an adjunctive soft tissue procedure after implant placement. The most common finding for esthetic implant sites was inadequate bone and soft tissue, requiring both bone and soft tissue augmentation.[13]

Patients have either a tooth in need of extraction or an edentulous space from a prior extraction. When extracting a tooth with plans for its replacement with an implant, the clinician must decide whether to perform an immediate implant placement or a delayed placement.[10,14-18] Implants are not placed at the time of extraction when signs of infection are present. These signs include the presence of granulation tissue, hyperplastic and hyperemic gingivae, periapical radiolucency, exudate (serous or purulent), and lack of adequate bone for the restoration. If an infection occurs after placement of an implant in the esthetic zone, severe gingival compromise results, and an ideal esthetic restoration is difficult to achieve. Therefore, delaying implant placement for 8 weeks after tooth extraction is the safest method for esthetic implant restoration. However, delaying implantation may result in loss of labial bone. Careful clinical judgment needs to be used in these cases.

At the time of tooth extraction, no incisions are made. The tooth is gently subluxed, and gentle curettage is performed to remove granulation tissue from the socket. The walls of the extraction site are gently probed to determine the amount of bone available when the implant is placed. The natural healing response of the extraction site forms woven bone within 8 weeks. If labial bone is missing, grafting with anorganic bovine bone may prevent excessive hard tissue grafting 3 to 4 months later. Techniques used to replace the missing tooth temporarily include removing a partial prosthesis, bonding a temporary pontic to the adjacent teeth, and using a type of Essix device.

Approximately 6 weeks after extraction of the tooth, or after assessment of the patient who has had extraction before the initial examination, the diagnostic procedures involving fabrication of an esthetic setup and a surgical stent are confirmed or started, as appropriate. These diagnostic procedures are performed 6 weeks after extraction to ensure that no delays occur in the placement of the implant 8 weeks after tooth extraction.

Based on the esthetic setup and the evaluations of the surgeon and restorative dentist, bone and soft tissue may be inadequate, in which case appropriate bone and soft tissue grafting must be added to the treatment plan. The patient is informed of the suggested plan, alternatives, risks, timing, and financial aspects before the surgical visit. Consent forms are reviewed before the day of surgery.

Most anterior maxillary single-tooth sites have inadequate bone and soft tissue, requiring both bone and soft tissue augmentation. The height of the papilla reflects the underlying crestal bone height on the adjacent teeth.[11,19,20] Careful assessment of the bone levels on the adjacent teeth enables the surgeon and restorative dentist to inform patients of the realistic expectations of retaining or creating papilla for an esthetic single-tooth restoration. For example, when the level of crestal bone on a central incisor is apical to the CEJ of the incisor and the distance from the crestal bone to the proposed contact of the lateral incisor single-tooth implant restoration is greater than 7 mm, the chances of achieving adequate papilla are low.[20-22] Patients are counseled before surgery concerning the realistic expectations of the papillary prognosis, based on the adjacent bone-tooth height relationship. For patients with 7 mm or greater distance from the contact area to the crestal bone, papilla-sparing incisions are used rather than sulcular incisions and an enveloped reflection.

The presurgical assessment, using the esthetic tooth waxup, enables the surgeon to estimate the height and width of a bone graft, if indicated. For severe bone deficiency, which prevents implant stabilization, a bone graft should be placed at least 4 months before implant placement, allowing the placement of future implants in the ideal locations horizontally and vertically. When the deficit of the bone is such that the implant can be placed and is mechanically stable with a portion of its surface exposed through the bone, a hard tissue particulate graft is placed at the same time as implant placement. The material used for grafting depends on the extent of the implant bone fenestration. Autogenous bone is used for larger fenestrations, with a gradual increase in HA as the implant bone dehiscence becomes smaller. If coronal implant threads are exposed, a membrane is placed to stabilize the graft in position and to prevent exposed threads and subsequent long-term hygienic soft tissue problems (see Figure 8-11).

Incision Design

For the esthetic single-implant site, the location of the incisions can influence the result. When possible, incisions involving the papilla should be limited to one elevation. If papillae are elevated multiple times, blunting of the papillae may ruin an esthetic restoration or require adjunctive procedures to attempt a correction of the deficiency. Thus, sulcular incisions with an enveloped flap are used only for placement of the implant, with subsequent soft procedures performed through small, crestal, papilla-sparing incisions.

The decision to use a sulcular or vertical papilla-sparing incision is influenced by the crestal bone levels on the adjacent teeth. If 2 mm or greater crestal bone resorption is present, which would place the proposed contact point 7 mm or more from the crestal bone, a papilla-sparing incision is used. When excellent bone levels are present on the adjacent teeth, a sulcular incision is used to place the implants. Subsequent soft tissue grafting can be performed

with minimal vertical incisions, keeping the appearance of the implant site free of vertical scars.

Implant Location

The location of the implant depends on the presurgical workup, which reveals the vertical and horizontal location of the implant. The locations of the proposed gingival margin and the incisive edge of the tooth are the two critical landmarks for proper implant placement.

Angulation of the implant should result in orientation of the axis of the implant to emerge slightly palatal to the incisive edge of the planned restoration. If the implant is placed at or anterior to the incisive edge of the tooth, developing the emergence profile of the restoration may be difficult. If the implant is placed too far labially, with the anterior edge of the implant at the edge of the gingival margin of the planned tooth, and with the addition of the abutment and porcelain, the gingival contour is excessive, and gingival recession results. As the platform (i.e., the diameter of the implant) increases, care must be taken to ensure that the labial edge of the implant is not excessively labial, or emergence of the crown is compromised and an obese crown form results.

The depth of the implant in relation to the planned gingival margin is also critical. If the implant is placed too shallow, with 2 mm or less from the top of the implant to the gingival margin, several adverse events can occur. The metal part of the implant may show through the gingival margin. Because the distance from the top of the implant to the gingival margin is minimal, metal show-through is difficult to camouflage. A minimal distance between the gingival margin and the top of the implant may also result in difficulty adjusting the margins of the abutment, causing porcelain to extend to the implant itself. It then is difficult to develop a natural appearance, because the gingival margin region of the restoration is excessively bulked or round. The use of ceramic abutments may help these adverse situations. However, the following guidelines to proper implant placement can prevent these problems:

1. The implant should be placed 3 mm countersunk from the planned gingival margin of the restoration. This measurement assumes a polished collar less than 1 mm in height to ensure a final 4-mm space from the gingival margin to the crestal bone level.
2. The angulation of the implant should place it slightly palatal to the incisive edge of the restoration.
3. The labial edge of the implant should be at least 1 mm palatal to the planned labial edge of the gingival margin portion of the restoration.

At surgery, a local anesthetic is administered, and incisions are made slightly palatal to the crest. To spare papillae, vertical incisions can be used, extending beyond the junction of the attached and unattached gingivae. Sulcular incisions, which include elevation of the papillae, also can be used with the enveloped flap, often extending to the molars. With proper elevation, larger grafts can be visualized with either incision design. After the full-thickness flap has exposed the bone, the implant is placed in its ideal location. A round bur is used to locate the point of entry into the crest, which is often thin. With the surgical guide in place, the pilot bur is used to develop the location of the implant, and a guide pin is placed to determine the orientation of the implant. At this point, the pilot hole may need to be located more palatally than first anticipated, especially in sites with thin crestal bone. If the entry point of the implant is positioned too far labially, dehiscence of the implant through the bone may occur. The pilot hole is redrilled as needed to obtain ideal implant placement. If necessary, graduated-sized osteotomes can be used to enlarge the implant preparation, expanding the labial portion of the crest. The remaining drill sequence is used. In thin bone, the thread-former may not need to be used. The implant then is placed, engaging apical bone near the nasal floor and piriform rim. The implant site is carefully examined. If possible, bone from the preparation site is saved either from the burs themselves or through a sieve device placed in the suction line.

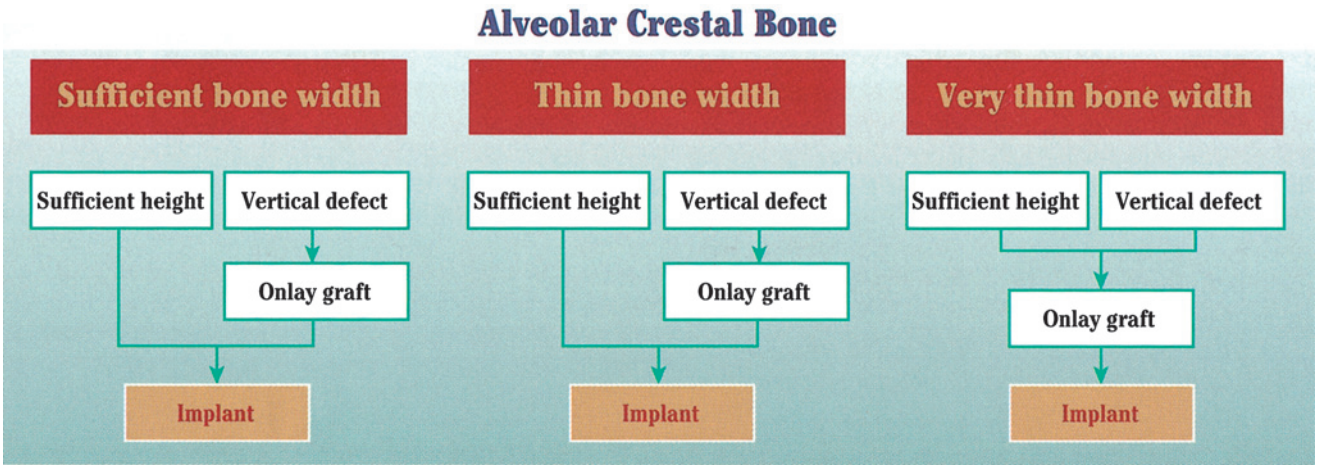
Bone may be lacking at the apical third, middle third, or coronal third of the implant body, or there may be combinations of fenestrations or dehiscences. These areas require hard tissue grafts to prevent epithelial downgrowth and potential soft tissue problems. In addition, thin bone covering the implant is most likely insufficient to restore horizontal bone contours, mimicking root prominence; therefore, thin bone also needs to be grafted to achieve the desired esthetic result.[23-25]

Decisions Affecting Treatment

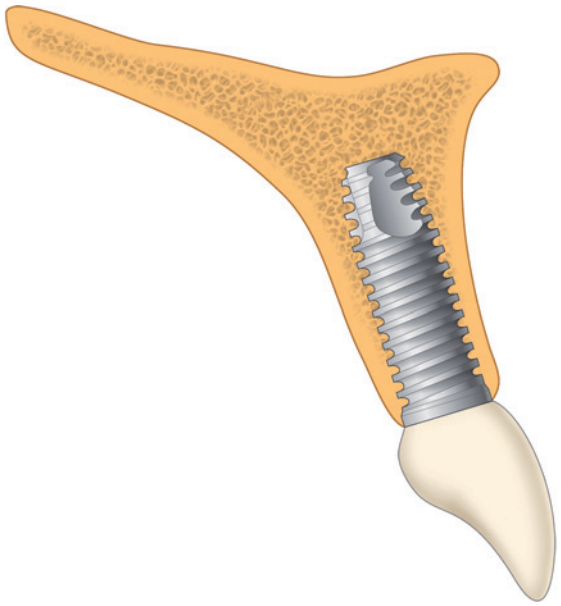
The decision tree in Figure 8-11 outlines the major choices the surgeon and restorative dentist face when placing anterior maxillary implants, as well as implants for other sites in the jaws.

The first decision concerns the adequacy of alveolar bone. Is the alveolar bone width satisfactory? Is the alveolar bone height satisfactory? The preoperative physical examination and the diagnostic setup, with appropriate radiographic studies (e.g., panoramic and periapical views and tomograms), should provide the surgeon with an accurate understanding of the anatomy of the surgical site as follows (Figure 8-12, A-D):

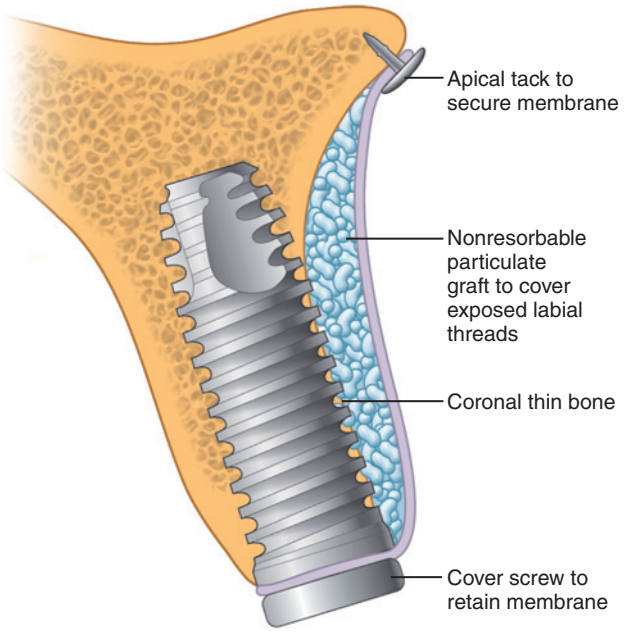
1. If both the alveolar bone width and the alveolar bone height are satisfactory, the implant can be placed without hard tissue grafting.
2. If a vertical bone defect is present with adequate alveolar bone width, an onlay bone graft or other bone-regenerative process is indicated before placement of the implant.



● **FIGURE 8-11** Decision tree for treatment of the anterior maxillary esthetic implant site. The thin bone width with sufficient height proceeds to the procedure shown in Figure 8-19.



● **FIGURE 8-12** **A,** Ideal bone is present for placement of an implant. The planned emergence of the implant is slightly palatal to the incisive edge of the crown.



● **FIGURE 8-12** **B,** Implant is placed with lack of bone covering the coronal region of the implant; this requires grafting. One treatment method involves placing nonresorbable particulate graft material, such as bovine bone or synthetic HA, over the dehiscence. A membrane then is placed and secured to the implant with a cover screw, and apically with tacks, resulting in coverage of the coronal portion of the implant. This also prevents epithelial downgrowth and subsequent soft tissue problems.

3. For thin bone, which is slightly less than or greater than the diameter of the implant, the implant can be placed and the area grafted simultaneously, as long as the vertical height of bone is adequate. Grafting the labial surface helps form a root eminence, which enhances the natural appearance of the final restoration.

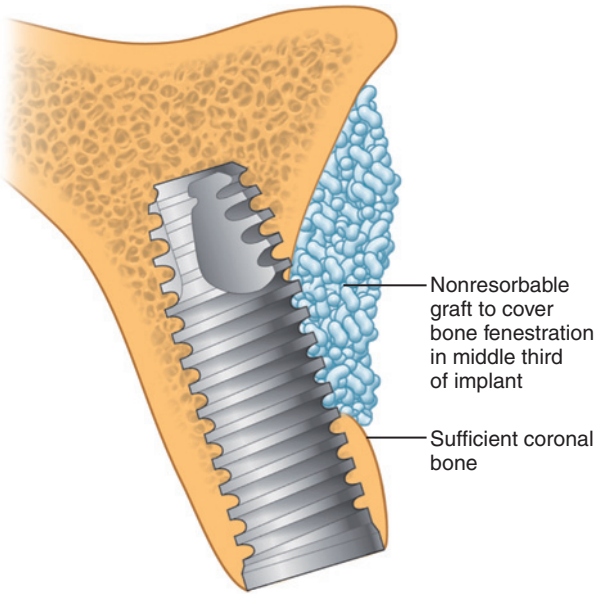


FIGURE 8-12 C, Concavity in the midportion of the implant site. The midimplant region, which has no bone coverage, is grafted with dense particulate HA. No membrane is needed.

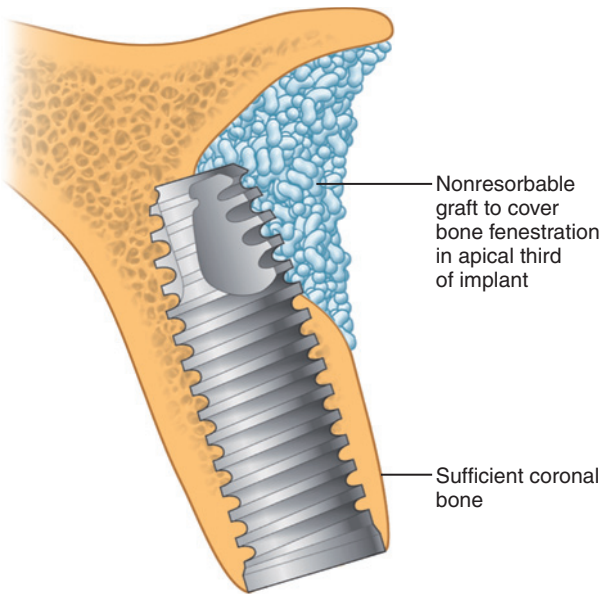


FIGURE 8-12 D, Concavity in the apical portion of the implant site. The apical implant region, which has no bone coverage, is grafted with dense particulate HA. No membrane is needed.

4. If the vertical alveolar bone height is deficient along with a thin ridge, an onlay graft or other regenerative procedure is indicated before the implant is placed.
5. If the bone is severely thin, preventing implant stability at placement, with or without a vertical defect, an onlay graft or other bone-regenerative procedure is indicated before the implant is placed.

Sufficient bone width and height

In patients with sufficient bone width and height, implants can be placed with minimal surgical incisions, without vertical release incisions, on the facial aspect of the ridge. Avoiding incisions along the facial aspect of the ridge in the esthetic zone increases the potential for an exquisite esthetic restoration of the missing tooth. At the time of implant exposure, a tissue punch or a small, semicircular incision can be used to avoid vertical incisions. The resultant restoration then is surrounded by gingivae that show no scars from incisions.

At surgery, preoperative photographs are taken before the administration of a local anesthetic. The ridge shape is examined, and the surgical guide is tried in place to allow adjustments, if necessary, while the local anesthetic takes effect. The local anesthesia should extend superiorly into the piriform rim to anesthetize the nasal floor, because many anterior implants are placed engaging the nasal floor.

Patients with adequate bone height and width for anterior maxillary implant placement usually have excellent crestal bone levels at the CEJ of the adjacent teeth. In such cases, the distance from the crestal bone to the proposed contact area of the restoration usually is less than 7 mm. This is an excellent prognosticator of papillary health, even after incisions have been made through the papillae and they are elevated.

Two incisions can be used, depending on the clinician's preference. One incision is on the crest with palatal release, leaving the labial facial tissue intact. The implant site is prepared without visualizing the facial cortical bone. This preparation requires a fine tactile sense so that the surgeon can determine whether the apical portion of the implant is confined within the cortical bone or fenestrates through the bone.

This author prefers to use a crestal incision across the edentulous site, combined with sulcular incisions extending at least two to three teeth distal to the surgical site. A full-thickness reflection is accomplished, exposing the labial bone at the implant site to the piriform rim and anterior nasal spine. The advantages of this incision and reflection are that direct visualization is accomplished, and vertical incisions are not made. The disadvantage is that the papillae must be raised and sutured back to their original position. The key to success with this technique is gentle tissue

management, avoiding tears in the circumdentate gingivae, and an atraumatic suturing technique to close the incisions. The papillae are closed with vertical mattress sutures, everting the papillae back to their original height.

A small, 15c scalpel blade is used to make the sulcular incision. The blade is directed against the surface of the teeth to the alveolar bone, severing the gingival fiber attachment without removing the inner portion of the gingival sulcus. These incisions must be made without cutting the papillary gingivae. A small, fine periosteal elevator is used to gently reflect the papillae and the circumdentate papillae without placing excessive pressure on the gingival margin tissue as the flap is elevated. The elevation of the flap is less traumatic and easy to achieve if a hydropic dissection with local anesthetic has been performed. In addition, the flap elevation may take several minutes to accomplish to prevent tearing from overaggressive tissue manipulation.

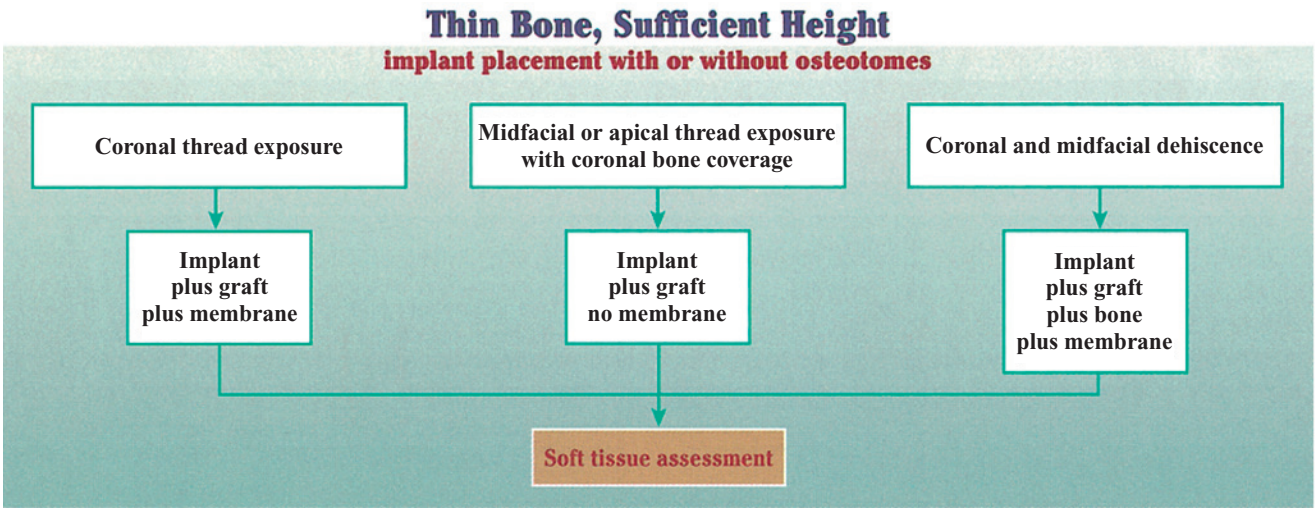
After the periosteum has been reflected with the flap, a round bur is used to identify and place the implant site within the center of the alveolar bone crest. The implant site should allow for adequate bone labially and palatally to the implant after it has been placed. The surgeon needs to determine that the distance from the entry site to the facial bone is adequate and will not result in excessively thin bone. After the round bur has been used, the graduating-sized burs are taken to depth, using the surgical guide stent. The guide pins should show the implant emerging just palatal to the incisal edge of the planned restoration and positioned apically 3 mm from the planned gingival margin. The implant is then placed. Because many anterior maxillary implants require an angle correction, it is important to align the antirotational features of the implant to ensure that the angled abutments can be placed and angled directly palatal to the implant's axis. For example, external hex implants should have the flat surface of the hex parallel to the facial cortex.

Thin bone width, sufficient bone height

Ridge shapes can lead to thin bone in the apical, middle, or coronal third of the implant site, or any combination of these three areas. Thus the implant surgeon must be aware of these potentially thin areas, which require grafting to obturate the defect and reduce the possibility of soft tissue invagination along a portion of the implant (Figure 8-13).

Thin Coronal Bone. Thin coronal bone is common. The alveolar crest is slightly larger than the diameter of the implant, or the crestal region can be widened to accommodate an implant by using graduating-sized osteotomes. In either situation, thin bone exists over the labial aspect of the implant. The implant is covered with bone, but it is minimal, and a deficiency in ridge projection exists, as well as potential resorption of the thin bone and subsequent thread exposure. In this situation, augmentation of the ridge is accomplished by onlaying a nonresorbable graft material, such as anorganic bovine bone. No membrane is necessary, because bone is present on the implant (Figure 8-14, A-I).

At surgery, full-thickness flaps are elevated to expose the crest. The pilot hole is made, and as necessary, osteotomes are used or the drilling sequence is performed. With extremely thin bone, thread-forming is not necessary, and the implant is self-tapped into place. After the implant has been positioned and the cover screw has been placed, the periosteum is released to allow tension-free closure, which



● **FIGURE 8-13** Decision tree for implant site with thin bone and sufficient height.

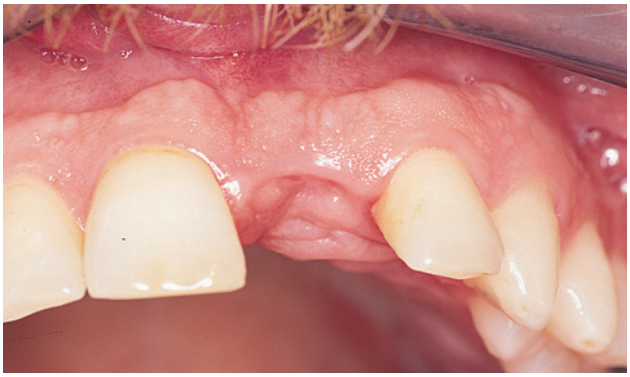


FIGURE 8-14 **A,** This 25-year-old patient had lost the left central incisor secondary to trauma 5 years earlier. The roots are parallel to each other, and there is 18 mm of vertical height to the floor of the nose. The ridge contour is concave.

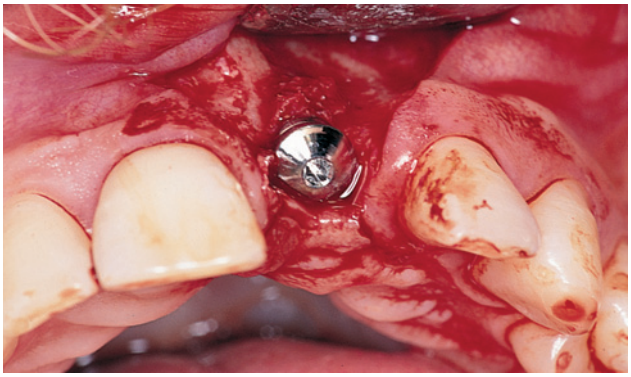


FIGURE 8-14 **B,** Crestal incision with papilla-sparing vertical release is chosen. Osteotomes are used to widen the crest. A threaded implant 16 mm long and 3.8 mm wide is placed. Bone covers the implant, but it is thin along approximately 10 mm of the implant's length.

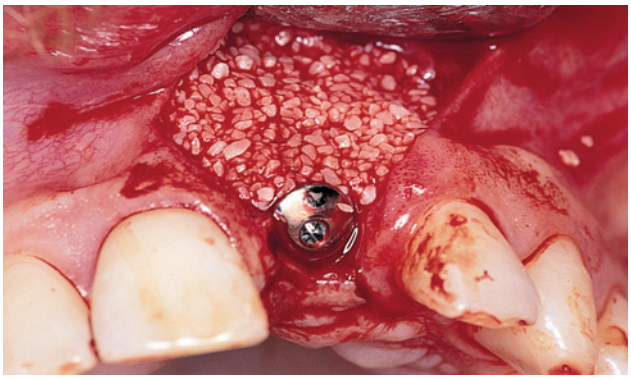


FIGURE 8-14 **C,** Dense particulate HA is placed over the thin bone. (Xenograft is also acceptable.) No membrane is used. The periosteum is released, and the incisions are closed without tension.

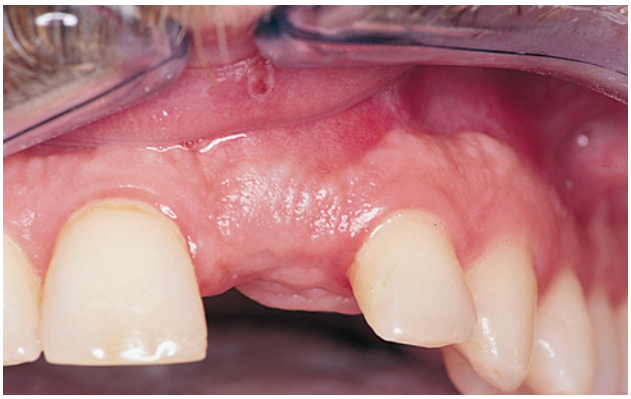


FIGURE 8-14 **D,** Approximately 3½ months after implant placement, the patient is evaluated. Improvement in the ridge contour is observed.

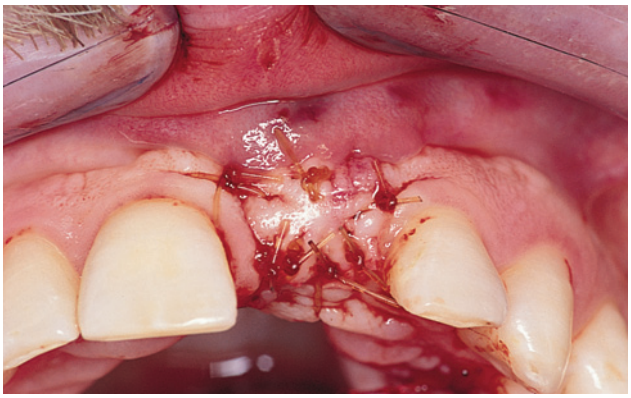


FIGURE 8-14 **E,** Subepithelial connective tissue graft is harvested from the palate. The graft is placed into a pouch, which is created to allow augmentation of the labial ridge contour.

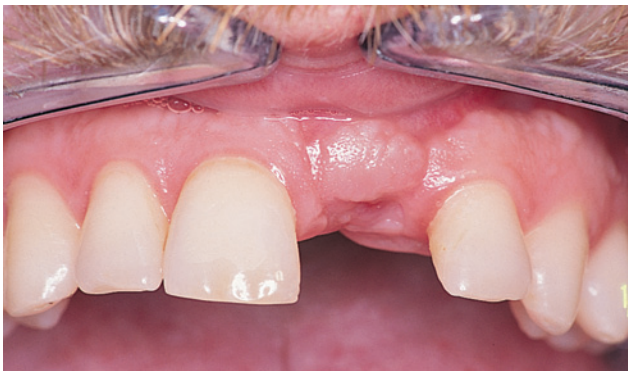
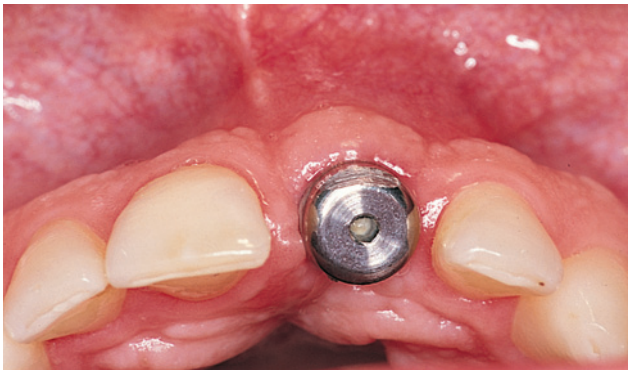
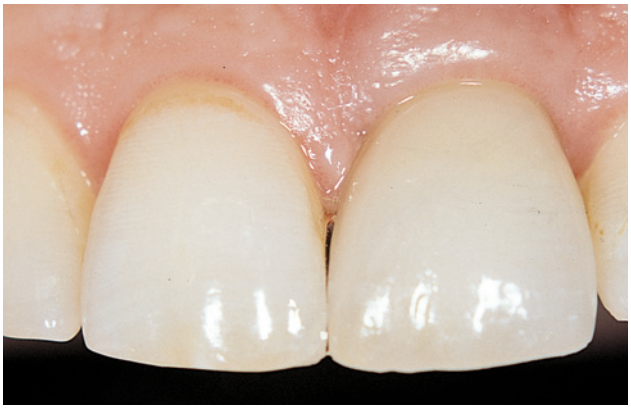


FIGURE 8-14 **F,** Six weeks after placement of the connective tissue graft, the implant is exposed. A bulk of soft tissue now is observed on the implant site.



● **FIGURE 8-14 G,** Tissue punch is used to expose the cover screw, and a temporary healing abutment is placed.

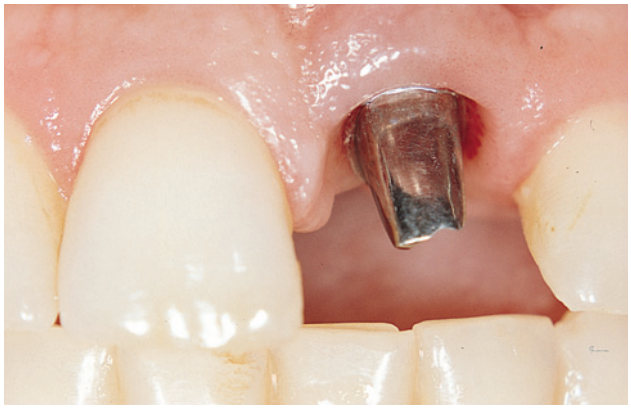


● **FIGURE 8-14 I,** All-porcelain crown is cemented in place. Note the natural appearance of the gingiva for texture, color, translucency, and form. (Prosthetics by Dr. Thomas Salinas.)

is performed before the alloplast augmentation material is placed. After hemostasis has been achieved, the alloplast is placed and molded into position. The incisions then are closed, with care taken to avoid inversion of the wound edge. The augmentation provides up to 2 mm of added thickness for the ridge form. A soft tissue graft provides an additional 2 mm of thickness, and tissue punch exposure from the palatal aspect provides another 1 mm of tissue thickness, which is completed by the potential for another 1 mm of subgingival thickness from the emergence profile of the crown. Thus, more than 5 mm of horizontal defect can be restored to result in an esthetic restoration (DVD Figure 8-7, A-H).

DVD Images 8-7, A-H

Midfacial or Apical Thread Exposure with Coronal Bone Coverage. Some patients have adequate bone width at the coronal region of the implant, but the ridge contour



● **FIGURE 8-14 H,** Approximately 4 weeks after placement of the temporary healing abutment, the gingival form adapts and assumes the shape of a natural tooth. The final abutment is in place.

is so concave that fenestrations will be present in the midfacial or apical regions after the implant has been placed.

After the flap has been raised and the contour of the palatal and facial bones visualized, the implant site is prepared and the implant placed. It is important that the implant engage sufficient apical bone so that its position is mechanically stable, without mobility. If bone fenestrations are visible, they are grafted with nonresorbable synthetic or bovine graft materials to obturate the defects. When graft particles are used over a fenestration, a membrane is not required, for the following reasons:

1. Bone is present along the most coronal aspect of the implant.
2. The periosteum can maintain the graft in position in the middle and apical thirds of the implant site.
3. The concavity of the ridge acts as a natural barrier to prevent excessive movement of the graft.

After the graft has been placed, the periosteum is scored and a supraperiosteal dissection is performed to allow tension-free closure (Figures 8-15, A-N, and 8-16, A-K).

Coronal Thread Exposure. After the flap has been raised, the thickness of the bone from the alveolar crest to the floor of the nose can be easily visualized. As mentioned earlier, thin crestal bone is relatively common. The bone often increases in thickness as it reaches the nasal floor. The surgical guide stent and the landmarks of the adjacent teeth guide implant placement along the correct axis and depth. When the implant has been placed in the ideal location, and after a tooth and a portion of bone have been lost secondary to a destructive process, intact palatal bone may be present with loss of a portion of the facial aspect of the ridge. Clinical judgment and experience direct the surgeon to initiate the drilling sequence or delay implant placement

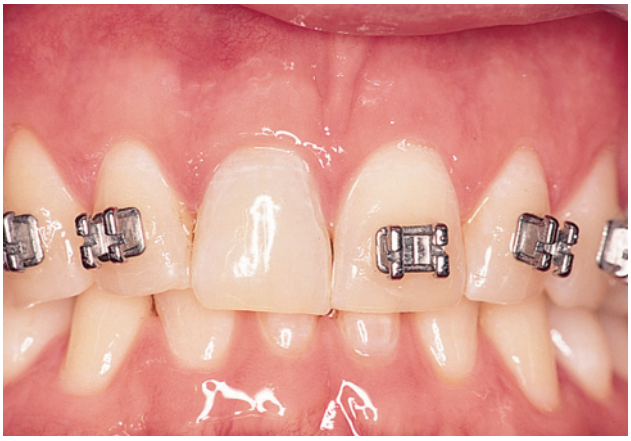


FIGURE 8-15 **A,** This 26-year-old orthodontist has external resorption of the maxillary right central incisor secondary to injury when he was 12 years old. He has a high smile line and desires an esthetic restoration. He has purulent drainage on gentle probing. The tooth is extracted with minimal incisions.

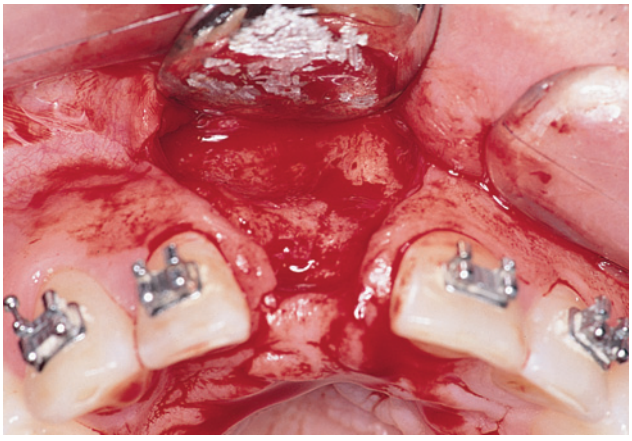


FIGURE 8-15 **B,** To avoid incising the papillae completely, a crestal incision combined with vertical release is used to expose the bone.

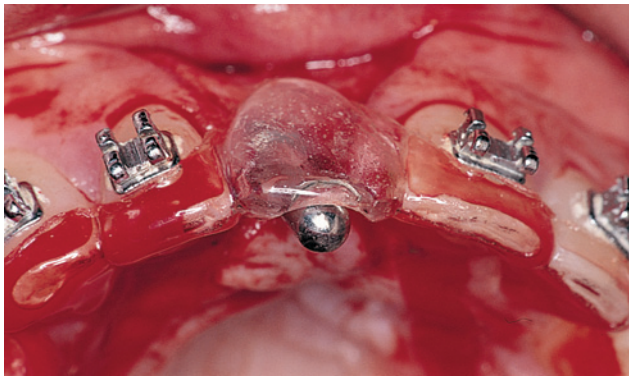


FIGURE 8-15 **C,** With a surgical guide stent in place, the pilot hole is drilled into the bone and the guide pin is placed, showing appropriate angulation of the implant.

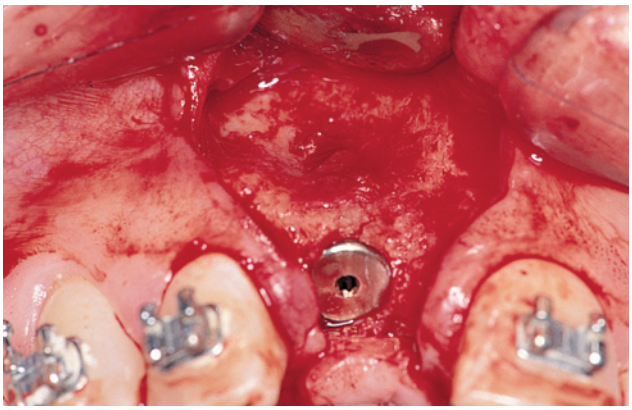


FIGURE 8-15 **D,** Cover screw is placed. The implant is completely within alveolar bone, but there is still a horizontal deficit when the ridge form is compared with the adjacent teeth.

and perform a bone graft. The drilling sequence should allow placement of an implant that is mechanically stable. If the implant can be placed without excessive micromotion, the membrane-guided bone regeneration can be performed at the time of implant placement.

A round bur is used to initiate and define the implant location. It is important that the surgeon remember to make this initial hole more palatal than initially thought to ensure that the implant is placed with as much stability as possible. The palatal location of the implant still must be within the confines of the planned restoration. Typically, a pilot drill 1.25 mm in diameter is taken to the depth of the planned implant site, often engaging the nasal floor. Graduating-sized osteotomes can be used to expand the thickness of the alveolar crest bone. However, as the thickness of the osteotome increases, the chance of labial bone fracture also increases. Ultimately, the implant site preparation is completed using the manufacturer's recommended drilling sequence, and the implant is placed. The implant should be mechanically stable in the bone. In the thin crestal or coronal bone site, several threads of the labial surface of the implant may be exposed or dehisced through bone. A membrane is used to retain the graft over the coronally exposed implant threads.

After the implant has been placed and the decision has been made to use a membrane, the membrane is trimmed

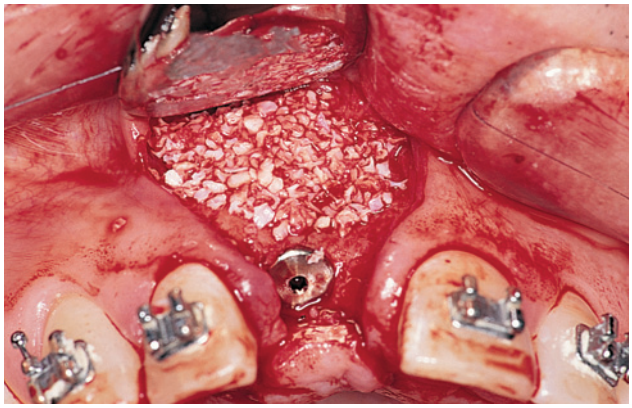


FIGURE 8-15 E, Because bone covers the implant but the ridge contour is still deficient, a dense particulate graft is placed to augment the labial aspect of the ridge.

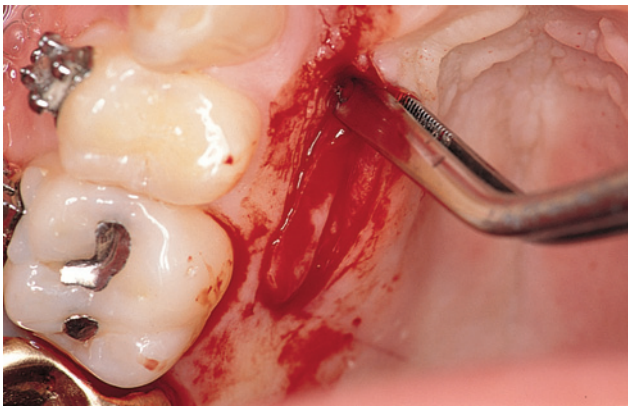


FIGURE 8-15 G, Subepithelial connective tissue is harvested from the palate.

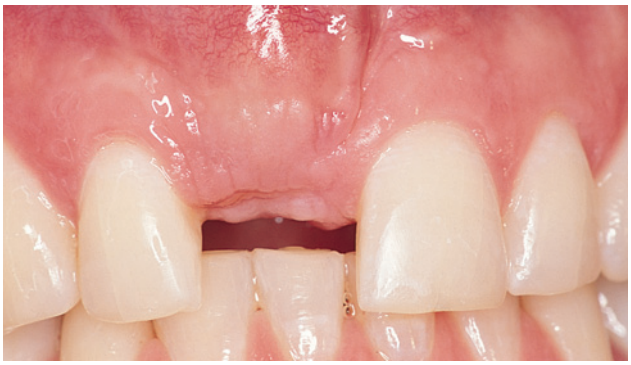


FIGURE 8-15 I, Approximately 6 weeks after placement of the connective tissue graft, the ridge form shows adequate contour.

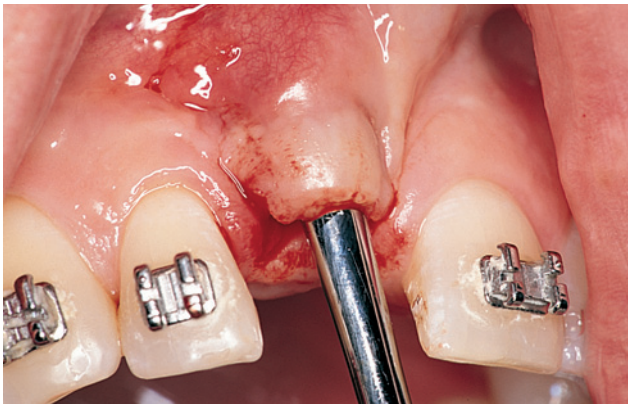


FIGURE 8-15 F, Approximately 3½ months after augmentation, the deficiency in the ridge contour remains, indicating the need for a subepithelial connective tissue graft. Because no membrane was placed during the implant placement procedure, a small crestal incision is made without vertical incisions to create a pouch.

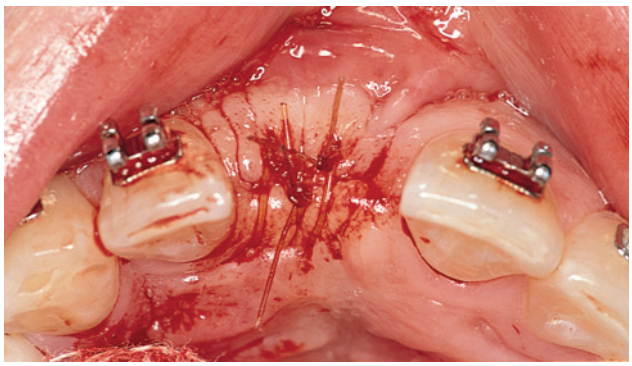


FIGURE 8-15 H, Connective tissue graft is placed into the pouch and is retained with one horizontal mattress suture placed from the depth of the vestibule and two or three interrupted crestal sutures.

to allow at least 1 mm of space between the edge of the membrane and adjacent teeth. The membrane is trimmed to widen as it reaches the apical region of the implant site. A hole is placed into the coronal aspect of the membrane, which allows the membrane to be secured to the implant. After the membrane has been secured to the implant with the cover screw, the graft material is placed over the exposed threads and over thin bone. The membrane then is draped over the graft and secured to the apical bone with two small screws or tacks. For small areas of dehiscence, the graft can be dense, particulate, and nonresorbable synthetic or bovine material that remains in place for an extended period and is eventually incorporated with bone. The purpose of the membrane is to (1) maintain contour of

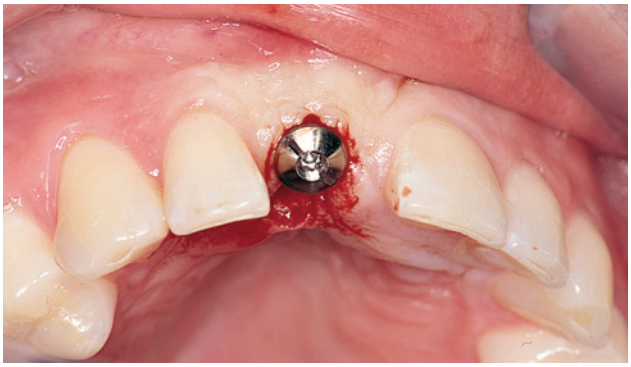


FIGURE 8-15 **J,** Implant is exposed using a tissue punch and without the need for incisions. A 5-mm-tall, straight-contour, temporary healing abutment is placed. Blanching of the labial tissues occurs when the abutment pushes the palatal tissue labially, which further augments the implant site. A temporary crown is placed 2 weeks later.

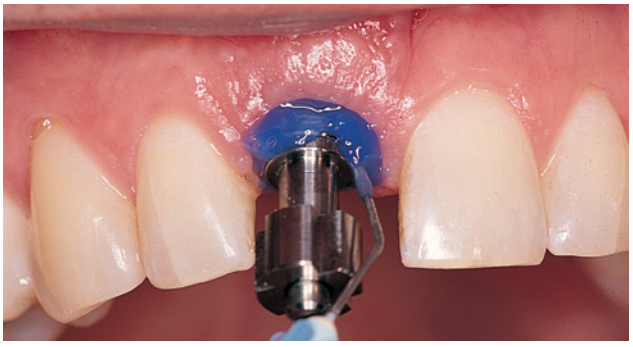


FIGURE 8-15 **L,** Light-cured resin is inserted into the space between the transfer coping and the gingival sulcus; it is polymerized by ultraviolet light. When the transfer impression is made, the contours of the gingival sulcus are in the model, allowing accurate subgingival contour fabrication of the final crown.

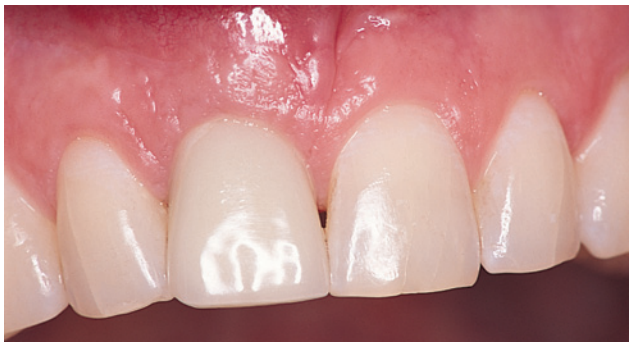


FIGURE 8-15 **N,** Final crown in place. The symmetry of the gingival architecture is the result of hard and soft tissue augmentations. (Prosthetics by Dr. Thomas Salinas.)

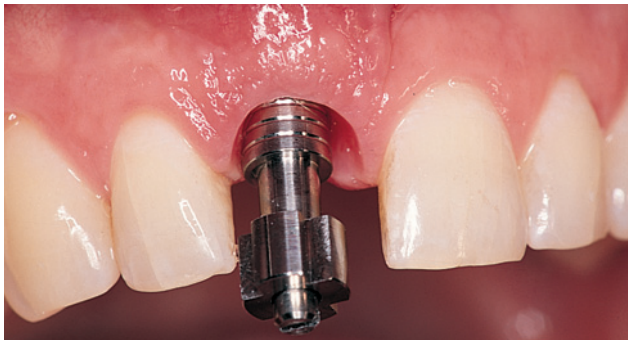


FIGURE 8-15 **K,** Approximately 5 weeks after placement of the temporary crown, the temporary abutment is removed. The contour of the gingival sulcus now mimics that of a natural tooth. A transfer coping is placed; however, it does not match the contour of the gingival sulcus.

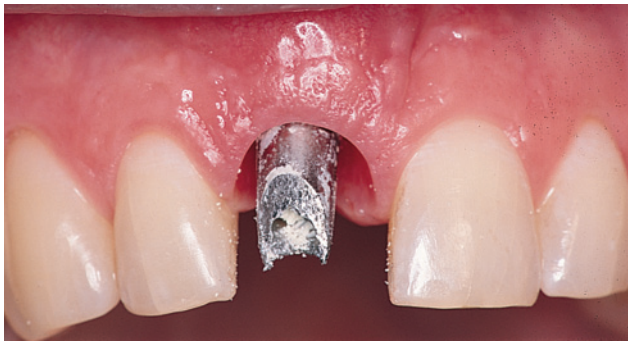


FIGURE 8-15 **M,** Final abutment in place.

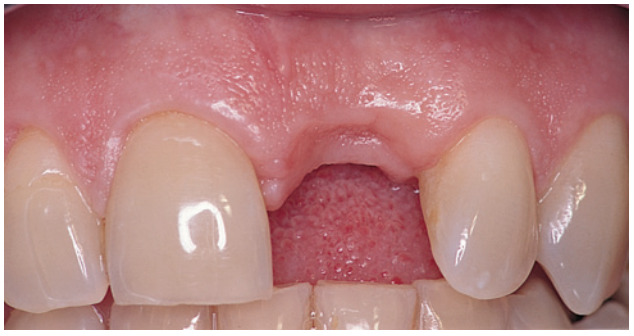


FIGURE 8-16 **A,** This 58-year-old patient had lost the maxillary left central incisor secondary to caries and periodontal disease. His periodontal status is stable. A horizontal ridge deficiency is observed. Despite a 2-mm loss of crestal bone adjacent to the remaining incisor, he has excellent papillae.

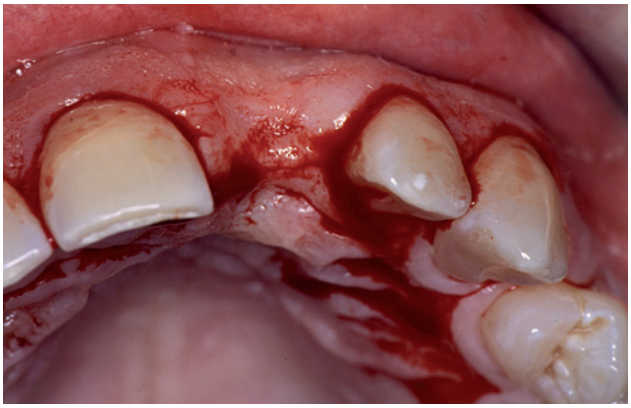


FIGURE 8-16 B, Because of the patient's thick gingivae and his concern about vertical scars, a crestal incision is used to expose the implant site, and intrasulcular incisions are used around the teeth.

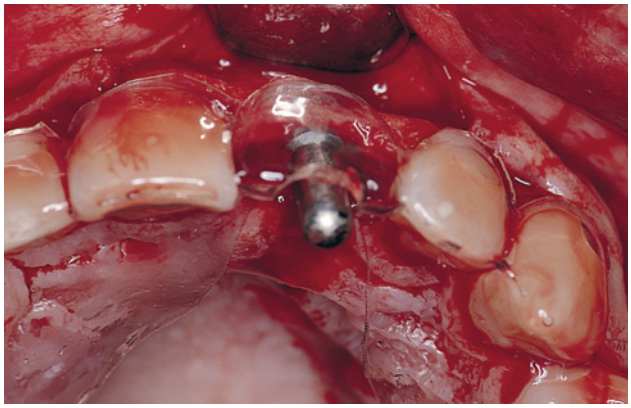


FIGURE 8-16 C, Full-thickness reflection extends from the distal aspect of the right canine to the distal aspect of the left canine. The surgical guide stent is used to make pilot holes. The position of the guide pin is slightly palatal to the incisive edge of the planned restoration.

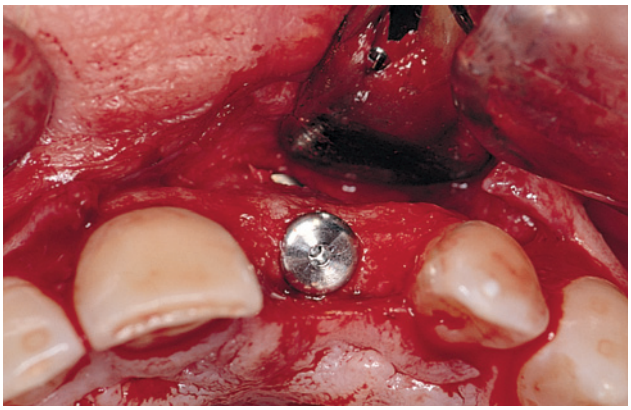


FIGURE 8-16 D, Implant is placed. As expected, the horizontal ridge deficiency is observed, even though the implant is placed completely within alveolar bone.

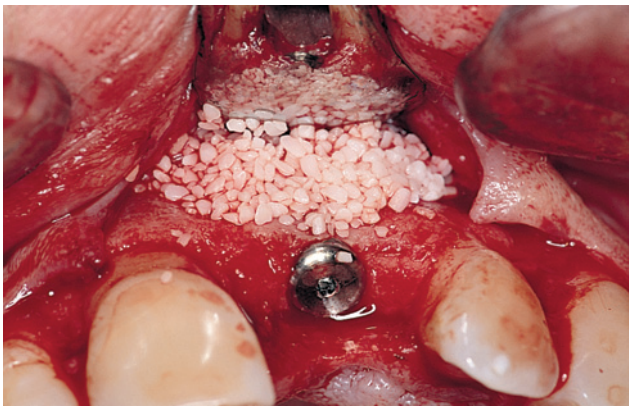


FIGURE 8-16 E, Dense particulate HA is placed to augment the labial aspect of the ridge. The periosteum is released, and the incisions are closed without tension.

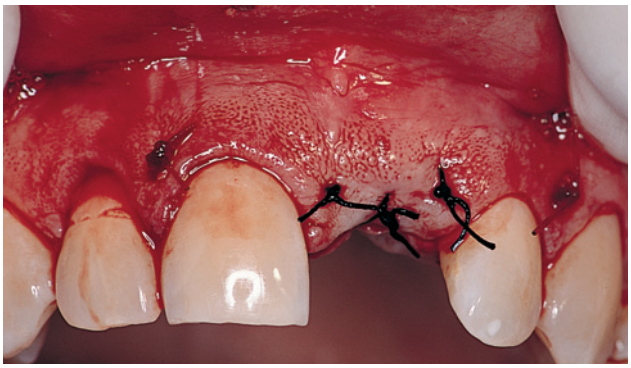


FIGURE 8-16 F, Vertical mattress sutures are placed in the interdental regions to evert the papillae. Interrupted, nonresorbable sutures are placed across the crest of the edentulous space.

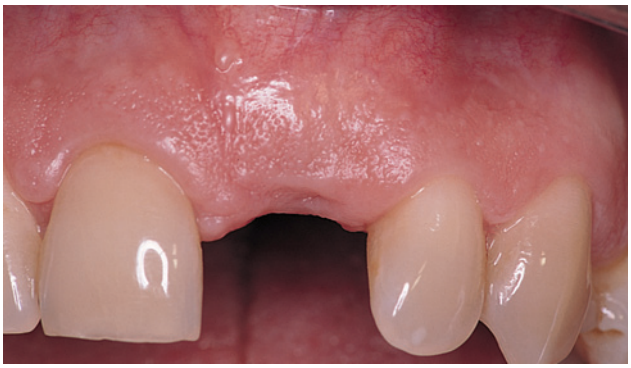


FIGURE 8-16 G, Five months after augmentation, a small, residual horizontal deformity is seen.

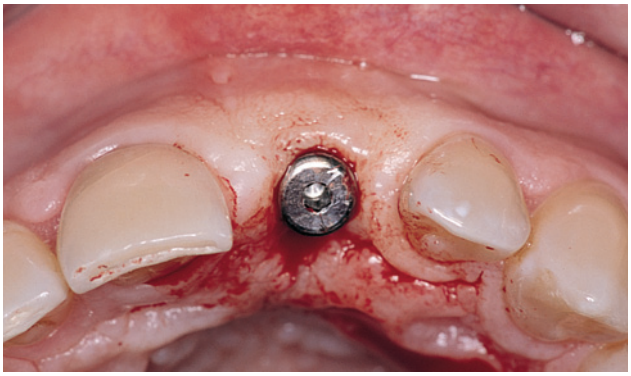


FIGURE 8-16 H, Small horizontal deficiencies with otherwise healthy and esthetic gingivae can be corrected by prosthetic abutments. A tissue punch is used to expose the implant and abutment.

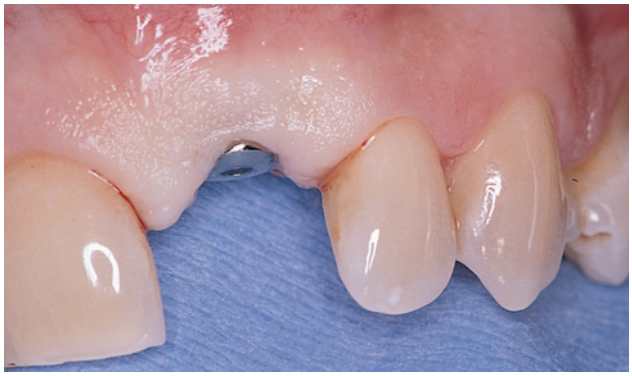


FIGURE 8-16 I, When the temporary abutment is placed, blanching of the gingivae is observed as the abutment pushes the gingivae labially.

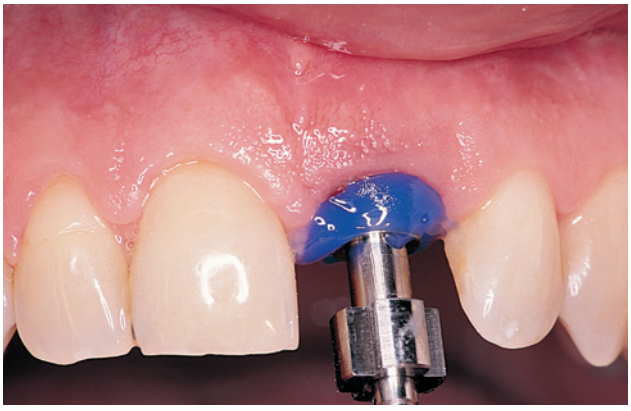


FIGURE 8-16 J, Transfer coping is placed after the temporary crown has been in place for 6 weeks. Light-cured resin is used to ensure accurate transfer of the gingival sulcus to the models.

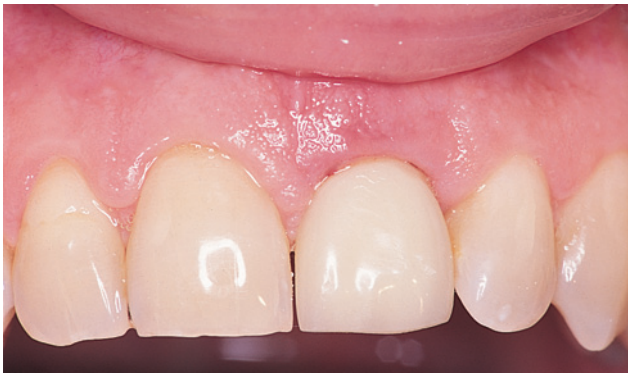
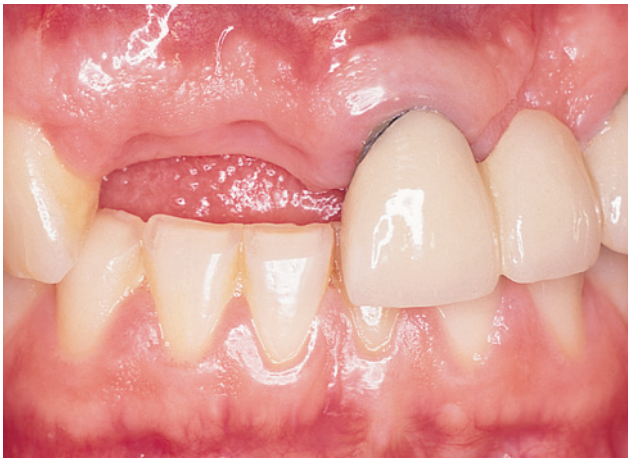


FIGURE 8-16 K, Temporary crown is in place. (Prosthetics by Dr. Avishai Sadan.)

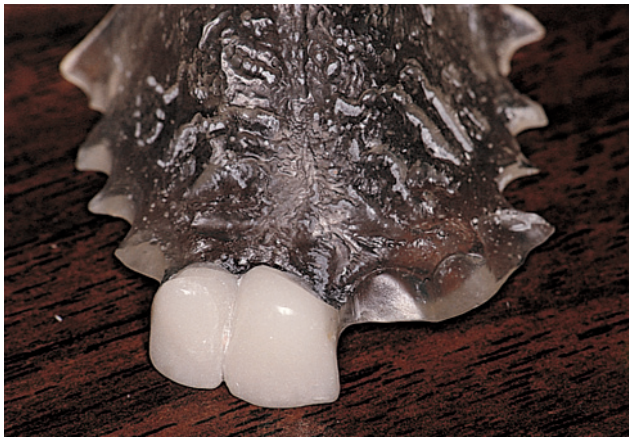
the graft at the most coronal aspect of the implant without thread exposure, (2) facilitate bone fill in the HA graft, and (3) help maintain ridge augmentation in the desired coronal location.

A supraperiosteal dissection is performed at the base of the flap to allow tension-free closure. Nonresorbable sutures are used in the crestal region, combined with resorbable sutures on a tapered needle to align the vertical release incisions as necessary or to close the sulcular incisions to evert papillae to achieve esthetic closure (Figure 8-17, A-Q).

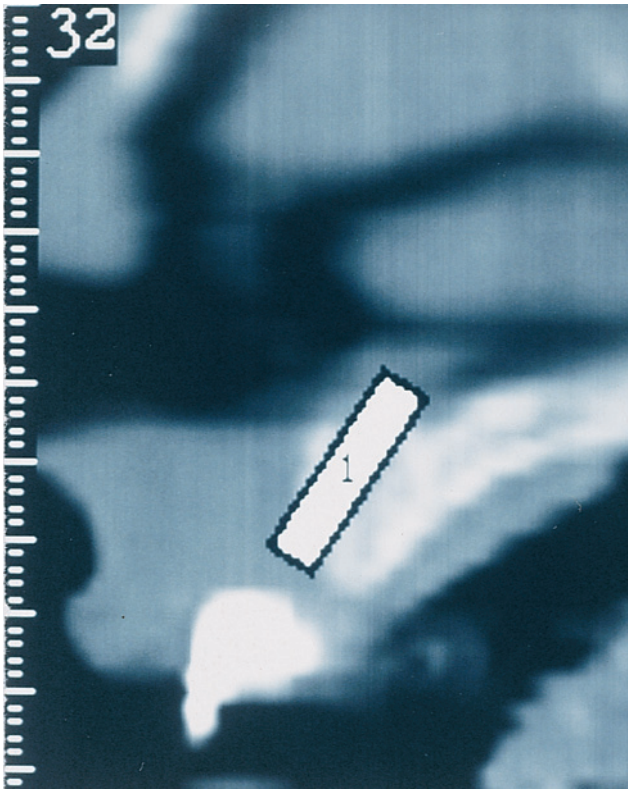
Coronal and Midfacial Bone Dehiscence. After loss of a tooth from trauma or a chronic infectious process, facial bone loss may be significant, without loss of palatal bone height. The resultant ridge is thin up to the apical third. On implant placement, the palatal aspect of the implant is in contact with bone, but up to half of the implant's length is not covered with bone, with 50% of the implant engaged circumferentially in apical bone. The implant is mechanically stable, but it requires grafting. For this situation, where bone is needed to increase the amount of integration of the implant, autogenous bone is harvested for use as a graft material. Bone can be collected from a sieve attached to the suction line; maxillary tuberosity bone can be harvested from the posterior maxilla, ramus, symphysis, or particulate bone; or another source of bone can be used, depending on the clinician's preference. After the bone is harvested, it must be particulated to result in smaller particles, which can be adapted over the ridge to form a smooth graft. The particulated bone is placed over the implant and covered with a nonresorbable membrane. As previously described, the coronal aspect of the membrane is secured to the implant by the cover screw, and the apical portion of the membrane is secured to the apical bone with tacks or small screws.



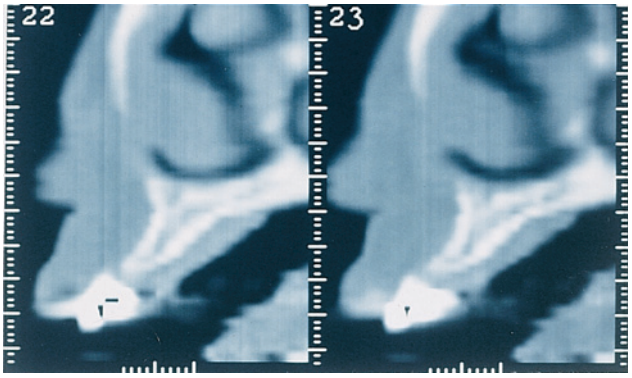
● **FIGURE 8-17** **A,** This 29-year-old patient with a high smile line had lost the right central and right lateral incisors after endodontic failures. The teeth were removed by an endodontist approximately 5 months before her examination. She desires an esthetic restoration, including the left anterior quadrant. Her problem list includes gingival recession around previous crowns, concave ridge form under the left lateral incisor pontic, and a horizontal deficiency of the right anterior edentulous site.



● **FIGURE 8-17** **B,** Esthetic setup is made with 30% barium sulfate (by weight) mixed with acrylic. The patient approves the setup. A setup is necessary because the temporary removable partial denture has short, nonesthetic crowns and is not useful for diagnostic purposes. The esthetic setup is adapted to be a type of flipper prosthesis, which the patient can wear during diagnostic imaging.



● **FIGURE 8-17** **C,** Computed tomography (CT) scan is reformatted. Several coronal threads are exposed after placement of the implant in the central incisor region.



● **FIGURE 8-17** **D,** Reformatted CT scan shows the left lateral pontic position, and a 4-mm horizontal defect is observed. A combination of hard and soft tissue grafting, performed in a staged manner, is used to treat a defect of this size.

The periosteum is scored, and a supraperiosteal dissection is performed to allow tension-free closure. Nonresorbable sutures are used to close the site. A tapered needle with 4-0 sutures is used to align the edges of vertical incisions when vertical incisions are used. For larger membrane-assisted grafts, the clinician allows 5 months for graft consolidation before assessing the soft tissue status in preparation for a soft tissue augmentation procedure (DVD Figure 8-8, A-N).

DVD Images 8-8, A-N

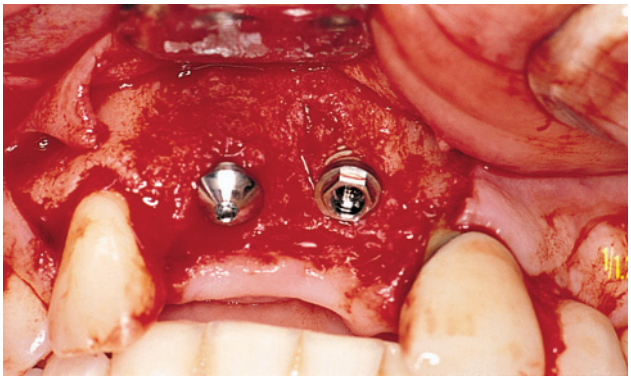


FIGURE 8-17 **E,** Crestal incision with vertical release is used, and the implants are placed. Coronal thread exposure is seen on the right central incisor implants. At the pontic region, the pontic is revised to create space, and a crestal incision is made. A subperiosteal pocket is formed, and HA is placed to augment the site.

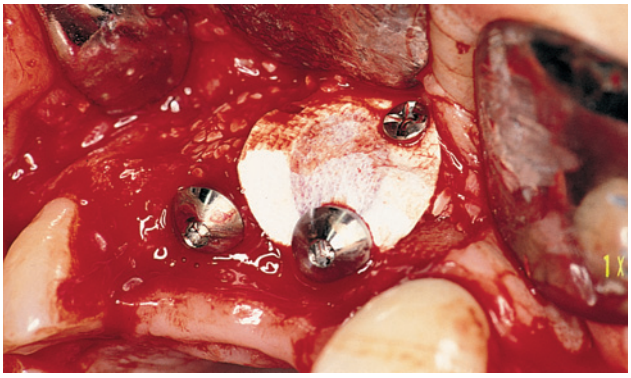


FIGURE 8-17 **G,** Nonresorbable membrane is secured to the bone and the implant.

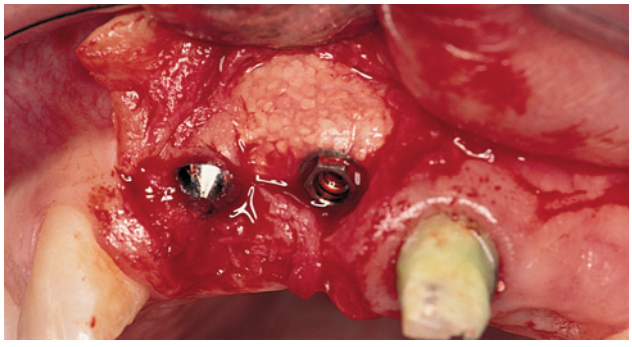


FIGURE 8-17 **I,** Membrane is removed after the apical screw and the cover screw have been removed.

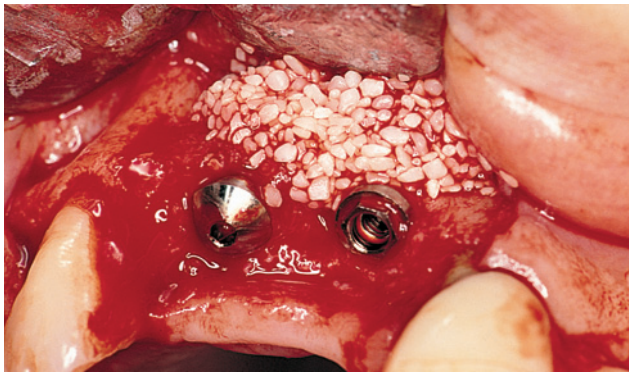


FIGURE 8-17 **F,** Dense particulate HA is placed to augment the coronal aspect of the implants. (Bovine xenograft can also be used.)

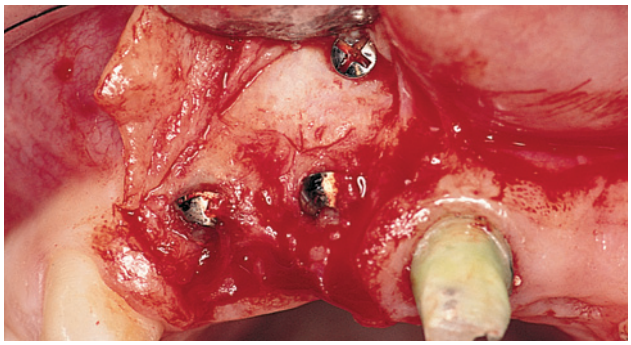


FIGURE 8-17 **H,** Approximately 3½ months after membrane placement, incisions are made to remove the membrane and place a subepithelial connective tissue graft. The membrane is visible before its removal.

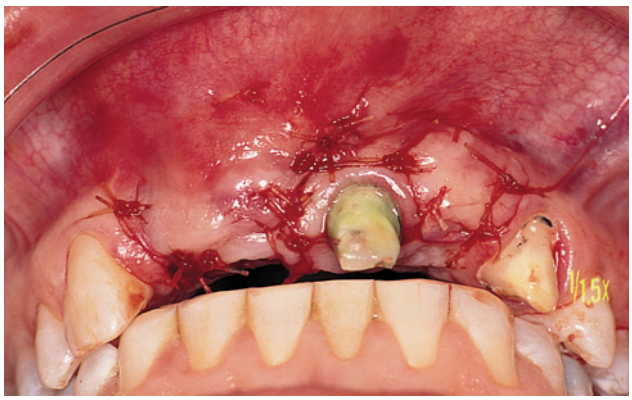


FIGURE 8-17 **J,** Subepithelial connective grafts are harvested from the palate and placed over the right incisor regions, as well as the left lateral incisor pontic region, to further augment the gingival contours.

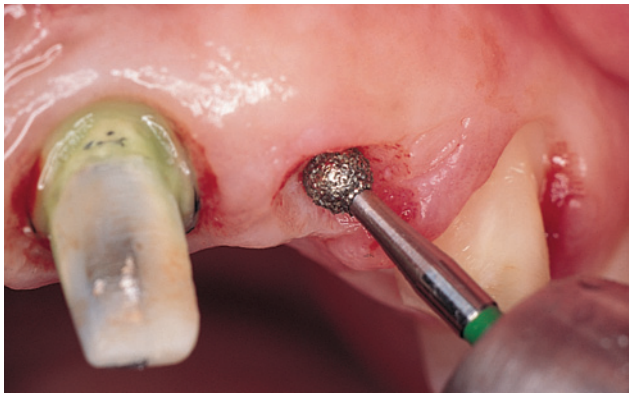


FIGURE 8-17 **K,** In the left lateral incisor pontic region, a diamond bur is used to create a depression in the ridge to simulate subgingival emergence of the pontic.

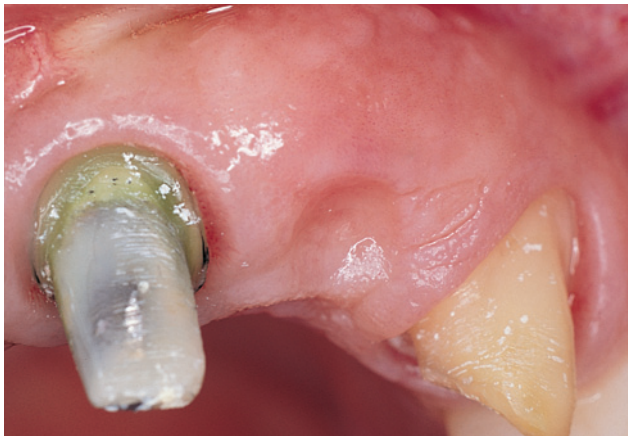


FIGURE 8-17 **L,** Depression in the ridge is ready for the final prosthesis.

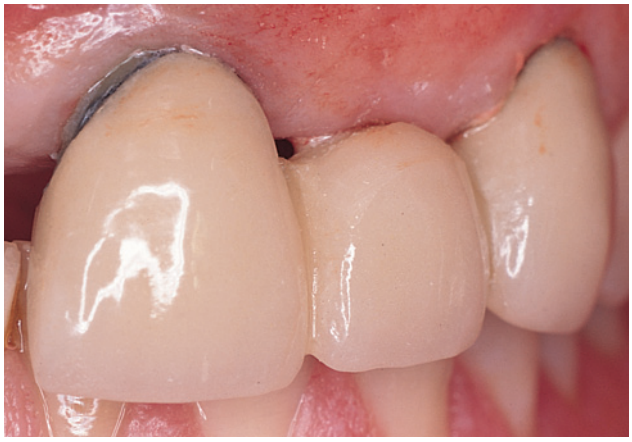


FIGURE 8-17 **M,** Initial view of the left anterior maxilla.

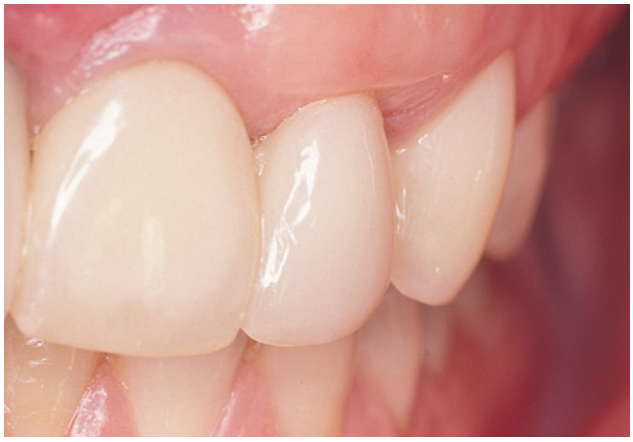


FIGURE 8-17 **N,** Final prosthesis of the left side of the maxilla. Augmentation of the pontic region allows fabrication of an esthetic restoration.

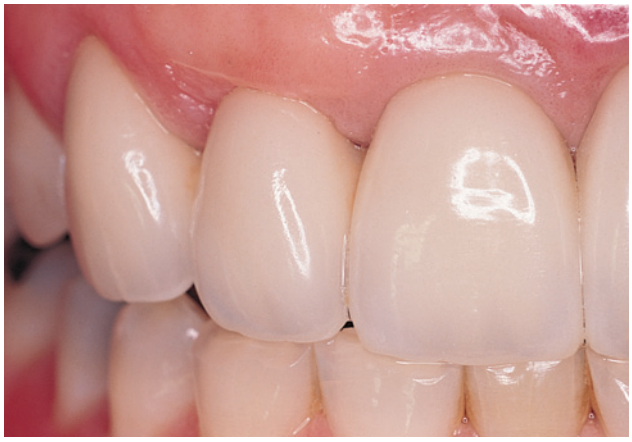


FIGURE 8-17 **O,** Final view of the right side of the maxilla.

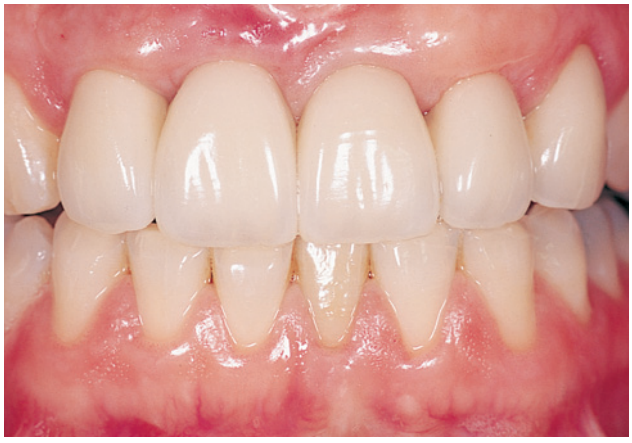


FIGURE 8-17 **P,** Final frontal view. (Prosthetics by Dr. Gerald Chiche.)

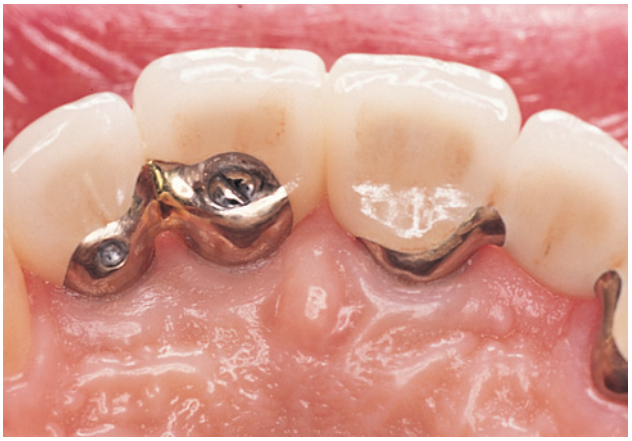


FIGURE 8-17 **Q,** Final occlusal view.

Thin Bone Preventing Implant Stability with Adequate Vertical Bone Height. In some patients, the alveolar ridge is too thin for immediate stabilization of the implant. The clinical impression is that the apical bone at the nasal floor may be used to stabilize the implant, but the clinician has minimal confidence in the implant's ability to integrate in such a situation. For these patients, either onlay bone grafting or ridge widening may be accomplished with a ridge-splitting technique.

Onlay bone grafting with a solid block of bone is demonstrated in a case involving vertical and horizontal augmentation (Figure 8-18, A-J; the entire case is presented in

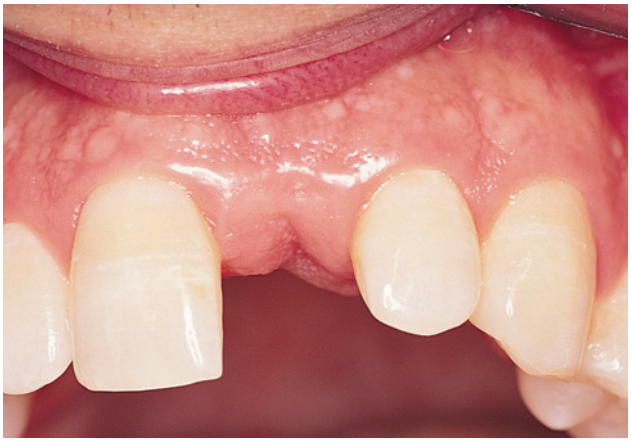


FIGURE 8-18 **A,** This 29-year-old patient desires a single crown to replace the missing left central incisor. Palpation of the ridge indicates a thin ridge that does not widen superiorly. The remaining central incisor is stable, tall, and oval with greater than 7 mm from the contact area to the crestal bone.

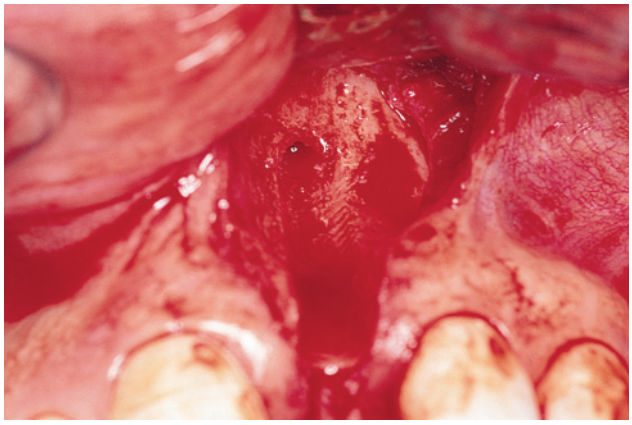


FIGURE 8-18 **B,** Crestal incision is combined with vertical papilla-sparing incisions, and a full-thickness reflection is made, revealing the thin ridge.

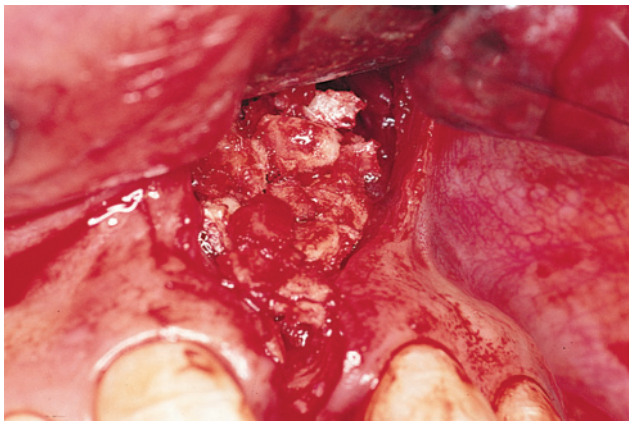


FIGURE 8-18 **C,** Bone is harvested from the maxillary tuberosity, particulated, and placed over the thin ridge.

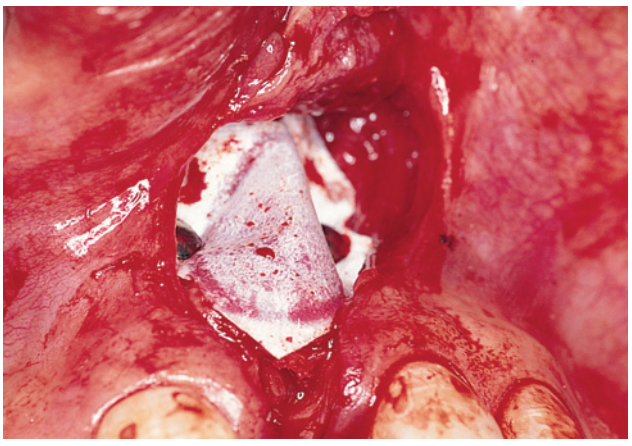


FIGURE 8-18 **D,** Nonresorbable membrane is placed and secured with tacks.

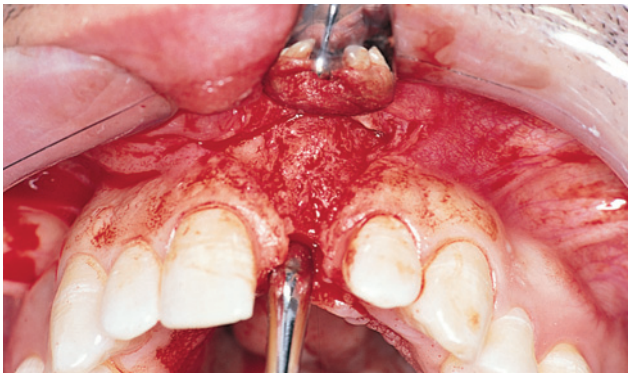


FIGURE 8-18 E, Four months after membrane removal (7 months after the initial grafting), the area is again exposed for implant placement. The graft is found to have consolidated.

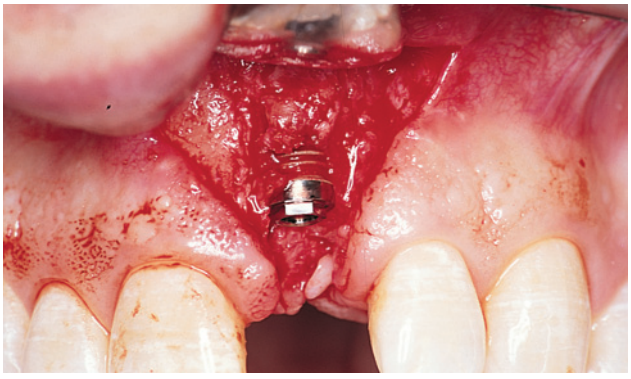


FIGURE 8-18 F, Implant 18 mm long is placed, with a small area of coronal threads exposed.

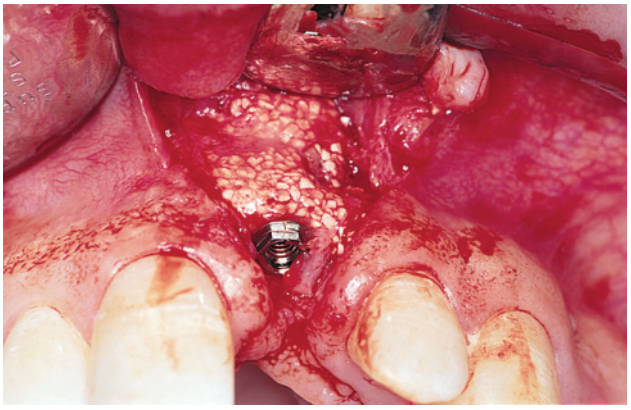


FIGURE 8-18 G, Membrane is removed, exposing well-consolidated augmentation over the prior bone graft.

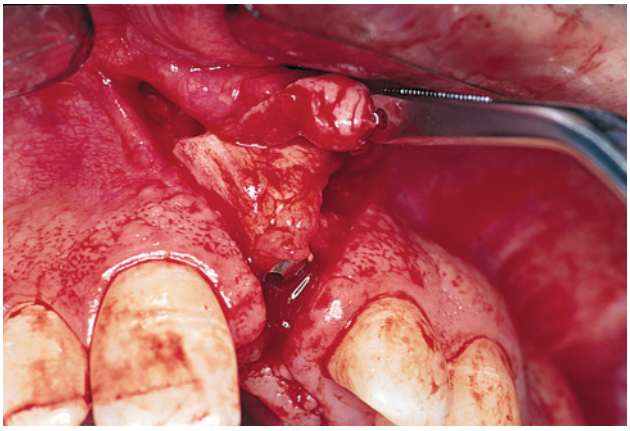


FIGURE 8-18 H, Subepithelial connective tissue graft is harvested from the palate and contoured to fit over the graft site to augment the alveolus.

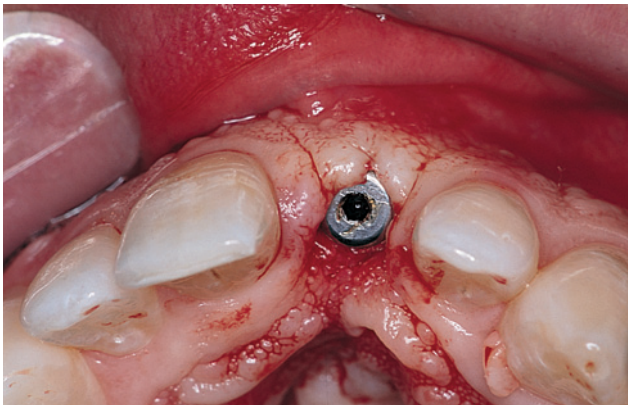


FIGURE 8-18 I, Temporary healing abutment is placed. The ridge contour appears satisfactory.

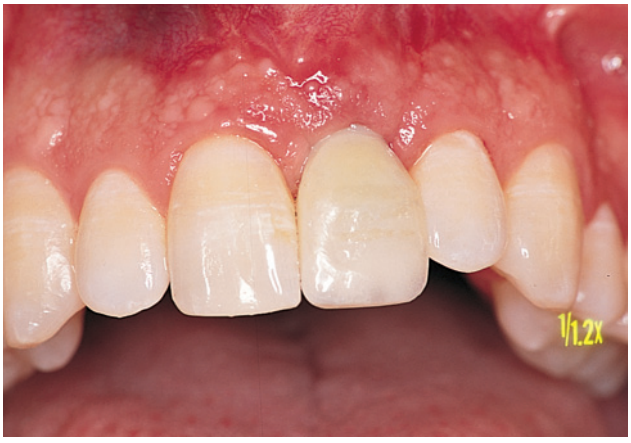


FIGURE 8-18 J, Final crown in place. (Prosthetics by Dr. Thomas Salinas.)

8-9, A-P

DVD Figure 8-9, A-P). Onlay bone grafting can be performed successfully using particulate bone and membrane-guided tissue regeneration. For the patient with a thin ridge that does not widen as the ridge is followed to the nasal floor, particulate bone is harvested from the maxillary tuberosity and placed over the ridge as an onlay graft. The membrane is tacked to simulate a root form eminence. If the particulate graft does not provide enough stability to maintain the space under the graft, titanium-reinforced membranes can be useful. When these membranes are used, a healing period of at least 6 months and often 9 months is allowed before the membrane is removed and the implants placed. This delay allows graft revascularization and remodeling into compact bone, which can stabilize an implant.

8-10, A-C

For select patients, *ridge splitting* is a technique that involves moving the labial plate of bone facially after an osteotomy is accomplished (DVD Figure 8-10, A-C). This procedure can be performed either in the operating room under general anesthesia or under intravenous sedation, depending on the patient's level of cooperation.

Preoperative planning includes fabrication of a surgical guide stent with the locations of the planned implants incorporated into its design. The surgical guide stent provides important information about the extent of necessary widening of the anterior maxilla. In selected patients, the stent also guides the surgeon in placing the implants at the time of the ridge widening.

An antibacterial solution is applied to the mouth, and a local anesthetic then is infiltrated into the labial and palatal tissues. At least 10 minutes must elapse to allow absorption of the local anesthetic and resolution of the swelling caused by infiltration. The planned dissection is full thickness to the junction of the attached and unattached gingivae, where it is carried apically in a supraperiosteal plane. The incision can be made slightly palatal to the crest and then extended distally within the sulcus at least three teeth from the edentulous site. A periosteal elevator is used to raise a subperiosteal flap to the junction of the attached and unattached gingivae, where the periosteum is scored and a split-thickness dissection is carried apically as far as needed. Extensive reflection and dissection of the soft tissue over the planned osteotomy site should be avoided to minimize vascular compromise of the facial plate of bone.

After the reflection has been completed, a round bur is used to create small depressions in the crest, after which a pilot bur is taken to a depth engaging the nasal floor, paralleling the palatal plate of bone, and keeping a significant thickness of facial bone intact. In severely thin ridges, this step may be eliminated, and the surgeon may proceed directly to a sagittal saw. A thin sagittal saw blade is used to create an osteotomy, splitting the ridge extending to the nasal floor. The use of thin, flat osteotomes is an alternative. Small osteotomes are used from within the alveolus to complete the osteotomy vertically along the facial bone. A thicker osteotome is used to outfracture the labial plate. Often a simple greenstick fracture without extensive mobilization of the facial bone is sufficient to achieve the desired widening.

Once the bone has been outfractured, the surgeon has the option of grafting the site and returning after healing to place the implants. If the apical bone is satisfactorily thick to allow stability of the implants, they can be placed at the time of outfracture. The drilling sequence is initiated, and the implants are placed, engaging the apical bone; this stabilizes the implants if the bone has been gently outfractured in a greenstick manner. If the clinician does not choose to place implants, interpositional grafts are needed to maintain the new width of the bone. Typically, the bone does not have to be secured with screws. If implants are placed, a surgical guide stent should be used to guide their placement into ideal locations. A particulate graft is then placed into the defects adjacent to the implants and along the crestal defects, if present. A membrane is not necessary, because the graft is placed within a bone defect, which should heal without a membrane. The addition of a membrane may increase the incidence of incision breakdown, which results in bone loss, possible loss of the implants, and loss of the labial bone plate (DVD Figures 8-11, A-F, and 8-12, A-I).

8-11, A-F
8-12, A-I

Bone can be harvested from the drills through a sieve placed in the suction line or from the other areas of the jaws, such as the ramus, tuberosity, or chin. The graft is particulated to allow packing among the plates of bone. Xenogenic anorganic bone or other bone substitute materials may be used only if they eventually resorb and are replaced with bone. Bone is needed in this clinical situation to support the process of integration.

After the implants and grafts have been placed, a supraperiosteal dissection is performed as necessary to allow tension-free closure with 4-0 sutures on a tapered needle, so as to prevent mucosal tears. At the depth of the dissection, superficial to the periosteum left on the outfractured bone, the periosteum is scored with a scalpel or sharp scissors. The supraperiosteal dissection is performed as necessary. It is imperative to have a tension-free closure to prevent breakdown of the crestal incision. The enveloped flap design makes closure easy to perform. The interproximal areas are closed with sutures placed in a vertical mattress fashion to evert the papillae and avoid reducing their height. A prosthesis is not placed until the incisions have healed unless the prosthesis is definitely not touching the operative site. After 6 months, the implants are exposed for restoration.

Augmentation of the Thin Maxillary Alveolus in the Esthetic Zone. After traumatic avulsion of teeth, severe periodontal disease, or a series of failed apicoectomy procedures, the patient may present with missing anterior

central incisors and request replacement of the missing teeth with single crowns rather than a fixed bridge. These patients may have sufficient vertical palatal bone, but the horizontal dimension may be deficient, the gingiva thin and often deformed by scars, and the adjacent teeth malposed. This case illustrates the treatment of a woman with a high smile line and high esthetic expectations.

The patient had a traumatic episode when she was younger that resulted in secondary root canal therapy and two apicoectomies. The teeth became mobile secondary to root shortening and labial bone loss. The central incisors were removed by a general dentist without grafting. A temporary removable prosthesis was placed, which the patient disliked. After 3 years, in an attempt to restore her pretrauma status, the patient presented for evaluation for implant-supported single crowns. The lateral incisors were found to be malposed, with the roots angled into the missing central incisor locations. Orthodontic therapy was used to restore the lateral incisors to a correct anatomic position (Figure 8-19, A).

Models were mounted, and an esthetic waxup was created and tried in the mouth. The patient agreed to the prosthetic plan. A stone model was made of the waxup, and a vacuum form was created. Barium sulfate (15% by volume) was mixed with acrylic and placed into the vacuum form. A cone beam scan then was performed. Cross-sectional images were examined (Figure 8-19, B-C). These images were not found to provide sufficient information for implant choice; consequently, computed tomography (CT) planning software was used. The DICOM data from the cone beam scan were placed on a CD and loaded into a computer.

The Simplant Pro planning software was used. The apical sections were chosen and segmented. The barium sulfate, radiopaque planned crowns were split and recolored

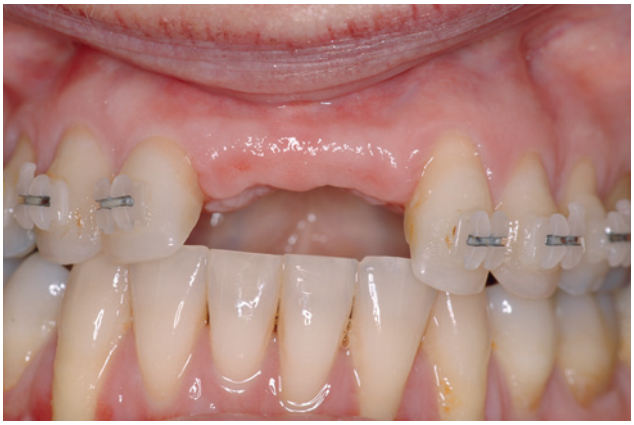


FIGURE 8-19 **A,** Preoperative view shows missing central incisors. The patient has had orthodontic alignment of the lateral incisors. An esthetic setup is fabricated for CT scanning and planning because of the known thin bone.

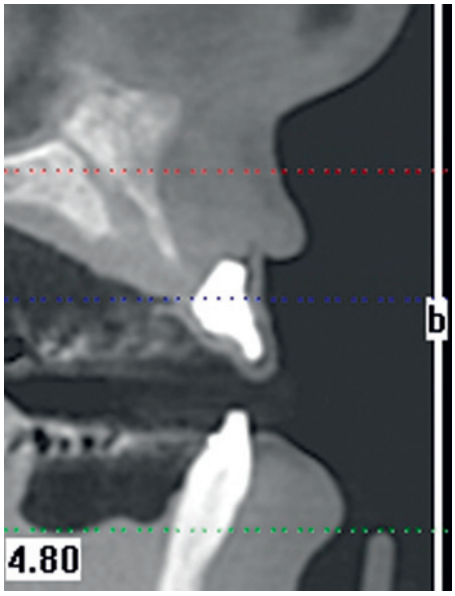


FIGURE 8-19 **B,** Cross-sectional image of the thin bone on the mesial aspect of the right central incisor.

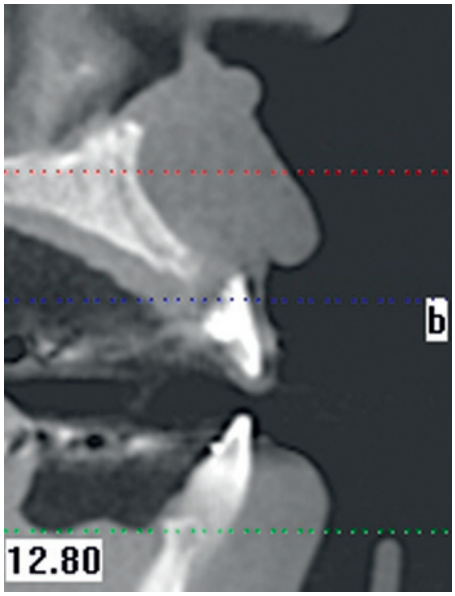


FIGURE 8-19 **C,** Cross-sectional image of the bone in the center to slightly distal aspect of the site of the right central incisor.

(Figure 8-19, D) to allow the clinician to remove the plan and examine the implant placement separately or with the plan in place. Cross-sectional images then were used to virtually place two small-diameter implants (3.25 × 15 mm long) with angulation that would be adequate for the prostheses (Figure 8-19, E-F). These implant were positioned 0.5 mm distal to the middle of the central incisors, with

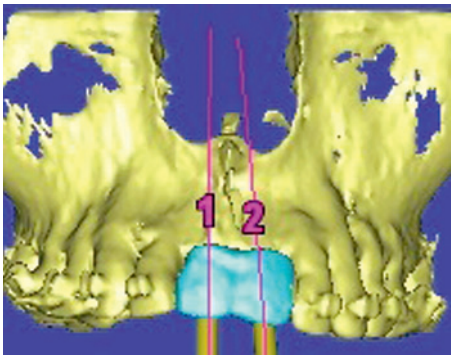


FIGURE 8-19 **D,** CT scan DICOM data are used for further planning using the Simplant software (Materialise, Brussels, Belgium). This three-dimensional image shows two implants virtually placed. Their emergence is acceptable.

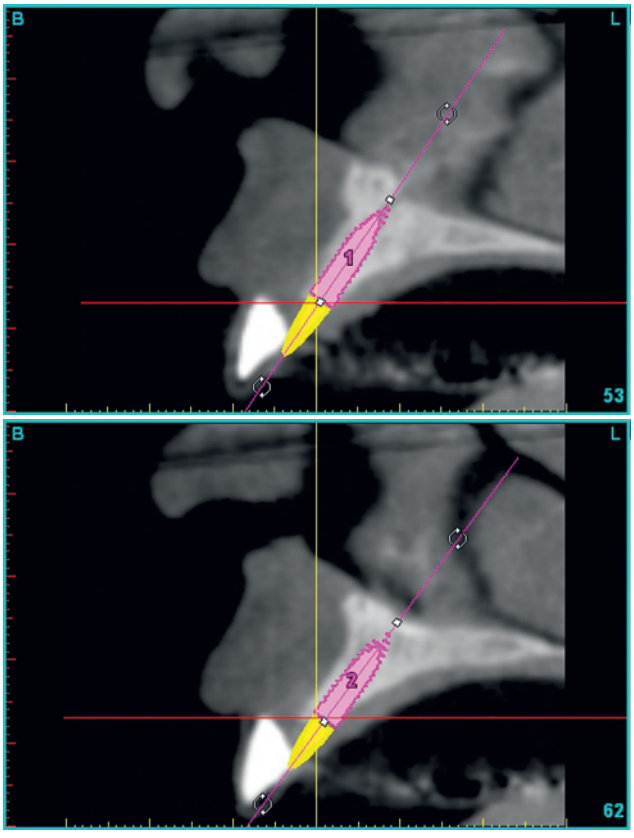


FIGURE 8-19 **E-F,** Cross-sectional images from the CT planning software show that two implants can be placed within the bone. The implants must be small diameter, and the labial bone must be grafted at the time of implant placement.

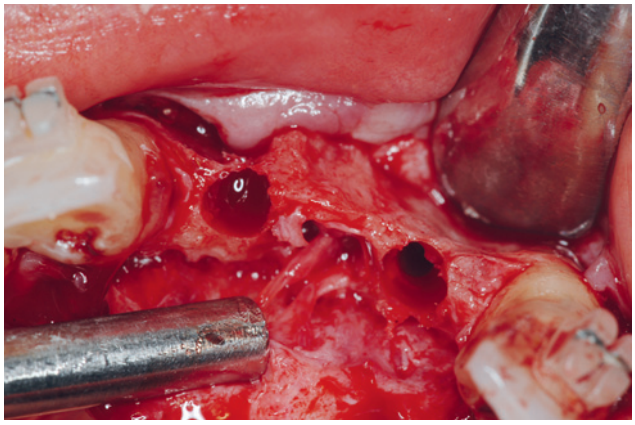


FIGURE 8-19 **G,** Based on the planning software, two implant sites are prepared. A crestal incision is used with sulcular incisions around the adjacent lateral incisors and canines. A full-thickness envelope flap is elevated to the piriform rim. The periosteum is released to allow a tension-free closure. Two implant sites are prepared. The bone from the drills is collected to be combined with the xenograft. Here, the two implant sites are shown with the expected thin bone, and the incisive foramen also is exposed.

total contact of the implants with palatal bone and thin bone on the labial in the crestal region.

Given this information, the surgical plan was amended to include simultaneous labial bone augmentation aided by a resorbable membrane that would slowly resorb over 6 months. The augmentation would be performed with autogenous bone combined with bovine xenograft.

At the time of surgery, the orthodontic wire was removed. A local anesthetic was infiltrated from canine to canine in the maxilla. A crestal incision was made with a 15c blade, with sulcular incisions around the lateral incisors and the canines. A small Hirschfeld #20 periosteal elevator was used carefully to elevate the facial gingiva. It is critical to prevent tears in the gingiva to create a perfectly containing flap for the eventual closure over the graft material. The subperiosteal flap was elevated to the piriform rims. The palatal mucosa also was elevated to expose the palatal slope of the alveolar bone and the incisive foramen. The implant sites were prepared as in the plan (Figure 8-19, G). The bone from the drills was collected, placed into a sterile bowl (Figure 8-19, H), and combined with the xenograft (Figure 8-19, I-J).

Scissors were used to release the periosteum at the base of the flap; the release was kept to the periosteum, and dissection of the muscle layers was avoided. Care was taken to prevent perforation of the nasal mucosa. After release of the periosteum, a small amount of bleeding may occur, which is controlled by pressure. A gauze is placed under

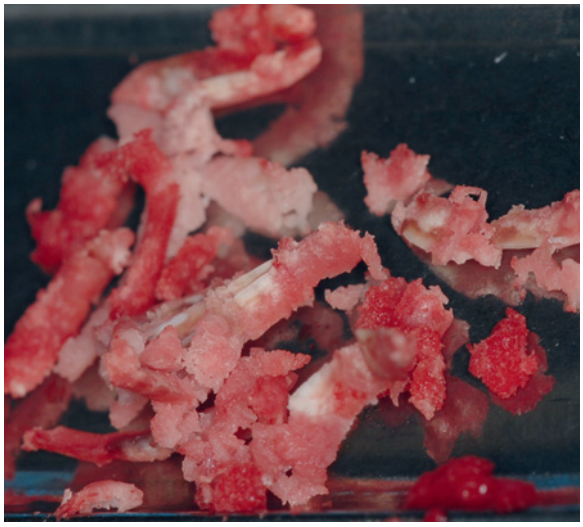


FIGURE 8-19 H, Bone collected from the drills is used as an autograft.

FIGURE 8-19 J, Autogenous bone and the xenograft are combined approximately 50:50, or at the most 80:20, xenograft to autogenous bone. This is the initial mixture, which is more thoroughly mixed as a composite graft.

the flap and left in place for 5 minutes. It is critical to have excellent hemostasis, because bleeding in the postoperative period results in a hematoma that breaks down the incision, creating a milieu for infection, and the graft migrates with the fluid of the hematoma.

The implant sites were prepared according to the plan. Care was taken to place the implants at the correct angulation and depth to allow the implants to emerge slightly palatal to the incisor edges of the planned crowns. The depth was 3 to 4 mm apical to the planned gingival margin.

FIGURE 8-19 I, Bovine xenograft (Endobon, Biomet 3i, Palm Beach Gardens, Florida) is dampened with a small amount of saline.

After placement, the radiofrequency index value (implant stability quotient [ISQ]) was 70 for each implant. Cover screws were placed.

The collagen membrane was trimmed to fit passively under the flap. The combined autogenous bone and bovine xenograft was carefully packed under the flap and directly on the labial bone (Figure 8-19, K). The graft was very carefully and meticulously compacted over the implants to convert the ridge from concave to convex. The implants were completely within bone in the apical region; therefore, the most important region to augment was the thinner labial bone at the crestal two thirds of the implants. The incision was closed. This author first places vertical mattress sutures at the papilla areas of the teeth and then runs a baseball-type suture on the crestal incision (Figure 8-19, L). It is crucial to perform a tension-free closure. Most clinicians fail to release the periosteum sufficiently, which results in incision breakdown. Another common complication is incision breakdown secondary to lack of adequate hemostasis.

Postoperative cone beam scans showed accurate placement of the implants and the augmentation (Figure 8-19, M-R).

Palatal Approach for Single-Stage Implant Placement. This case (Video Box 8-1) demonstrates the use of a palatal approach for implant placement. The patient had external resorption of the central incisor with thin tissue and a lack of labial bone. Anticipation of gingival recession after final crown placement resulted in orthodontic extrusion of the tooth to overcorrect the level of

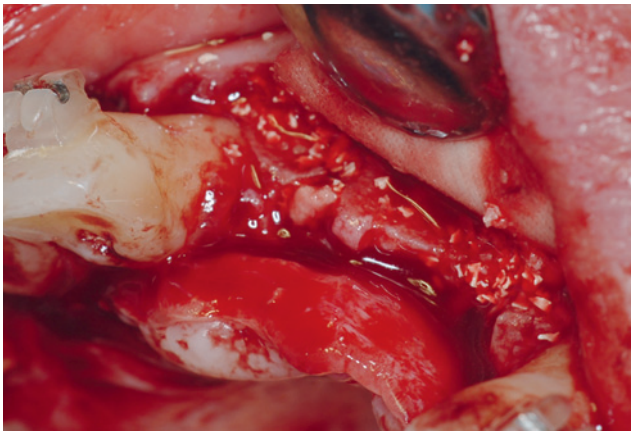


FIGURE 8-19 **K,** Occlusal view after placement of the implants and graft. A collagen membrane (Osseoguard, Biomet 3i) has been placed under the mucosa. The composite graft is compacted firmly under the collagen membrane and directly against the bone. The membrane has been trimmed to fit passively to the level of the piriform rim. The graft is placed, and the membrane is draped to reach the crest without needing to be tucked under the palatal periosteum. Although the graft is placed to the level of the anterior nasal spine, it often migrates slightly coronally.

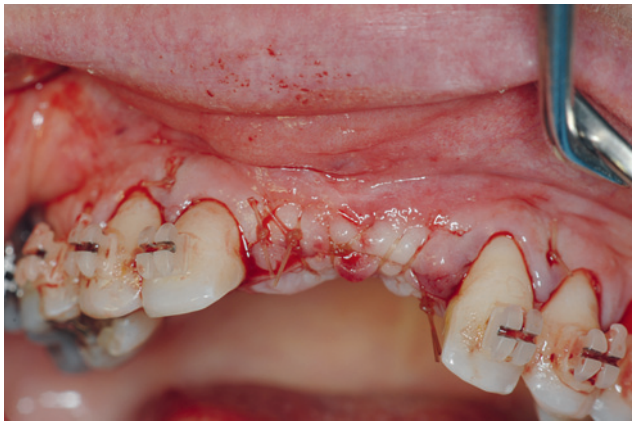


FIGURE 8-19 **L,** Incisions are closed tension free with sutures using a tapered needle. The use of resorbable or nonresorbable suture depends on the clinician's choice.

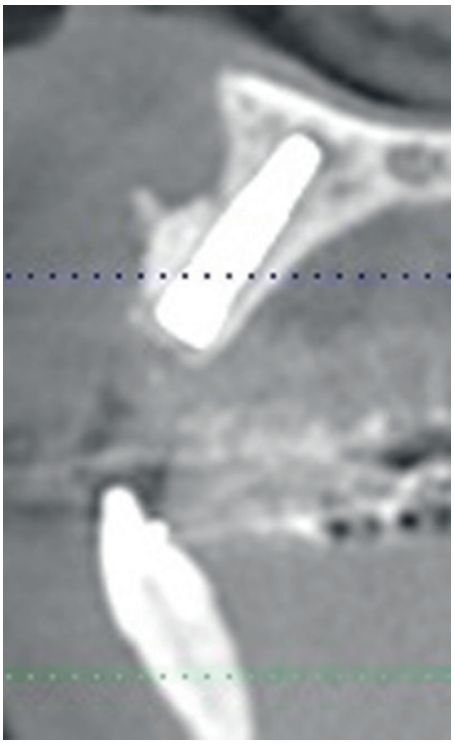


FIGURE 8-19 **M,** Postoperative cross section of the right central incisor from a cone beam scan shows the implant in bone with the graft covering the thin bone on the labial surface.

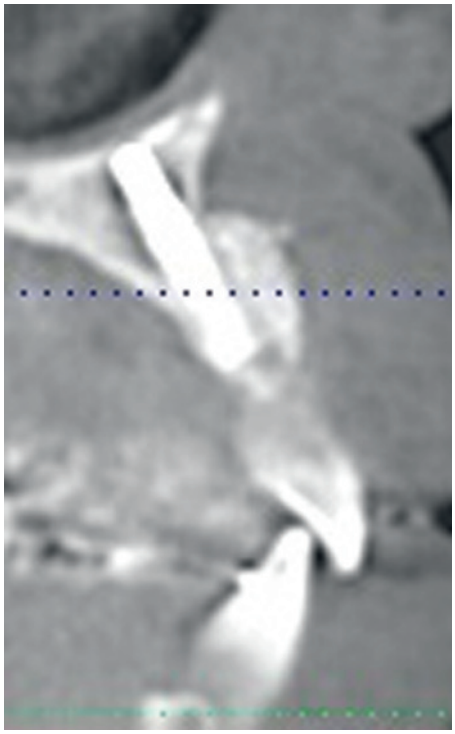


FIGURE 8-19 **N,** Cross-sectional image of the left central incisor with the orthodontic-retained pontic shows the correct angulation of the implant, similar to the planned implant placement.

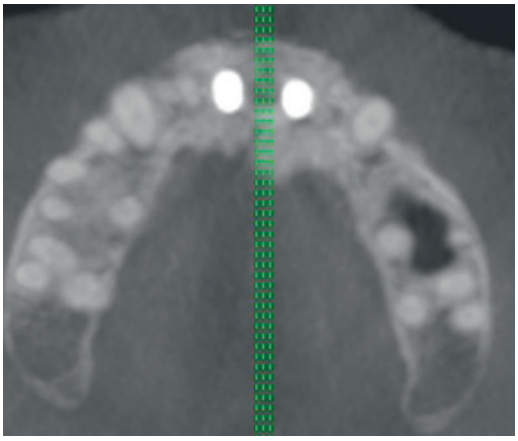


FIGURE 8-19 O, Axial postoperative view from the cone beam scan shows the augmentation of the alveolar ridge.

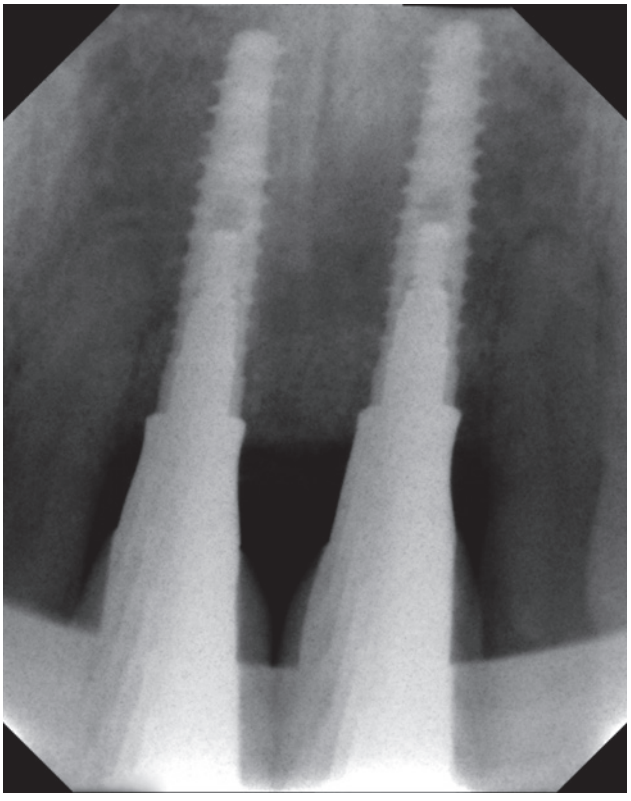


FIGURE 8-19 Q, Final radiograph showing excellent bone levels on implants. Note the flat bone profile between the implants. This resulted in slightly deficient papilla between the central incisor crowns.

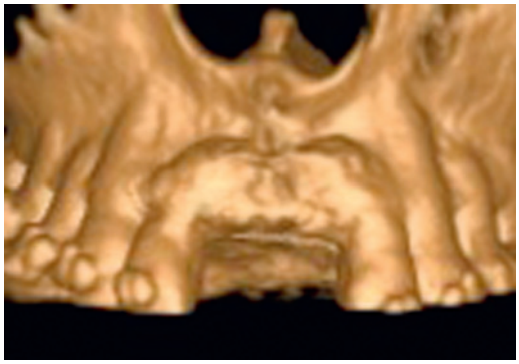


FIGURE 8-19 P, Three-dimensional reconstruction shows the extent of the augmentation. After the graft has healed for 4 months, a connective tissue graft will be placed to convert the gingiva from thin to thick.

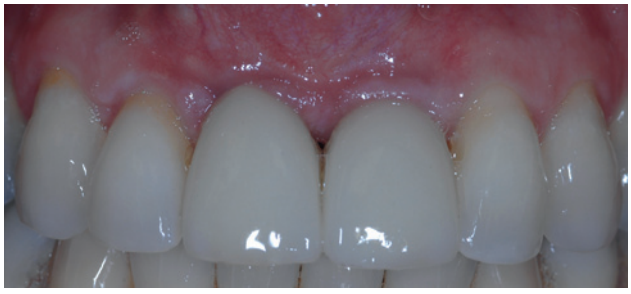


FIGURE 8-19 R, Final restoration. The patient's smile line did not reveal the facial gingival margin. She was quite satisfied with the final result.

the facial gingival margin (Figure 8-20, A-B). A diagnostic cast was used to place an implant analog in the ideal prosthetic position, and a custom healing abutment was fabricated using a screw-retained implant abutment. The margins of the custom healing abutment were polished to ensure ideal gingival health and to prevent the accumulation of plaque (Figure 8-20, C-F).

At the time of tooth extraction, a local anesthetic was infiltrated, and sulcular incisions were made around the tooth to allow its removal. As expected, no labial bone was seen (Figure 8-20, G). The tooth had significant external resorption and an apical granuloma (Figure 8-20, H). The site was grafted with human mineralized bone allograft and covered with a piece of hemostatic collagen (Figure 8-20, I-K). Four months after removal of the tooth, a cone beam image showed excellent labial ridge form. A palatal approach was used to place the implant (Figure 8-20, L).

At the time of implant placement surgery, the labial and palatal tissues were infiltrated with a local anesthetic. A 15 blade was used to incise the palatal gingiva at the sulcus

Palatal Approach for Implant Placement

DVD Video 8-1

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for palatal approach for implant placement performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient's central incisor had been extracted, and a graft was placed into the socket. There was no labial bone after the tooth had been orthodontically extruded to provide ideal gingival margin position. Because of the excellent position of the facial gingiva, the decision is made to use a palatal approach for implant placement. This approach eliminates the need for labial periosteal reflection, which may contribute to facial bone resorption and gingival migration apically.

After infiltration of a local anesthetic, a 15 blade is used to make a sulcular incision on the palatal aspect of the adjacent teeth and across the edentulous space. Note the shape of the incision in the crest, made to accommodate the curvature of the planned placement of a custom healing abutment.

The palatal tissues are reflected to expose the palatal aspect of the crest. No labial tissue is reflected. The palatal cortical bone is used as a guide for orientation, and guidance also is provided by a cross section from a preoperative cone beam scan. With these aids, the round bur is used to determine the initial implant location. A pilot drill then is used, and the emergence of the implant is kept palatal to the incisor edge of the adjacent teeth. A probe is used to confirm bone integrity on all sides of the planned osteotomy site. The drills are used in graduating size, and the implant is then placed. The depth of the implant is 3 mm apical to the facial gingival margin. The lines on the implant driver mount are used to control implant depth, and the hand ratchet is used to orient the flats on the driver mount to rotate the implant so that the internal flat of the hex is parallel to the labial. After placement of the implant, a custom healing abutment is secured to the implant with a screw, and the gingiva is closed around the abutment with 4-0 chromic sutures.

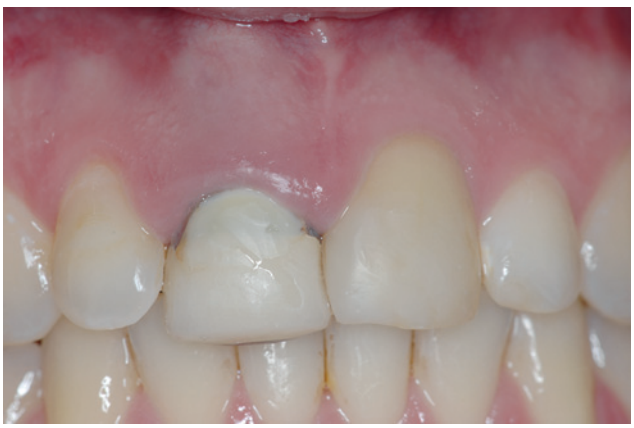


FIGURE 8-20 **A,** This patient's right central incisor was orthodontically extruded to position the facial gingival margin 2 mm coronal to the adjacent tooth. This tooth has no labial bone present, and gingival recession after placement of the implant crown would be expected.

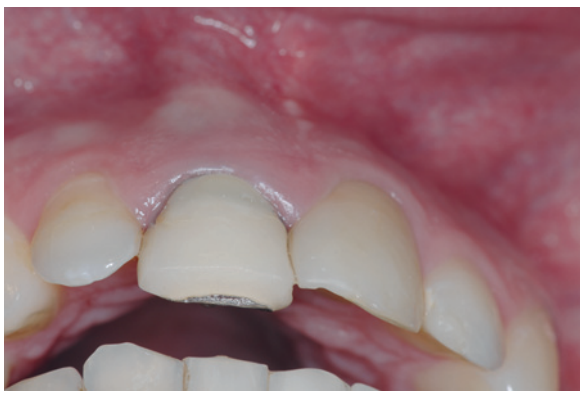


FIGURE 8-20 **B,** Thin labial tissue over the tooth root.

of the teeth. A full-thickness palatal flap was reflected to expose the palatal slope of the alveolar bone at the edentulous site. The palatal bone was used to guide implant placement, with care taken to have the emergence of the implant slightly palatal to the incisive edge of the adjacent teeth. The implant platform was placed 3 mm apical to the facial gingival margin. The use of an implant driver mount with lines to judge implant depth, as well as rotational position, was important in this case. After the implant had been placed, the custom healing abutment was secured. A postoperative scan showed that the healing abutment had not been properly seated (Figure 8-20, M); therefore, it was reseated. The socket graft has produced excellent labial ridge form. The patient was restored 4 months after implant placement (Figure 8-20, N). The final position of the facial gingival

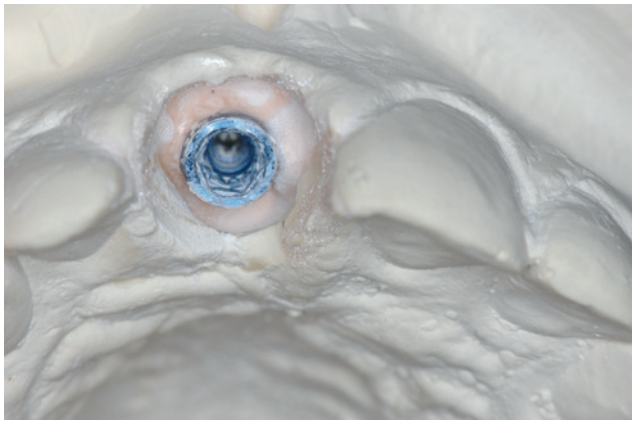


FIGURE 8-20 C, Preoperative cast is used to place an implant analog in the desired position before removal of the tooth.

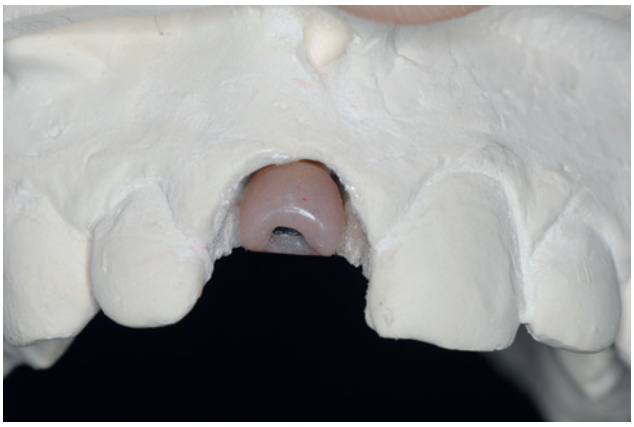


FIGURE 8-20 D, Custom healing abutment is fabricated to support the papilla during the healing period after placement of the implant.

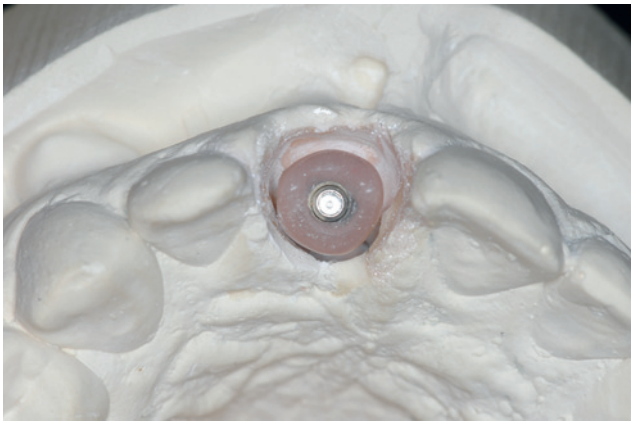


FIGURE 8-20 E, Occlusal view showing support for the papilla. Note the undercontouring on the facial aspect to prevent apical pressure on the facial gingival margin.

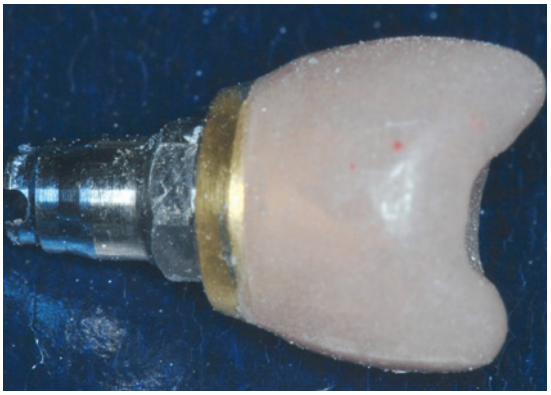


FIGURE 8-20 F, Custom healing abutment on the implant abutment. Note the excellent gingival margins to ensure healthy gingiva.

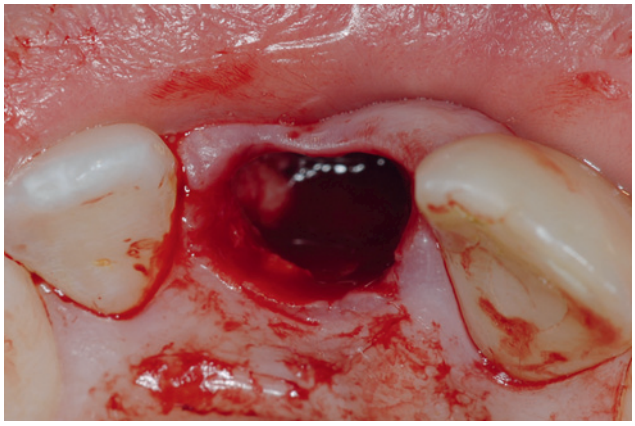


FIGURE 8-20 G, Tooth was removed with incisions only around the tooth, without damage to the papilla. No labial bone was present. Note the concave appearance of the facial gingiva immediately after tooth removal.

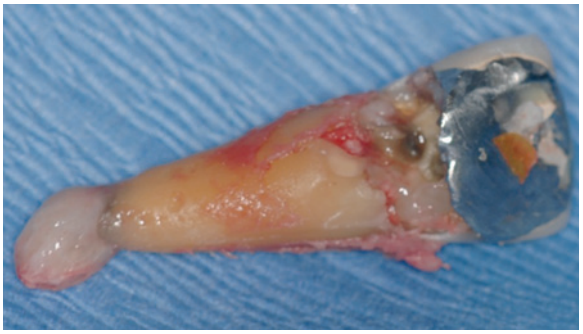


FIGURE 8-20 H, Tooth had a periapical granuloma and significant external resorption with bone loss.

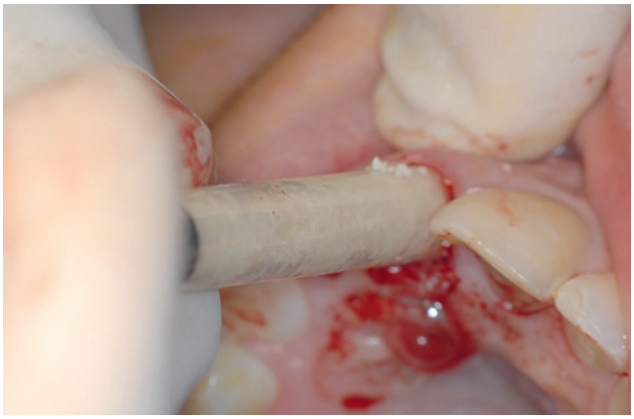


FIGURE 8-20 **I,** After removal of the tooth and granulation tissue from the socket, a 1-ml syringe, with the tip removed, is filled with allograft. The syringe is used to introduce the graft material into the extraction socket.

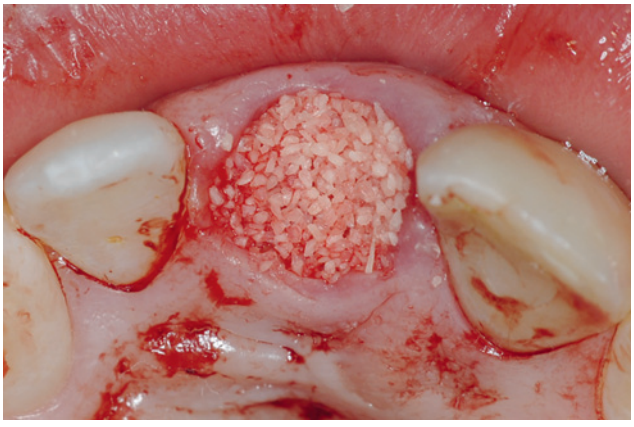


FIGURE 8-20 **J,** Graft is firmly compacted into the extraction site, recreating the labial convex ridge form present before tooth removal.

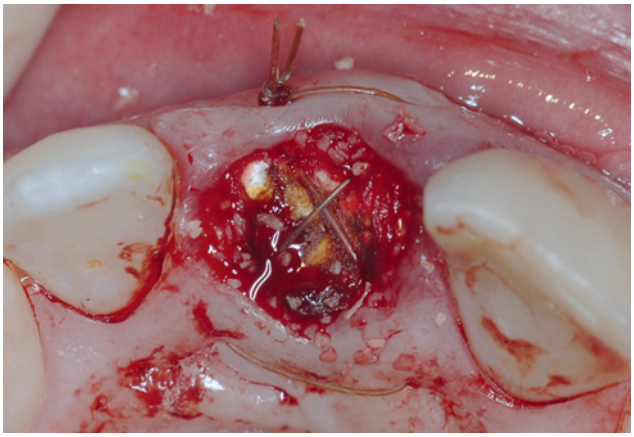


FIGURE 8-20 **K,** Piece of collagen (CollaPlug, Zimmer Dental, Carlsbad, California) is used to cover the graft. One resorbable 4-0 chromic suture is placed in a horizontal mattress fashion to cover the collagen and hold it in place during the first week of healing.

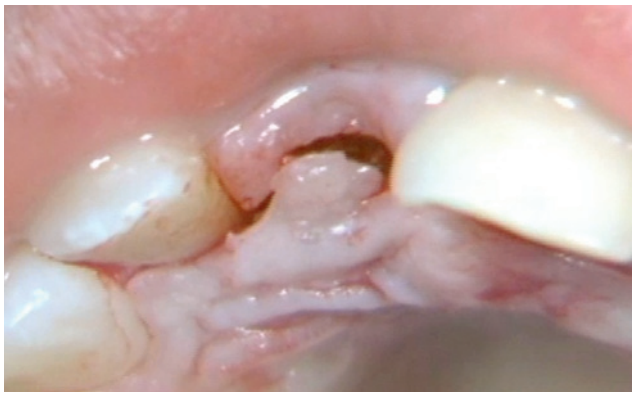


FIGURE 8-20 **L,** Because the facial gingival form, thickness, texture, and appearance are excellent after healing of the graft, a palatal approach is used for implant placement. The preoperative scan shows excellent labial graft take. The implant should be placed parallel to the palatal cortical slope of bone. An incision is made on the palatal aspect to expose the crest. The implant is then placed.

margin was optimal. If the graft had not been successful, if a gingival flap had been raised, or if the custom healing abutment had put pressure on the gingival margin during the healing period, the gingival margin position would have migrated apically.

Use of Model-Based Surgery for Guided Implant Placement. Placement of an implant in the lateral incisor location requires very careful angulation to prevent damage to adjacent structures, labial malposition, and lack of depth control after flaps have been raised. Use of an esthetic setup to fabricate a radiographic stent and a surgical template reduces technical problems that occur secondary to malpositioning of the implant. The specific morphology of the esthetic tooth setup dictates the ideal location of the implant. The following case demonstrates the use of the planned restoration to guide placement of an implant analog in a cast, from which a surgical guide stent is fabricated using master cylinders similar to those used for CT-generated guide stents. The surgical drill set and sleeves used for navigation surgery are used on this model-based guide.

The patient presented with a missing left lateral incisor. Orthodontic appliances had been used to align the adjacent teeth in an ideal position. This resulted in a 5.5-mm distance in the edentulous space (Figure 8-21, A). The lateral incisor site had a concave appearance (Figure 8-21, B). A cone beam image showed adequate bone thickness for implant placement.

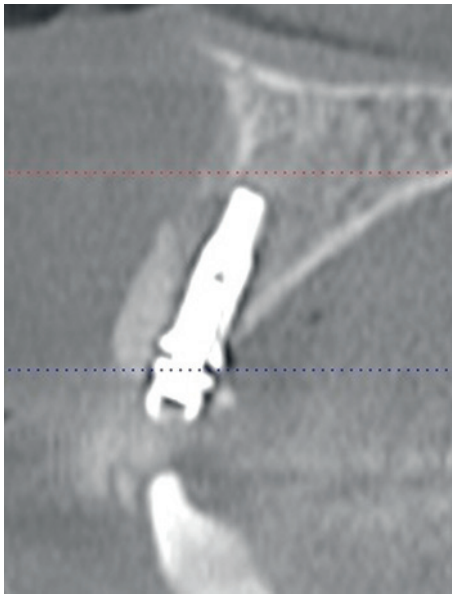


FIGURE 8-20 **M,** Cross-sectional image from a cone beam scan immediately after implant placement. Note that the healing abutment is not seated. The patient immediately has the abutment reseated without complication. The graft placed in the extraction site that had no labial bone has restored the labial ridge form. Because of the excellent labial ridge form, a palatal approach for implant placement is chosen.

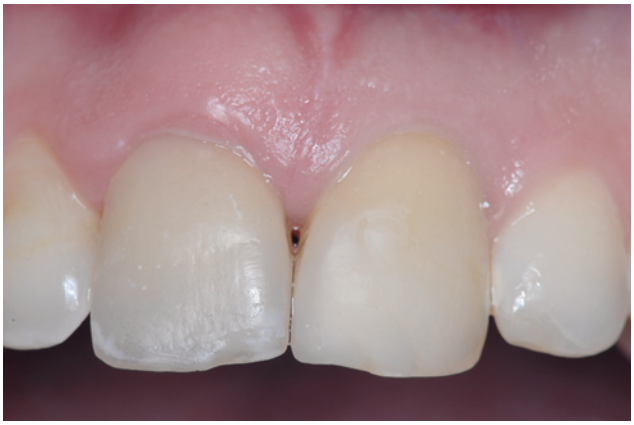


FIGURE 8-20 **N,** Restoration in place. Note the excellent facial gingival margin position. (Prosthetics by Dr. Ace Jovanoski).

The orthodontic appliances were removed and impressions were taken so that an ideal plan could be fabricated. An ideal waxup was fabricated (Figure 8-21, C). This was transferred to models, and a vacuum form was made to simulate the planned restoration (Figure 8-21, D). A small-diameter implant analog was placed into the model, taking

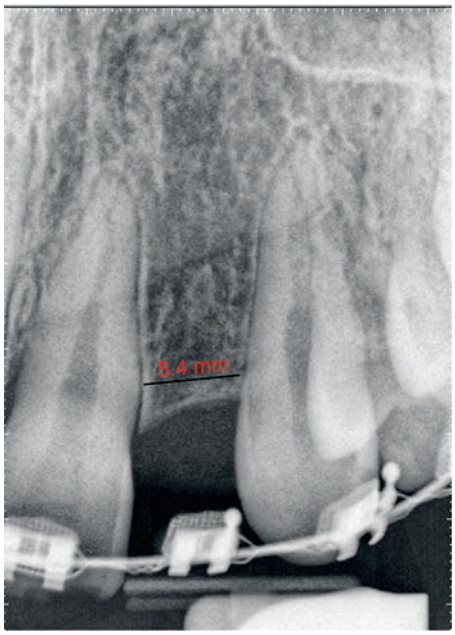


FIGURE 8-21 **A,** Periapical radiograph showing 5.4 mm of space for the lateral incisor implant.

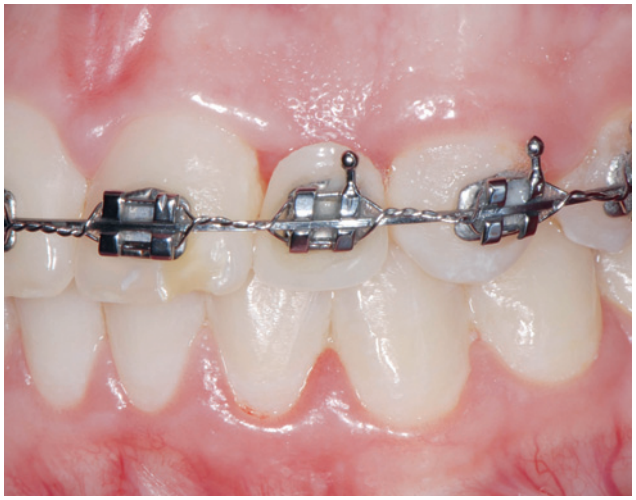


FIGURE 8-21 **B,** Preoperative view showing a concave edentulous site with the orthodontic pontic in place. This is not the ideal tooth form required for this patient.

into consideration the angulation of the ridge, which resulted in the ideal position for the planned restoration (Figure 8-21, E).

Three parts must be combined to create a guide stent. An implant analog is attached to a prosthetic connector, which has a master cylinder on it (Figure 8-21, F-G). This allows accurate positioning of the master cylinder on the implant analog on the model (Figure 8-21, H-I). Acrylic then is placed around the master cylinder so that it can be

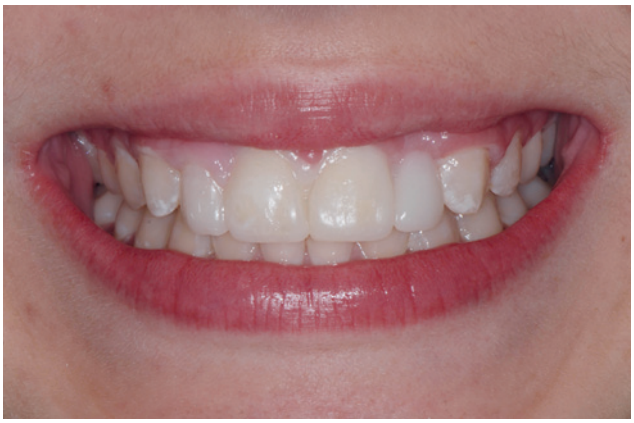


FIGURE 8-21 **C,** Orthodontic appliances are removed, and an esthetic waxup is made and approved by the patient. This waxup will be used for planning the implant placement.

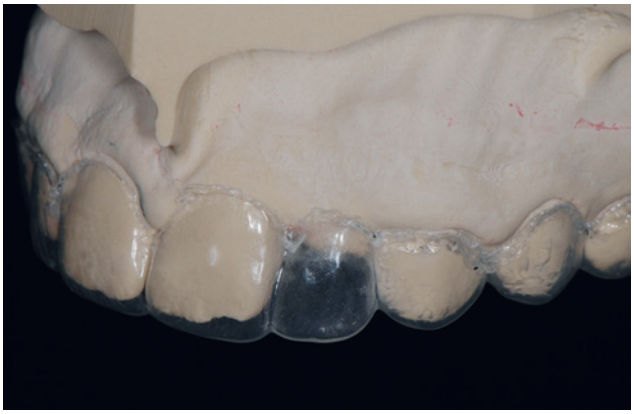


FIGURE 8-21 **D,** Vacuum form is made over a stone model of the esthetic waxup. This will be used to place the analog into the master cast.

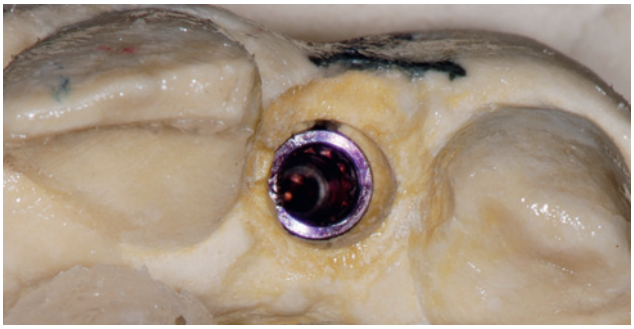


FIGURE 8-21 **E,** Implant analog is placed into the master cast in an ideal position based on the esthetic setup.

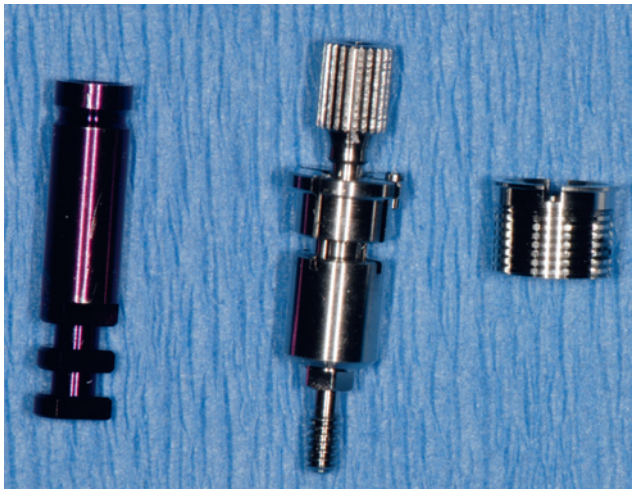


FIGURE 8-21 **F,** Three parts are necessary to make the guide stent. From the left, an implant analog will be connected to a prosthetic part (middle). The master cylinder (right) will be placed on the prosthetic part, which will be luted to an acrylic clear material to direct implant placement.

repositioned and guide implant site preparation and ultimately implant placement. At the time of surgery, the acrylic stent fits on the teeth with the master cylinder in it (Figure 8-21, J). The drill sleeves used for implant placement with CT-generated stents are used, and the implant site is prepared (Figure 8-21, K). After the pilot drill has been used, guide pins are placed to confirm accurate preparation of the site (Figure 8-21, L-M). The implant driver mount is used to direct the implant to its final position with great accuracy (Figure 8-21, N-O).

In the case under discussion, a connective issue graft was harvested and placed under the labial flap to enhance the soft tissue profile and convert the thin gingiva to thick gingiva (Figure 8-21, P-Q).

Lack of Vertical Bone Height. A deficiency of vertical bone height in the esthetic zone usually does not by itself prevent implant placement. However, unless the vertical bone height is restored, an esthetic restoration is difficult to accomplish, because the gingiva is positioned more apically (Figure 8-22, A-S).

Vertical bone height can be restored with a variety of regenerative procedures (Figure 8-23, A-D). Distraction osteogenesis has been proposed to augment the alveolar ridge vertically, but long-term experience is not well established at this time. Membrane-assisted grafting for vertical dimension regeneration has been suggested by a variety of surgeons, but it is technique sensitive, and its success may depend on a significant learning curve and specialized

FIGURE 8-21 **G,** Three parts of the guide stent put together as a unit. The implant analog will be in the model, and the master cylinder will be attached to the guide stent.

FIGURE 8-21 **H,** Prosthetic connector with the master cylinder attached to the analog, which has been placed into an ideal position based on the esthetic setup.

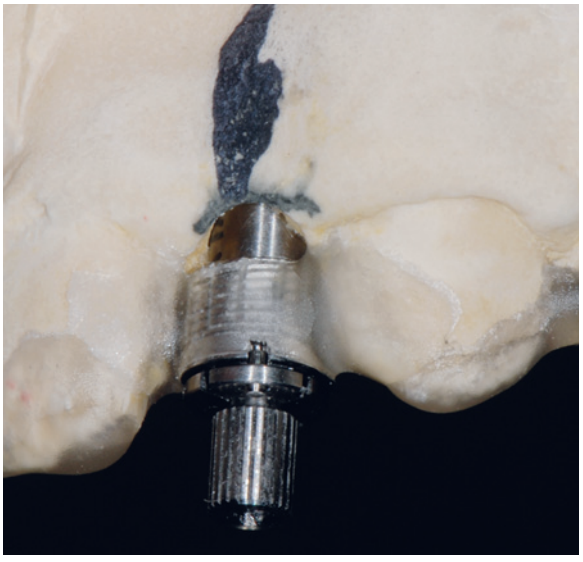


FIGURE 8-21 **I,** Clear acrylic has been used to connect the master cylinder to the surgical guide stent.

surgical experience. Osteotomies and careful outfracturing of the facial aspect of the alveolus have been used to increase the width of the anterior maxilla, but not for the correction of vertical loss of bone because of limitations of stretching the overlying soft tissue.

The current standard technique for restoring vertical bone height is an onlay graft from a piece of corticocancellous bone harvested from the iliac crest, symphysis, or external oblique ridge of the ramus. For many patients, intraoral bone is used because of the ease of harvesting, the relatively low rate of postoperative morbidity, and the avoidance of general anesthesia in a hospital setting.

It is important to establish an accurate assessment of the expected graft thickness before surgery. Relatively thin grafts (i.e., less than 4 mm) can be easily harvested from the external oblique region, and thicker grafts can be harvested from the symphysis.[26] Grafts can be made of a single block of bone without additional particulate bone. The alternative procedure is to use a small block of bone to tent and support a membrane, with the addition of particulate bone under the membrane.[24] The choice of one procedure over another is based on the preference of the clinician and the patient.

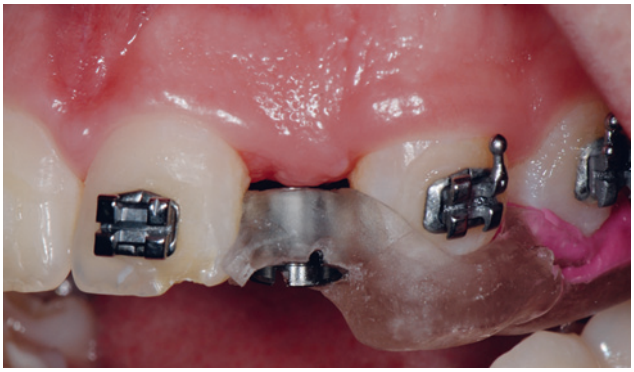


FIGURE 8-21 **J,** Guide stent with the master cylinder is tried in place before surgery.

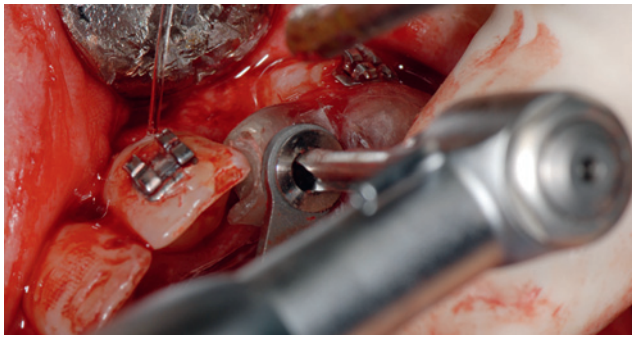


FIGURE 8-21 **K,** Drill sleeves are used similar to the use of CT-generated surgical guide stents for preparation of the implant site.

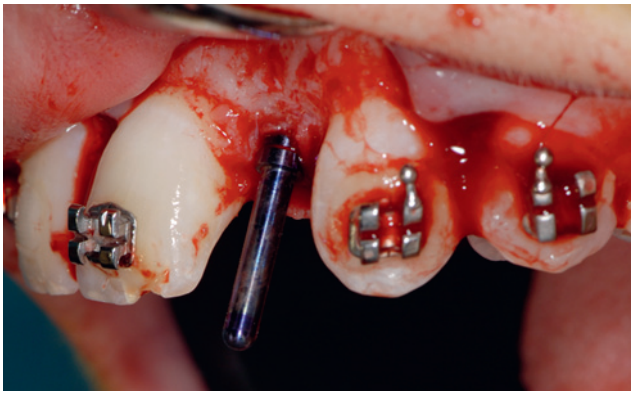


FIGURE 8-21 **L,** Parallel pin is used after the first drill to confirm accurate positioning of the implant drill.

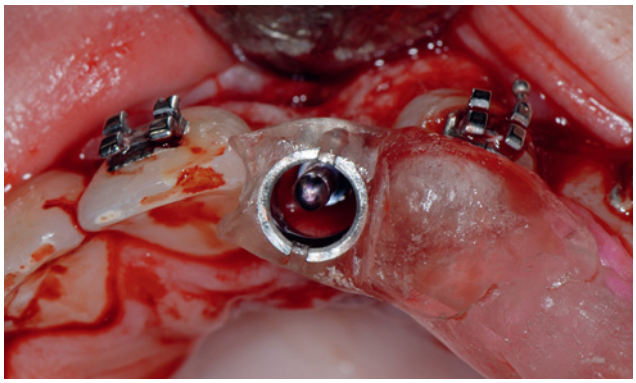


FIGURE 8-21 **M,** Parallel pin is in the center of the master cylinder within the guide stent.

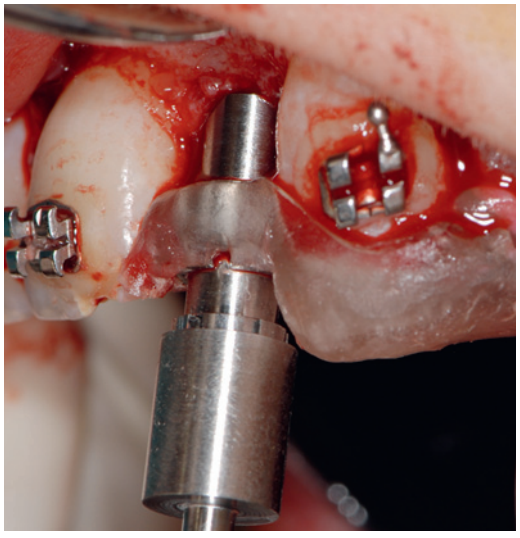


FIGURE 8-21 **N,** Implant is connected to a driver mount and placed into its planned position.

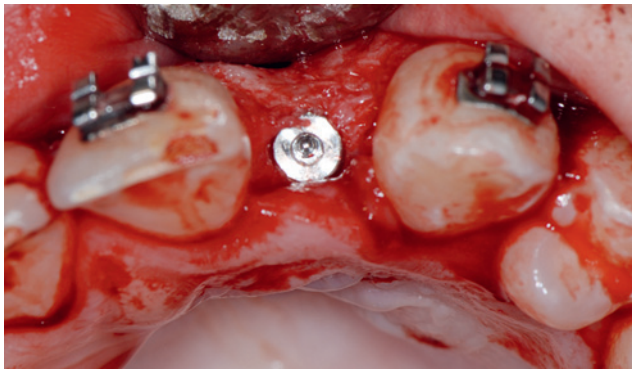


FIGURE 8-21 **O,** Implant has been accurately positioned.

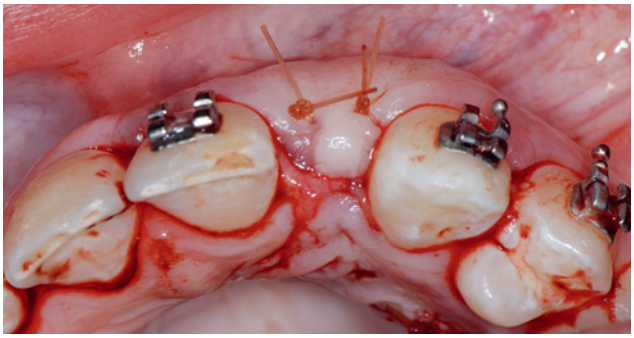


FIGURE 8-21 P, After placement of the implant, a subepithelial connective tissue graft is harvested from the palate and placed under the flap to convert thin gingiva to thick gingiva and enhance the final results.

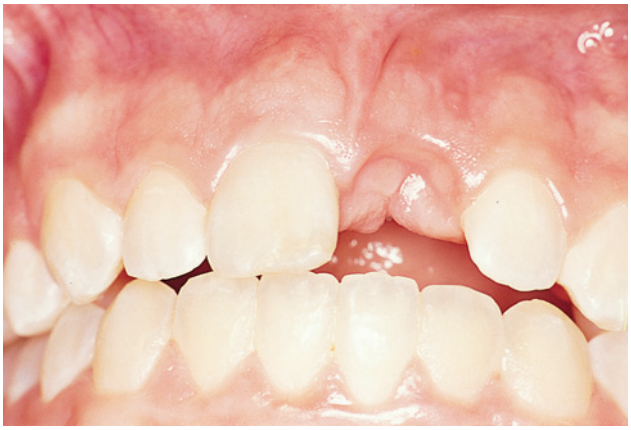


FIGURE 8-22 A, This 14-year-old patient experienced trauma to the maxillary left central incisor when she was 8 years old. The tooth was replaced and functioned just until her clinical presentation. The crown fractured, and the root was removed by a prosthodontist, who explained that minimal bone remained after extraction and that the patient would require bone grafting and an implant to support a single-tooth restoration. He also explained that the parents and patient were concerned about esthetics. The patient has a high smile line. A temporary removable partial denture allows esthetic function and is used to fabricate a barium sulfate–impregnated stent, which is worn during imaging of the defect.

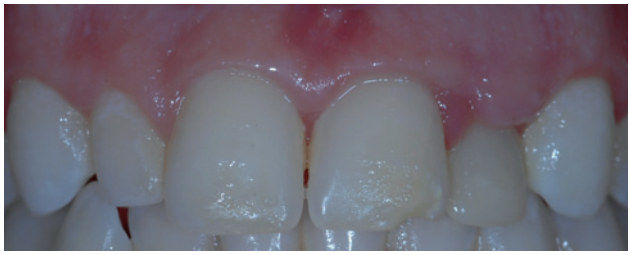


FIGURE 8-21 Q, Provisional restorations are used to develop the final profile prior to the definitive restoration. After satisfactory gingival hygiene has been demonstrated and the soft tissues mature in position, the final restoration will be fabricated.

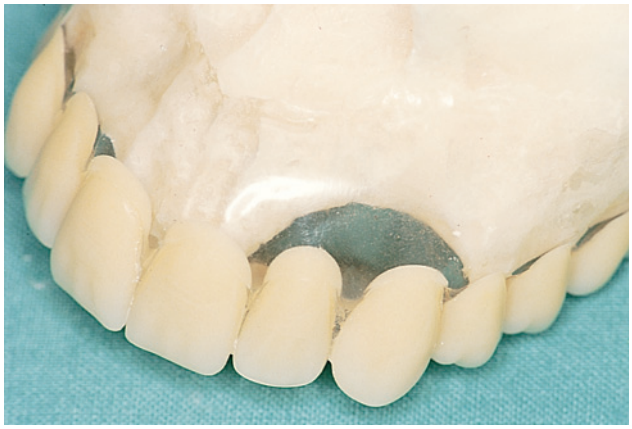


FIGURE 8-22 B, Model simulates a vertical defect. The vertical height of the alveolar process must be reconstructed to give the implant restoration an esthetic and natural appearance.

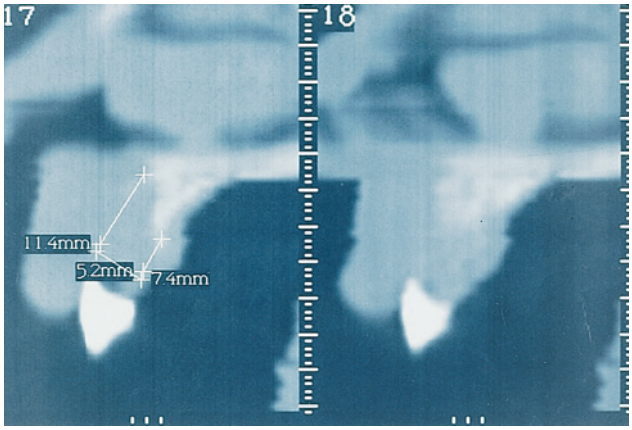


FIGURE 8-22 C, CT scan is reformatted. Measurements are easily made using cross sections to determine the amount of bone needed. Based on the image, the symphysis is chosen as the harvest site for the graft.

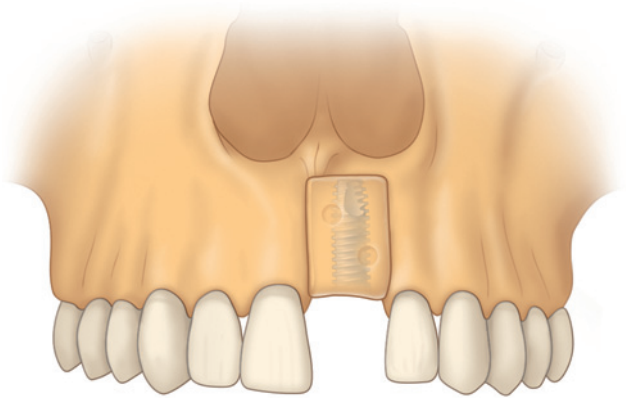


FIGURE 8-22 **D,** Diagram of an onlay graft of bone. The implant is placed after the graft has healed.

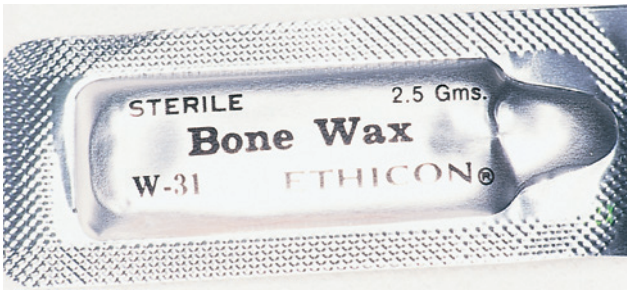


FIGURE 8-22 **F,** Sterile bone wax is used to help form a template for the graft.

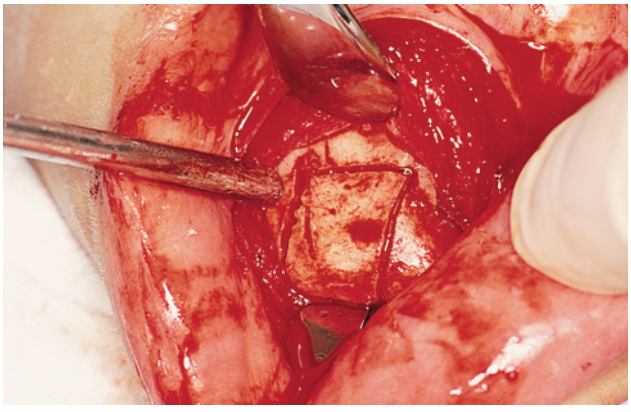


FIGURE 8-22 **H,** To harvest bone from the symphysis, a vestibular incision is made, and blunt and sharp dissection is used to reach the lateral surface of the symphysis. The periosteum is reflected to expose the mental foramina bilaterally, as well as the inferior border of the mandible. For this graft, a partial thickness of the inferior border is used to augment the coronal aspect of the alveolus. A thin fissure bur is used to outline the graft. Bone cuts are made to the desired depth of the graft.

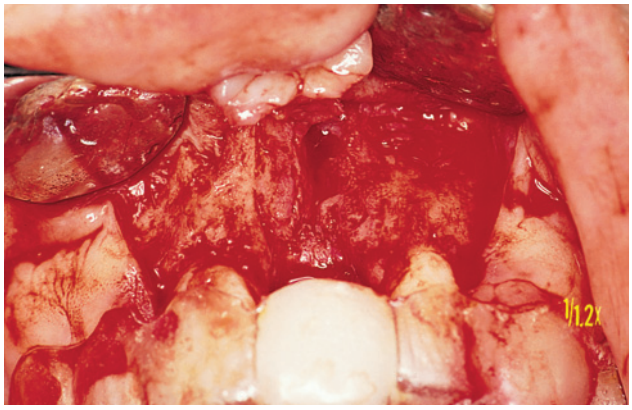


FIGURE 8-22 **E,** At surgery, a crestal incision is combined with vertical release one tooth distal to the graft site, and a full-thickness reflection is performed. The surgical guide stent is placed, and the defect is visualized.

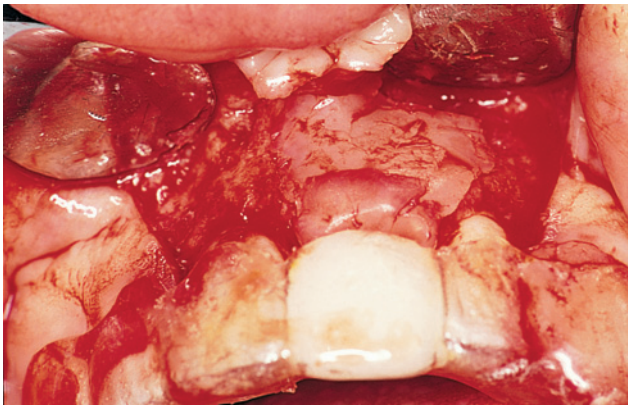
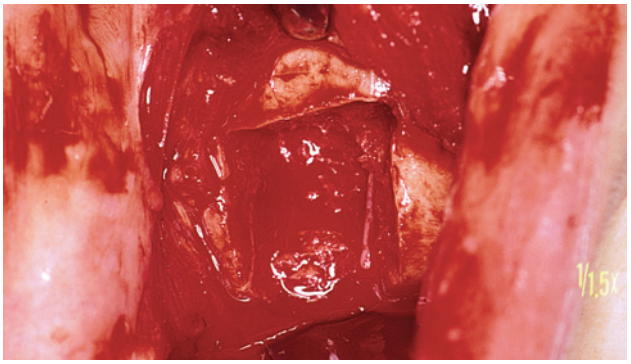
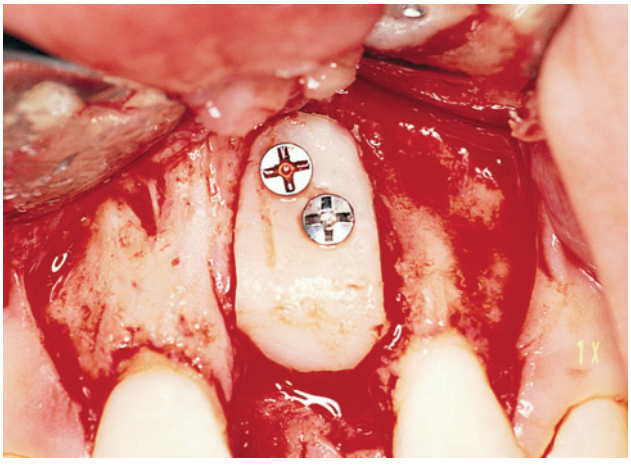


FIGURE 8-22 **G,** Bone wax is placed into the defect and molded to form the desired shape of the graft. It is then removed, and its dimensions are measured to allow accurate harvesting of the graft.

Preoperative Planning. If the patient has or is suspected to have a vertical bone deficiency in the anterior maxilla, a diagnostic setup of the available planned esthetic restoration must be provided. This setup prescribes the necessary location of the implants and can be duplicated in acrylic, with 20% to 30% barium sulfate mixed into the acrylic powder to create a radiopaque image of the planned tooth. Alternatives include a gutta percha–filled, hollow-shell crown, or guide tubes made of copper or other metals can be placed into an acrylic replica of the planned restoration, indicating the ideal location and angulation of the implants.

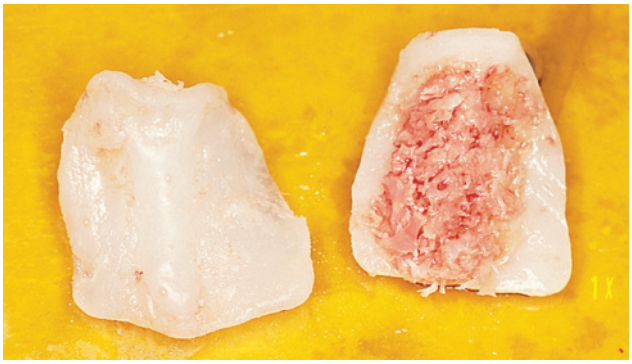


● **FIGURE 8-22 I,** Graft is harvested from the symphysis using curved and straight thin osteotomes. A retractor is used to elevate the soft tissue from the inferior border, and a curved osteotome is used to allow access to the inferior border. HA is placed into the symphyseal defect. The incision is closed in layers, with careful approximation of muscle fibers. An atraumatic suture needle is used for the mucosa.

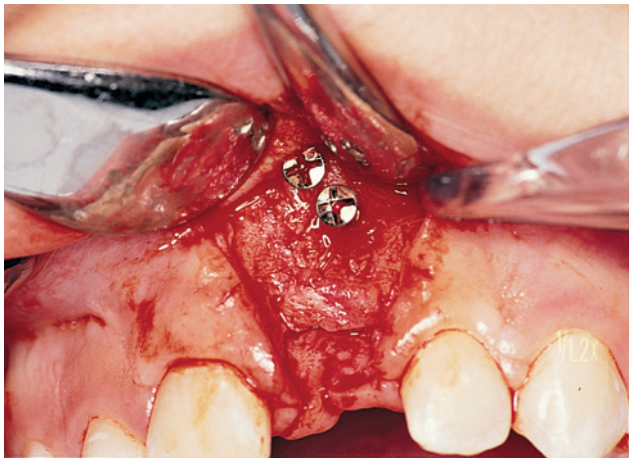


● **FIGURE 8-22 K,** Graft is positioned, and as needed, small modifications of the recipient bed are made to stimulate bleeding and to allow stable mortising of the graft to the host bed. Two 1.5-mm screws are placed to retain the graft in position. The periosteum is released, and the incisions are closed without tension using nonresorbable sutures.

A cross-sectional radiograph shows the bone morphology for many patients with vertical bone deficiency. The radiograph can be made using complex motion tomography or reformatted CT scans. Both provide information on the volume and width of the bone graft needed. From these radiographs, the implant team can complete the treatment planning and provide the patient with a detailed treatment plan, which includes the planned procedure; the risks of the procedure; the timing of events, including temporary



● **FIGURE 8-22 J,** Graft is trimmed to match the wax template. Cancellous bone is present on the graft.



● **FIGURE 8-22 L,** Four months after graft placement, the patient returns for implant placement. Papilla-sparing incisions are used to expose the graft site. The graft appears to be revascularized.

prostheses; and the costs. After the patient has accepted the treatment plan and has signed the consent forms, the surgery can be performed.

Recipient Site Preparation. For onlay block grafts, the incisions should be kept away from the graft. In the anterior maxilla, however, incisions far onto the palate or within the vestibule do not work well. An incision made well onto the palate is prone to breakdown because of the minimal blood supply crossing the crestal tissues. A vestibular incision results in scar formation and deformation of the vestibule in certain patients. Based on the experience of this author and others, a crestal incision is recommended. However, as the size of the graft increases to six-teeth reconstructions, vestibular incisions may provide a greater margin of safety to prevent incision breakdown. The incision can be extended around the sulci of the

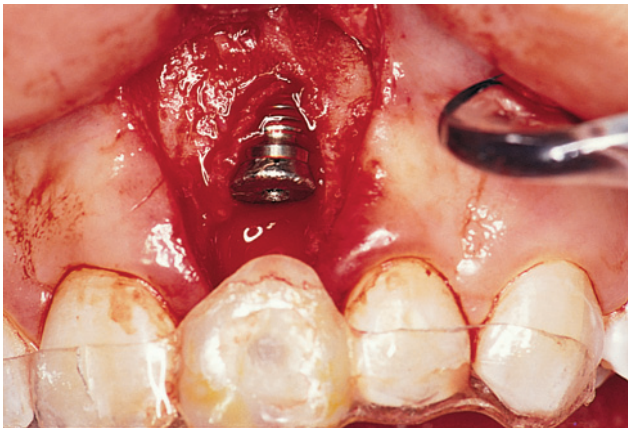


FIGURE 8-22 **M,** Implant is placed with its vertical position prescribed by a new surgical guide stent. Two threads are exposed at the coronal aspect.

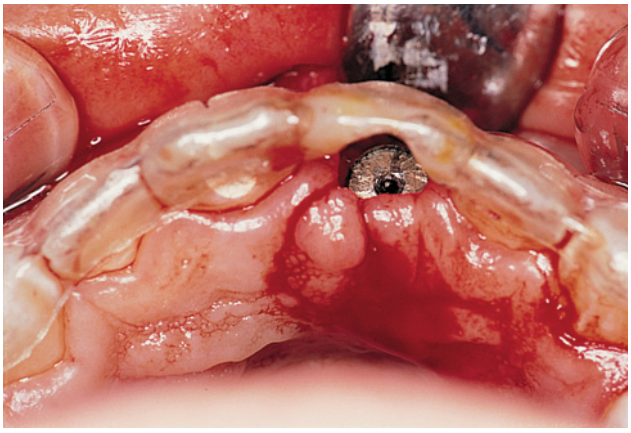


FIGURE 8-22 **N,** Occlusal view showing that the implant has been placed according to the surgical guide stent. If the grafting had not been performed, the implant could not have been placed in the ideal location.

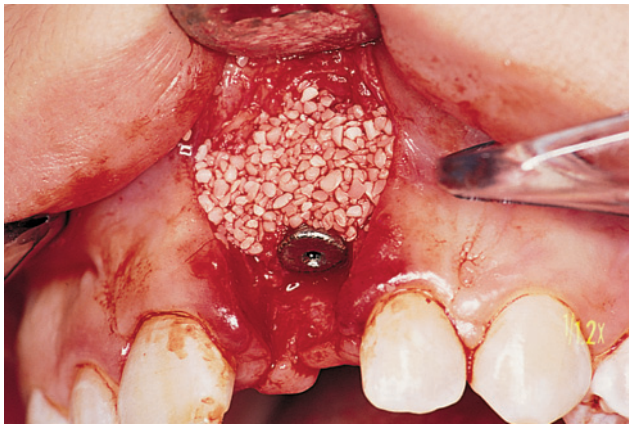


FIGURE 8-22 **O,** Small amount of dense particulate HA is placed to graft the labial defect. No membrane is used. Six months after implant placement surgery, the implant is exposed. HA augmentation, combined with the bone graft, results in an adequate ridge form.

adjacent teeth from first molar to first molar for a full-thickness envelope flap reflection. For some patients, vertical release incisions one tooth distal from the graft site can be used and may provide easier access to the crest for less experienced surgeons.

A local anesthetic is applied to the anterior maxilla, the incisions are made, and a full-thickness flap is reflected to expose the surgical site. It is important to be gentle during elevation of the papillae on the teeth to prevent trauma and potential blunting. After the recipient site has been exposed, the surgical guide stent is placed, and a bone wax pattern is made of the desired graft form. The wax pattern then is measured, and the graft is harvested as described next. If no bleeding occurs from the cortical bone in the recipient site, holes 0.25 to 0.50 mm in diameter should be created in the bone with a round bur, because this reportedly promotes graft healing.

During graft placement, it may be prudent to adjust the recipient site to allow mortising of the graft to the recipient site. Clinical judgment is needed to estimate the appropriate removal of the bone from the graft or recipient site. For example, the recipient site may be irregular in contour, making it difficult to create an intimate interface between the graft and the recipient cortical bone. The recipient site can be prepared to create straight edges and uniform, concave, convex, or flat contours. The graft also can be prepared to match the contours of the recipient site. The key is to remove as little bone as possible, retaining as much recipient bone as possible, and to keep as much marrow as possible on the inner aspect of the graft.

After the graft has been placed, its edges are smoothed with a bur to remove sharp edges that may traumatize the overlying mucosa. The incisions are closed with nonresorbable sutures using a tapered needle. Careful approximation of the vertical incisions is important to allow an esthetic result with minimal visible scars.

Use of a solid piece of onlay bone to correct vertical deficiency can be performed according to two general techniques. A single piece of bone can be used to reconstruct the entire defect. The advantage of using one piece of bone is that it eliminates the need for a membrane, as well as the increased incidence of incision breakdown over large grafts. Unfortunately, few clinical studies have documented long-term retention of bone graft volume using any bone-grafting technique for the correction of vertical deficiency.

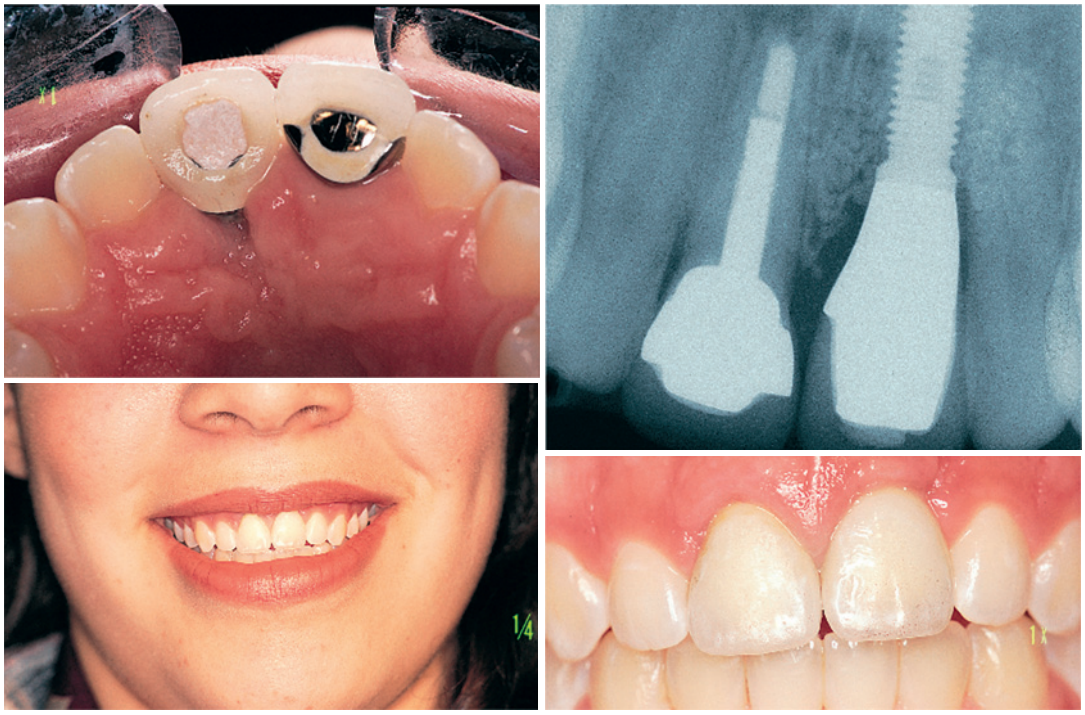


FIGURE 8-22 **P-S,** Three clinical photographs and a radiograph show the final restoration, which is screw retained with a prosthesis fabricated to meet the esthetic expectations of the parents and the patient. (Prosthetics by Dr. Roger Vitter.)

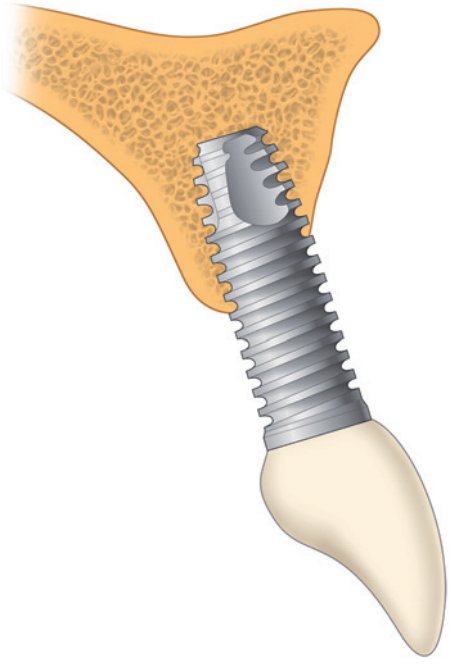


FIGURE 8-23 **A,** Diagram showing the vertical deficiency in relation to the necessary implant length and crown relationship.

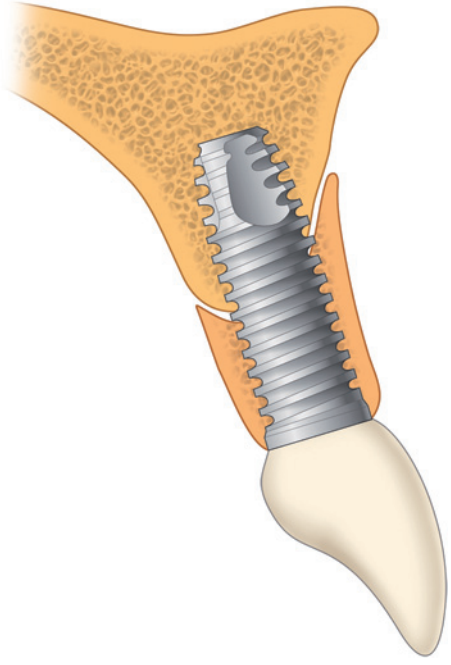


FIGURE 8-23 **B,** Onlay of a block of bone can be grafted, after which the implant is placed.

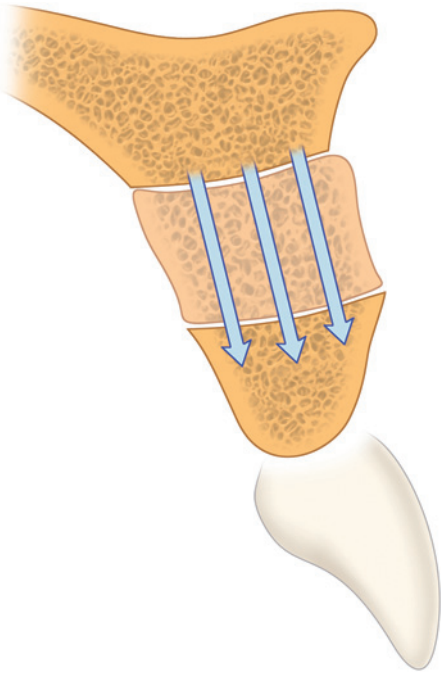


FIGURE 8-23 **C,** Segment of bone can be distracted inferiorly, resulting in ridge augmentation.

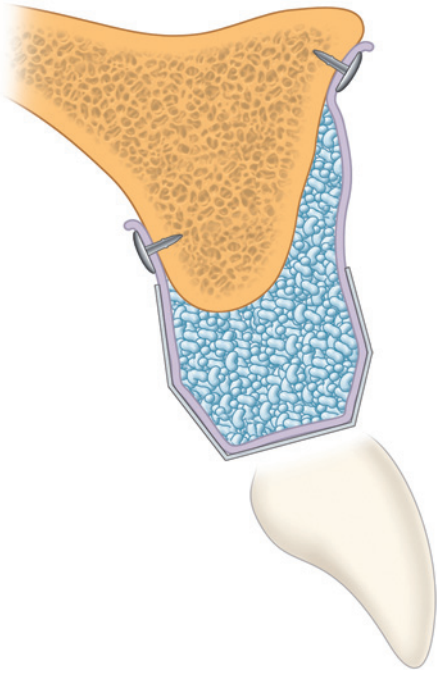


FIGURE 8-23 **D,** Particulate bone can be placed over the ridge, in combination with a reinforced membrane, to prevent the space from collapsing. After 6 to 9 months, the implants can be placed after the membrane has been removed.

The second method of correcting vertical deficiency is to use a small piece of bone to establish the vertical dimension, with particulate bone then placed to complete the bulk of the graft. A nonresorbable membrane is placed to enhance bone formation and retention of graft volume. The advantage of this technique is enhanced vascularity of the graft, because less cortical bone is replaced. However, the addition of the membrane may lead to a greater risk of incision breakdown in less experienced hands. The following discussion focuses on the single piece of bone as a graft material.

The single block of bone graft to be harvested must meet several requirements. It must be large enough to cover the entire defect, so that no additional particulate bone needs to be placed. The graft should have marrow on its inner surface. The graft also should be large enough to allow for a small amount of shrinkage before implant placement and final restoration.

A block graft harvested from the symphysis or external oblique ridge is predominantly cortical bone with minimal marrow. The recipient site is prepared to increase the vascularization of the graft; this is done by creating small-diameter holes (0.25 to 0.50 mm) through the cortex in the recipient site. The graft initially is revascularized through the marrow portion of the graft, with replacement of the cortical bone through gradual resorption and replacement, commonly known as "creeping substitution." The vascular supply to these grafts is from the inner surface of the graft at the interface of the graft with the underlying recipient bone, as well as minimally from the labial surface. Consequently, allowing sufficient time for healing before placement of endosseous implants is imperative; otherwise, the graft may lose its blood supply. Small grafts are more prone to loss of blood supply than larger grafts, which have a larger surface to become revascularized. Because the replacement of the cortical bone in symphyseal or ramal bone proceeds more slowly than for bone harvested from the iliac crest, the clinician can wait 4 to 9 months before implant placement. Iliac crest grafts, which have more marrow and a thinner cortex, are revascularized sooner and thus resorb sooner. For iliac onlay block grafts, implants should be placed approximately 4 months after graft placement.

External Oblique Bone Grafts. Harvesting of external oblique grafts requires infiltration of a local anesthetic solution into the region of the third molars, with additional solution placed along the lateral aspect of the mandible. An inferior alveolar block is not administered, allowing the inferior alveolar nerve to retain its function. If the surgeon gets close to the nerve, its sensitivity alerts the surgeon to retract from that position, preventing damage to the inferior alveolar nerve.

An incision is made around the sulci of the molars, if present, and angled along the external oblique ridge. It is important to angle the incision obliquely from the mandible to avoid the lingual nerve in the retromolar region. A full-thickness reflection is performed, exposing the retromolar region and the lateral surface of the mandible. Graft size is measured, and its dimensions plus 2 mm are etched into the bone with a small fissure bur. Increasing the size of the harvested bone 2 mm compensates for small angulation and the thickness of the bur and ensures that the resultant graft is not undersized. After the dimensions of the graft have been confirmed by additional measurement with a caliper, the cortical bone cuts are completed into the marrow space. The depth of these cuts should be carefully controlled to prevent penetration of the bur into the inferior alveolar nerve. The corticotomy through the lateral surface of the mandible can be made with a round bur, a fissure bur, or an oscillating saw, depending on the type of handpiece available.

Small osteotomes are used to confirm the completeness of the corticotomies, and the graft then is loosened from the mandible with the osteotomes and removed. The graft is wrapped in saline-dampened gauze. The harvest site is examined, and the incisions are closed with resorbable suture. Placement of material into the graft harvest site is unnecessary. The graft is then contoured to match the recipient site.

Symphyseal Bone Grafts. Before harvesting symphyseal grafts, the surgeon should take a lateral cephalometric radiograph to gain an understanding of the amount of marrow within the symphysis and the angulation of the labial and lingual cortical bone. Most patients are more comfortable with sedation for symphyseal bone harvesting. The incisions can be made in the vestibule of the mandible or around the sulci of the teeth, depending on the clinician's preference.

A local anesthetic is infiltrated into the labial tissues and the lingual aspects to the inferior border of the mandible to anesthetize the branches of the mylohyoid nerve. After a satisfactory plane of anesthesia has been reached, the incisions are made.

For the vestibular approach, the incision first is made in the depth of the vestibule through the mucosa, extending from the first premolar to first premolar regions. Branches of the mental nerve are identified. The dissection is carried sharply and bluntly to the surface of the mandible, avoiding the nerve branches. After the bone has been reached, incisions are made through the periosteum, which is carefully reflected to allow identification of the location of the mental foramen and the inferior border of the mandible. With the appropriate retractors in place, the dimensions of the bone graft are marked with a small fissure bur. The superior cut should be at least 5 mm and preferably 10 mm from the apex of the incisor teeth to prevent their desensitization. The lateral cuts should be at least 5 mm and preferably 8 to 10 mm anterior to the mental foramen to prevent damage to the anterior extension of the inferior alveolar nerve.

After confirmation of the dimensions of the graft, which are slightly larger (i.e., 2 to 3 mm) than the final graft size, the cortical bone is cut with a small fissure bur to the intended depth of the graft. No vital structures are present around the graft; therefore, the bone cuts can be taken to the depth needed for the graft. In the symphysis, because of the thickness of the cortical bone, the cuts must be deeper than those previously described for the ramal graft. After the bone cuts have been completed, small osteotomes are used to remove the bone carefully. Depending on the anatomy of the symphysis, beveling of the distal surface of the cortical bone may be necessary to allow the osteotomes access to remove the graft. This technique is similar to that used to harvest calvarial grafts. Excessive force is avoided, to prevent inadvertent fracture of the mandible. After the graft has been removed, the harvest site is inspected, and bleeding is controlled. Usually the defect does not need to be grafted; however, if desired, an alloplast can be placed and retained in position with a resorbable membrane and resorbable tacks. When two symphyseal blocks of bone are harvested, a midline strut of bone is left to preserve the chin profile.

The incisions are closed in layers. If a vestibular incision has been used, the mentalis muscle must be reapproximated to restore both the mentolabial angle and the function of the mentalis muscle. Resorbable sutures are used. The mucosa is closed with a resorbable suture using a tapered needle to prevent mucosal tearing. A chin dressing is placed along the inferior aspect of the symphysis and in the mentolabial crease. The dressing applies moderate pressure to the soft tissues; this pressure prevents hematoma formation, which can result in excessive scar formation and blunting of the contours of both the external mentolabial concave tissue and the submental soft tissue. Postoperative antibiotics and analgesics are prescribed, because the chin donor site tends to be associated with moderate postoperative pain (Figure 8-24, A-G; see also Figures 8-22 and 8-23).

Vertical Ridge Augmentation Using Particulate Bone. Long-term clinical data are not available on the use of particulate bone, which may be combined with a larger piece of corticocancellous bone to establish vertical ridge augmentation of the anterior maxilla. One must extrapolate from work performed in the posterior mandible by Buser et al.[23,24] However, this technique may be chosen by the clinician who believes that the recipient site is less prone to revascularize a cortical graft than a particulate graft (Figure 8-25, A-I).

The recipient site is exposed in a manner similar to that for a single block graft. Bone is harvested from any source that can contribute viable endosteal osteoblasts. Cortical shavings can be used to augment the graft

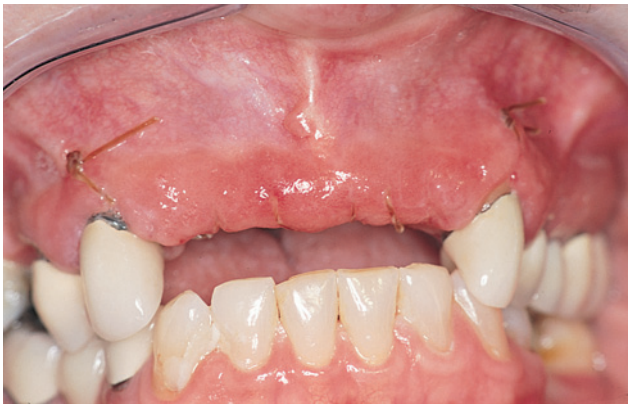


FIGURE 8-24 **A,** Anterior view showing a 49-year-old woman who desires implant restoration. A relatively thin anterior alveolus is observed. The treatment plan calls for ridge splitting to expand the alveolar bone width and the placement of implants. Using a local anesthetic, the ridge is exposed; however, on exposure, the ridge is too narrow and does not expand superiorly. The incisions are closed, and the patient returns 2 weeks later for symphyseal bone graft harvesting and 4 mm of augmentation.

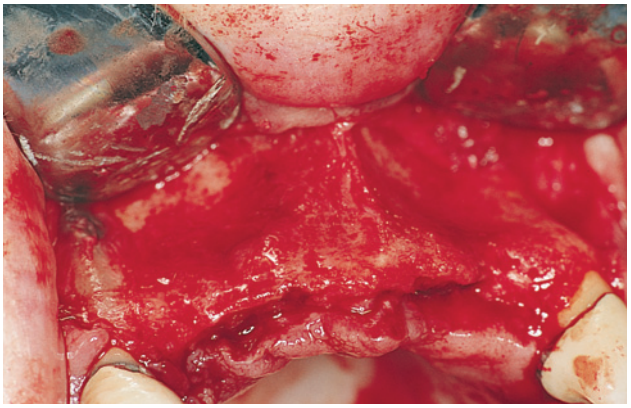


FIGURE 8-24 **B,** Exposure of the ridge shows the thin alveolar bone extending to the piriform rim without widening.

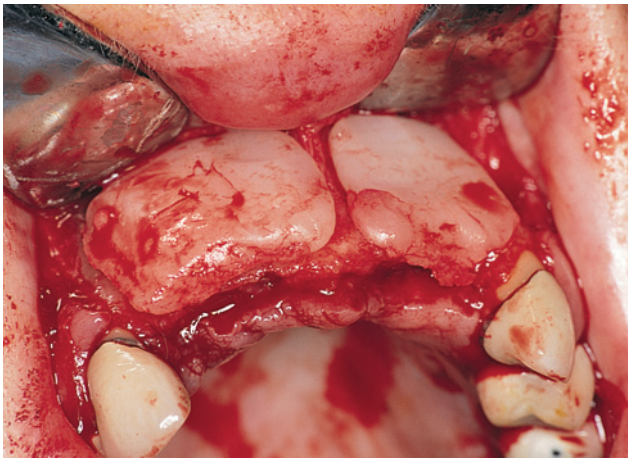


FIGURE 8-24 **C,** Bone wax is placed to simulate the necessary bone graft bulk.

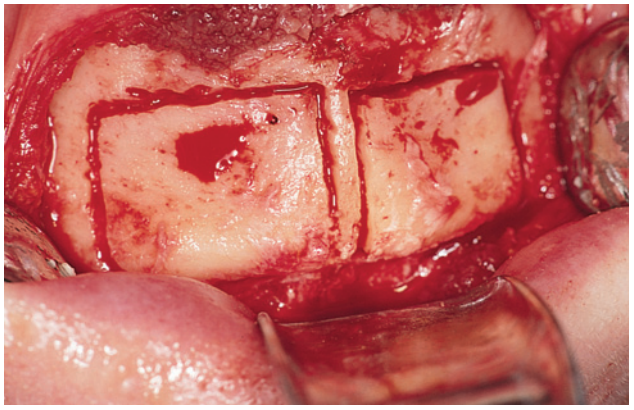


FIGURE 8-24 **D,** After a vestibular incision has been made, followed by blunt and sharp dissection, bone grafts are outlined using the dimensions established by the wax patterns.

volume. A membrane that is reinforced to maintain its shape is then adapted to the recipient site and is retained in position by small tacks or screws. Depending on the size of the defect, palatal retention may be required in addition to labial retention. The particulate bone is placed under the membrane. The recipient site bone may need to have several small holes made in it to promote graft revascularization. After the bone has been placed, the reinforced membrane is secured in position. A supraperiosteal dissection releases tension on the flap, and the incision is closed using atraumatic needles with nonresorbable sutures. A prosthesis is avoided and later must be carefully relieved to prevent pressure on the augmented ridge.

Immediate Loading and One-Stage Protocol

The evolution of implant-related therapies in the modern era was based on the work of Branemark and others, who scientifically validated the process of placing an implant into bone, waiting a period for the bone to heal to the implant, after which long-term functional loading followed. During the 1970s and early 1980s, a one-stage, threaded,

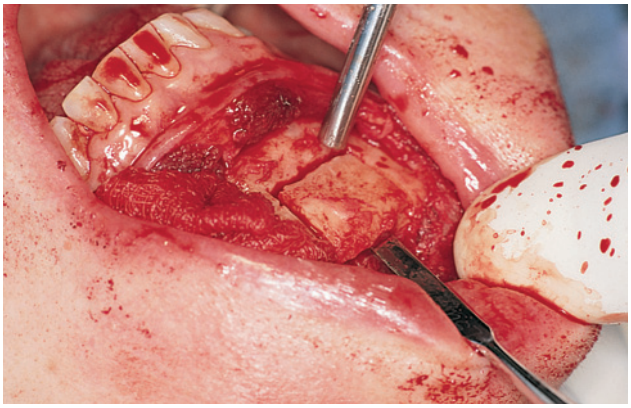


FIGURE 8-24 E, Sharp, thin osteotomes are used to remove the grafts from the symphysis. An inferior border osteotome is placed from the inferior aspect to cleave a graft from the donor site.

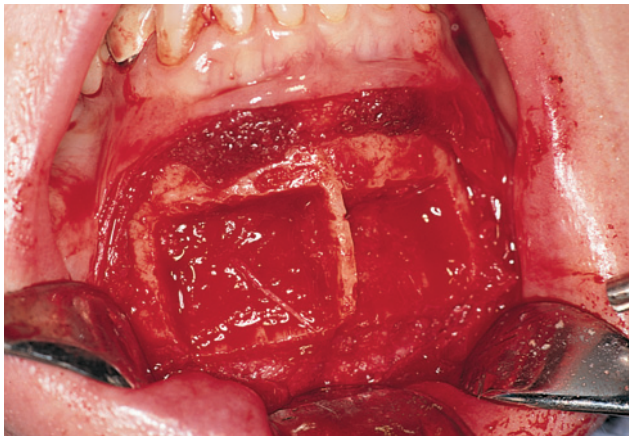


FIGURE 8-24 F, After the grafts have been removed, the defects are filled with collagen, and the incisions are closed in layers, keeping the midline isthmus to maintain the chin form.

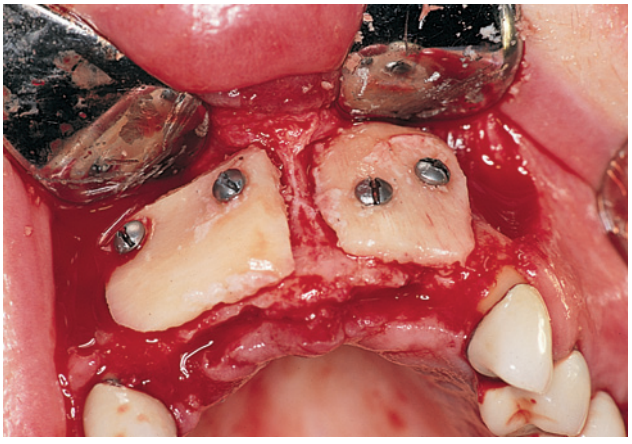


FIGURE 8-24 G, Grafts are carved to mortise accurately in place and are secured with two screws 1.5 mm in diameter and 12 mm long.

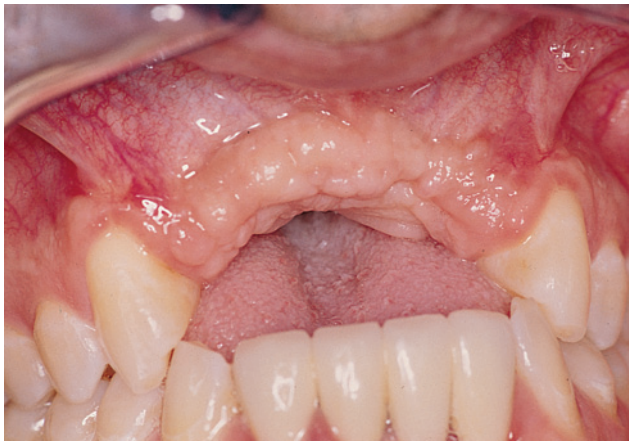


FIGURE 8-25 A, This 32-year-old man received four endosseous implants that became infected and were removed, resulting in loss of bone. One subsequent onlay graft with symphyseal bone failed secondary to infection, with further loss of bone. The patient was referred for a second attempt at grafting and subsequent implant placement. The patient wanted to avoid a six-unit bridge because of previous problems with fixed bridgework.

titanium plasma–coated implant was used for overdenture retention with immediate loading. The "Swiss screw" was placed into the anterior mandible and resulted in excellent long-term success.

Other one-stage implant systems (i.e., no need for exposure surgery) were slow to emerge, but as they became established with supporting data, the concept of one-stage endosseous implant therapy gained credibility. Long-term data on the Straumann implant system indicate that a one-stage, unloaded implant system can work in all areas of the mouth, distinct from the "Swiss screw" and the Branemark protocols.

Recently, more interest has arisen in the placement of implants into the esthetic zone of the maxilla, with either immediate loading or the use of a healing abutment that mimics the natural shape of the tooth. The hypothesis is that placement of a healing abutment with natural contours enhances the soft tissue response, potentially resulting in a more esthetic final restoration (Figures 8-26, A-K, and 8-27, A-R).

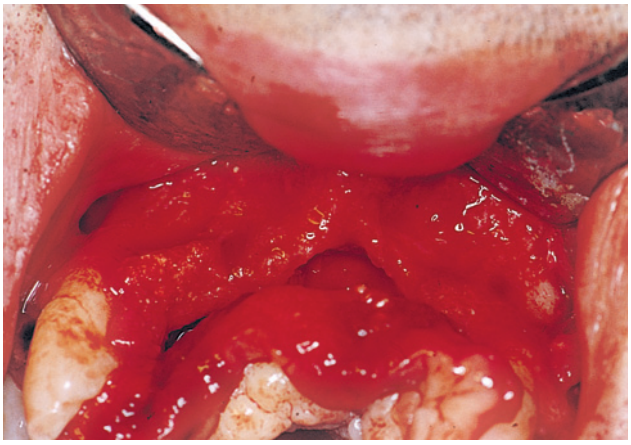


FIGURE 8-25 **B,** At surgery, a crestal incision is used with vertical release distal to the premolars. As expected, reflection revealed vertical and horizontal deficiencies. The treatment plan is to harvest cancellous bone from the left tibia for particulate onlay grafting, with the use of a titanium-reinforced, nonresorbable membrane to promote bone formation.

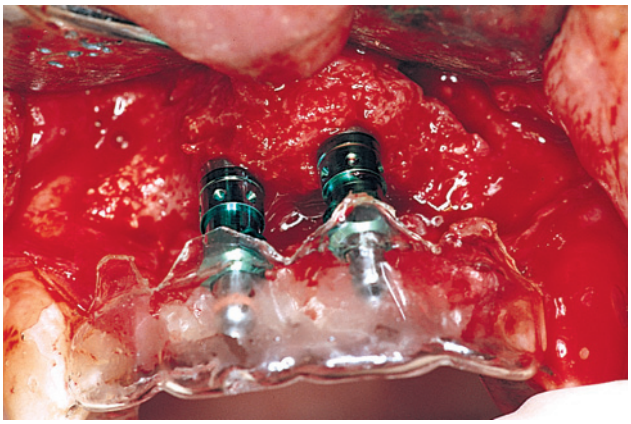


FIGURE 8-25 **D,** After 32 weeks, the incision is re-entered and the membrane is removed, exposing woven bone under the membrane. No bone formation outside the margins of membrane is observed. Two implants are placed into the central incisor regions.

Treatment planning for a one-stage or immediately temporized anterior maxillary restoration begins with a list of contraindications. If a tooth is present and must be extracted, single-stage, exposed implant placement at the time of extraction requires the following:

1. No purulent drainage or exudate from the site
2. Excellent quality of gingival tissue, without excessive granulation tissue

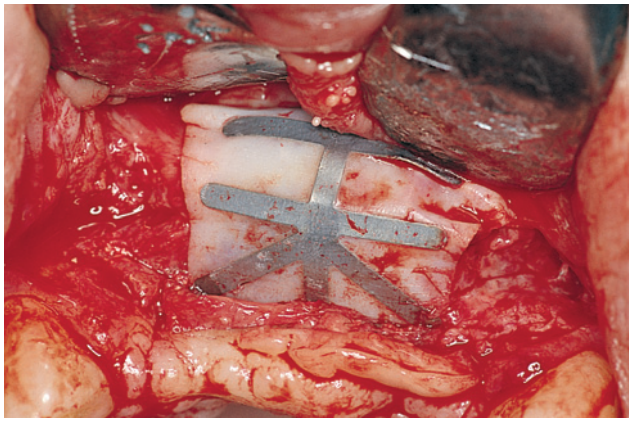


FIGURE 8-25 **C,** Bone is harvested and placed over the ridge. The membrane is shaped and secured to the alveolar bone with tacks.

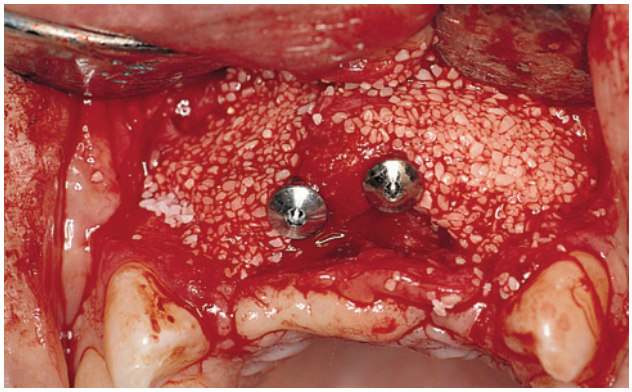


FIGURE 8-25 **E,** Particulate HA is placed over the lateral incisor sites for augmentation and anticipated implant placement after 4 months of healing.

3. Lack of periapical, uncontrolled radiolucency
4. Adequate bone levels circumferentially, without the need for additional soft or hard tissue grafting

The clinician has the following three choices:

1. After extraction of the tooth and a waiting period of approximately 8 weeks, the implant is placed using the previous protocols.
2. After extraction of the tooth and a waiting period of 8 weeks, minimal incisions are used, and the implant is placed with the addition of an anatomically shaped healing abutment or a temporary crown.
3. After extraction of the tooth, an implant and a temporary crown are placed immediately.

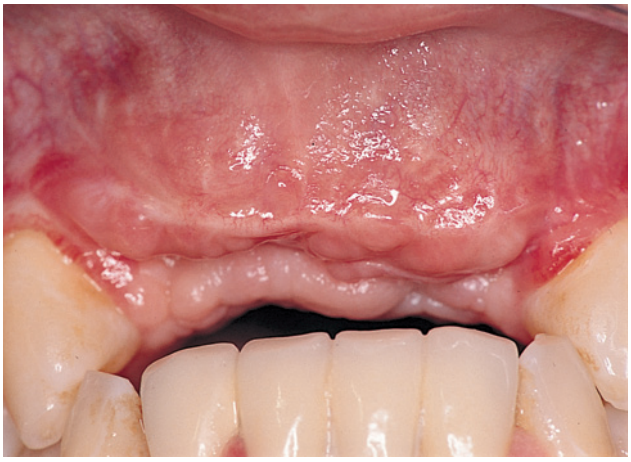


FIGURE 8-25 F, Palatal split-thickness graft is placed over the augmented ridge after 2 months to increase the width of the keratinized gingiva. The ridge is shown before placement of one additional implant in the lateral incisor region.

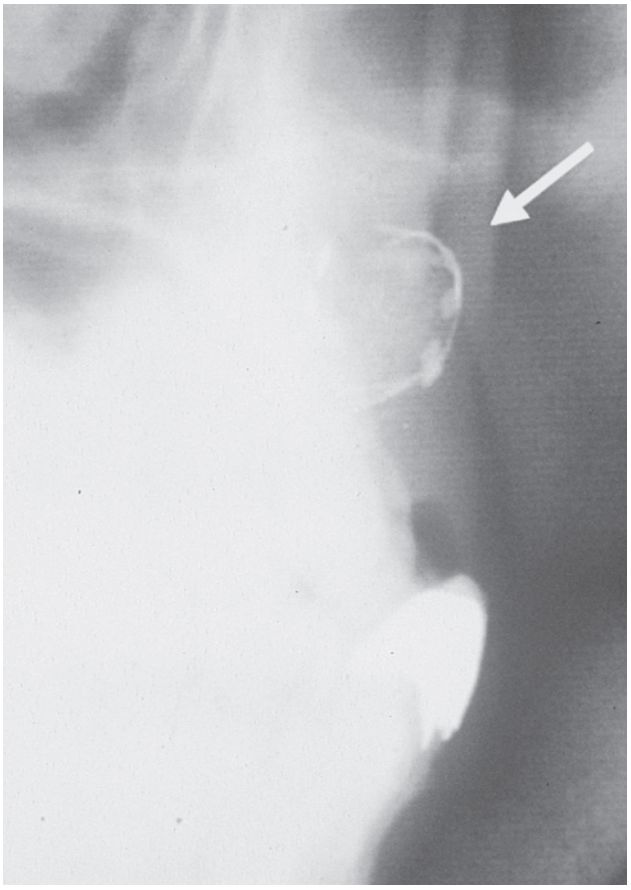


FIGURE 8-25 H, Lateral cephalogram taken after anterior graft consolidation, which is evidenced by the titanium-reinforced membrane *(arrow)*.

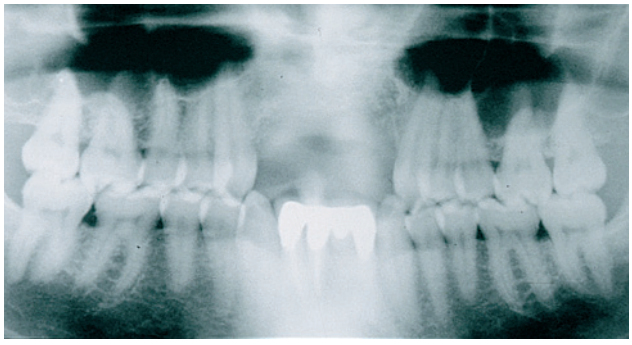


FIGURE 8-25 G, Pregraft panoramic radiograph showing the vertical ridge deformity.

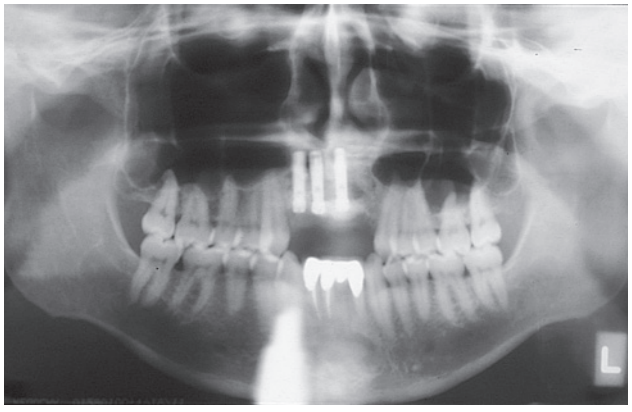


FIGURE 8-25 I, Four months after placement of the two central incisor implants and placement of an additional graft, one additional implant is placed in the right lateral incisor location.

One-Stage Technique for Implant Placement after Tooth Extraction

Preoperative planning for immediate temporization after implant placement involves fabrication of a surgical guide that precisely locates the implant in one position. The surgeon must work closely with the restorative dentist to ensure that the planned location of the implant is possible. The restorative dentist should be available during surgery to guide the surgical placement and adapt the temporary restoration after implant placement. The surgeon must discuss the plan with the patient, who must understand that if bone fenestrations are found, a traditional technique (as previously described) will be used.

Incisions for these cases can be kept isolated to the crestal and intrasulcular areas, with minimal elevation of the labial and palatal mucosa. After infiltration of a local

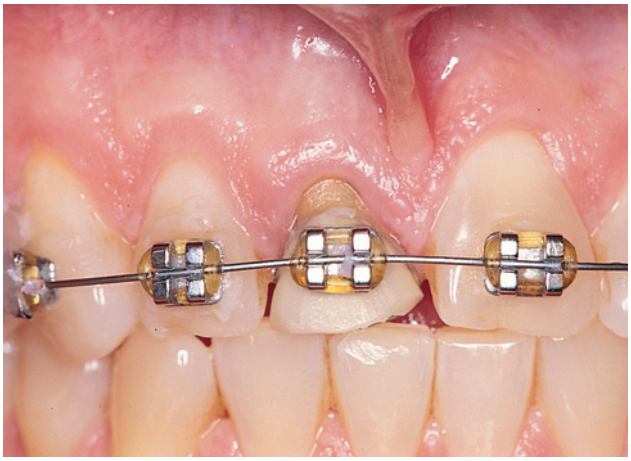


FIGURE 8-26 **A,** This 45-year-old patient had multiple endodontic treatments for the right central incisor, including apicoectomy. External resorption is occurring, resulting in the need for tooth extraction and replacement with an implant-supported restoration. The tooth has been extruded 4 mm orthodontically to advance the bone and gingival tissues coronally. The treatment plan is to extract the tooth; immediately place an implant; and place a custom-made, anatomically shaped healing abutment.

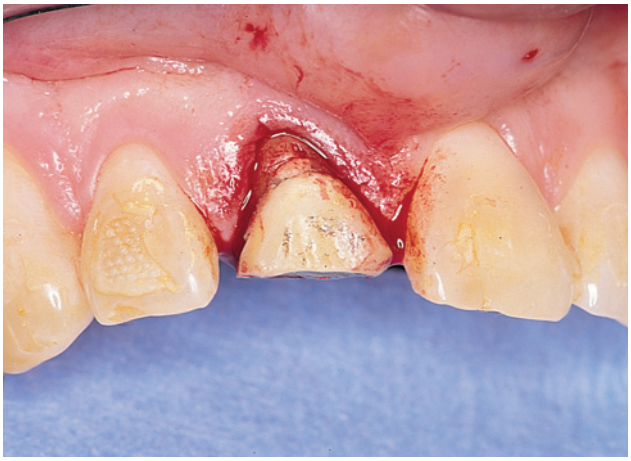


FIGURE 8-26 **B,** After administration of a local anesthetic, an incision is made only around the tooth.

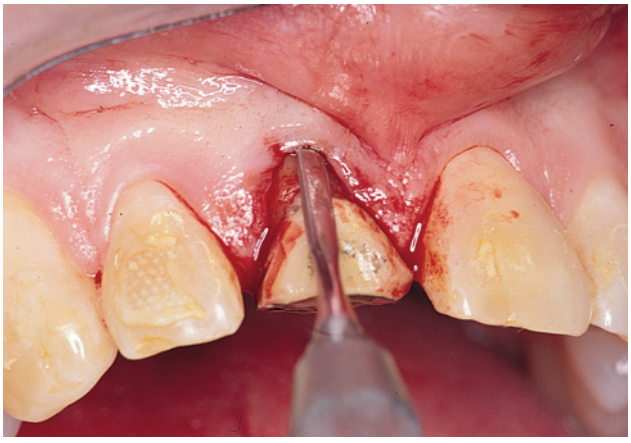


FIGURE 8-26 **C,** Periotome elevator is used to extract the tooth. This thin elevator is wedged between the tooth and the bone to gently separate the tooth from the bone. This procedure is performed circumferentially around the tooth. It is critical to be especially gentle when separating facial bone from the tooth.

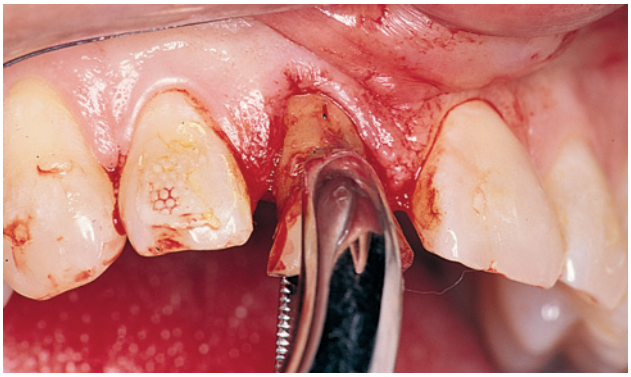


FIGURE 8-26 **D,** Tooth is extracted with minimal effort, preserving the bone around the tooth.

anesthetic, the incisions are made and the flap is elevated. The labial dissection can include a subperiosteal tunnel to confirm the presence of bone along the labial plate. After the bone contour has been confirmed, the surgical guide is placed and the initial site is scored with a round bur. It is important that the round bur locate the entry point of the implant in the middle of the crest to avoid thin labial bone after the implant has been placed. After the round bur has been used, the pilot bur is taken to depth, keeping the emergence of the bur slightly palatal to the incisal edge of the planned restoration. The drilling sequence is continued to completion, and the implant is placed. It is important to know the orientation of the antirotational aspects of the implant—flat or point of a hex—or similar specific orientation of internal connections. The depth of the implant must also be exactly as planned.

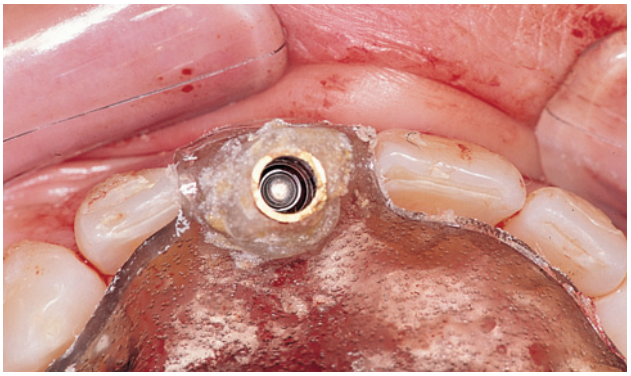


FIGURE 8-26 **E,** Surgical stent is fabricated to guide the surgeon in placing the implant into the prescribed location. The guide pin is visible through the surgical guide stent after the pilot drill has been used. Often a round bur is required to create a channel along the palatal aspect of the extraction site; pilot twist drills may have difficulty engaging the sloped palatal wall of the extraction site because of its smoothness.

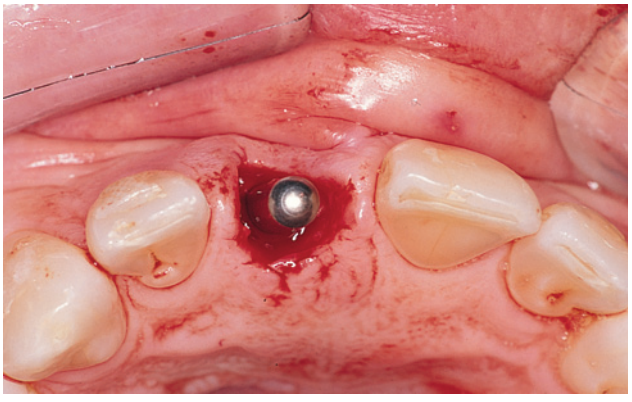


FIGURE 8-26 **G,** Guide pin illustrates the position of the implant site hole.

After the implant has been placed and the orientation approved by the restorative dentist, the abutment is placed and removed as necessary so that changes in its height and contours can be made outside the mouth. The abutment and temporary crown may be prepared on a model before surgery in selected patients. The abutment is placed and tightened to the implant, and the temporary crown is completed. The occlusion should be relieved to prevent loading of the implant during the healing period. In patients who may be prone to loading the implant because of athletics, weightlifting, or their occlusion, an anatomic or custom-made healing abutment can be placed to preserve the morphologic condition of the

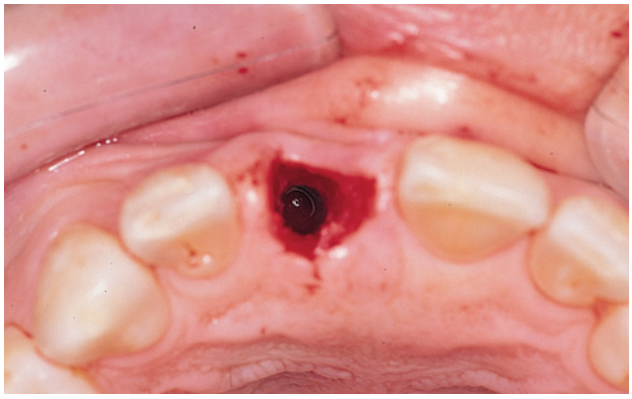


FIGURE 8-26 **F,** Implant site hole is visible through the extraction site.

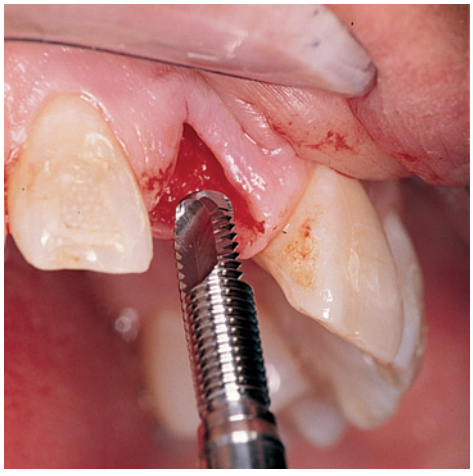


FIGURE 8-26 **H,** Implant 3.75 mm in diameter is shown on its driving mount before placement.

gingiva, without the presence of a tooth form. Vertical mattress sutures are placed to evert the papilla.

General Considerations and Follow-Up Treatment

The patient takes antibiotics for 2 weeks when a graft and membrane are used. If a membrane is not used, antibiotics are taken for 7 days. Sutures usually are removed 2 weeks after surgery. The removable prosthesis is generously relieved to prevent pressure on the surgical site, relined with a soft lining material if necessary, and placed back into the patient's mouth 7 to 14 days after the implant placement surgery. A type of Essix appliance or bonding may also be used immediately after surgery to prevent pressure on the ridge from

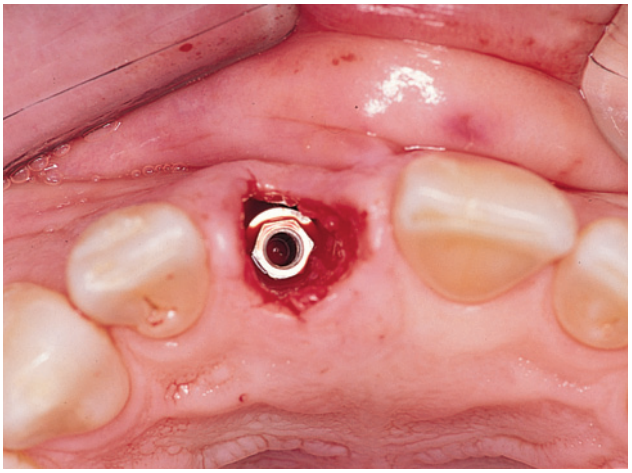


FIGURE 8-26 I, Implant is placed to the appropriate depth.

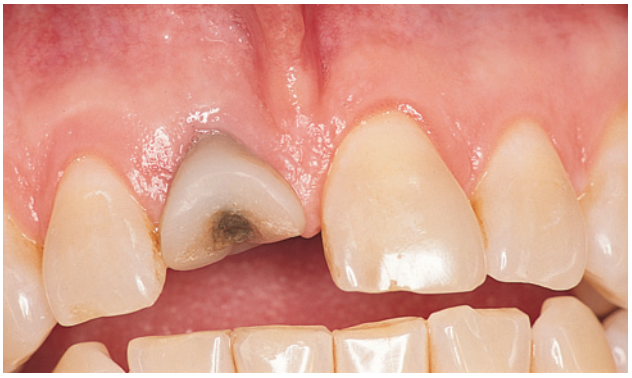


FIGURE 8-26 J, Anatomic healing abutment is placed. After 6 months for integration, the healing abutment is removed and a temporary restoration is made, followed by the final restoration.

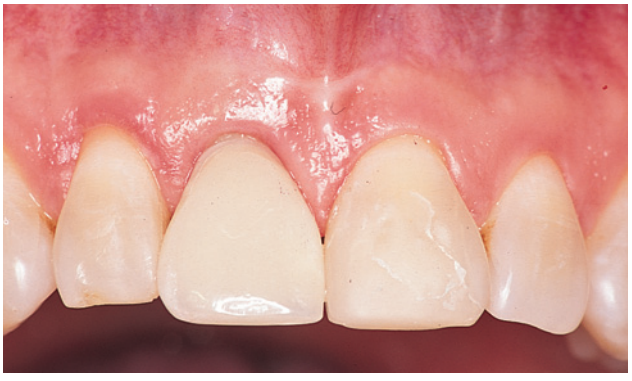


FIGURE 8-26 K, Final restoration. (Prosthetics by Dr. Ariel Rodroski.)

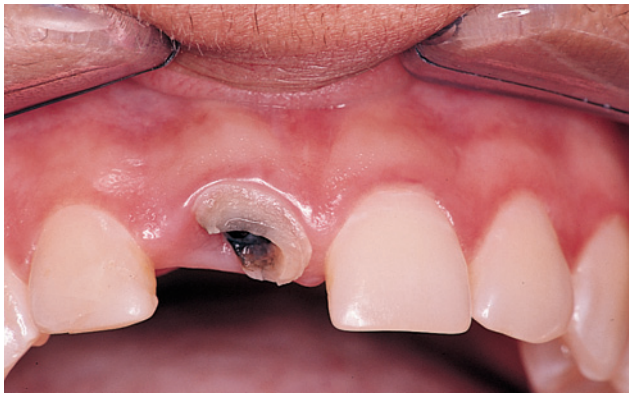


FIGURE 8-27 A, Maxillary right central incisor in a 24-year-old woman is considered nonrestorable by the prosthodontist. The gingiva appears healthy, but purulent exudate is observed on probing. The tooth is extracted.

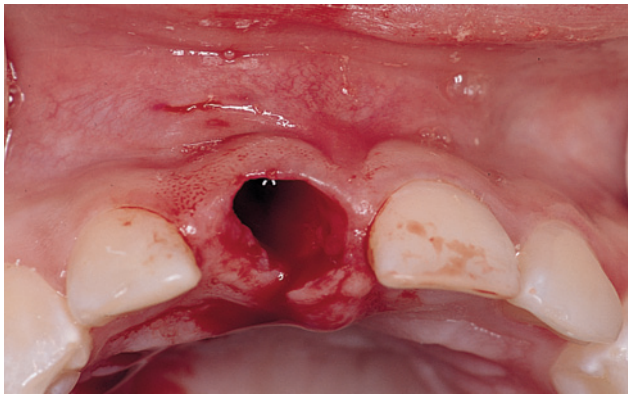


FIGURE 8-27 B, Minimal incisions and careful technique are used for the extraction to preserve the labial and facial bone.

conventional removable partial denture (RPD) prostheses. Membranes are removed either at the time of subepithelial connective tissue grafting (3½ months after placement) or at the time of implant exposure, which is at least 5 months after implant placement.

Most of these cases require soft tissue grafts because of an associated gingival deficiency in thickness and color. To correct this deficiency, a subepithelial connective tissue graft is placed approximately 3½ months after implant and graft placement. The timing of the soft tissue graft allows implant exposure at 5 months from implant placement; thus, the total time from implant placement to exposure has not been excessively lengthened.

Procedures performed during the integration or healing period are delayed until implant integration has

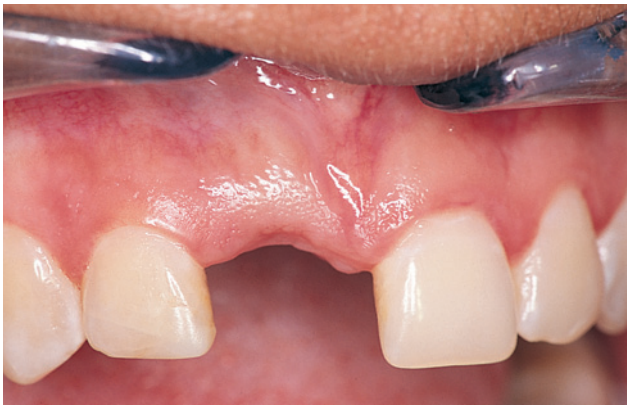


FIGURE 8-27 **C,** Approximately 8 weeks after extraction of the tooth, the patient returns for immediate implant placement. The ridge is palpated to be intact and without concavities in the coronal or apical region. The gingiva has healed uneventfully, with adequate maintenance of papilla and color.

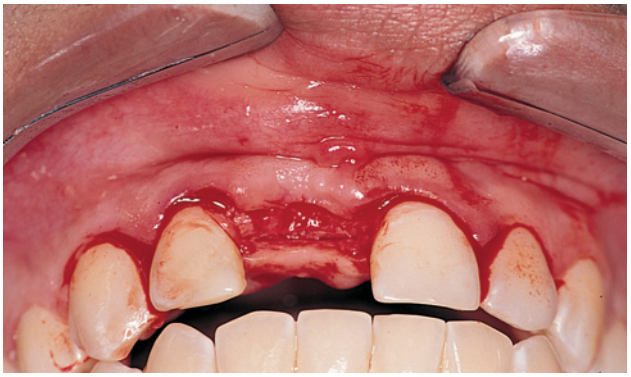


FIGURE 8-27 **E,** After administration of a local anesthetic from canine to canine, a crestal incision is made across the edentulous region, combined with intrasulcular incisions. A full-thickness flap is elevated.

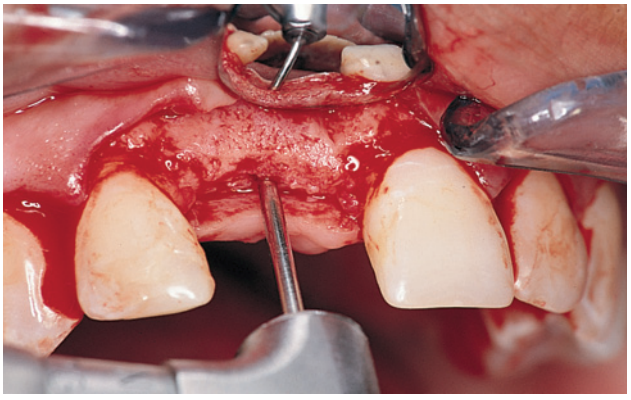


FIGURE 8-27 **G,** Pilot drill is used with palpation of the labial aspect to confirm a lack of cortical bone perforation.

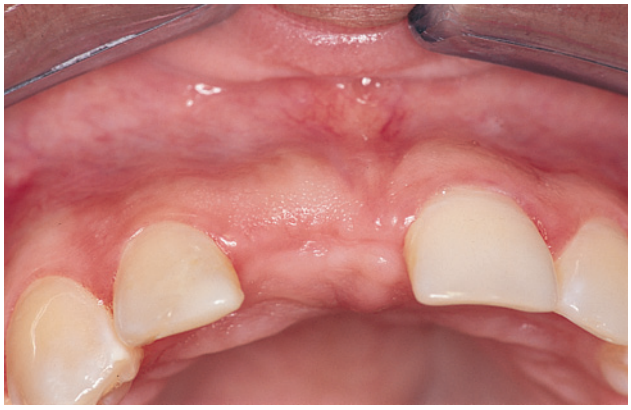


FIGURE 8-27 **D,** Occlusal view showing adequate ridge bulk without an obvious need for augmentation.

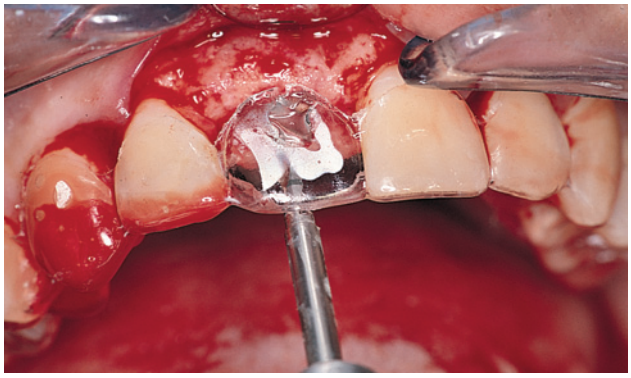


FIGURE 8-27 **F,** Surgical guide stent is placed, and a round bur is used to mark and initiate the implant site, followed by a pilot drill 1.25 mm in diameter.

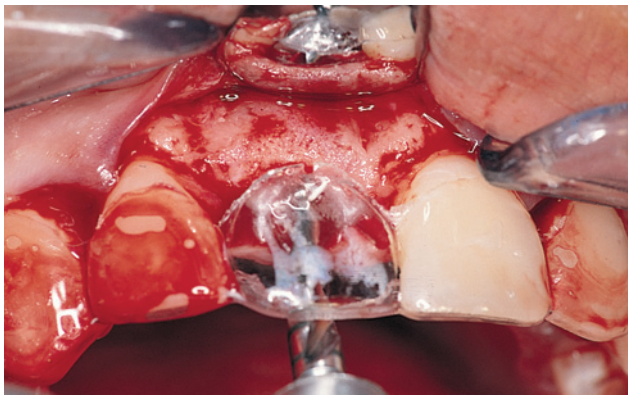


FIGURE 8-27 **H,** Subsequent sequence of drills is completed with the aid of the surgical template to guide accurate placement of the implant.

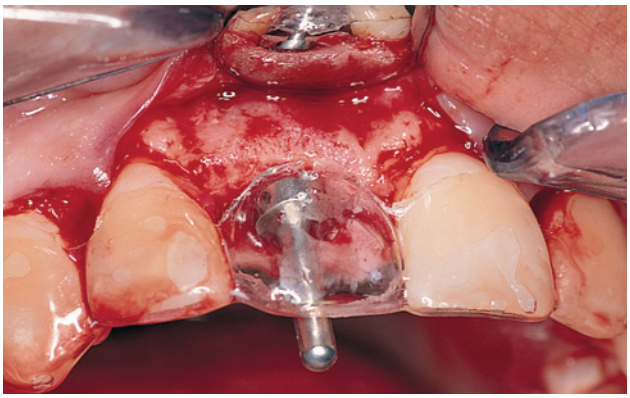


FIGURE 8-27 **I,** Guide pin is shown in the final preparation hole before placement of the implant.

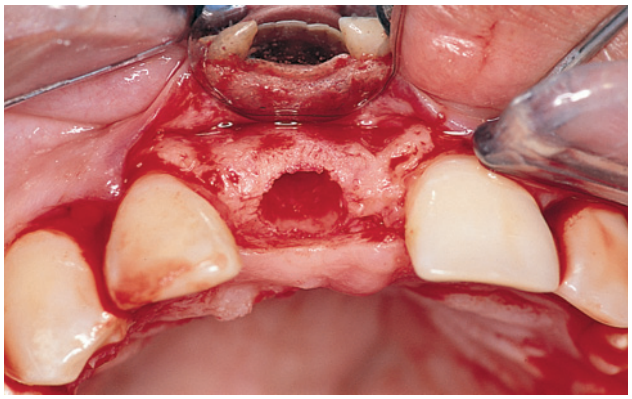


FIGURE 8-27 **J,** Implant site hole on the ridge.

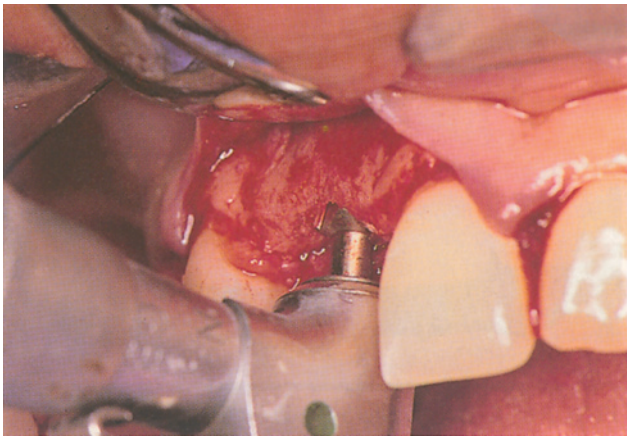


FIGURE 8-27 **K,** Because of excess availability of bone, a countersinking drill is used to position the implant 3 mm apical to the planned gingival margin.

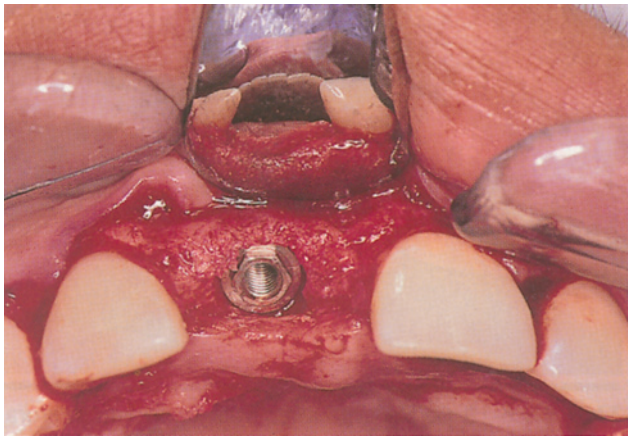


FIGURE 8-27 **L,** Implant is in position at the appropriate depth.

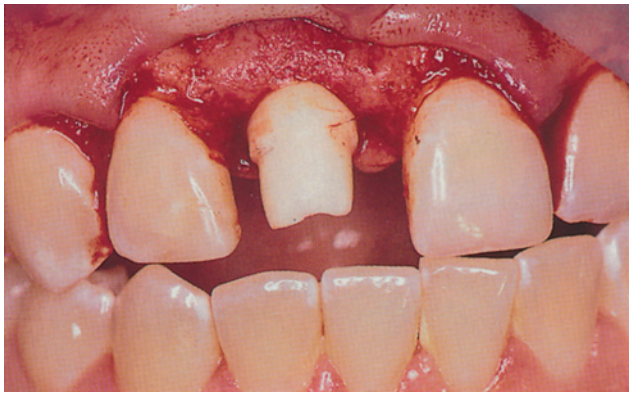


FIGURE 8-27 **M,** Ceramic abutment is placed into the implant. A small modification is necessary, which is performed with the abutment out of the mouth on the implant analog.

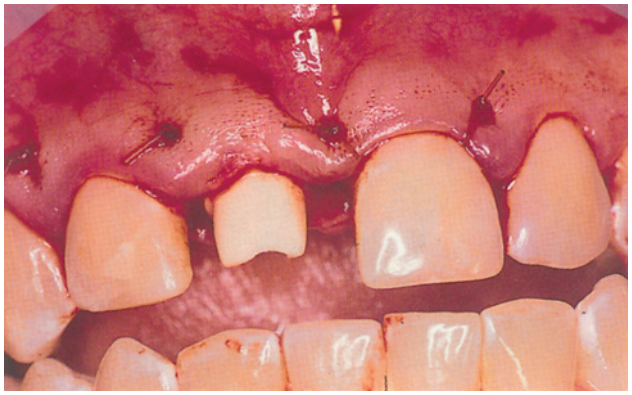


FIGURE 8-27 **N,** Ceramic abutment is in place with incisions closed around it. Vertical mattress sutures are used to evert the papillae atraumatically.

FIGURE 8-27 O, Hollow-shell crown of appropriate shade is chosen and modified at chairside. The inner aspect is filled with acrylic and placed over the abutment. Excess material is then trimmed.

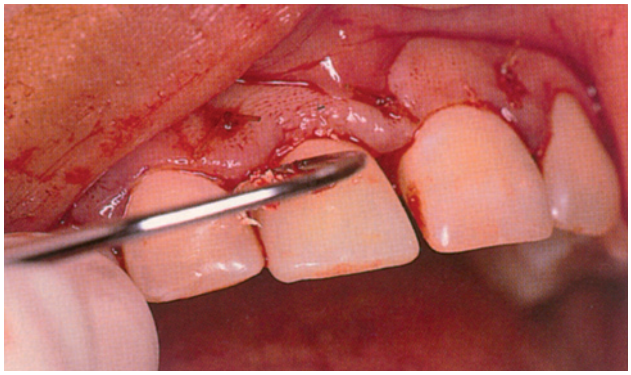


FIGURE 8-27 P, After the hollow-shell crown has been trimmed and polished, it is cemented with temporary cement. Excess cement must be removed from the wound.

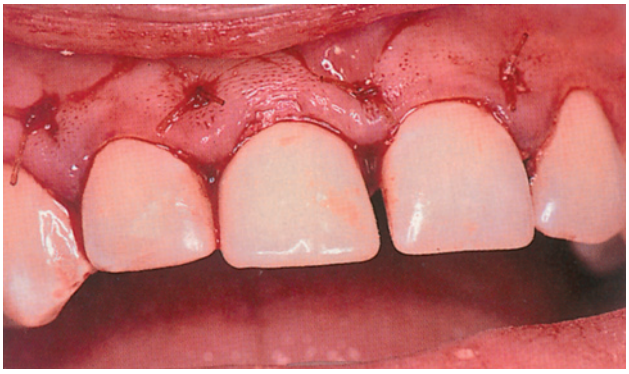


FIGURE 8-27 Q, Patient leaves with temporary restoration in place. It does not occlude in any pathway. Restoration is for esthetics only and not for function.

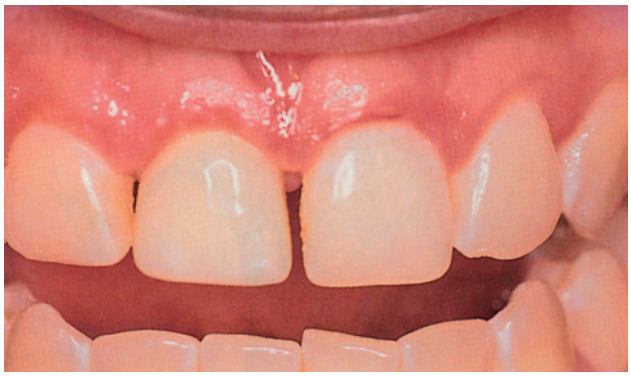


FIGURE 8-27 R, Two-week follow-up shows an integrated implant; the final restoration is made 6 months after implant placement. (Prosthetics by Dr. Thomas Salinas.)

occurred, to prevent disturbance of this critical aspect of implant success. Approximately 2 months after placement of the implants, the restorative dentist and surgeon examine the patient to decide, based on the esthetic setup, whether the implant site requires additional augmentation of the ridge. The goal is to achieve a convex ridge profile and develop the site's shape to allow the restoration to emerge from the gingiva similar to a natural tooth. This author's experience indicates that 70% of the implant sites that required hard tissue grafts also benefited from subepithelial connective tissue grafts 3½ months after implant placement.

For patients who require removal of previously placed membranes, crestal and bilateral vertical releasing incisions are made, sparing the papillae. A dissection is made to expose the membrane, which is removed with accompanying tacks, and a subepithelial connective tissue graft is harvested from the palate.[16,27,28] After the soft tissue has been placed, the incision is closed primarily; alternatively, a small band of keratinized gingiva (KG) is placed if additional width of KG is needed. These soft tissue grafts are approximately 2 to 3 mm thick.

If the subepithelial connective tissue graft has been performed without the need to remove a membrane, the incisions are limited to the crest without vertical release. A crestal incision is made without engaging the papilla to avoid papillary loss. A supraperiosteal dissection then is performed to create a pocket, which extends apical beyond the junction of the attached and unattached gingivae. The width of the pocket is increased apically to beyond the width of the edentulous site. The labial flap is kept relatively thick to prevent necrosis of the labial tissue after placement of the connective tissue graft. If necessary, the dissection depth is at the level of the periosteum of the underlying

Anterior Maxillary Interpositional Osteotomy for Vertical Ridge Augmentation

DVD Video 8-2

Before watching the video, please read the following narrative. The narrative describes in detail the procedure for anterior maxillary interpositional osteotomy for vertical ridge augmentation performed in the video. It is recommended that you read the narrative before watching the video and then refer back to the narrative as needed.

This patient is missing her anterior four incisors and desires an esthetic restoration. Diagnosis with an ideal tooth setup revealed that the vertical position of the crestal bone is 10 mm apical to the planned contact point between the central incisors and between the central and lateral incisors. To provide her with the ideal esthetic result, the bone should be within 5 mm of the planned contact point to support the papilla. For this patient, the vertical ridge deficiency was corrected by inferiorly positioning the anterior maxilla by an interpositional osteotomy. Prior to surgery, a template was fabricated to indicate the necessary position of the ridge to place it at the correct vertical position.

The patient was premedicated with diazepam (10 mg by mouth) 30 minutes prior to the procedure. She had been rinsing with an antibacterial mouth rinse for 3 days prior to the procedure. A povidone-iodine (Betadine) preparation was used on the face and mouth. Local anesthesia was infiltrated into the palate and vestibule (approximately 7.2 ml 2% lidocaine [Xylocaine] with 1:100,000 epinephrine). After a satisfactory time elapsed for the effect of the anesthetic and vasoconstrictor, the incisions were made.

An incision was made with a 15 blade in the vestibule, from canine eminence to canine eminence, at a Le Fort I level. The incision was made through mucosa and then sharply through the muscles to the underlying bone, with care taken to avoid the nasal mucosa along the piriform rim. The periosteum was incised with the scalpel.

A small periosteal elevator was used to elevate the periosteum superiorly. The elevator was then used to elevate the periosteum at the canine region to the crest, avoiding elevation of the periosteum anteriorly, at the expense of the canines to preserve the vascular supply to the crest. The roots of the canines were clearly visible under the labial bone.

A caliper was set at 8 mm to identify the level of the horizontal cut. A curved freer elevator was placed under the labial tissue in the area of the planned vertical cut on the left. The piezotome was used to create a full-thickness osteotomy approximately 2 mm anterior to the canine.

The osteotomy was first outlined and deepened gently. When the cuts were getting close to the palatal bone, the surgeon placed a finger along the palatal mucosa to feel the piezotome as it exited the palatal bone, without cutting the palatal mucosa.

After the left vertical cut was completed through the palatal bone, the surgeon performed a similar procedure on the right side, again approximately 2 mm anterior to the canine.

The periosteum was reflected superiorly along the entire length of the planned horizontal osteotomy. The cut was made with the piezotome, angling the cut toward the palate to allow for ease of segment mobilization. The soft tissues over the anterior nasal spine were elevated to allow for clean access to the bone. The cut was carried to the left from the right to meet the vertical bone cuts. When the cuts were close to the palatal bone, the surgeon placed a finger along the palatal mucosa to confirm completion of the osteotomy. After the cuts were completed, they were again checked to confirm completion of all of the bone osteotomies.

The segment was easily mobilized inferiorly. The segment is slowly moved inferiorly to avoid trauma to the overlying gingiva. The stent was placed to confirm adequate inferior displacement of the anterior segment.

Two bone plates were adapted to the segment. Two screws were placed in the bone plate on the mobilized bone segment. The screws were 1.0 mm in diameter and varied from 4 to 6 mm in length depending on the density of the bone. A drill was used to drill the hole for the screw and then the screw was immediately placed. After the four screws were placed to stabilize the two plates, the segment was mobilized symmetrically in its final, 1-mm overcorrected position.

The segment was stabilized in position by placement of the superior screws in the intact maxilla. After the four screws were placed, allograft bone was placed into the gap. A total of 1.0 ml mineralized bone allograft, 350 to 500 μm in diameter, was placed firmly into the gap. Excess graft material was removed to result in a clean bone surface away from the osteotomy gap.

The incision was closed with a horizontal mattress suture with additional interrupted sutures. The patient was prescribed a second-generation cephalosporin antibiotic, was told to consume a full liquid pulverized diet, and was provisionalized by having teeth placed on the orthodontics brackets.

bone or augmentation to keep the labial flap well vascularized. The necessary dimensions of the graft are measured and recorded so that a graft of proper dimensions can be harvested without excessive removal of tissue.

Conclusions

The following protocol is shown to be predictable and associated with a low complication rate:

1. Treatment planning results are determined with an esthetic setup that indicates the need for hard and soft tissue grafting.
2. At the time of implant placement, placing the implant and performing hard tissue augmentation are most common.
3. After approximately 3½ months, a subepithelial connective tissue graft is placed to augment and improve the quality of the soft tissue.
4. Five months after implant placement and approximately 6 weeks after placement of the soft tissue graft, the implant is exposed using a tissue punch.
5. Using a gradual increase in the size and shape of the abutments and temporary crowns, the emergence of the soft tissue restoration is refined.
6. An esthetic crown is fabricated after the soft tissue profile has developed, is stable in appearance, and has minimal inflammation.

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Chapter 9

Soft Tissue Manipulation around Implants in the Esthetic Zone

Chapter Outline

After an implant has been placed and all hard tissue grafting procedures have been completed, the implant site is evaluated to determine the need for additional soft tissue manipulation (Figure 9-1). Adjunctive procedures may be necessary to complete the surgical preparation of the implant site or to modify an existing implant restoration to achieve an esthetic restoration. The initial diagnostic esthetic setup or the current esthetic temporary prosthesis can be used to assess the need for further ridge augmentation with soft tissue or for modification of the position of the gingival margin.

Physical examination of the patient is necessary, with attention given to specific anatomic and restorative details (Box 9-1). After the examination has revealed tissue characteristics that would benefit from an adjunctive soft tissue procedure, the specific soft tissue procedure is performed to correct the soft tissue deficiency or to modify the gingival margins, resulting in symmetry and an esthetic smile. Soft tissue deficiency usually involves a thin gingiva, which benefits from increasing its thickness with connective tissue. When the connective tissue thickness is normal or slightly thicker than normal, the resulting texture, tone, color, and general appearance become similar to adjacent normal gingiva around natural, esthetic teeth.

The metal of the implant's cover screw may also be visible through thin gingiva. The gingiva may appear glossy without its esthetic stippled appearance. A loss of keratinized gingiva (KG) and scars may be seen at the crestal region. These conditions are treated with placement of an interpositional subepithelial connective tissue graft or other soft tissue procedures combined with a subepithelial connective tissue graft. The timing of the procedure

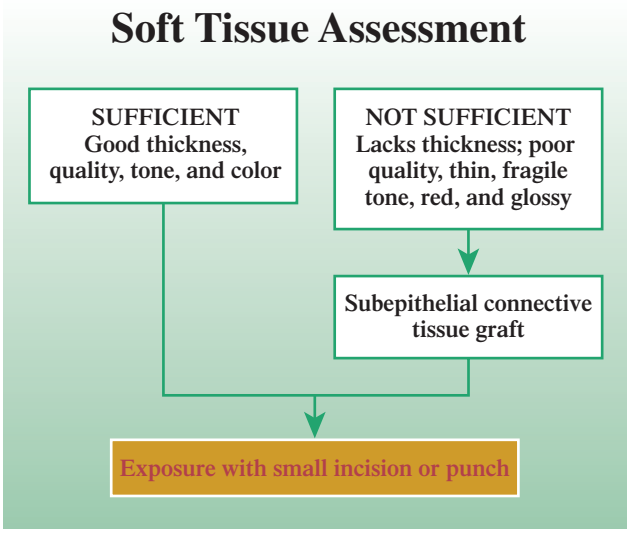


FIGURE 9-1 Decision tree showing the soft tissue assessment for ridge augmentation using subepithelial connective tissue grafts.

BOX 9-1 Soft Tissue in the Esthetic Zone: Anatomic and Restorative Considerations

- Horizontal position of the gingiva in relation to the gingival margin of the planned restoration
- Color of the gingiva in relation to the gingival margin of the planned restoration
- Texture of the gingiva in relation to the gingival margin of the planned restoration
- Presence of keratinized gingiva in relation to the gingival margin of the planned restoration
- Metal show-through at the gingival margin of the planned restoration secondary to thin gingiva or perhaps labial placement of the implant
- Symmetry of the gingival margin in relation to the need for crown lengthening or root coverage
- Presence of scars from prior surgical procedures or the result of previous trauma or other dental or surgical procedures (e.g., apicoectomy)

depends on the clinician. To prevent complications from performing multiple procedures simultaneously, the connective tissue surgery is performed as an isolated procedure. When more than one procedure is performed in the same surgical site at the same time (e.g., hard and soft tissue grafting), a compromised vascular supply and subsequent healing problems may result in necrosis of the graft and gingival recession. Vascularization of the connective tissue graft is critical to a successful outcome. If the tissue graft does not revascularize, it becomes necrotic; after its removal and subsequent healing, the gingiva appears scarred and recessive in height, severely compromising the final esthetic result.

The best course is to perform the hard tissue grafting first and establish the hard tissue foundation for the implant site. The implant is placed at the time of hard tissue grafting (see Chapter 8), or the connective tissue grafting is done after implant placement as a separate procedure approximately 3½ months later. Six weeks after placement of the connective tissue graft, the implant is exposed with minimal incisions, usually using a circular tissue punch. Placement of connective tissue grafts at the time of hard tissue grafting or at implant exposure may yield satisfactory results in select cases, but this timing may also result in an esthetic problem if the connective tissue graft does not become revascularized and, as a result, becomes necrotic.

Approximately 3 months after implant placement, the implant site is examined to determine whether the bone and gingival contour mimic the root eminences of the adjacent teeth. From the occlusal view, it can be ascertained with direct visualization whether the root prominence over the implant site is adequate. If any doubt exists, augmentation is indicated. If the necessary augmentation is limited to 3 mm, 2 mm can be gained from a connective tissue graft, with the final 1 mm obtained through the subgingival labial contour of the final restoration. If the necessary augmentation exceeds 3 mm, it may be necessary to augment the site again with a hard tissue graft, because connective tissue grafts more than 3 mm thick in a single-tooth implant site may not revascularize and thus are less predictable. Gingival recession and an esthetic disaster accompany the necrosis of a connective tissue graft; therefore, the clinician must carefully consider the correct timing of the procedures to achieve the desired result predictably.

For the implant or pontic site with a horizontal defect greater than 3 mm, a crestal incision made, followed by a subperiosteal dissection to create a well-confined pocket in the area of the necessary augmentation. Particulate, dense, nonresorbable graft material such as synthetic hydroxylapatite (HA) or anorganic bovine xenograft is placed, and the incisions are closed. A subepithelial connective tissue graft may be placed 3 months later to further augment the site if needed.

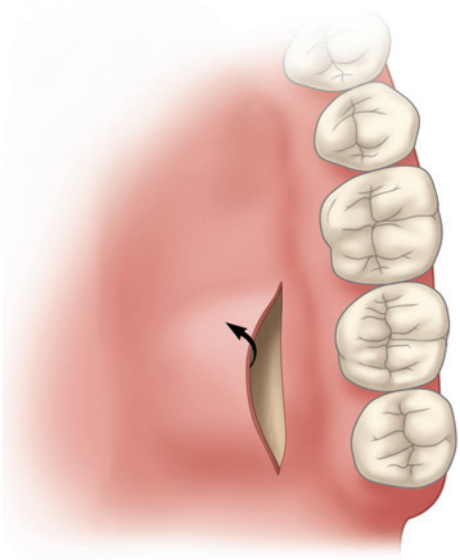
Adjunctive procedures are used to augment the alveolar crest to create a convex ridge profile. Soft tissue augmentation procedures include a subepithelial connective tissue graft, a palatal roll-in procedure at the time of implant exposure, and repositioning of adjacent palatal tissue at implant exposure. For most patients, the placement of a subepithelial connective tissue graft as a separate procedure 6 weeks before implant exposure results in adequate tissue bulk

and gingival appearance. If approximately 1 to 2 mm of soft tissue is required to reduce gingival translucency, a palatal roll procedure can be used at implant exposure. However, caution is necessary, because the thickness of the transposed, denuded palatal tissue may limit the augmentation to only 1 mm.

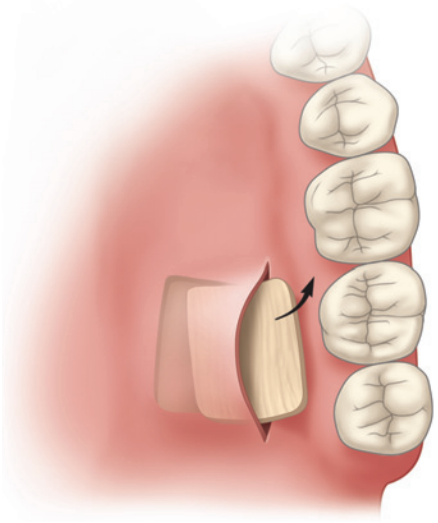
Soft Tissue Manipulation for Ridge Augmentation

The subepithelial connective tissue graft is a sheet of connective tissue harvested from the palate (Figure 9-2, A-I). This soft tissue graft initially was described by Langer et al.[1-3] to correct ridge concavities and for root coverage, without de-epithelialization of the palate.[4,5] The connective tissue graft is quite versatile and flexible in its uses. Indications for use of a subepithelial connective tissue graft in dental implant sites include the following:

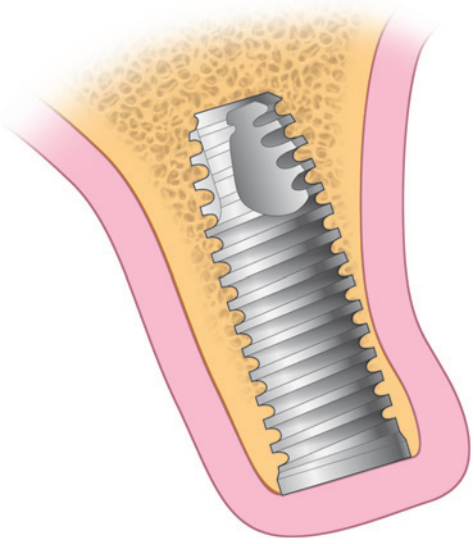
1. *Thickening the gingiva to eliminate metal show from an underlying dental implant.* The subepithelial connective tissue graft can thicken the gingiva 1 to 3 mm, depending on the thickness of the graft and contracture or shrinkage of the graft during healing.
2. *Improving poor quality of the crestal gingiva.* The gingiva's appearance may be glossy rather than that of normal, healthy gingiva. The subepithelial connective tissue graft can change the appearance of thin, red, glossy gingiva to thick, pink, and normal stippled gingiva.



● **FIGURE 9-2** **A,** To harvest a piece of subepithelial connective tissue graft, incisions are made, and the palatal mucosa is reflected.



● **FIGURE 9-2** **B,** Desired thickness of connective tissue is harvested. The palatal flap then is reapproximated.



● **FIGURE 9-2** **C,** Cross section of an anterior maxillary site shows sufficient bone thickness for the implant; however, a concave labial profile exists.

3. *Increasing the labial convex contours of the soft tissue for a natural appearance of the final esthetic, implant-supported restoration.* The 1 to 2 mm of additional crestal width provided by the subepithelial connective tissue graft can allow the restorative dentist to achieve an esthetic and symmetric soft tissue profile on the restoration.
4. *Increasing the thickness of the gingiva to allow for sculpting.* The restorative dentist can create an ideal gingival

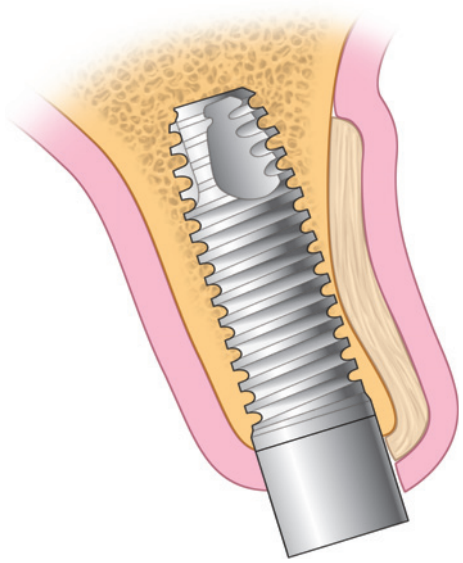


FIGURE 9-2 D, Connective tissue graft is placed after gingival reflection, plumping out the labial portion of the ridge and providing a convex ridge form.

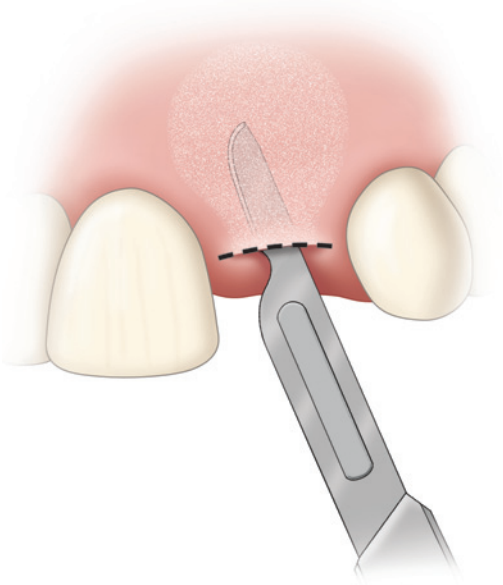


FIGURE 9-2 F, Small (15c) scalpel blade is used at the periosteal level (i.e., deep but not superficial) to develop a pouch that typically is 10 to 12 mm vertical; its apical base is wider than the crestal incision. As necessary, the dissection can be altered to include the tissues adjacent to the papillae from a deep aspect.

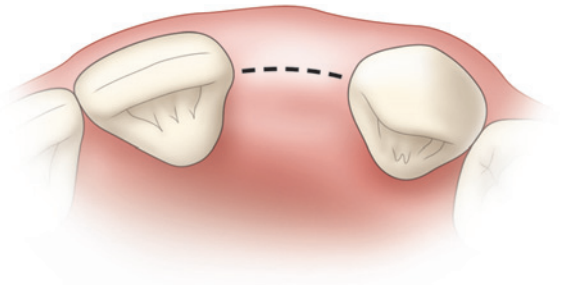


FIGURE 9-2 E, Conservative crestal incision is made in preparation for placement of a subepithelial connective tissue graft in an implant site or for ridge augmentation.

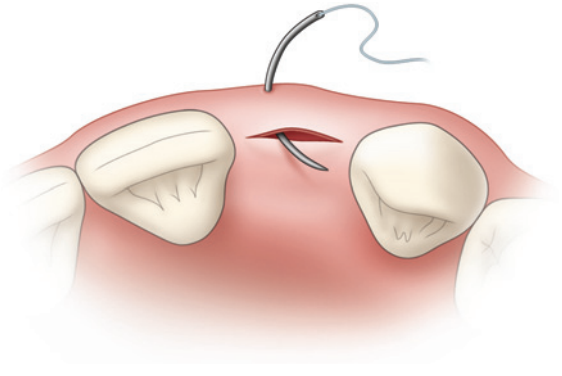


FIGURE 9-2 G, After the connective tissue graft has been harvested and trimmed to the appropriate size, a tapered needle is passed from the vestibule into the pouch, exiting from the crestal incision.

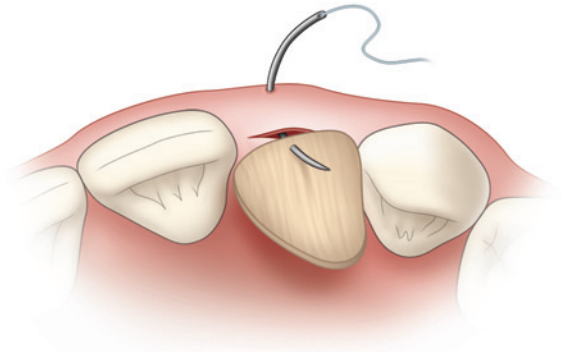


FIGURE 9-2 H, Needle and suture are passed through the connective tissue graft near its apical base. The needle re-enters the crestal incision to exit in the vestibule adjacent to the initial suture location.

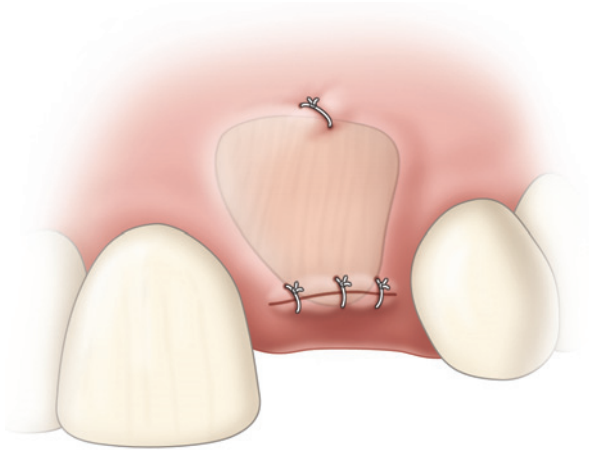


FIGURE 9-2 **I,** Vestibular suture is tied to position the graft gently in the vertical direction. Interrupted sutures are then placed to close and secure the connective tissue graft in the pouch, resulting in ridge augmentation.

form for the esthetic restoration. By using the additional soft tissue thickness, the dentist can carve an esthetic form of the gingiva.

5. *Correcting vertical height.* The subepithelial connective tissue graft can be placed on the alveolar crest to augment the vertical height of the ridge 1 to 3 mm. The limit of this technique is not known at this time; however, 2 mm of augmentations is predictable.

Subepithelial Connective Tissue Grafting for Ridge Augmentation

With dental implants, the subepithelial connective tissue graft is useful for augmenting the labial gingiva and eliminating metal show from the underlying implant. By increasing the thickness of the crestal gingiva, this graft reconstructs the appearance of the gingiva to mimic the appearance of the adjacent gingiva. The thickness and underlying connective tissue quality of normal gingiva often are altered in form when bone and teeth are lost. Thinner gingiva is more glossy and red in appearance, with a loss of its normal texture and general tone. After the subepithelial connective tissue graft has been placed, it can match the adjacent gingiva in form, color, and appearance.

The use of the subepithelial connective tissue graft to augment dental implant sites is based on the premise that after a tooth has been extracted, both the hard and the soft tissues change in form and quantity. (See Chapter 8 for discussions on hard tissue.) Interpositional soft tissue grafts can augment approximately 2 to 3 mm of width, but they contract over time and may lose 20% to 40% of their original thickness.[6] Therefore, the clinician should expect some shrinkage from these grafts. The exact amount of shrinkage is not well documented and may vary from patient to patient. Fortunately, if the grafts do not shrink and the excess is not esthetically pleasing, the surface of the gingiva can be easily shaped by a diamond, football-shaped bur to the desired contour.

Timing the Placement of Soft Tissue Grafts

The timing for the placement of interpositional connective tissue grafts in the implant site depends on the clinician. Some clinicians place the subepithelial connective tissue graft at implant placement, using the sheet of connective tissue in a manner similar to that used with membrane placement. The advantage of placing the subepithelial connective tissue graft at the time of implant placement or at the time of implant exposure is that it eliminates the need for a separate surgical procedure.

The disadvantage of placing the graft simultaneously with implant placement or at implant exposure is the decrease in potential vascular supply to the graft. The subepithelial connective tissue graft traditionally is placed with its future blood supply arising from the underlying and overlying soft tissues. When placed at implant placement or implant exposure, the undersurface of the connective tissue graft may be placed against metal, denuded bone that has just been traumatized by intraosseous surgery, or other graft materials. Thus the vascular supply to the graft may be compromised. If the graft does not become revascularized, necrosis of the graft may occur. When the connective tissue graft necroses, incision breakdown occurs, and the remnants of the graft are exfoliated from the site. The subsequent healing response results in gingival recession that can ruin the appearance of an esthetic restoration.

Because of this potentially disastrous complication, the best course is to place the subepithelial connective tissue graft as a separate procedure. With this approach, the surgeon has control of the host tissue bed and can engineer the surgical procedure to optimize the vascular supply to the graft, thus increasing the chances of success and reducing the chances of graft necrosis.

Placing the soft tissue grafts at the time of hard tissue grafting may result in an excellent result. However, this author has found the incidence of complications to be as high as 25% when the soft tissue graft is placed at the time of implant exposure or at the time of hard tissue grafting.

When is the best time to place interpositional connective tissue grafts? If the clinician's philosophy is to use soft tissue procedures to fine-tune the esthetic result, the procedure should be delayed until later in the chronology of implant therapy. Predictability and an extremely high success rate are critical for an esthetic implant restoration. This author recommends that soft tissue grafts be performed 3½ months after implant placement. When combined with the subsequent 6 weeks' healing time for the subepithelial connective

tissue graft, the total time from implant placement to exposure usually is 5 months.

Palatal Roll Technique

The palatal roll technique uses local tissue to augment the labial aspect of the alveolar ridge. The palatal roll technique was introduced by Abrams[7] as a way to augment edentulous pontic sites for fixed prostheses. Tarnow and Scharf[8] described a modified palatal roll technique for smaller ridge defects and for use when implants are exposed. Its use to augment implant sites has also been described by Block.[9,10]

The palatal roll technique is simple and predictable. An incision is made parallel to the alveolar crest, avoiding the interdental papillae. Two vertical incisions are made toward the middle of the palate. A flap of tissue is developed; it is kept quite thin and based off the palatal tissue. This dissection exposes the underlying denuded palatal mucosa. Incisions through the periosteum are made along the previous vertical incisions and through the denuded tissue at the base of the flap. A full-thickness reflection is performed, elevating the denuded palatal mucosa off the palate. This mucosa then is "rolled" under the labial periosteum, augmenting the labial gingiva (DVD Figure 9-1, A-F).

DVD Images 9-1, A-F

The indications for use of this technique have been narrowed. The use of subepithelial connective tissue grafts with a pouch procedure can predictably result in augmentations 2 mm thick, whereas the palatal roll may result in a gingival augmentation only 1 mm thick, with an occasional augmentation of 2 mm. Therefore, the palatal roll technique is reserved for small defects that primarily need small increases in gingival thickness to eliminate implant metal show through thin gingiva or for 2-mm horizontal gingival defects (Figure 9-3, A-K). This augmentation technique is useful at the time of implant exposure. When it is properly performed, papillae are preserved, and scars from incisions do not show, because they are palatal in location with minimal labial reflection. The palatal roll technique is difficult to perform in regions where the palatal rugae are thick, preventing elevation of a thin palatal flap. For patients with thick rugae, a subepithelial connective tissue graft is used.

The palatal roll technique is useful after a tooth has been subluxed and lost from trauma without alveolar bone loss. Many of these patients have minor gingival tearing at the time of injury; when the gingiva heals, it is thinner than normal (see Figure 9-3).

Diagnostic examination usually reveals loss of the tooth with limited bone loss. Gingival tears heal with inversion into the extraction site. An esthetic tooth setup is used as the transitional appliance and to provide information for the surgical stent. The patient should approve the esthetic setup and receive a surgical plan, which includes placement of an implant, a 5-month period for healing, and a soft tissue procedure either before or during implant exposure.

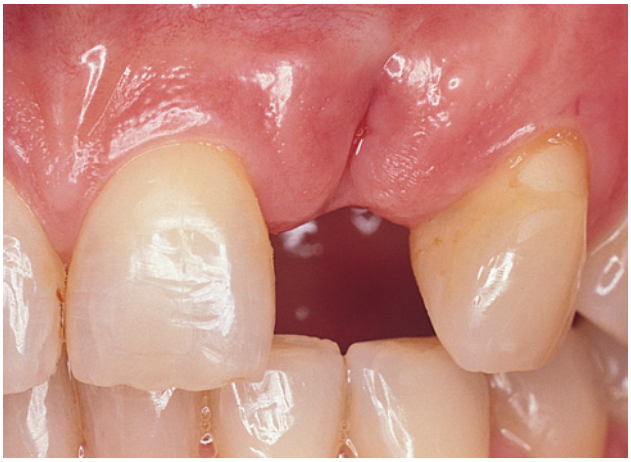


FIGURE 9-3 **A,** This 40-year-old patient lost the left lateral incisor after trauma, which resulted in avulsion of the tooth and laceration of the gingiva. Minimal bone was lost at the time of tooth avulsion.

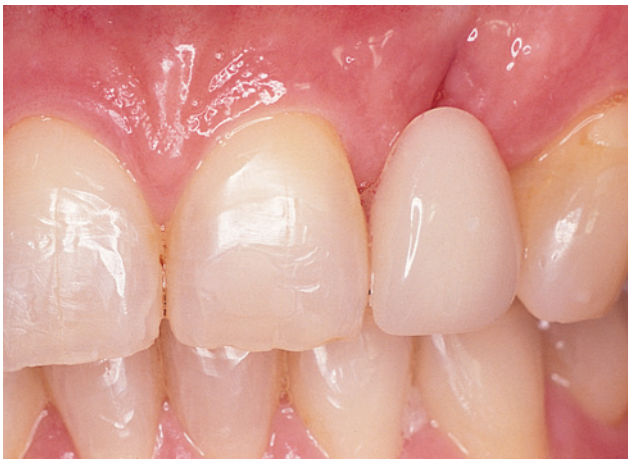


FIGURE 9-3 **B,** Esthetic removable partial denture (RPD) is fabricated to serve as the template for the surgical guide stent and to provide the patient with a temporary restoration. Her smile line exposes her gingiva.

At the time of implant placement, which may be 8 weeks or longer after the injury, the choice of incision design is no different than for any other implant placement. If the contact area between the teeth is less than 6 mm from the crestal bone, a sulcular incision from canine to premolar can be used. If the distance from the contact area to the crestal bone is 6 to 7 mm or more, a papilla-sparing incision is recommended.[11] After it has been determined that

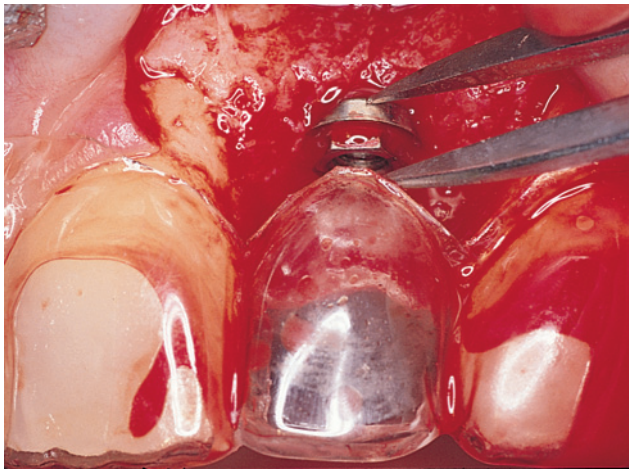


FIGURE 9-3 **C,** After the area has healed for 2 months, a papilla-sparing incision is used to place an implant 3.25 mm in diameter 3 mm apical to the planned gingival margin. The surgical stent is trimmed to identify the gingival margin, which then is used as the landmark to measure the depth of implant placement.

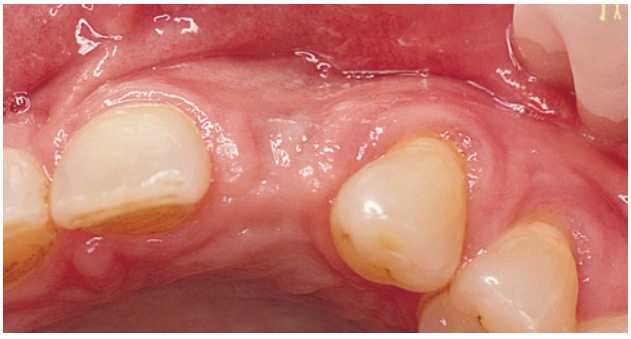


FIGURE 9-3 **E,** Occlusal view showing a small horizontal deficiency; note the thin gingiva.

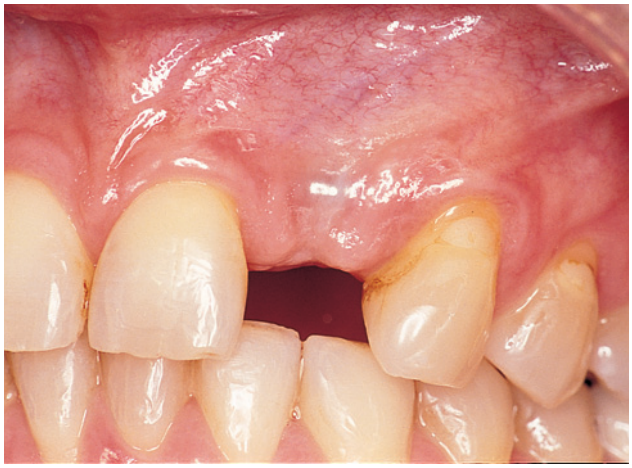


FIGURE 9-3 **D,** After 4 months, the patient is scscheduled for implant exposure. The thin gingiva is shown, with the implant slightly visible.

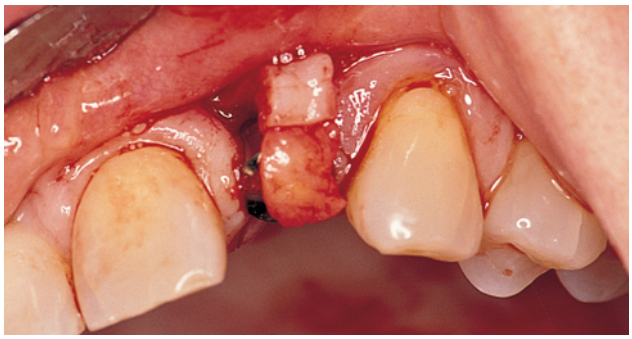


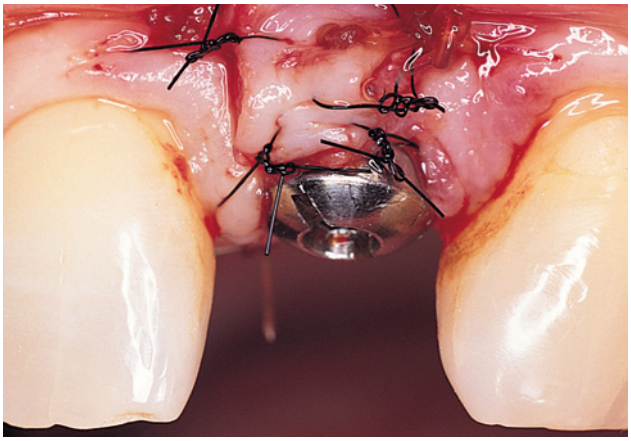
FIGURE 9-3 **F,** Palatal roll procedure is performed simultaneously with implant exposure. The denuded palatal mucosa attached to the full thickness of the crestal and labial gingivae is shown. The de-epithelialized palatal tissue will be rolled in under the labial gingiva to augment and re-establish proper gingival texture, color, and translucency.

adequate bone is present, the implant is placed. The esthetic stent is used to guide the surgeon on the vertical positioning of the implant with regard to the planned gingival margin and the labial position of the implant emerging just palatal to the incisal edge of the planned restoration. The implant usually is placed 3 mm apical to the gingival margin of the planned restoration, and the incision is closed without tension.

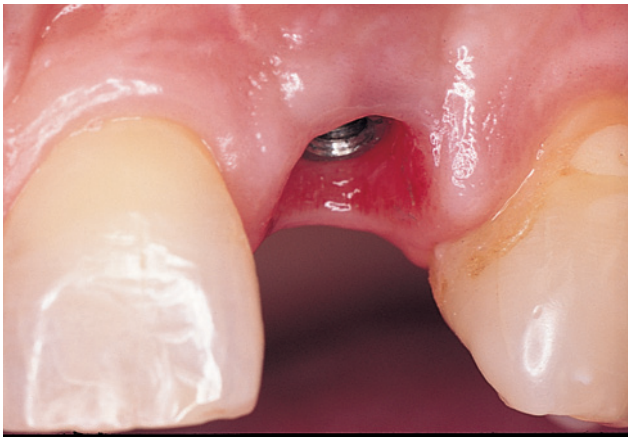
During the healing period, the gingiva appears thin. Four months after placement of the implant, metal shows through the thin gingiva. The metal shadow seen through the thin, translucent gingiva prevents an esthetic restoration.

The amount of horizontal gingival deficiency may be limited to 2 mm, based on the aesthetic tooth setup. For 2-mm defects, at least 1 mm can be predictably gained from the palatal roll technique, with the remaining 1 mm gained from the labial contour of the final prosthesis. A palatal roll technique can be planned to increase the thickness of the crestal tissue and eliminate metallic show of the underlying implant. The palatal roll technique can be performed at the time of implant exposure and placement of the healing abutment.

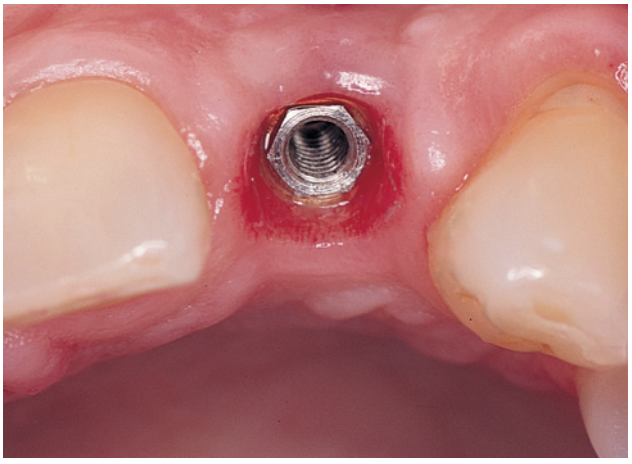
After time has been allowed for the infiltrated local anesthetic to take effect, an incision is made slightly palatal



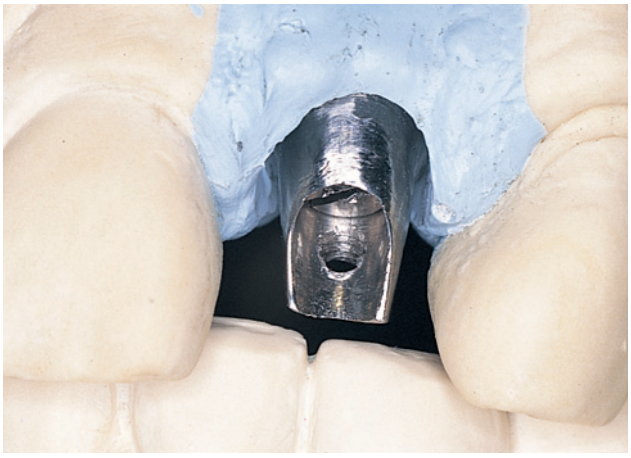
● **FIGURE 9-3** **G,** De-epithelialized palatal tissue has been sutured under the labial gingiva with a horizontal mattress suture that exits from the midcrestal region. The healing abutment has been placed. It is important to accurately position the flaps coronally.



● **FIGURE 9-3** **H,** Healing abutment has been removed, and a temporary restoration has been placed. After 3 months, the temporary abutment is removed. The implant and sulcus are shown before a final impression is taken. Note the excellent gingival tone and texture.



● **FIGURE 9-3** **I,** Occlusal view showing a healthy gingival sulcus.



● **FIGURE 9-3** **J,** Angled abutment is used for the final restoration. It is screw retained from the lingual aspect.

to the crest, between but not including the papillae. Vertical release incisions are made toward the palate. A palatal mucosa–only flap is raised with its base on the palatal aspect of the edentulous site. An incision is made into the underlying, denuded palatal tissue, adjacent to the base of the palatal mucosa flap. The incision is followed by full-thickness incisions along the vertical edges of the denuded tissue, which allows a subperiosteal reflection of the palatal denuded epithelium. Small vertical release incisions can be made, but these often are not necessary and should be avoided, if possible, to limit vertical scars. The dissection over the labial surface of the implant is subperiosteal, with tenting of the overlying gingiva. By not using vertical release incisions, the clinician prevents vertical scars, which can result in an unesthetic outcome. An appropriate pouch is created by full-thickness elevation of the labial gingiva. The denuded epithelium is folded under the labial gingiva, augmenting its thickness. Sutures are placed to secure and align the gingival margins. One suture is placed through the labial mucosa, engaging the rolled-in, denuded palatal tissue. This retaining suture should be placed with care, avoiding excessive vertical tension, which could result in apical migration of the gingival margin. A temporary gingival healing abutment is placed.

FIGURE 9-3 **K,** Final restoration in place. Adequate gingival texture, tone, and color are seen, without evidence of the underlying metal of the implant or abutments.

After the healing abutment has been placed into an implant, additional sutures are placed to hold the palatal tissues under the labial gingiva and to set the vertical position of the margin of the gingiva. It is critical to avoid vertical retraction of the gingival margin, which results in a poor final position of the gingiva. Additional sutures are placed to align the edges of the vertical incisions as necessary. The removable prosthesis is modified to avoid excessive pressure on the gingiva.

After the gingiva has healed for 4 weeks, a small gingivoplasty can be performed, if necessary, by the prosthodontist to create an anatomic sulcus. After the gingiva has been allowed to heal, anatomic impressions are taken, and a final restoration is placed.

Transposition of Palatal Tissue for Exposure of Implants

When the patient has adequate bone for implant placement, it is prudent for the clinician to assess whether a connective tissue graft is indicated. Not every patient requires a connective tissue graft for an esthetic result. If the bone support is adequate, the color, tone, and thickness of the overlying tissue may be sufficient for routine exposure, eliminating the need for a soft tissue graft. A crestal incision can be made and the palatal keratinized tissue can be transposed to the labial aspect of the abutment and implant restoration (DVD Figure 9-2, A-H), or a tissue punch can be used to expose the implant. Papillae can be raised during exposure of the implant only if less than 7 mm of space is present between the proposed contact area and the crestal bone.[11]

DVD Images 9-2, A-H

Placement of a Subepithelial Connective Tissue Graft as a Separate Procedure

For the anterior maxillary esthetic site, the goal of placement of the interpositional, subepithelial connective tissue graft is to complete the preparation of the implant site before implant exposure for abutment connection. No incisions are necessary at the exposure procedure when a tissue punch is used to remove a small circular patch of the overlying gingiva or when a small semicircular incision is used without vertical release.

Careful attention to the implant site before infiltration of the local anesthetic is critical to determine the necessary size and shape of the subepithelial connective tissue graft. Soft tissue grafting may be needed directly over the crest, along the greatest curvature of the alveolar crest, or along the labial aspect of the ridge. It is advantageous to have the esthetic removable prosthesis available to guide the placement of the soft tissue graft.

Preoperative photographs are taken to document the anatomy of the site. The local anesthetic is infiltrated at the site without excessive "ballooning" of the tissues. The palate also is anesthetized at the beginning of the surgery, because pocket development does not take an excessive amount of time. After an adequate interval, incisions are made.

Recipient Site Preparation: Placement of a Subepithelial Connective Tissue Graft without Simultaneous Removal of a Membrane

Placement of a subepithelial connective tissue graft without the need for removal of a membrane requires minimal incisions. Vertical release incisions are rarely needed, especially in the hands of the experienced clinician (see Figure 9-2 and DVD Figure 9-1). The goal is the placement of the soft tissue graft without creating vertical incisions, thus preventing scars. If vertical, inverted scars are present from a prior surgery, these scars can be undermined carefully and leveled with the development of the subcutaneous pocket and graft placement. A gingivoplasty of the tissue is performed to remove scar lines after the thickness of the gingiva has been increased to allow the surgical procedure.

After administration of a local anesthetic, a crestal incision is made across the edentulous region. This incision can be made slightly palatal to the ridge to keep it hidden and in the location of the eventual site of the incision or tissue punch for final exposure of the implant. After the incision has been made across the crest, up to but not including the papilla, a pocket is created using sharp dissection with a small (15c) blade and extending beyond the junction of the attached and unattached gingivae into the vestibule. Extension into the vestibule and crossing the junction of the attached and

unattached gingivae can be performed by sharp or blunt dissection. A subcutaneous pocket is developed over the labial aspect of the implant site. The ideal plane of the dissection is supraperiosteal, but care must be taken to prevent the development of the pocket at the expense of the thickness of the labial tissues. If necessary, the dissection should be kept near the underlying bone to maintain the thickness of the overlying gingiva and to prevent potential soft tissue fenestration of the overlying mucosa. The pocket that is formed should be slightly larger than the graft, with its lateral extent in the apical region at least to the line angles of the adjacent teeth. The pocket will be pear shaped, with the widest portion apical and the thinner portion coronal.

After the pocket has been developed, a foil template is made. The foil template is placed over the implant site and trimmed to the intended size of the connective tissue graft. The graft should extend to the edge of the papilla and should widen apically to gain potential blood supply. The graft then is harvested as described in the following section. The graft is trimmed to the appropriate contour and shape and sutured into position.

Subepithelial Connective Tissue Graft Harvesting

The subepithelial connective tissue graft can be harvested with either an open or a closed technique. The open technique involves elevating a palatal flap of tissue and excising a sheet of the underlying subepithelial palatal tissue (see Figure 9-2, B). For the closed technique, the connective tissue graft is harvested without developing a palatal flap. A horizontal incision is made, and the pocket is developed without the vertical incisions, avoiding a flap. The underlying palatal mucosa is harvested after four incisions have been made through periosteum within the pocket. For thinner grafts of 1.5 to 2 mm, a double-bladed scalpel handle can be used to harvest grafts of specific thickness, depending on the patient's needs.

Open technique

For the open technique, the palatal mucosa is incised and a pocket or flap is raised, exposing the underlying submucosal palatal tissue (see Figure 9-2, B). Three incisions are made on the palate. The first two incisions are made only through the palatal mucosa. These two incisions run vertically and determine the width of the graft. An extra 2 mm of width on both the anterior and the posterior vertical edge is recommended to avoid harvesting a graft that is too small. A horizontal incision is made approximately 2 mm from the gingival sulcus of the maxillary teeth. This horizontal incision can be made to bone or superficially to aid in the reflection of the thin palatal flap. To raise a thin palatal flap based on medial palatal tissue, a scalpel blade (typically 15b or 15c) is used to undermine the palatal tissue, with the blade kept parallel to the palatal mucosa. The palatal flap should be quite thin, because preserving the thickness of the underlying palatal connective tissue is desirable. The palatal flap is elevated, with its base kept intact. From the inside aspect of the dissection, incisions are made to bone along the four edges of the planned subepithelial connective tissue graft. Because the incisions through the connective tissue graft are made through periosteum, a small periosteal elevator is used to separate the graft from the bone. The periosteum is raised and harvested as the undersurface of the graft. The connective tissue graft is removed with minimal instrument pressure placed on the tissue. Hemostasis is achieved with the aid of sutures or pressure. The palatal flap is sutured to its original position with resorbable 4-0 chromic sutures on a tapered needle.

The palatal vessels in the mesial posterior corner of the harvest site may bleed, especially when a large graft is harvested from a shallow palate.[4,5] Often the graft's longer length is taken anteroposteriorly, and the width is oriented toward the medial aspect of the palate, with the edge of the eventual graft kept away from the palatal vessels. If bleeding is encountered, the vessel may be identified and sutured, cauterized, or stick-tied through the posterior palatal tissue to gain pressure hemostasis. Surgicel or another hemostatic material can also be sewn within the confines of the flap. The overlying palatal tissue may become necrotic if excessive pressure is applied.

Closed technique

The closed technique for harvesting subepithelial connective tissue grafts was developed and popularized by Bruno.[4,5] The closed technique uses one horizontal palatal incision without the need for additional vertical incisions (Figures 9-4, A-L, and 9-5, A-W; the entire case for Figure 9-5 is

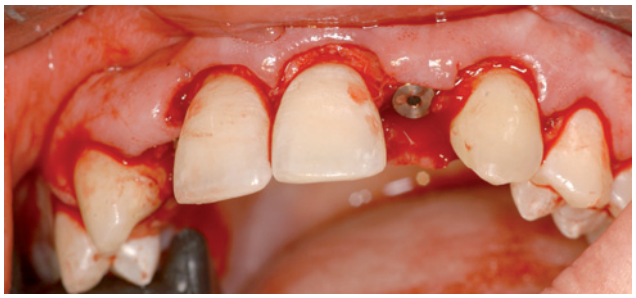


FIGURE 9-4 **A,** This patient had bilateral lateral incisors replaced with implants. The implants were placed into edentulous sites several years after the deciduous teeth had been extracted and orthodontic treatment had been completed. To access the ridge, sulcular incisions are made, avoiding vertical release.

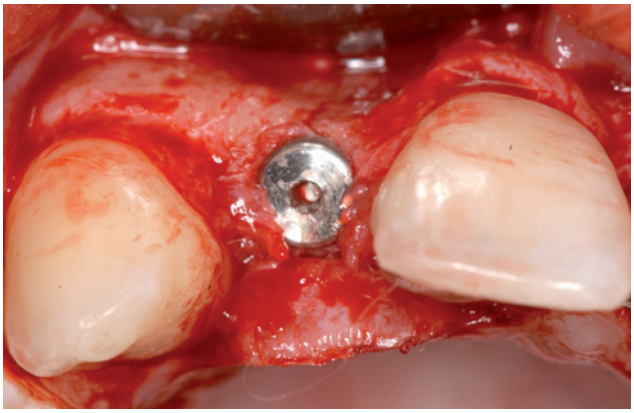


FIGURE 9-4 B, Implants are placed into the narrow ridge. Because the patient has narrow ridges, hydroxylapatite (HA) augmentation of the thin ridge is required at the time of implant placement.

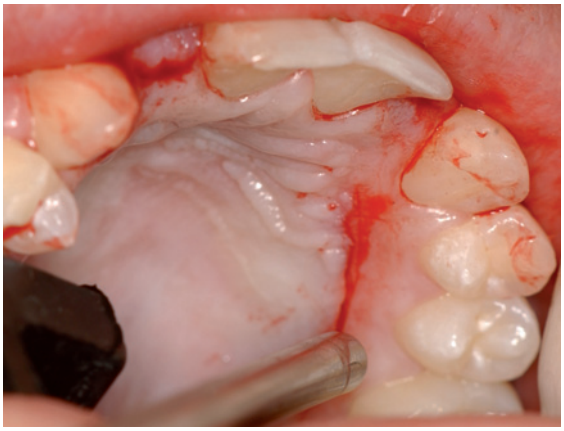


FIGURE 9-4 C, Palatal incision is made to access the connective tissue from the palate.

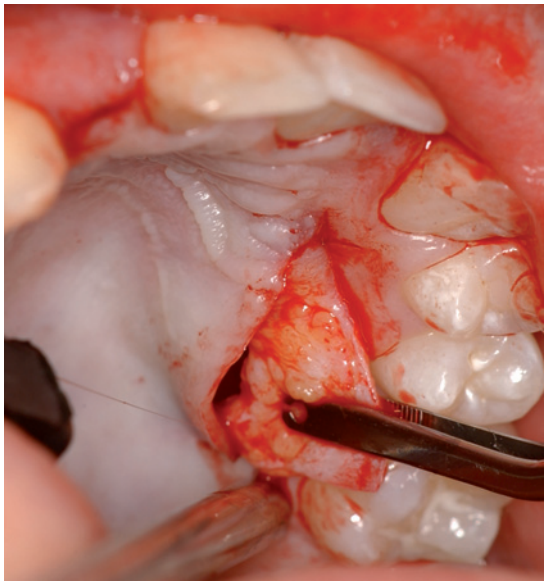


FIGURE 9-4 D, Dissection is made under the palatal mucosa, and the connective tissue is removed after the tissue has been cut to bone.

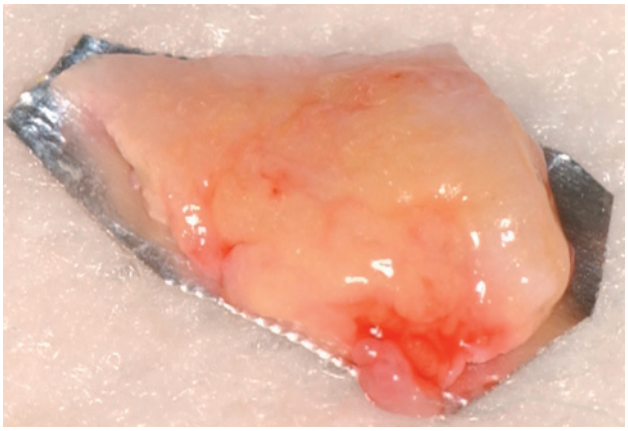


FIGURE 9-4 E, Connective tissue is trimmed to match the template.

DVD Images 9-3, A-DD

presented in DVD Figure 9-3, A-DD). This technique allows the graft to be harvested with minimal postoperative morbidity. The closed technique results in a graft that is thickest along the edge of the horizontal incision and becomes thinner as it reaches the edge close to the depth of the graft site.

A local anesthetic is administered, and time is allowed for fluid absorption in the palate. A horizontal incision is made along the palate 2 to 3 mm from the palatal gingival margins to prevent necrosis of the gingiva around the teeth. The horizontal incision should be slightly longer than the length necessary for the graft. A second incision is made 1 to 2 mm from the margin of the initial incision, and the blade is angled toward the confluence of the vertical and horizontal shelves of the palate. The incision is taken to the bone at the required depth, which establishes the graft's size. After the incision has outlined a sheet of subepithelial gingiva, incisions are made within the flap to separate the vertical edges of the graft. After the vertical incisions have been made through the graft only (avoiding external incisions), the graft is removed with the aid of a periosteal elevator. After hemostasis has been confirmed, the single horizontal incision is closed with resorbable suture.

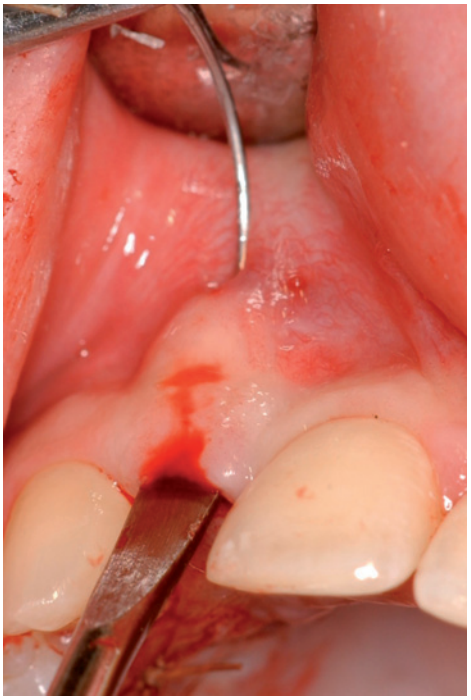


FIGURE 9-4 F, Small (15c) blade is used to create a pocket over the implant sites. The pocket is created from the crest and formed approximately 10 mm toward the apical. A needle with 4-0 chromic suture is placed through the unattached tissue into the pocket, exiting at the crest.

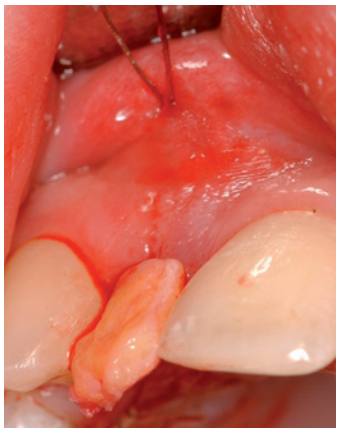


FIGURE 9-4 H, Suture then is passed back through the crestal incision, exiting the vestibule.

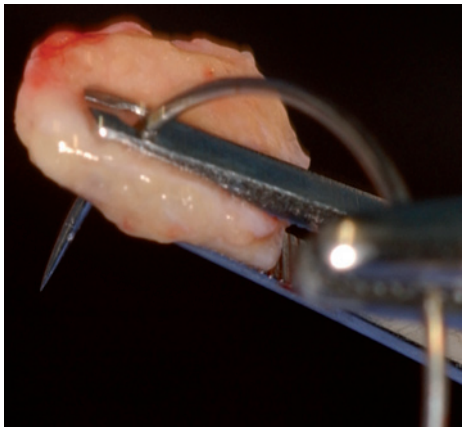


FIGURE 9-4 G, Suture is passed through the graft with a Korn tissue forceps.

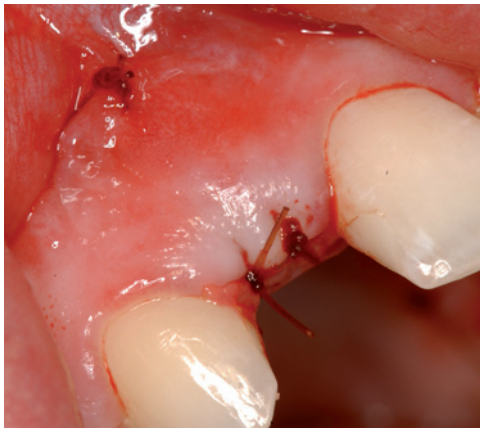


FIGURE 9-4 I, Graft is placed into the pocket to achieve ridge "plumping." The vestibular suture is tied to define the vertical position of the graft. The crestal incision is closed with two interruped sutures.

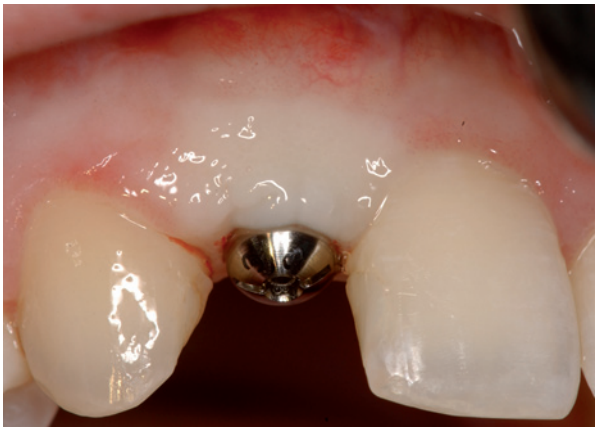


FIGURE 9-4 J, After 6 weeks, the healing abutment is placed through a small incision. Note the blanching of the tissue.

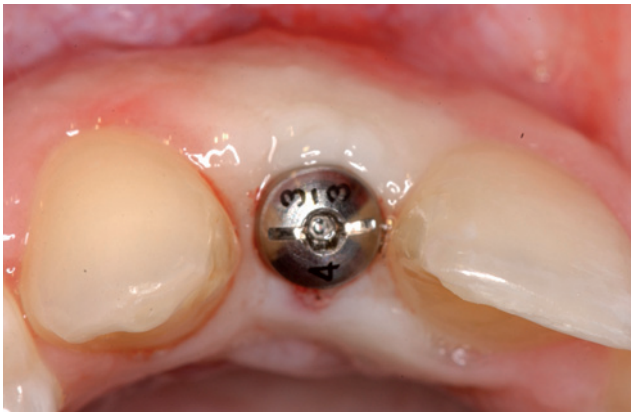


FIGURE 9-4 **K,** From the occlusal aspect, note the augmentation of the ridge.

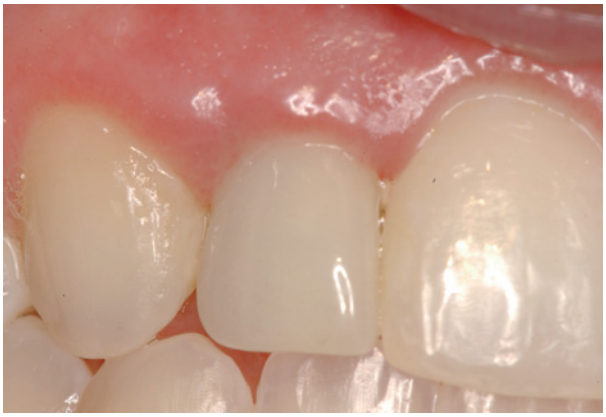


FIGURE 9-4 **L,** Final restoration with appropriate horizontal ridge width.

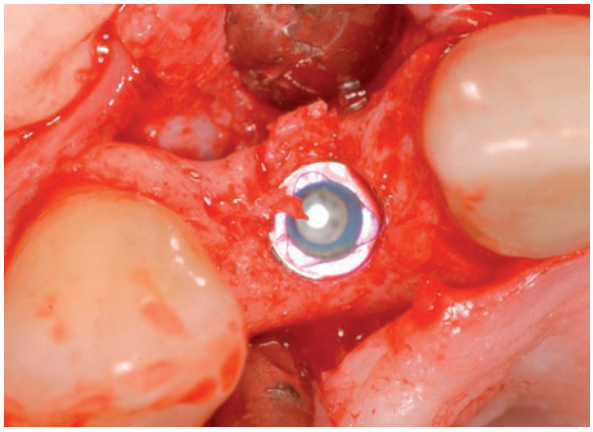


FIGURE 9-5 **A,** Crestal incision is combined with sulcular incisions to allow placement of a small-diameter implant. Note the flat ridge contour. In this patient, no onlay grafts are placed.

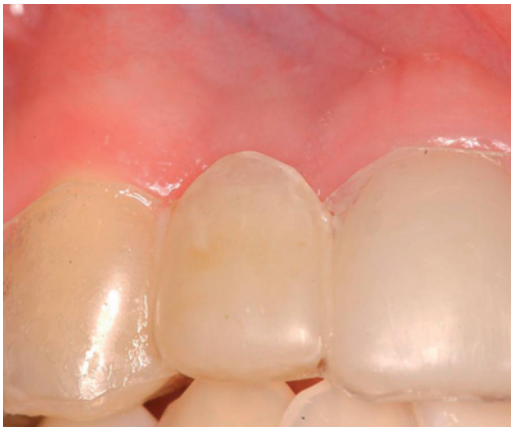


FIGURE 9-5 **B,** After 3 months for healing, the ridge flatness is still present. To achieve an esthetic restoration, a connective tissue graft is necessary.

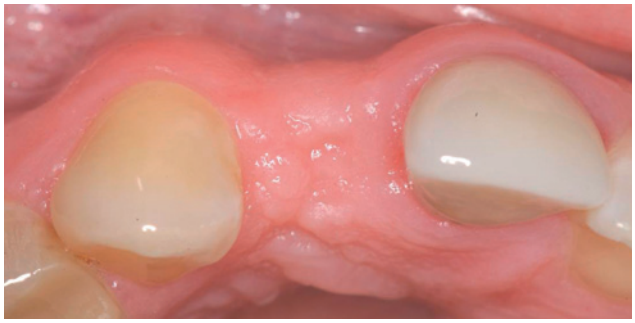


FIGURE 9-5 **C,** Flat ridge contour is well appreciated from the occlusal aspect.

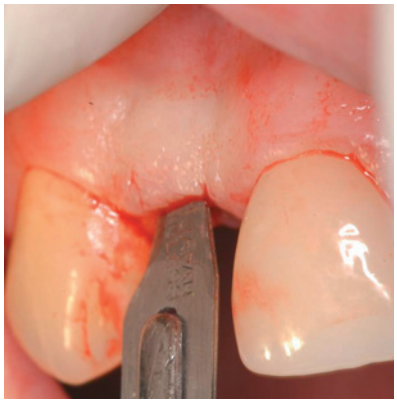


FIGURE 9-5 **D,** After administration of a local anesthetic, a 15c blade is used to develop a soft tissue pocket sharply at the periosteal tissue plane. The scalpel blade is directed distally to develop the distal aspect of the pocket.

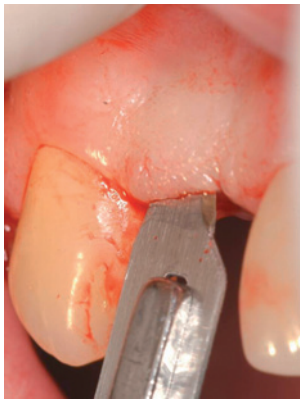


FIGURE 9-5 E, Blade is turned, and the mesial aspect of the pocket is sharply developed. The pocket must be kept deep to the facial gingiva.

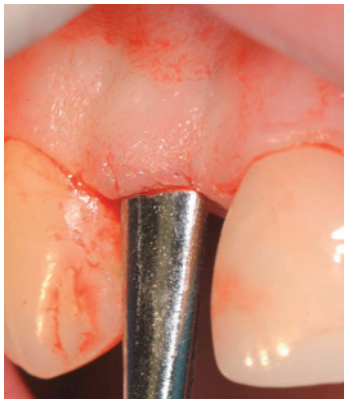


FIGURE 9-5 F, Small periosteal elevator is placed to show the surgeon that the pocket has been sufficiently formed to accept the graft.

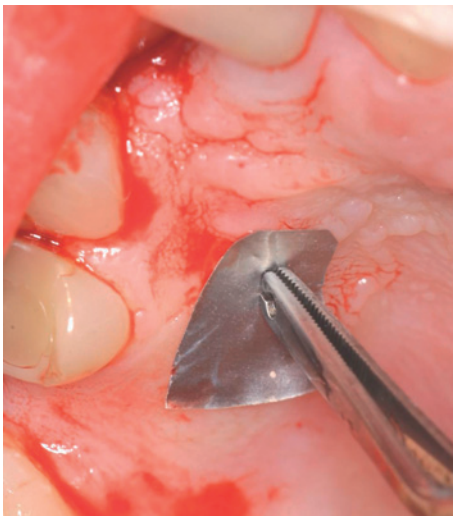


FIGURE 9-5 G, Small piece of foil from the suture pack is shaped as a template over the planned graft site. The foil is then placed over the palate to delineate the size of the graft at the harvest site.

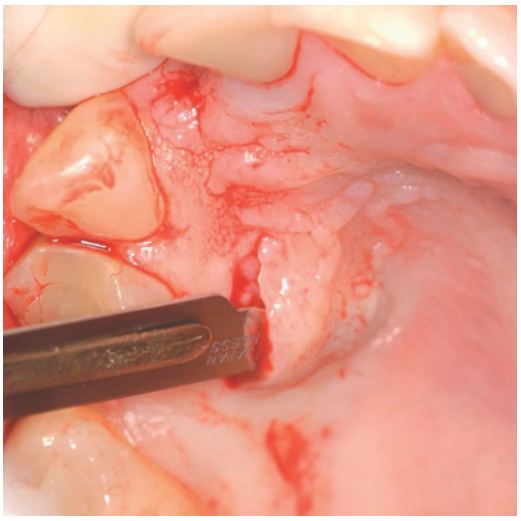


FIGURE 9-5 H, One incision is made parallel to the teeth approximately 3 mm from the palatal margin on the teeth. A 15 blade is used to develop a pocket, keeping close to the palatal mucosa and allowing the underlying tissue to remain thick for the harvest. The blade typically is 10 mm long, which is the usual width of the graft.

Handling and modifying the connective tissue graft

The submucosal connective tissue is harvested as a sheet of tissue, and the overlying palatal mucosa is replaced in its original position, preventing de-epithelialization of the palate. The subepithelial connective tissue graft contains a layer of periosteum, occasional fat cells, small blood vessels and nerves, and predominantly fibrous connective tissue. The harvested piece of connective tissue is placed on saline-soaked gauze while the palatal wound is closed.

The surface of the graft should be trimmed to be flat and without bumps. Fat is left on the graft as long as the fat and associated tissues are flat and without surface irregularities. The smoothness of the graft will be reflected by a smooth gingival surface after the graft heals. Conversely, a graft with an irregular surface will be reflected by a bumpy, irregular gingival surface after healing. Therefore, it is important to harvest a sheet of smooth connective tissue and to smooth its surface with scissors before placement.

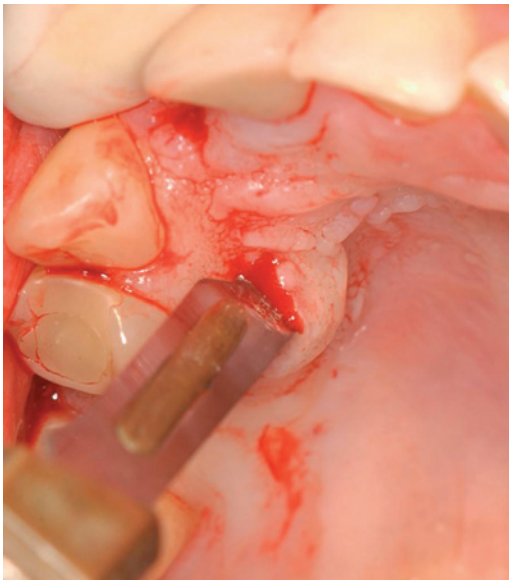


FIGURE 9-5 **I,** After the pocket has been developed to the desired size, the blade is turned 90 degrees, and the edges of the graft are cut through the graft and periosteum.

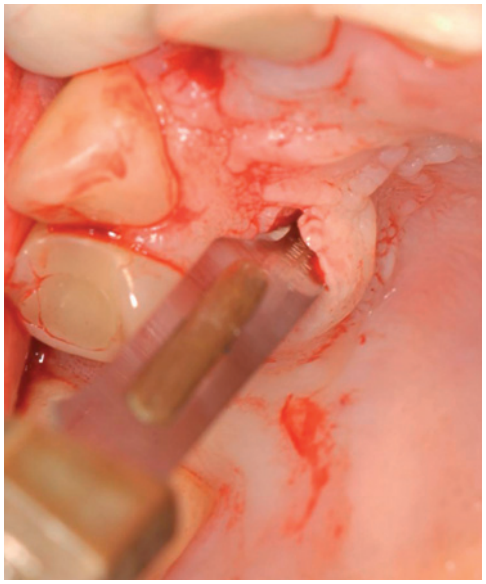


FIGURE 9-5 **J,** All four sides of the graft must be separated from the palate. Here, the blade cuts the anterior edge.

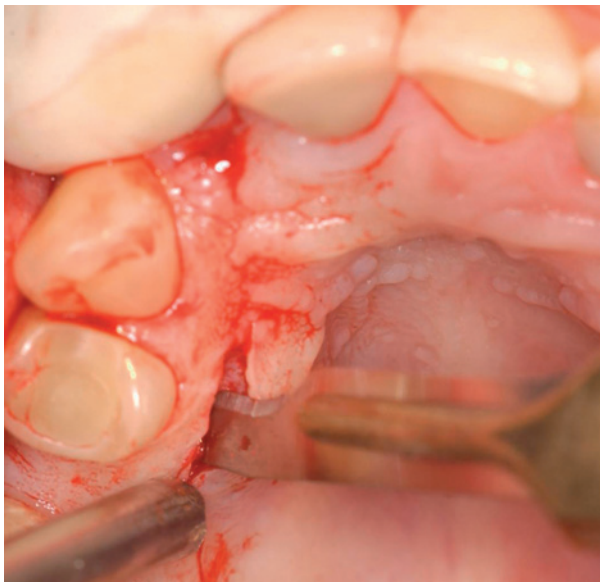


FIGURE 9-5 **K,** The blade cuts and defines the edge of the graft nearest the teeth.

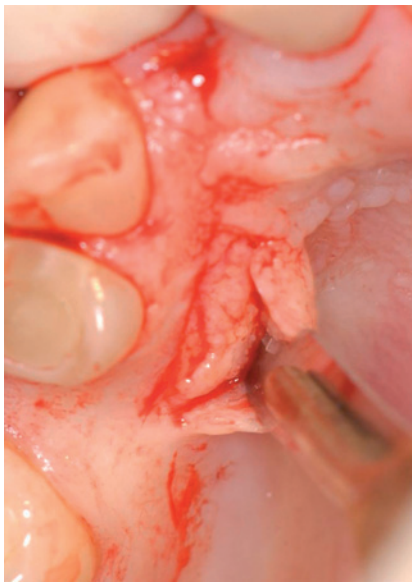


FIGURE 9-5 **L,** The last cut usually is the edge along the most medial aspect of the graft. If bleeding occurs, it originates from the medial posterior corner.

The periphery of the graft should be trimmed to match the size of the foil template. The graft is placed over the foil template, and its margins are trimmed with sharp scissors or a scalpel to match the shape of the template. The scissors are held parallel to the surface of the graft to smooth its surface, ensuring that the graft has a smooth, not irregular, contour. Thus the graft can be placed accurately into the host site with a smooth contour, giving the overlying gingiva its optimal final form. After the subepithelial connective tissue graft has been trimmed appropriately, it should fit precisely over the implant site, without excessive bulk.

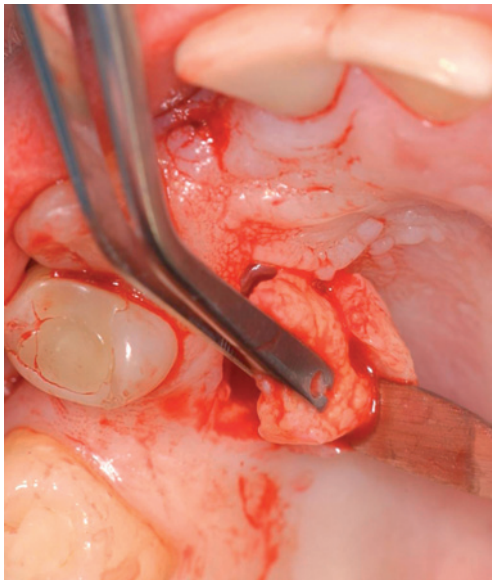


FIGURE 9-5 M, Graft is separated from the bone with a small periosteal elevator and delivered with atraumatic forceps.

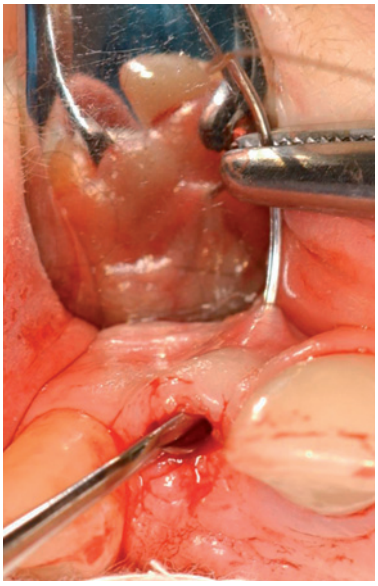


FIGURE 9-5 O, For placement of the graft, a needle is placed through the unattached gingiva, exiting the crestal incision of the pocket.

Placement of a Subepithelial Connective Tissue Graft

The connective tissue graft must be secured in its desired position. The sutures should hold the graft firmly in position against the underlying and overlying tissue beds to prevent hematoma formation. The graft's vertical location and its orientation on the alveolar crest are dictated by

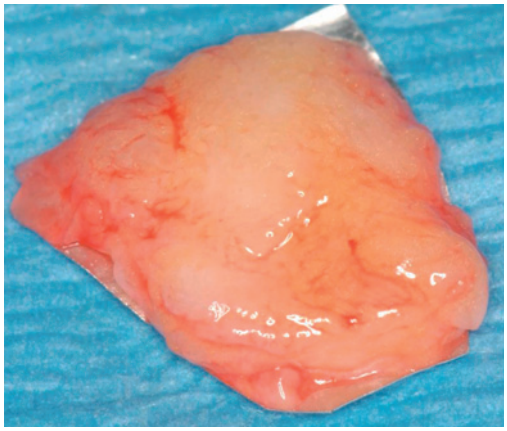


FIGURE 9-5 N, Graft is trimmed to match the foil template.

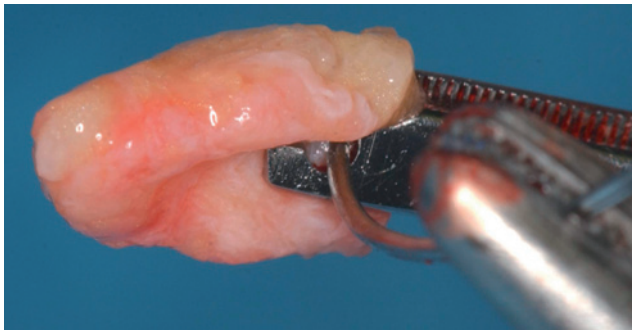


FIGURE 9-5 P, Suture is passed through the edge of the graft that will be the most apical aspect.

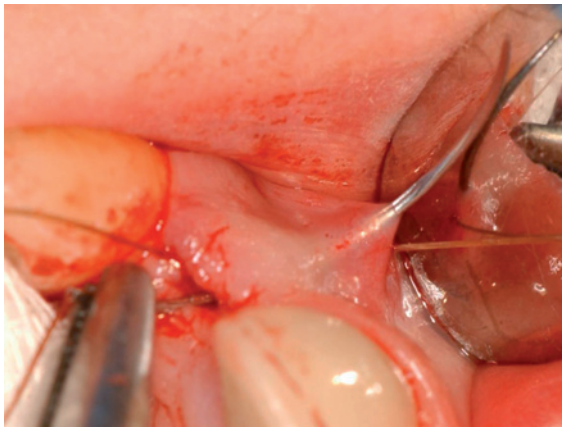


FIGURE 9-5 Q, Suture is taken back through the crestal incision, exiting the unattached gingiva.

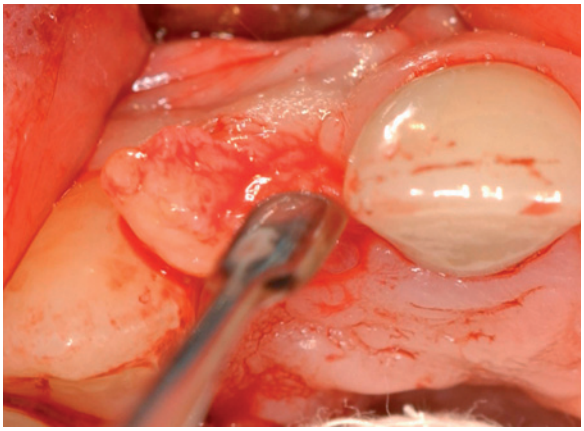


FIGURE 9-5 R, Graft is gently manipulated into the pocket.

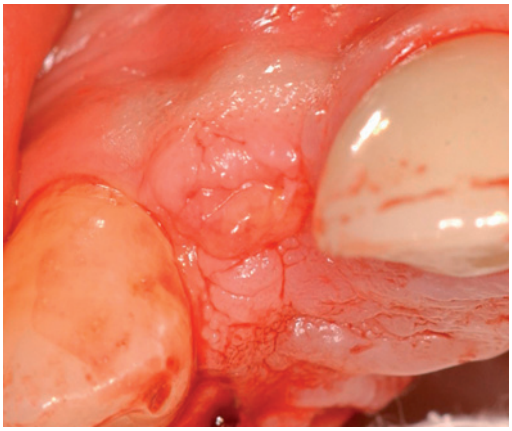


FIGURE 9-5 S, After the graft has been manipulated into the pocket, it is smoothed to allow the formation of the gingival root prominence.

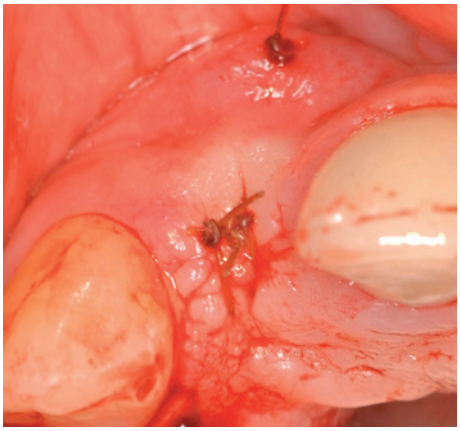


FIGURE 9-5 T, Suture is tied to define the vertical position of the graft. Simple interrupted sutures are placed over the crest.

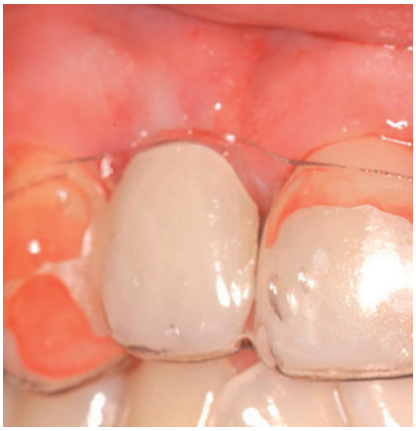


FIGURE 9-5 U, Temporary prosthesis is replaced.

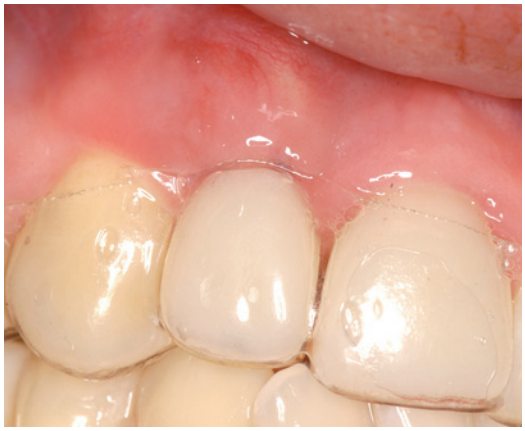


FIGURE 9-5 V, One week after surgery, excellent formation of the root prominence is seen.

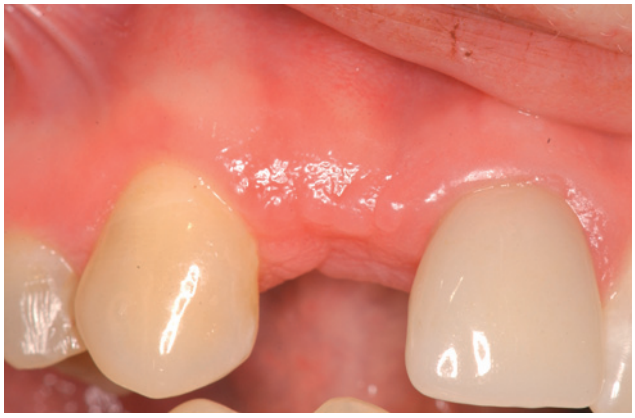


FIGURE 9-5 W, Six weeks after placement of the connective tissue graft; note the stippled, pink appearance of the gingiva after the graft heals, with at least 1.5 mm of thickening of the facial gingiva.

accurate placement of the sutures, the development of a well-defined pouch, and the prevention of folding or bunching of the graft on placement.

To secure the graft in its vertical position, one or two sutures are placed from a vestibular approach in a mattress fashion. The needle enters the overlying flap from the vestibule and exits the pouch at the crest through the previous incision. The needle is placed through the graft and then returns under the flap, exiting the vestibule. The suture, when tied gently, positions the graft vertically. Interrupted sutures are then placed through the overlying crestal gingiva, graft, and palatal tissue, securing the graft in position (Figures 9-6, A-L; 9-7, A-L; and 9-8, A-L; DVD Figure 9-4, A-K; DVD Figure 9-5, A-R, presents the complete case seen in Figure 9-8). Vertical incisions, if used, are esthetically closed without engaging the graft.

DVD Images
9-4, A-K
9-5, A-R

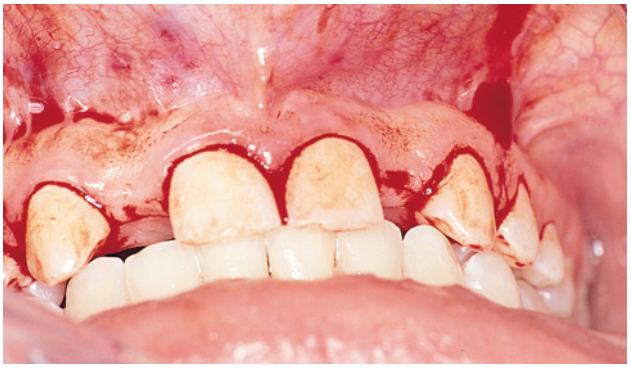


FIGURE 9-6 A, This 35-year-old patient has agenesis of the lateral incisors. She recently had the deciduous lateral incisors extracted in preparation for implant placement. The intrasulcular incisions combined with crestal incisions in the edentulous regions are shown here. An envelope flap has been elevated to expose the two edentulous sites.

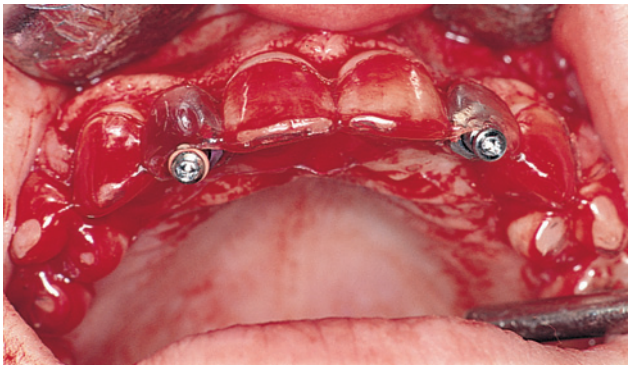


FIGURE 9-6 B, Implant driving mounts protrude through the surgical guide stent after implant placement.

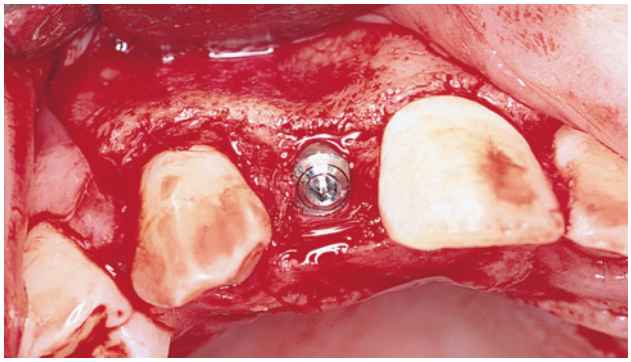


FIGURE 9-6 C, Implant is placed 3 mm apical to the planned gingival margin. No hard tissue graft is used, even though a concavity is present. An HA graft was not placed, because the horizontal defect was less than 2 mm. Most likely, a soft tissue graft will be needed before implant exposure to correct the gingival deficit.

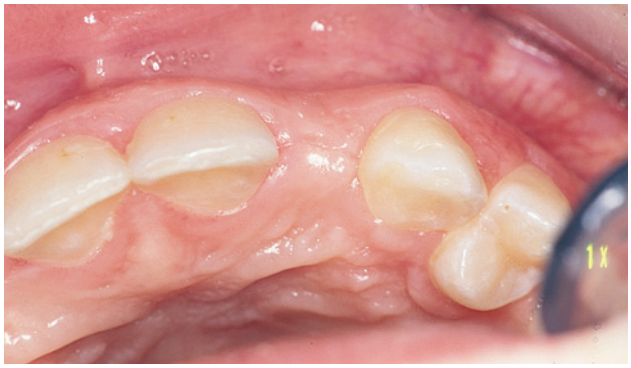


FIGURE 9-6 D, After 3½ months, the expected gingival deficit is seen.

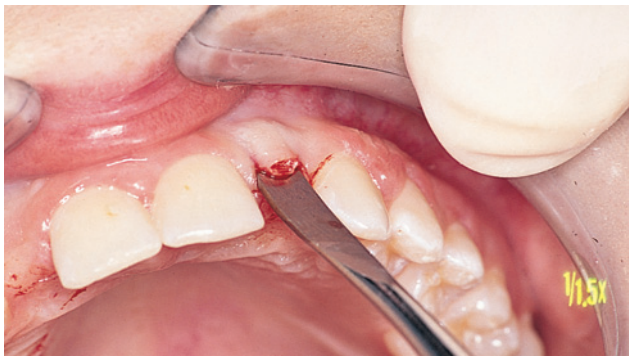


FIGURE 9-6 E, Crestal incision is made, and a partial-thickness dissection is created. The dissection is performed sharply with a small (15c) scalpel blade. Here, a periosteal elevator is seen within the subepithelial pouch.

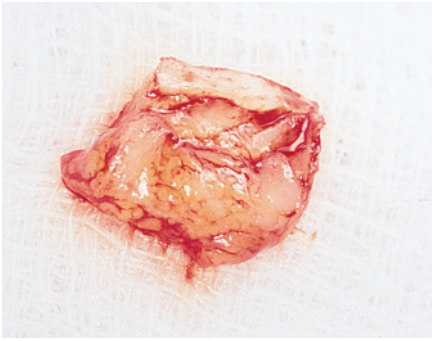


FIGURE 9-6 F, Piece of subepithelial connective tissue, 10 × 15 mm, is harvested for the graft site and bisected to provide tissue for each side. The grafts are then placed and sutured.

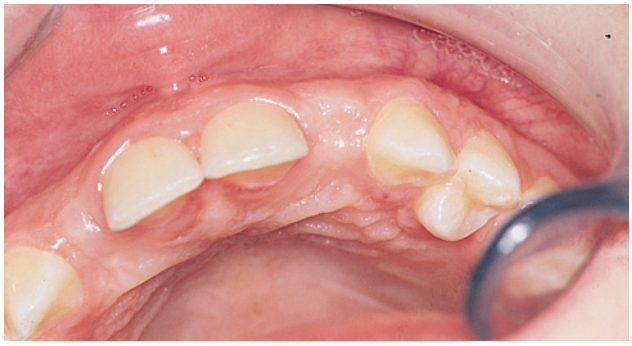


FIGURE 9-6 G, After 6 weeks, the graft site shows adequate contours for an esthetic restoration.

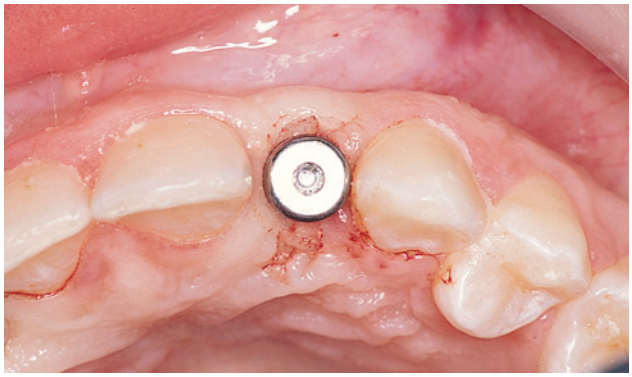


FIGURE 9-6 H, To expose the implant, small incisions are made to form a semicircle 2 mm in diameter. The hex drive is placed through this small hole. A 5-mm straight emergence abutment is then positioned. An improved ridge contour is seen.

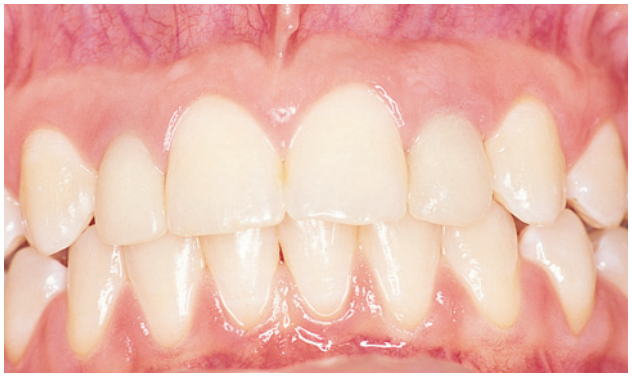


FIGURE 9-6 I, Final restoration shows a lack of vertical scars and adequate gingival bulk and color for a natural-appearing restoration. (Prosthetics by Dr. Thomas Salinas.)

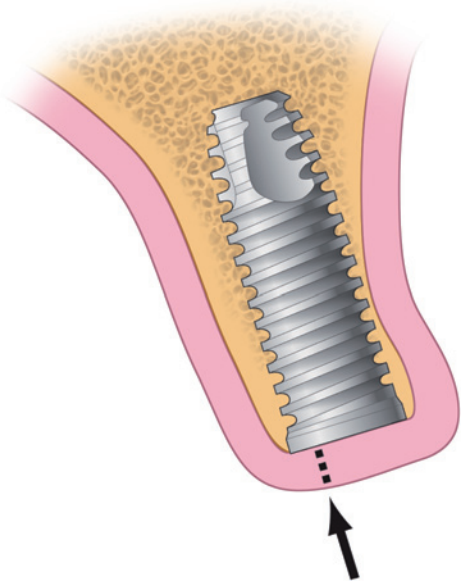


FIGURE 9-6 J, Diagram showing ridge before connective tissue grafting. *Arrow* denotes the planned crestal incision site.

If present, the removable prosthesis usually is not relieved unless it places excessive pressure on the graft. Typically, the removable prosthesis was relieved when the implant was placed, and appropriate space remains at the time of soft tissue graft placement. Bonded teeth must be relieved only if they prevent the establishment of an esthetic gingival form. Often an esthetic temporary prosthesis helps form the final implant site with gentle pressure on the surgical site. Excessive pressure by a temporary prosthesis results in incision breakdown and potential loss of the graft.

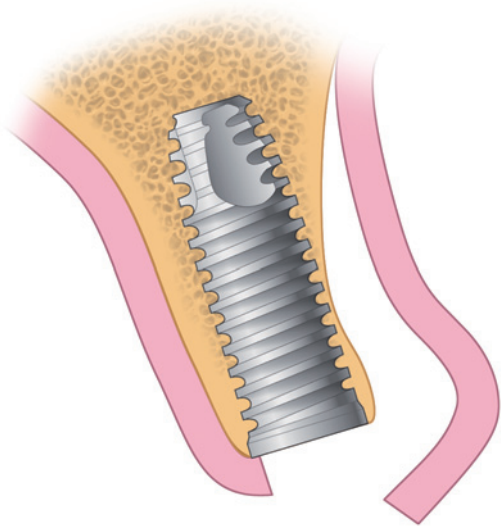


FIGURE 9-6 K, Diagram showing the pocket developed at least 10 mm apical to the crest.

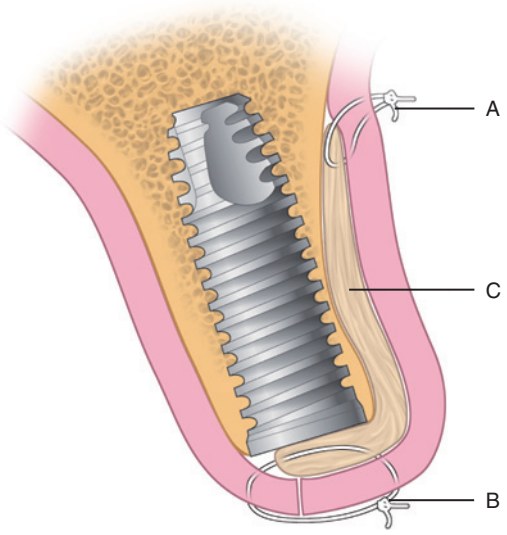


FIGURE 9-6 L, Diagram showing the connective tissue graft within the pocket. The vestibular retaining suture *(A),* crestal interrupted suture *(B),* and graft *(C)* are shown.

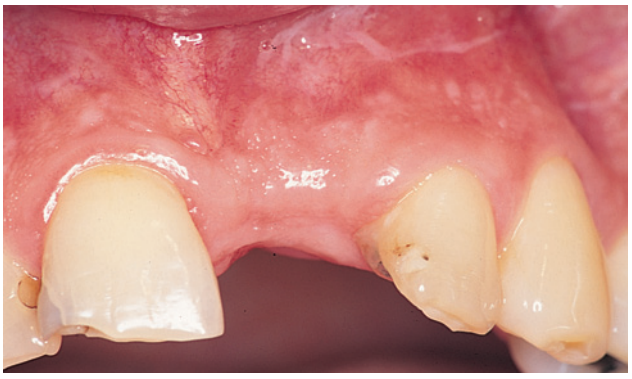


FIGURE 9-7 A, This 32-year-old patient lost the maxillary left central incisor secondary to internal resorption 10 years after subluxation of the tooth. Approximately 4 months after the tooth had been extracted, 2 mm of crestal bone loss is seen on the mesial aspect of the right central incisor. A 3-mm horizontal deficit of ridge contour is present compared with adjacent teeth.

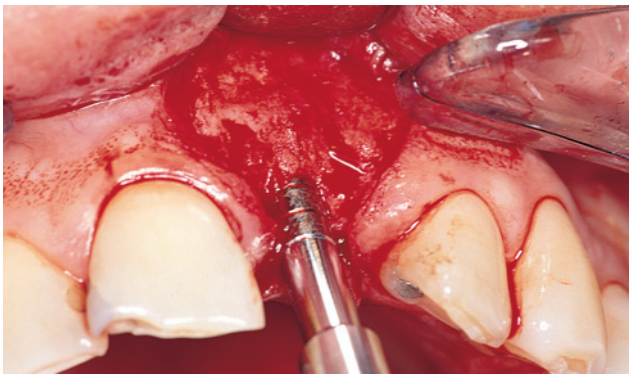


FIGURE 9-7 B, Papilla-sparing incisions are combined with vertical release incisions. The alveolus is 4 mm wide, requiring expansion. The pilot hole is drilled to the nasal floor, and the implant site is serially expanded with osteotomes. The 3.2-mm diameter osteotome is in place.

Subepithelial Connective Tissue Grafting with Simultaneous Removal of a Nonresorbable Membrane

Patients with implants and a hard tissue graft over the implant site who had a nonresorbable membrane placed over the graft, with the graft's correct position retained by the implant's cover screw and two apical tacks or screws, require a flap procedure (Figures 9-9, A-M, and 9-10, A-W). This procedure removes the membrane and apical tacks or screws with the simultaneous placement of a connective tissue graft. Attention to detail on closing the vertical incisions is critical. If an enveloped incision is used for a second time, care must be taken to prevent trauma to the papillae, which may blunt after a second elevation.

After administration of a local anesthetic in the vestibule and into the palate at the site of the planned graft harvest, a crestal incision is made to the level of the

Text continues on page 443

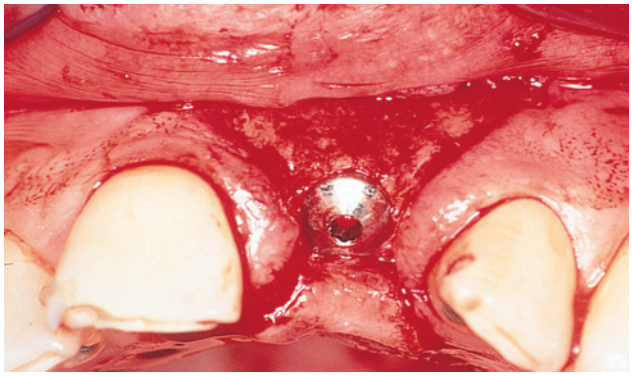


FIGURE 9-7 C, Threaded implant 16 mm long and 3.8 mm wide is placed. Bone is observed around the implant. No graft is placed at this time, because the surgeon sees the new ridge contour as satisfactory.

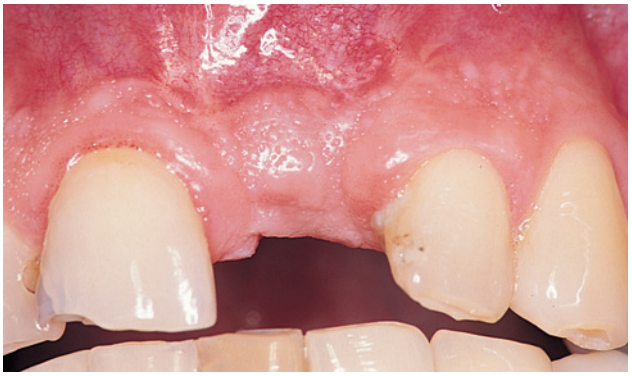


FIGURE 9-7 D, After 2 weeks, the horizontal defect is greater than 2 mm, and a soft tissue graft procedure is planned.

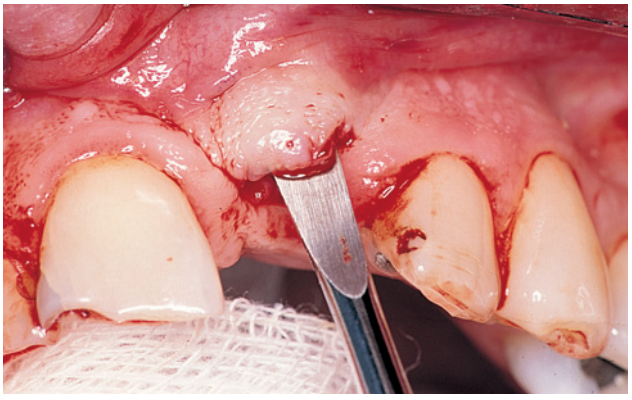


FIGURE 9-7 E, Crestal incision is made, followed by sharp dissection to form a pouch. A periosteal elevator depicts the extent of the subepithelial pocket, which is 10 mm vertically and 10 mm horizontally at the apical portion of the pocket, narrowing to 4 mm at the crest.

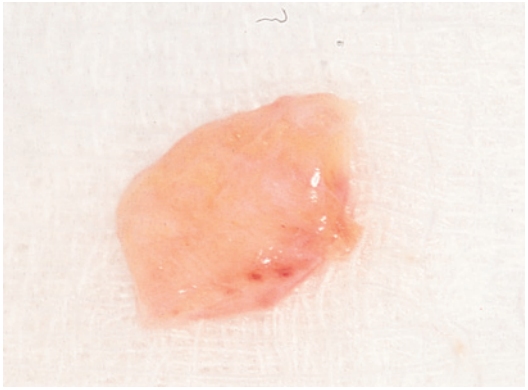


FIGURE 9-7 F, Subepithelial connective tissue graft is harvested from the palate.

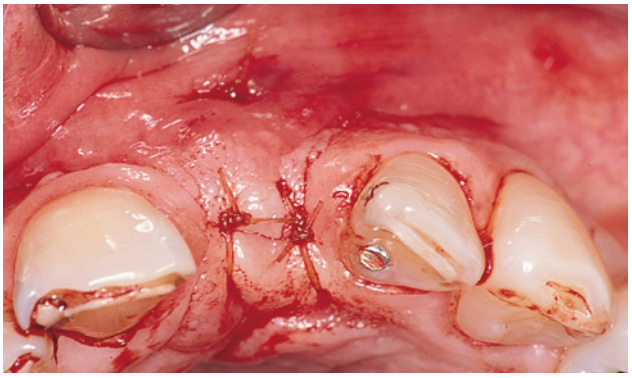


FIGURE 9-7 G, Graft is placed into the pouch and retained with a vestibular retention suture and interrupted crestal sutures.

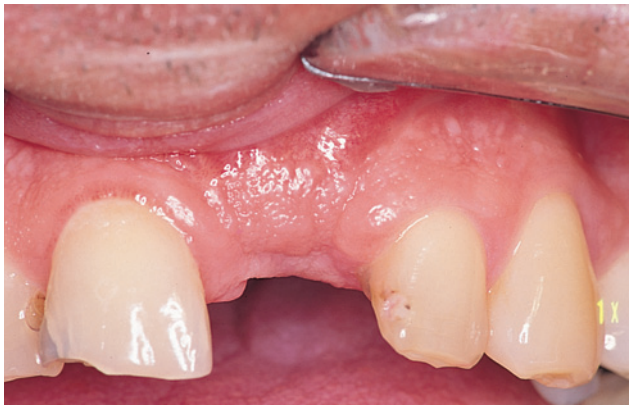


FIGURE 9-7 H, Immediately before implant exposure, 6 weeks after connective tissue grafting.

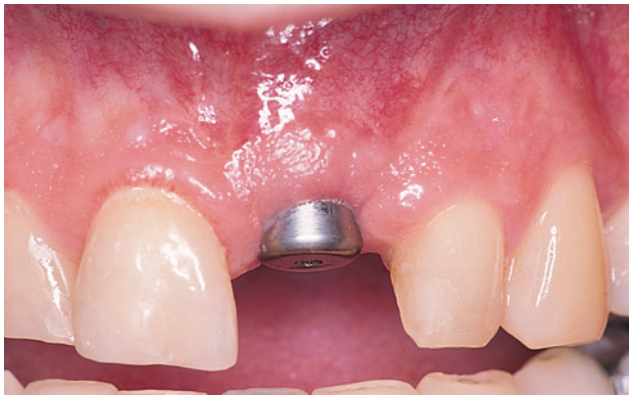


FIGURE 9-7 I, Tissue punch is used to expose the healing screw. A straight emergence healing abutment 5 mm tall is placed.

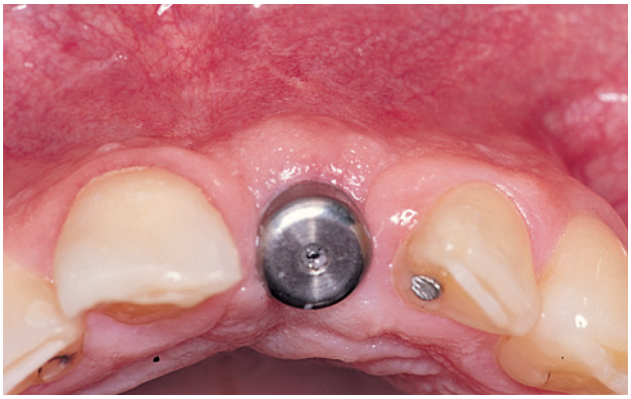


FIGURE 9-7 J, Gingival contour is now equal to the adjacent tooth.

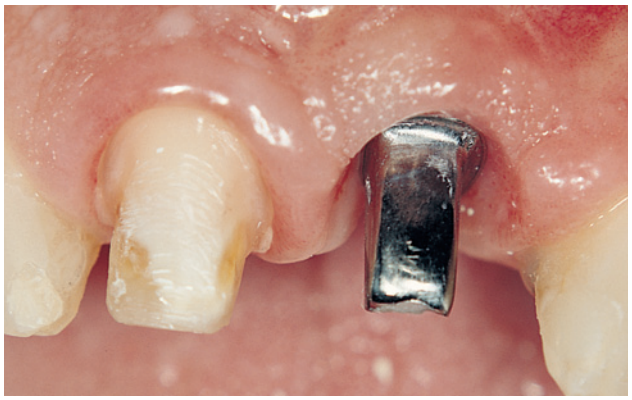


FIGURE 9-7 K, Right central incisor is prepared for a crown, and the final abutment is in place for the implant.

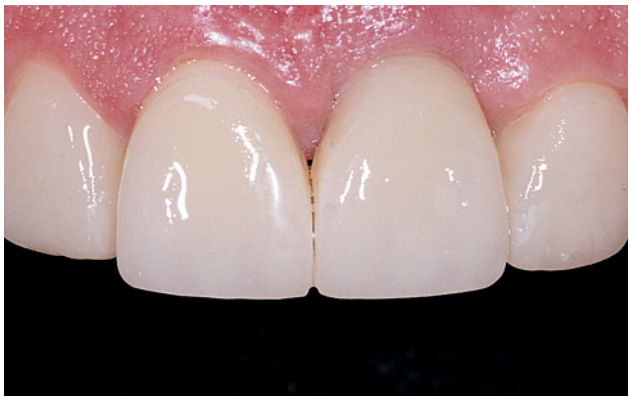


FIGURE 9-7 L, Final restoration, showing healthy gingiva. (Prosthetics by Dr. Thomas Salinas and Dr. Avishai Sadan.)

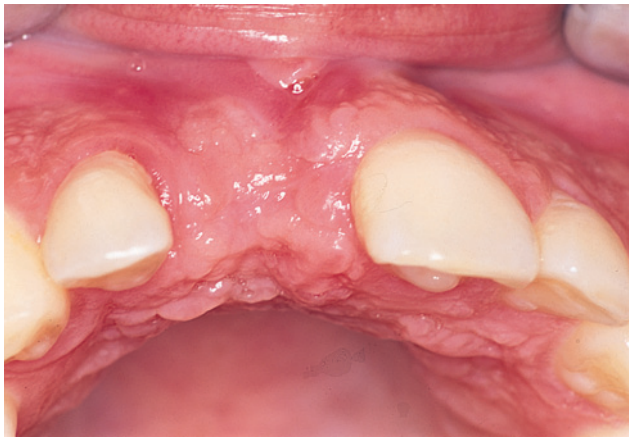


FIGURE 9-8 A, This 34-year-old patient lost the right central incisor secondary to external resorption and chronic periodontal disease. The tooth had been extracted 8 weeks earlier. The edentulous site has lost its normal gingival texture and tone and has a 3-mm horizontal defect. (For additional photographs of this case, see DVD Figure 9-5.)

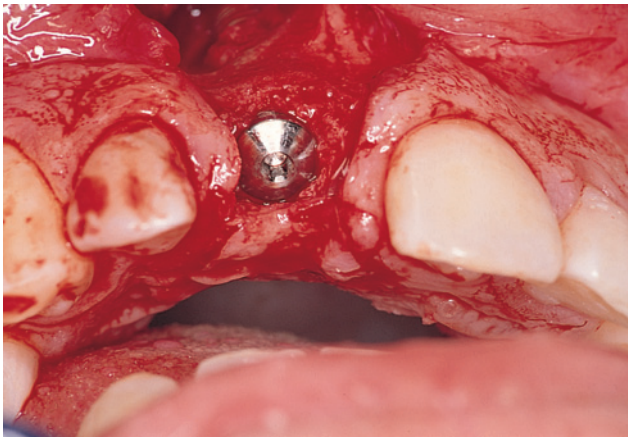


FIGURE 9-8 B, Because the distance between the contact area of the central incisor and crestal bone is greater than 7 mm, papilla-sparing incisions are combined with vertical incisions to expose the alveolus. A 3.8 × 16-mm threaded implant is placed. The ridge contour is deficient, and an apical fenestration is present.

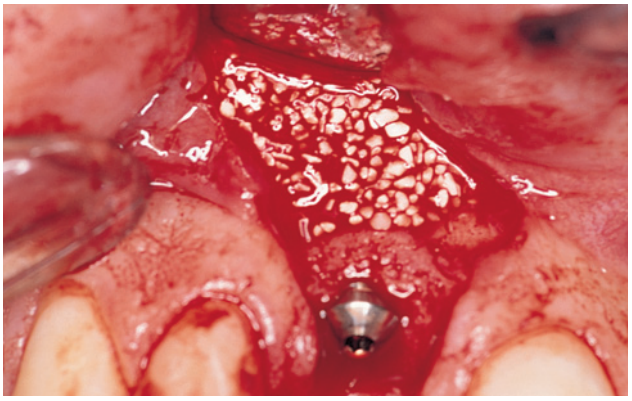


FIGURE 9-8 **C,** Dense particulate HA graft is placed. No membrane is used, because the coronal aspect of the implant is covered with bone. The HA layer is approximately 2 mm thick.

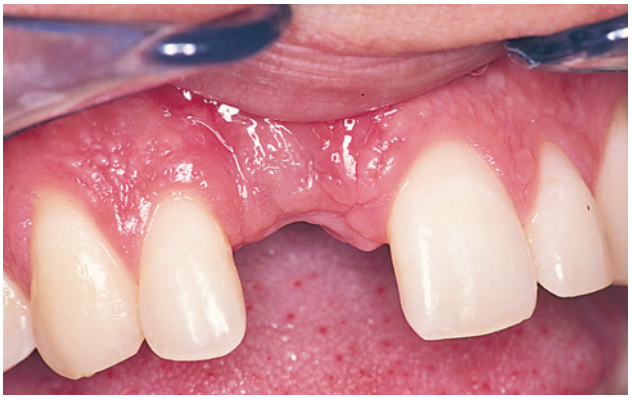


FIGURE 9-8 **D,** After 4 months, the prosthodontist asks for a connective tissue graft to help restore the quality of the gingiva and improve ridge contour.

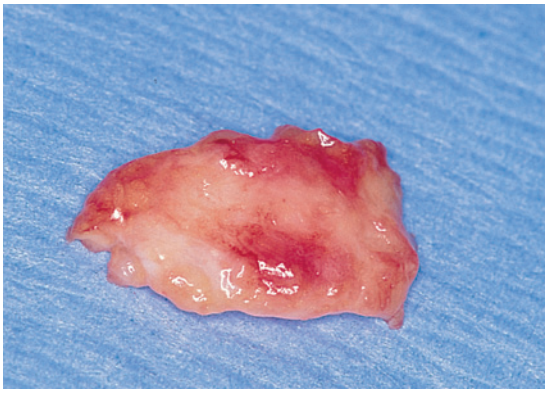


FIGURE 9-8 **E,** A 2-mm piece of subepithelial connective tissue is harvested from the palate.

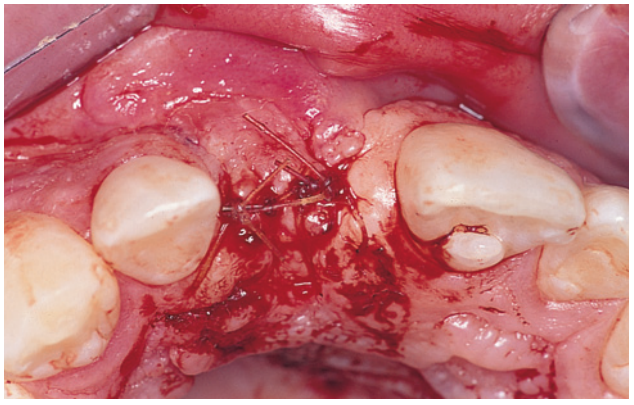


FIGURE 9-8 **F,** After development of a subepithelial pouch, the graft is sutured in place.

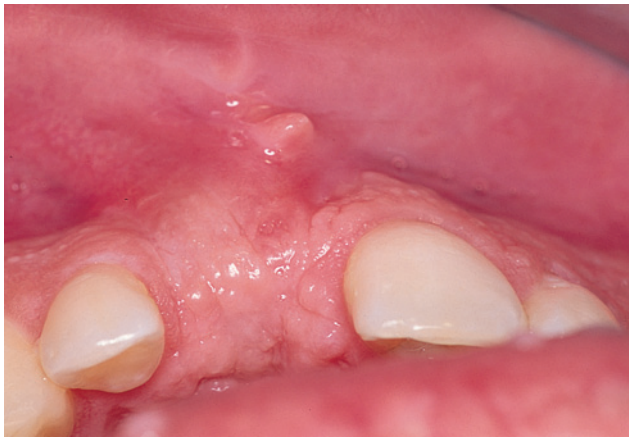


FIGURE 9-8 **G,** After 6 weeks, the implants are ready to be exposed. Some improvement in ridge contour is noted; however, a horizontal defect measuring at least 1.5 mm has yet to be corrected.

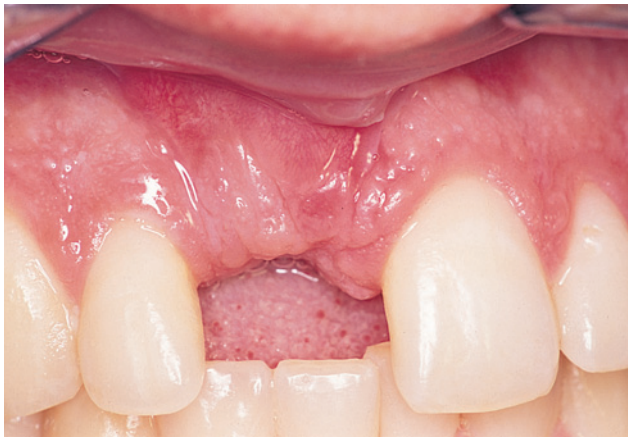


FIGURE 9-8 **H,** Quality of the gingiva has improved.

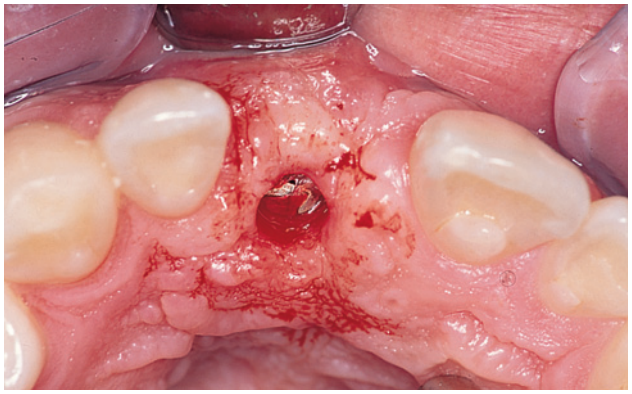


FIGURE 9-8 I, Tissue punch is used to expose the implant. The tissue punch is used palatal to the implant to allow a thicker dimension of crestal tissue to be pushed labially.

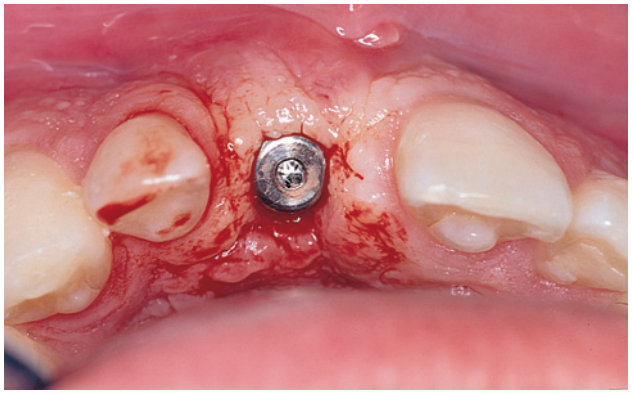


FIGURE 9-8 J, Healing abutment is placed. Some improvement in ridge contour is immediately noted.

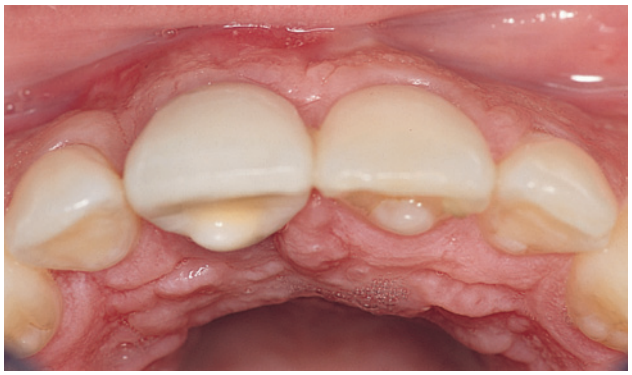


FIGURE 9-8 K, Final prosthesis is contoured to correct for a minor horizontal soft tissue deficiency.

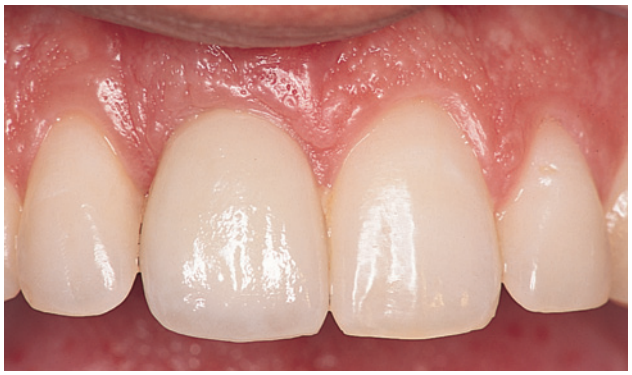


FIGURE 9-8 L, Final prosthesis shows an adequate gingival contour with return of normal, healthy texture. (Prosthetics by Dr. Thomas Salinas.)

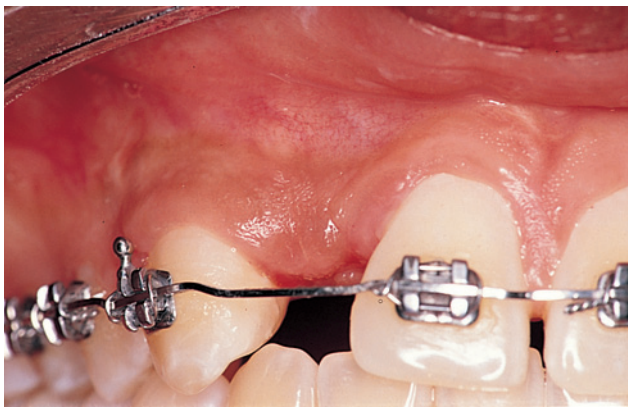


FIGURE 9-9 A, This 25-year-old patient with a high smile line has agenesis of the right lateral incisor. An obvious horizontal deficiency is seen in the thin ridge. Preoperative orthodontic treatment has been performed to create 5.5 mm of space for the implant, aligned with the roots of the adjacent teeth.

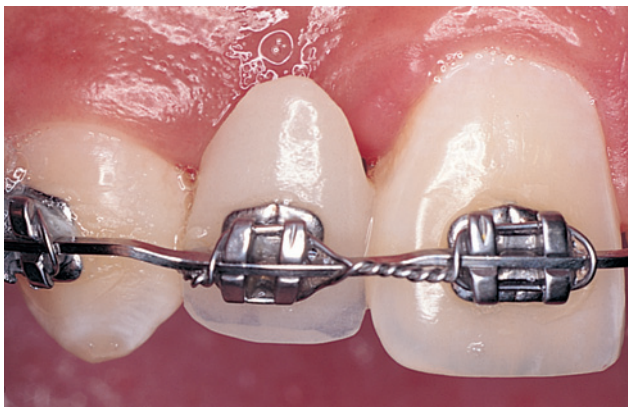


FIGURE 9-9 B, Esthetic setup is based on the use of a pontic, which is placed on the patient's orthodontic wire. The ridge deficiency is obvious.

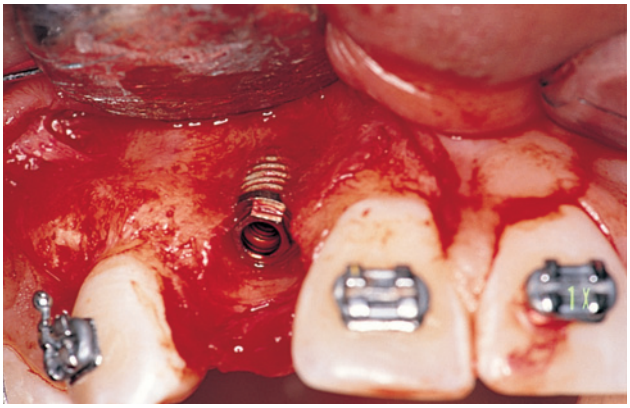


FIGURE 9-9 **C,** After exposure of the edentulous space, the implant is placed in the ideal location. As expected, several threads of the implant are exposed.

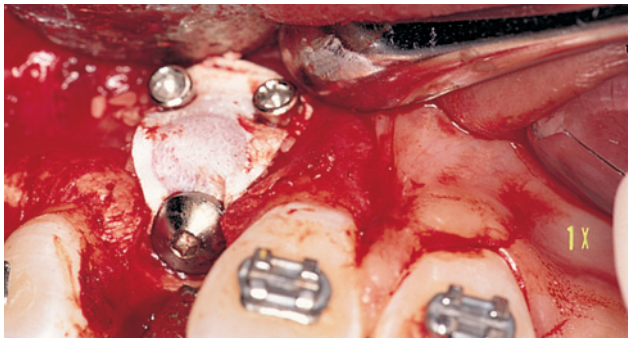


FIGURE 9-9 **D,** Particulate nonresorbable graft is placed over the threads of the implant, and a nonresorbable membrane is secured to the implant with the cover screw and with small screws apically.

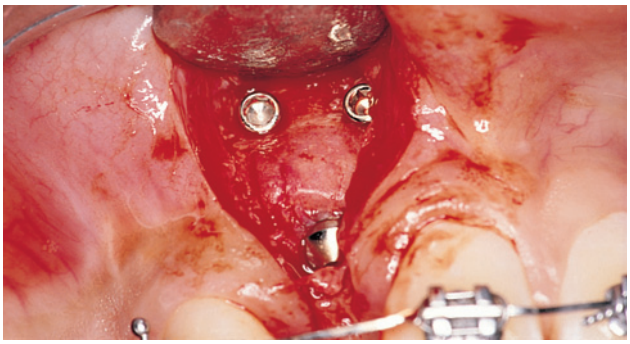


FIGURE 9-9 **E,** After approximately 2 weeks, papilla-sparing incisions are used in combination with a blunt and sharp dissection to expose the membrane. The membrane then is removed intact.

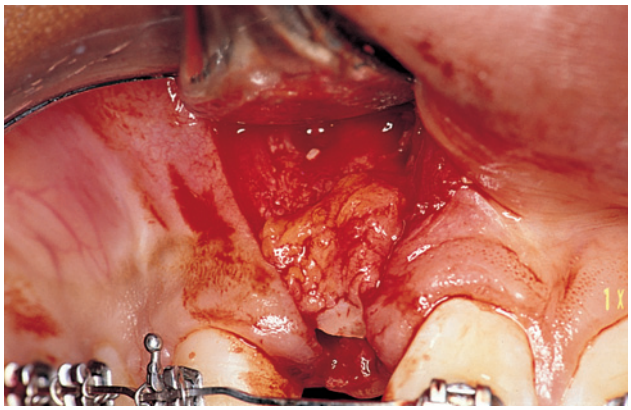


FIGURE 9-9 **F,** After removal of the membrane, a subepithelial connective tissue graft is harvested from the palate and accurately trimmed to fit precisely over the ridge.

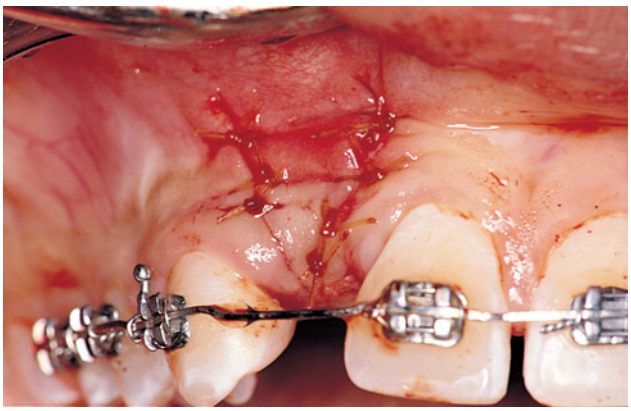


FIGURE 9-9 **G,** Incisions are closed with several resorbable sutures, fixing the connective tissue graft to the overlying labial flap and palatal tissues.

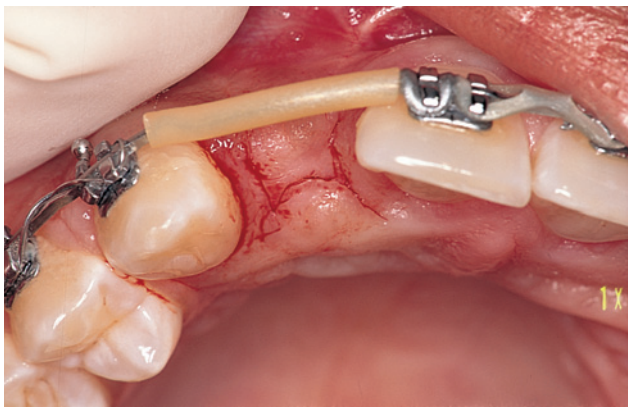


FIGURE 9-9 **H,** A small incision is made 6 weeks later on the crest to expose the implant.

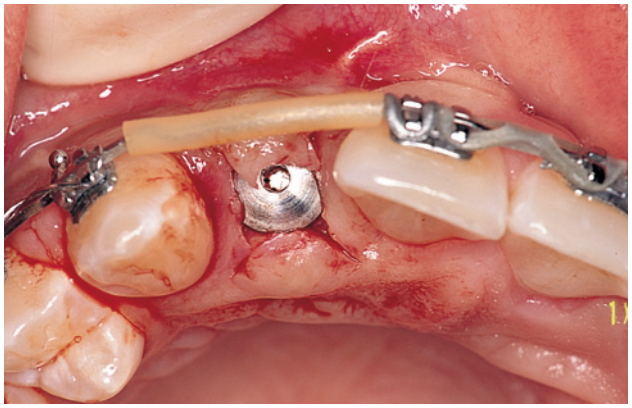


FIGURE 9-9 I, Crestal keratinized gingiva is elevated toward the facial aspect, and a temporary healing abutment is placed.

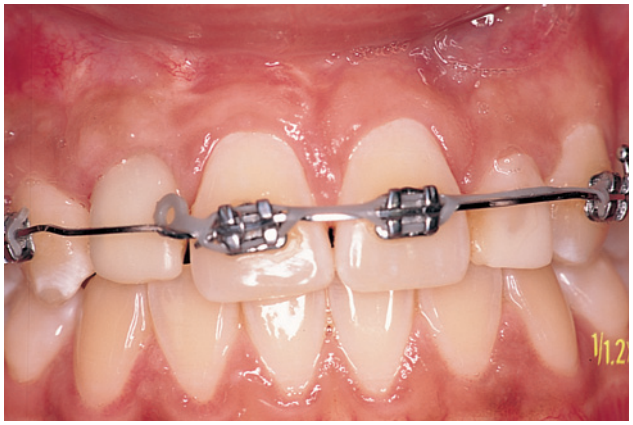


FIGURE 9-9 K, After 5 months, the gingiva has matured with a normal contour over the temporary crown.

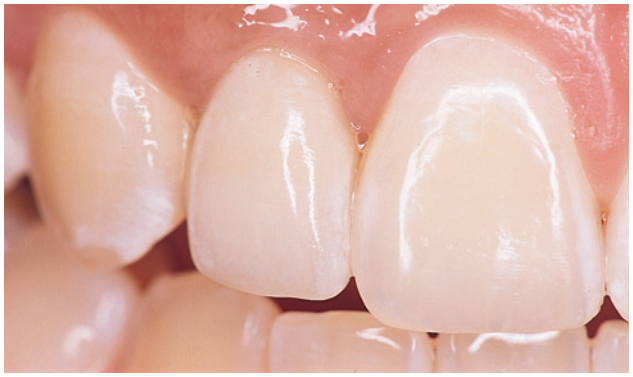


FIGURE 9-9 M, Final restoration. As a result of the reconstructive hard and soft tissue procedures, the crown has a natural appearance, without evidence of the underlying metal from the abutment or implant. (Prosthetics by Dr. Gerald Chiche.)

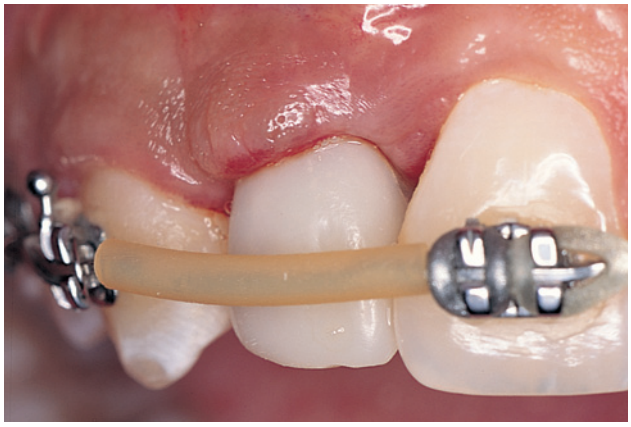


FIGURE 9-9 J, Temporary crown is placed 2 weeks after the exposure surgery. Excessive gingival profile is noted.

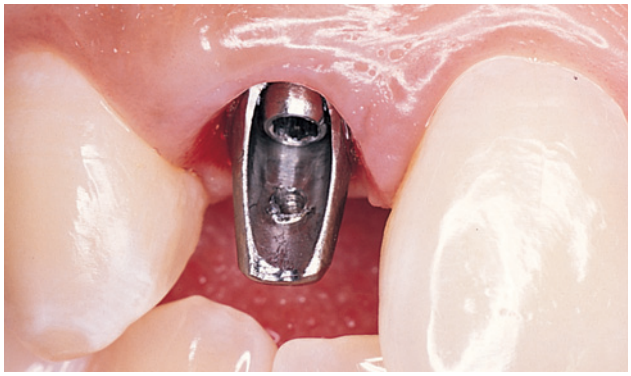


FIGURE 9-9 L, Final abutment in place.

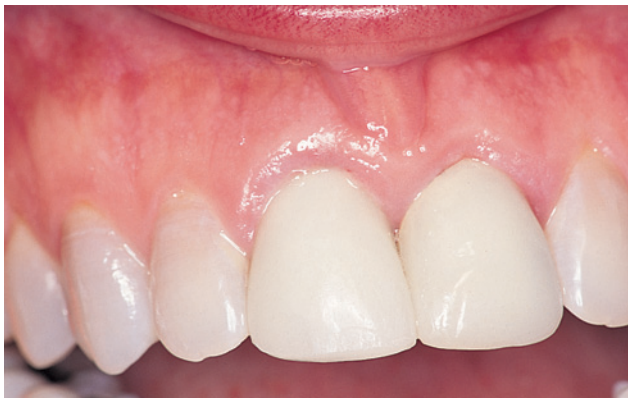


FIGURE 9-10 A, This 28-year-old patient's maxillary right central incisor will be extracted secondary to severe labial bone loss from endodontic complications. She has a high smile line and requests an esthetic single-tooth restoration. Her teeth are tall, with dominant central incisors. The distance from the contact area to the crestal bone on the adjacent teeth is greater than 7 mm.

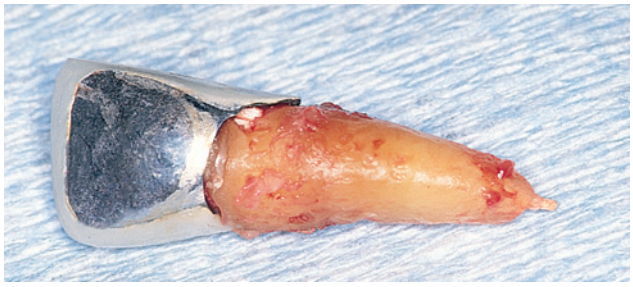


FIGURE 9-10 **B,** Tooth is extracted with minimal effort.

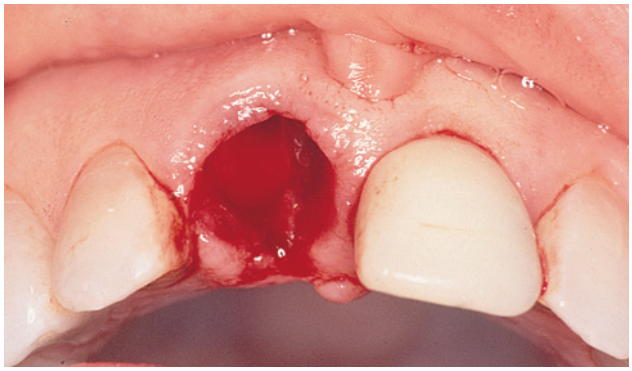


FIGURE 9-10 **C,** Extraction socket is probed, and 8 mm of labial bone is not present. Because purulent exudate is present, no graft materials are placed into the extraction site.

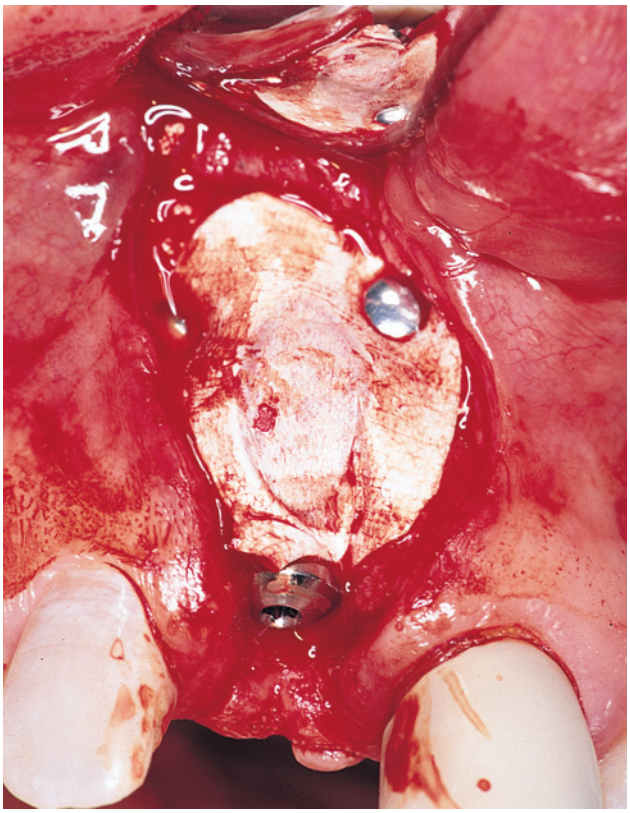


FIGURE 9-10 **D,** Area is allowed to heal for 12 weeks. A threaded implant 3.8 mm in diameter then is placed with 3 mm of the apical portion in apical bone. The palatal surface and the mesial and distal surfaces of the implant have bone contact, but there is 10 mm of labial thread exposure. The site is grafted with a mixture of autogenous bone and dense particulate nonresorbable graft material, such as synthetic HA or anorganic bovine xenograft, and is covered with a nonresorbable membrane, which is retained by the implant cover screw and apical tacks.

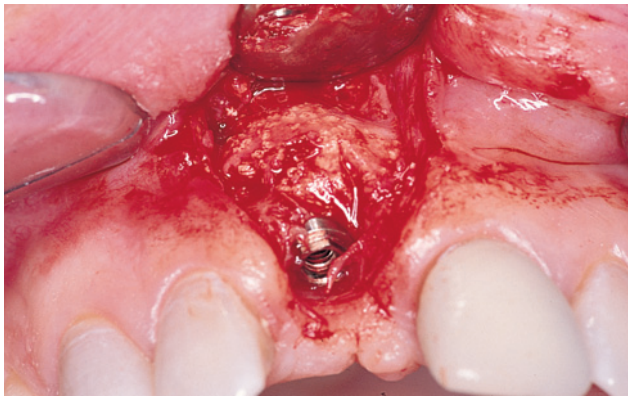


FIGURE 9-10 **E,** Membrane is removed, and a subepithelial connective tissue graft is placed 6 months after the membrane and bone grafting procedure. The papilla-sparing incisions are re-entered, and the membrane is removed. The graft covering the implant is shown. The connective tissue graft is harvested from the palate to provide an additional 2 mm of gingival thickness and to improve the quality of the overlying soft tissue.

membrane. Releasing incisions usually are necessary and spare the papillae. Papillae are usually not raised or incised in this procedure. Even if a sulcular incision is used to place the implants and membrane, conservative vertical incisions are recommended, because consecutive sulcular incisions occasionally may result in blunting of the papillae. The vertical incisions should be slightly beveled, with release of the distal edge to allow careful reapproximation of the edges of the incision after placement of the soft tissue graft.

Typically, a dense layer of fibrous tissue has formed over the membrane. This layer is dissected to expose the

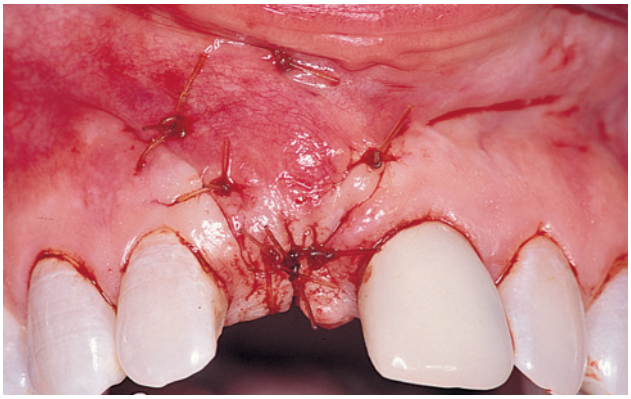


FIGURE 9-10 F, Area has been magnified to show the location of the vertical incisions, which will heal inverted on the right side of the implant site.

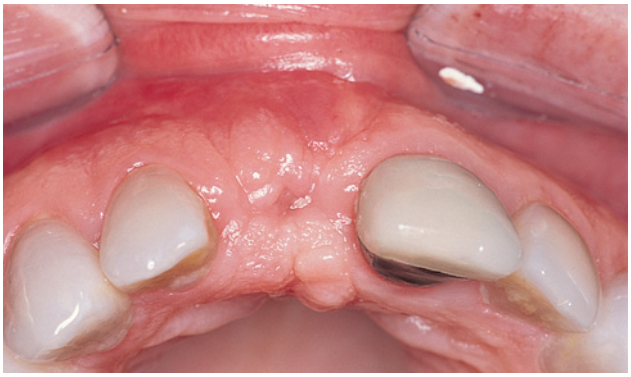


FIGURE 9-10 G, Implant exposure is performed 6 weeks after placement of the connective tissue graft. A 1-mm horizontal soft tissue deficit remains, which is to be augmented with the prosthesis' subgingival contour.

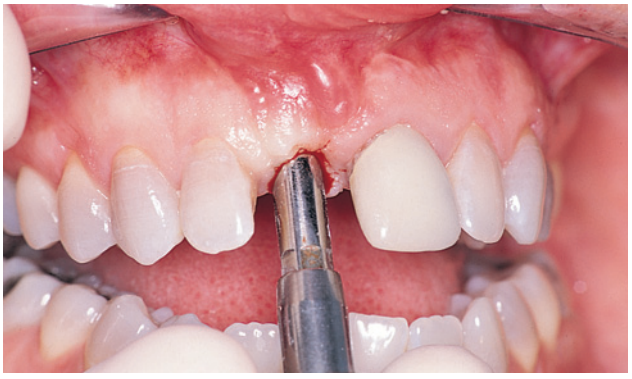


FIGURE 9-10 H, Tissue punch is used to expose the implant.

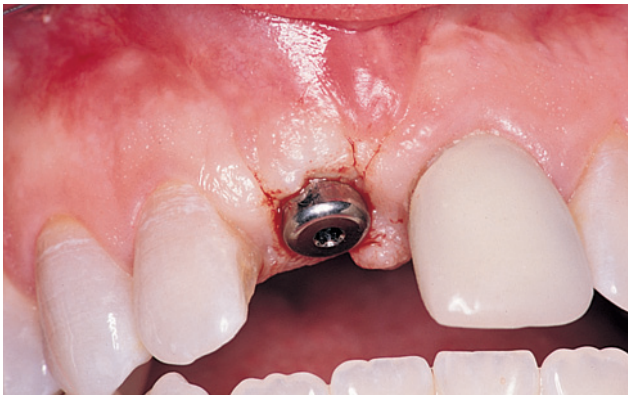


FIGURE 9-10 I, A straight emergence healing abutment that is 5 mm tall is placed. The tissue is very tight; despite the use of a straight emergence abutment, a small tear is present on the right side.

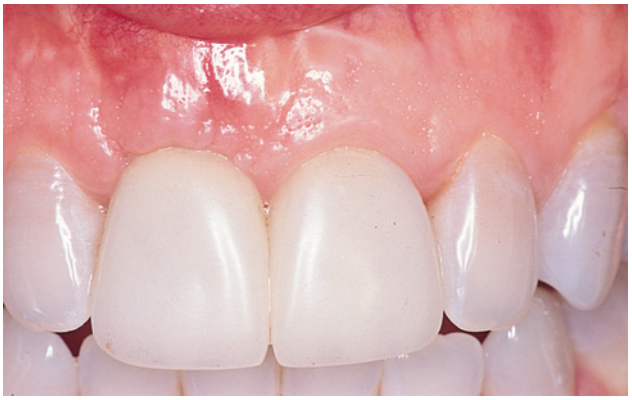
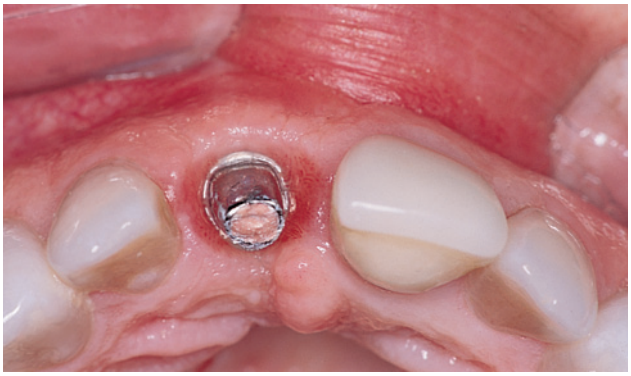


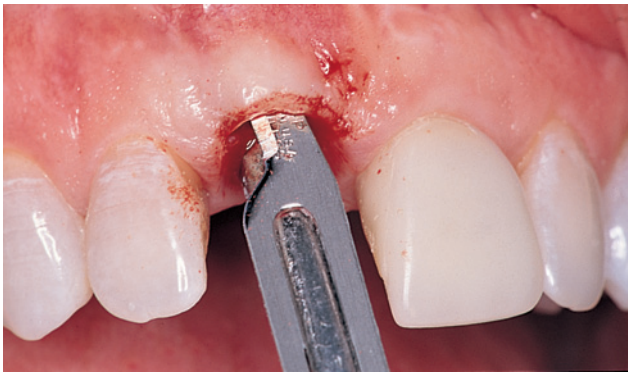
FIGURE 9-10 J, Temporary restoration. The patient and clinicians did not like the inverted scar on the right side of the gingival margin.

membrane. It can be left in the overlying flap and does not need to be removed; its removal can compromise the overlying soft tissue flap. Care should be taken to avoid damaging the membrane. Once the membrane has been entirely exposed, the cover screw and the apical tacks or screws are removed, depending on the clinician's choice.

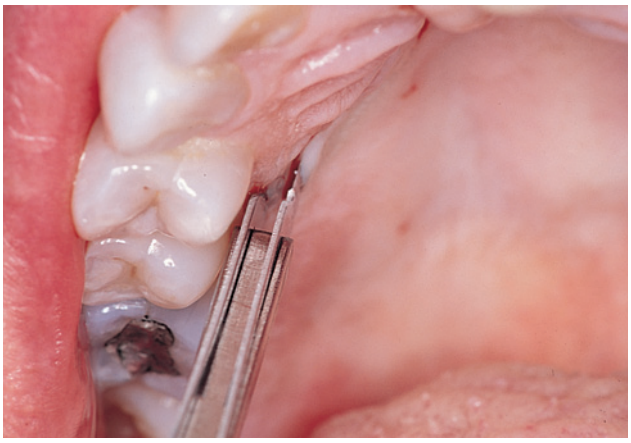
The peripheral edge of the membrane is identified and gently reflected from the underlying graft. The graft should be hard to the touch and stable in position. The membrane should be removed from the graft site in a single, intact piece. Fragments of nonresorbable membranes should not be left in the site. After the membrane has been removed, the cover screw is replaced into the implant. A piece of foil from a suture pack can be trimmed to match the planned graft size and shape. The foil is transferred to the palate to guide the surgeon in determining the necessary size of the



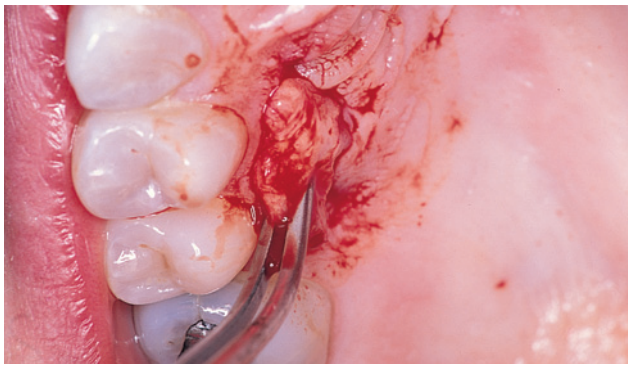
● **FIGURE 9-10** **K,** To correct the inverted scar that extends to the periosteum, a pouch procedure is planned with placement of a subepithelial connective tissue graft, followed by a gingivoplasty to smooth the contour. The connective tissue graft will provide the bulk to remove the inverted scar surgically. The temporary crown is removed to provide access to the sulcus.



● **FIGURE 9-10** **L,** Small (15c) scalpel blade is used to create a subepithelial pouch at the periosteal plane, keeping the overlying gingiva thick to prevent perforations or vascular compromise. The dissection includes the periosteal plane under the inverted scar, to allow placement of the tissue graft under the scar to lift it off the alveolus.



● **FIGURE 9-10** **M,** Double-bladed scalpel (2 mm) is used to harvest a sheet of subepithelial connective tissue. An open technique also can be used to harvest the subepithelial connective tissue.



● **FIGURE 9-10** **N,** Connective tissue graft is harvested from the palate as one sheet of tissue. The graft is trimmed to measure approximately 10 mm square.

harvest. The connective tissue graft is placed directly over the hard tissue material and covered with the labial mucosa.

After the graft has been harvested and trimmed to an appropriate smooth contour and size, it is placed over the implant site. The labial tissue is gently replaced in its original position to orient the location of the retaining vestibular suture. A needle is placed through the labial mucosa at the superior edge of the graft and engages the graft. The suture then is passed from within the flap, through the labial mucosa, and gently tied. This suture sets the vertical position of the graft. The labial crestal edge of the flap is sutured with interrupted sutures, engaging the labial flap, connective tissue graft, and palatal mucosa. Two or three sutures are used. These sutures are usually 4-0 resorbable sutures on a tapered, atraumatic needle. After the crestal sutures have been placed, the vertical incisions are carefully reapproximated and closed. The edges of the vertical incisions should be everted slightly to ensure that the eventual scar line will be flat and not inverted.

Coronal Correction of the Gingival Margin on Implants

For a number of reasons, the gingival margin on an anterior maxillary implant restoration may be apical in relation to the adjacent teeth. When a single-tooth implant

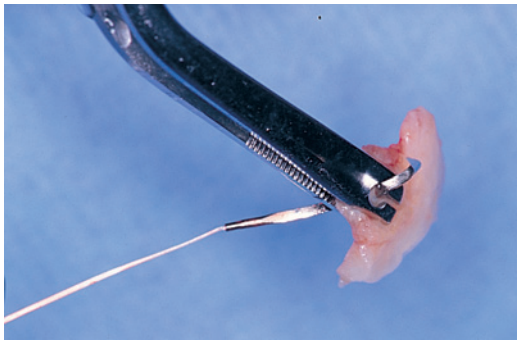


FIGURE 9-10 O, Tissue forceps are used to guide the suture through the graft. One suture is passed from the corner of the pouch from the vestibule through the pocket to emerge from the sulcular incision. The suture is then passed through one corner of the graft.

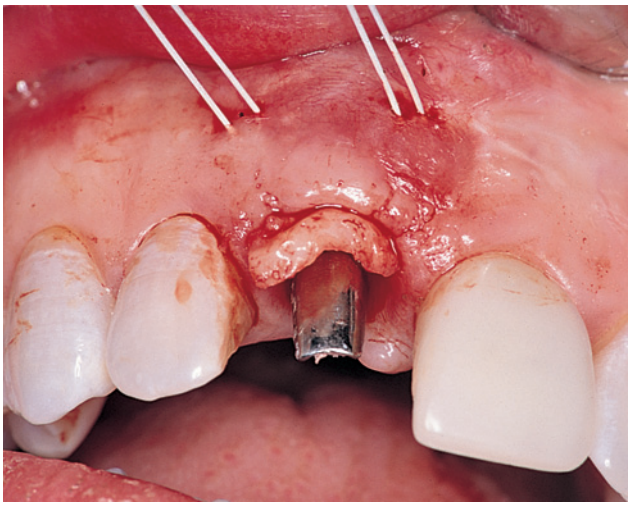


FIGURE 9-10 Q, Second suture is passed similar to the first suture, resulting in a two-suture hold on the graft in the correct vertical position.

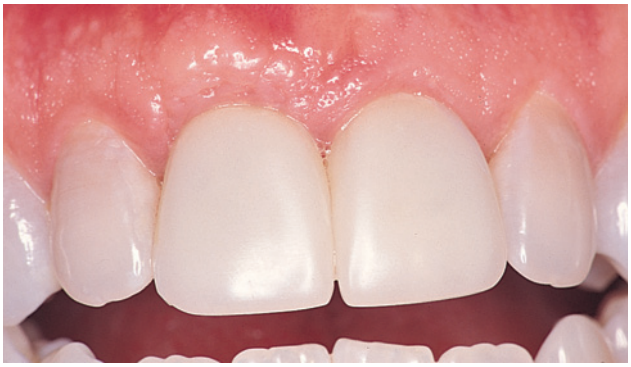


FIGURE 9-10 S, Six weeks after graft placement, the bulk of tissue now present under the inverted scar band is noted.

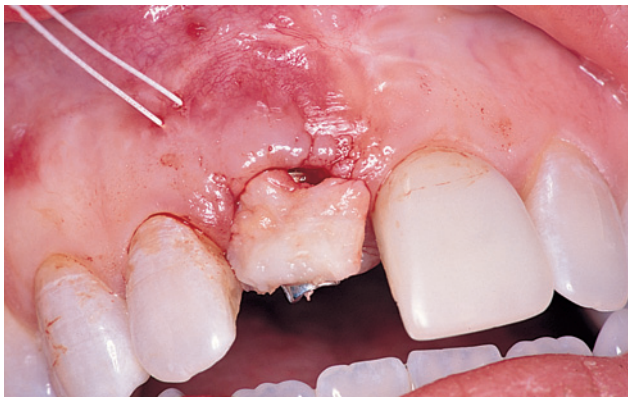


FIGURE 9-10 P, Needle is passed through the sulcular incision, exiting in the unattached gingiva. The graft is approximated into the edge of the incision.

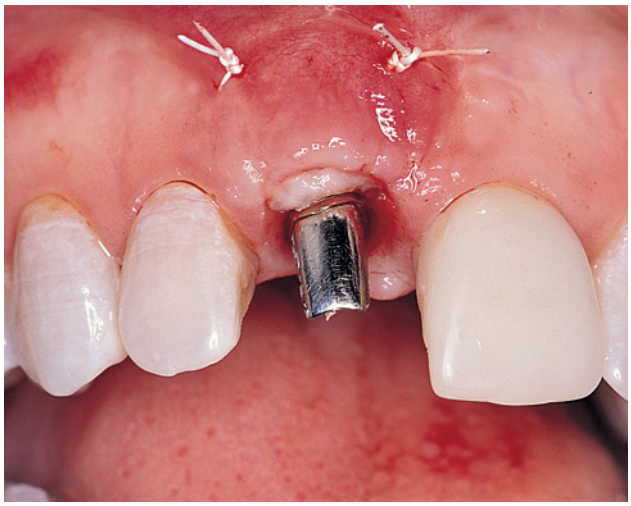


FIGURE 9-10 R, Sutures are tightened, and the graft is properly positioned in the pouch. The sutures then are tied. The abutment is placed by the surgeon to ensure that the graft continues to lie flat and is in the correct vertical position. The temporary prosthesis is replaced.

restoration is performed in the esthetic zone of the mouth, symmetry of the gingival margin is critical for a beautiful result. Gingival margin discrepancies occur with the following:

1. The implant is placed more than 5 mm apical to the ideal gingival margin of the planned restoration.
2. The gingiva is thin over the crest and implant.
3. During exposure of the implant, a tear is made in the gingival margin that heals poorly.
4. Excessive bone loss is not adequately grafted and reconstructed.
5. An adverse healing event, such as infection, occurs.

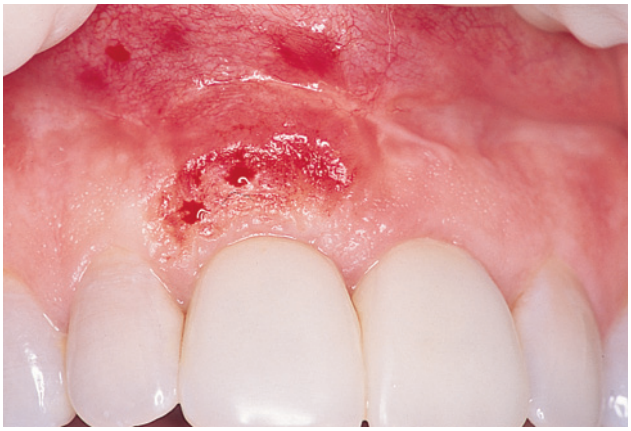


FIGURE 9-10 **T,** Diamond bur is used during the gingivoplasty to smooth the tissue contour.

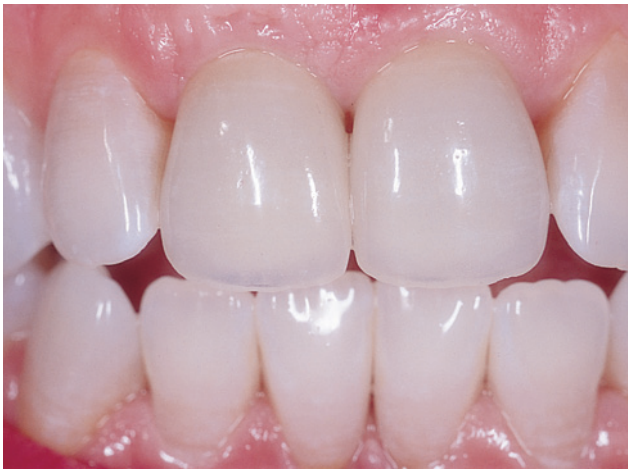


FIGURE 9-10 **W,** Final restoration shows excellent tissue texture, tone, and symmetry, which are required for an esthetic restoration. (Prosthetics by Dr. Gerald Chiche and Dr. Thomas Salinas; gingival surgery by Dr. Hishan Nasr and Dr. Michael Block.)

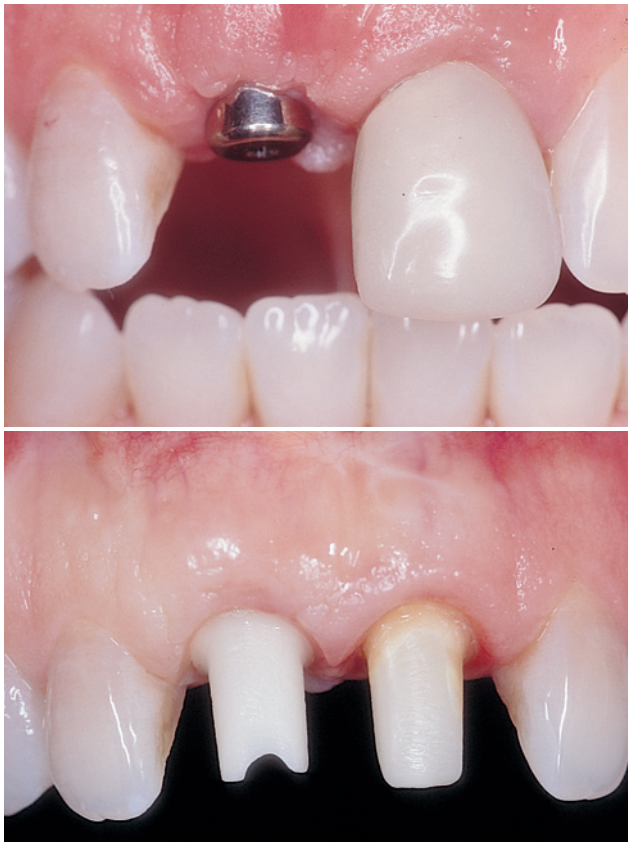


FIGURE 9-10 **U-V,** Comparison of the scar band before **(U)** and after **(V)** graft placement and gingivoplasty. The final abutment was placed approximately 2 months after the gingivoplasty.

The following options are available to the surgeon and restorative dentist to correct gingival margin discrepancies[12-16]:

1. A coronally repositioned flap[13] can be used, but it may not yield the esthetic result desired by many restorative dentists, because it has a tendency for apical migration.
2. The subepithelial connective tissue graft can be used in a manner similar to that often practiced for root coverage, except that the soft tissue may not adhere well to the materials used for implant restorations in the subgingival region.
3. A semilunar flap[12,14-16] is a simple alternative technique that can gain up to 1 to 2 mm of coronal gingival movement using a method similar to that for root coverage.

It is best to perform gingival margin manipulation surgery after the temporary crown has been in place for a satisfactory length of time to allow stabilization of the gingiva and an accurate prediction of the desired movements of the gingival margin to within 0.5 mm. After the gingiva has matured and has stabilized in position, coronal movement of the gingival margin is predictable. The semilunar flap technique is simple and less traumatic to the patient than the palatal subepithelial connective tissue graft. However, the subepithelial connective tissue graft is more useful in clinical situations involving inverted gingival scars from prior vertical incisions, because the subsequent increase in thickness of the gingiva allows surgical flattening of the scar to enhance the esthetic appearance.

Subepithelial Connective Tissue Grafting for Coronal Movement of the Gingival Margin and Elimination of Vertical Scars

The preoperative workup for this procedure must include detailed mapping of the gingival margins on all anterior maxillary teeth. The distances from the incisive edges to the current gingival margins are recorded for the mesial and distal line angles, as well as for the direct facial surface of the tooth. These measurements then are used to plan accurate movements of the gingiva for coronal repositioning and crown-lengthening procedures. When this information regarding the required changes in the gingival heights has been gathered, the patient is brought to surgery.

Once the distances are known, a local anesthetic can be administered. The temporary crown of the tooth is removed (see Figure 9-10). The implant abutment is left in the implant. A small (15c) blade is used to create an incision and to develop a pouch under the labial gingiva. The dissection is performed sharply with the scalpel blade. The length of the scalpel blade is measured to provide the surgeon with an idea of the apical length of the pocket. The dissection should be kept close to the periosteum to maintain an intact labial mucosa without causing excessive thinning or perforations. The pouch that is formed should extend under the papillae to allow for their augmentation, if necessary. A curved 12b blade can be used to develop the pouch under the papilla. Occasionally, the scalpel blade is used from the sulcus of the adjacent tooth to help mobilize the gingivae near the papillae, an important consideration when a vertical scar is close to the papilla. The base of the dissection in the apical region should be broad to allow revascularization of the graft, which will be wider in the apical than the coronal regions.

After the pocket has been completed, a periosteal elevator is used to confirm that the pocket is free of tissue adhesions and that the connective tissue graft will fit easily into the pocket. The dimensions of the pocket are measured to guide the trimming of the connective tissue graft. A foil template of the necessary graft size and shape can be made, if necessary.

The graft is harvested using either the closed technique, as described by Bruno,[4,5] or a double-bladed scalpel (see Figure 9-10, M). For this purpose, the graft can be thinner at the apical region than the grafts used for ridge augmentation. The graft is trimmed, and its surface is smoothed to ensure an esthetic gingival contour.

A vestibular suture is placed through the gingiva in the apical margin of the pocket, exiting through the crestal incision in the sulcus of the crown. The suture engages one edge of the graft, and the graft is placed partially into the pocket. A second suture is placed from the vestibule, exiting through the incision site; it engages the opposite corner of the graft. This suture then is placed through the pocket, exiting into the vestibule. The graft is inserted into the pocket, and the sutures are tied, ensuring that the graft is appropriately located and that it covers the gingival margin discrepancy with approximately 1 mm of excessive length (Figure 9-10, R). Sutures are removed 7 to 10 days after the procedure. Approximately 6 weeks later, a gingivoplasty may be performed to eliminate scar lines.

Creation of a Semilunar Flap for Coronal Repositioning of the Gingival Margin

The semilunar flap originally was described by Tarnow[15] as a procedure that could be used to cover root surfaces without the need for sutures. The requirements for performing this technique include an adequate width of keratinized gingiva, absence of excessive protrusive labial ridge contours, and relatively thick gingiva. Patients with root fenestrations or those with thin gingiva, which prevents manipulation, are not candidates for this procedure (Figure 9-11, A-T).

For patients who have received implants and have a deficient gingival margin from a gingival tear and subsequent gingival recession over an implant restoration, the semilunar procedure may be a simple, minimally morbid approach that can result in 2 mm of coronal repositioning of the gingival margin. Nasr and de Nasr[12] recommend placement of the semilunar incision within the mucosal tissue in the unattached labial vestibule rather than in the attached gingiva. The technique involves the development of a flap that is approximately 10 mm in height at its greatest curvature and that narrows to 3 mm near the papilla.

The semilunar flap technique can be used for root coverage of teeth and for coronal repositioning of the gingival

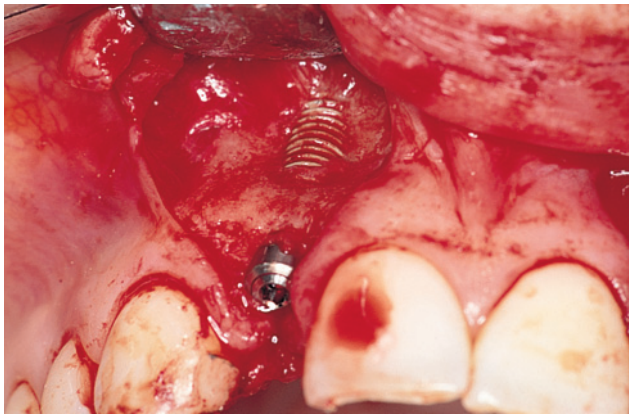


FIGURE 9-11 **A,** This 30-year-old patient has agenesis of the left and right lateral incisors. She has a high smile line and thin, delicate gingivae. Two implants 3.25 mm in diameter are placed at surgery.

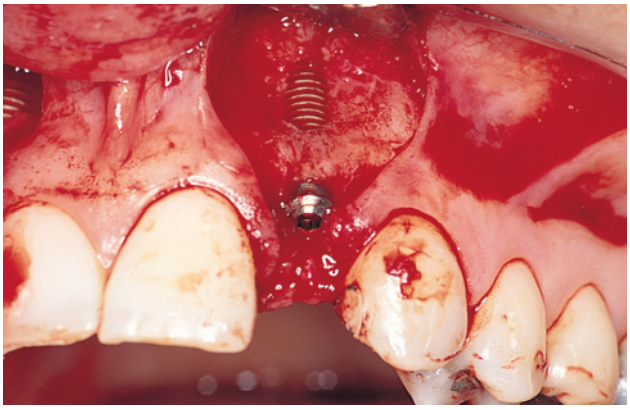


FIGURE 9-11 **B,** Each lateral incisor implant is placed with the aid of a surgical guide stent; the coronal bone is intact. However, a labial fenestration through bone is found for both implants. A dense particulate HA graft is placed, and the incisions are closed. No membrane is used. (The use of intrasulcular incisions was considered for this patient and may have been a viable alternative to the papilla-sparing incisions.)

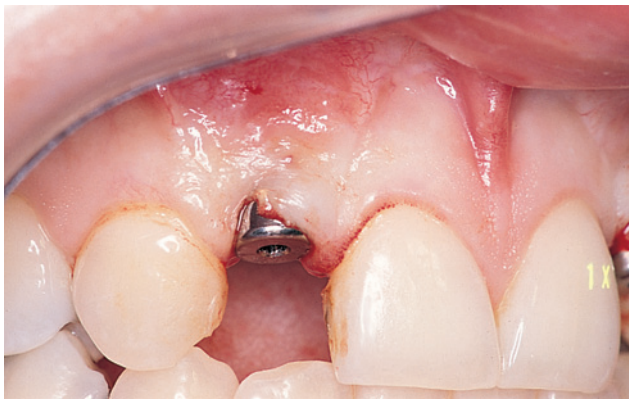


FIGURE 9-11 **D,** Implants are exposed with conservative incisions, mimicking a tissue punch. The right implant site develops a small tear at the gingival margin, which heals with a small cleft.

margin on implant restorations, as long as an adequate band of attached tissue and bone is available at the gap where the superior edge of the semilunar flap is moved coronally. If tooth structure or implant surface is present at the gap, this procedure will not be successful and is contraindicated.

Before the local anesthetic is administered, the distances from the incisor edge to the gingival margins are measured and recorded. The difference in crown length and the desired change in the amount of coronal gingival margin

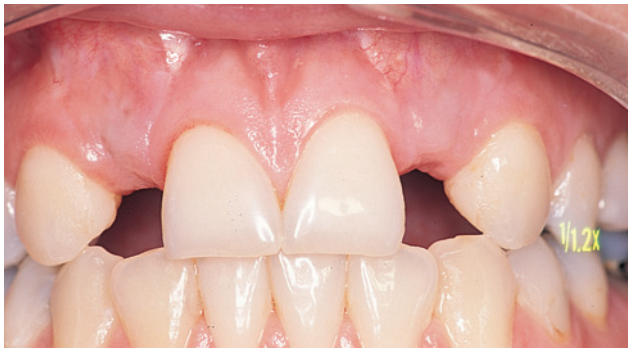


FIGURE 9-11 **C,** After 4 months, small pouches are developed through small crestal incisions, and bilateral subepithelial connective tissue grafts are placed. The implant sites are shown here 5 months after placement and 6 weeks after placement of the soft tissue grafts.

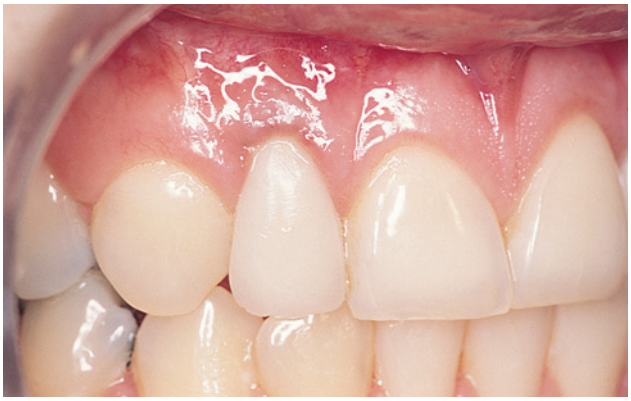


FIGURE 9-11 **E,** Temporary crown is fabricated. The gingival margin has receded, creating a poor esthetic result.

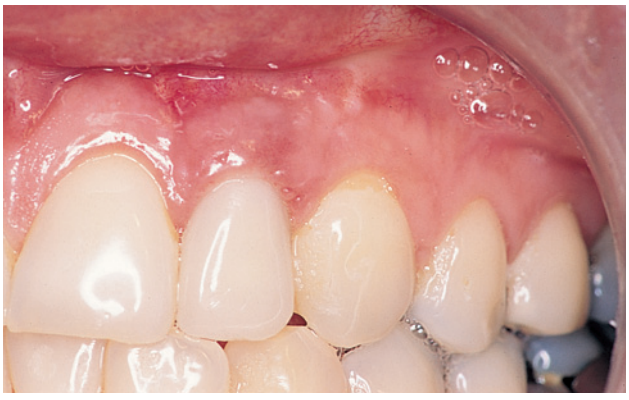


FIGURE 9-11 **F,** Left implant site has healed satisfactorily, with an excellent esthetic result.

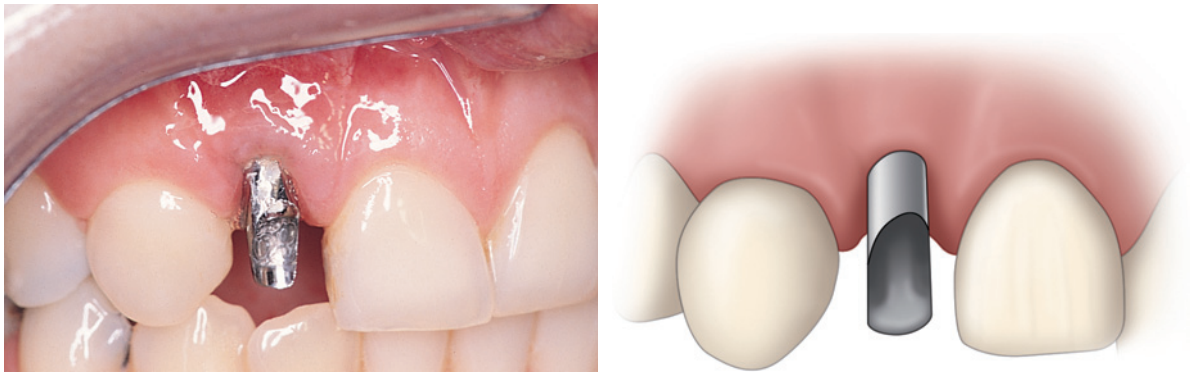


FIGURE 9-11 **G-H,** Crown is removed before a semilunar flap is created to correct the receded gingival margin. The gingival margin is 1.5 to 2 mm apical to the ideal location. In addition, crown lengthening of the right central incisor and right canine is planned to create a symmetric gingival profile.

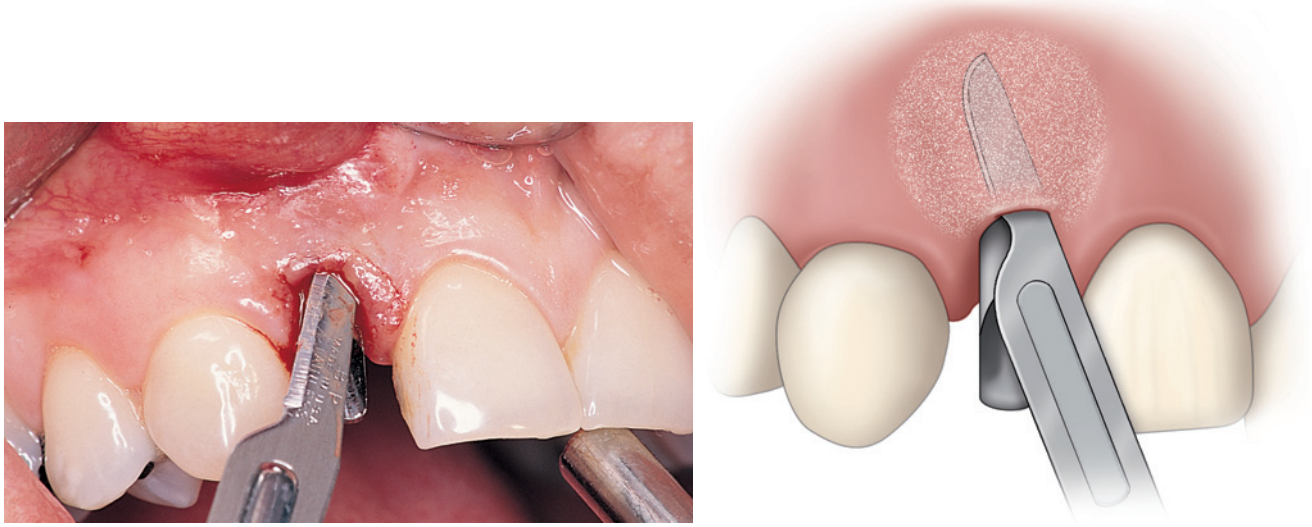


FIGURE 9-11 **I-J,** After administration of a local anesthetic, a 15c blade is used to create a subepithelial pocket, which extends 10 mm superiorly; its width ranges from the distal line angles of the adjacent teeth.

are important distances to know before the procedure is performed. Once these are known, the local anesthetic can be administered. The plan overcorrects the coronal gingival margin by at least 1.5 mm, because the healing process moves the gingival margin apically.

After the local anesthetic has been administered without "ballooning" the tissues, time is allowed for the hemostatic effect. The temporary crown is removed. For this procedure, it is recommended that the coronal edge of the mobilized gingival flap lie against porcelain, dentin, enamel, or bone, because these surfaces can form attachments to the gingiva. An acrylic temporary crown should be trimmed to relieve its apical margin away from the coronal tissue and to allow the gingiva to lie against the titanium of the abutments and not on top of the acrylic crown.

A small scalpel blade (e.g., 15c, 12b) is used to make an intrasulcular incision. From the sulcus, a split-thickness dissection is performed to develop a pocket, which extends apically at least 10 mm. The dissection should extend from the papilla on one side of the tooth to the papilla on the opposite side of the tooth, but it should be at a deep plane of dissection near the periosteum to prevent perforation of the gingival mucosa near the papilla.

A semilunar incision is made within the loose alveolar mucosa, curving apically far enough midfacially to ensure that the apical portion of the semilunar flap rests on bone

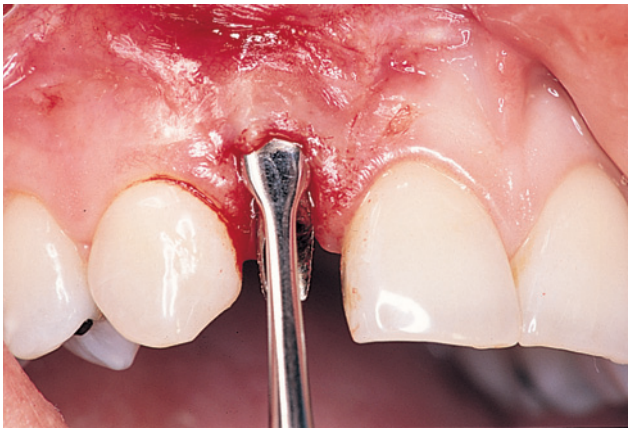


FIGURE 9-11 **K,** Depth of the dissection and confluence of the pocket are evaluated with the use of a small periosteal elevator. Additional lateral dissection and subepithelial release of the papilla are performed if indicated.

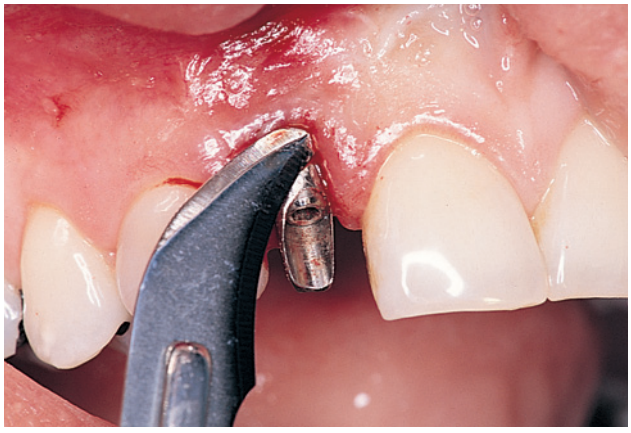


FIGURE 9-11 **L,** Curved 12b blade is used to extend the dissection and, at a deeper plane, elevate the attached tissue near the papilla.

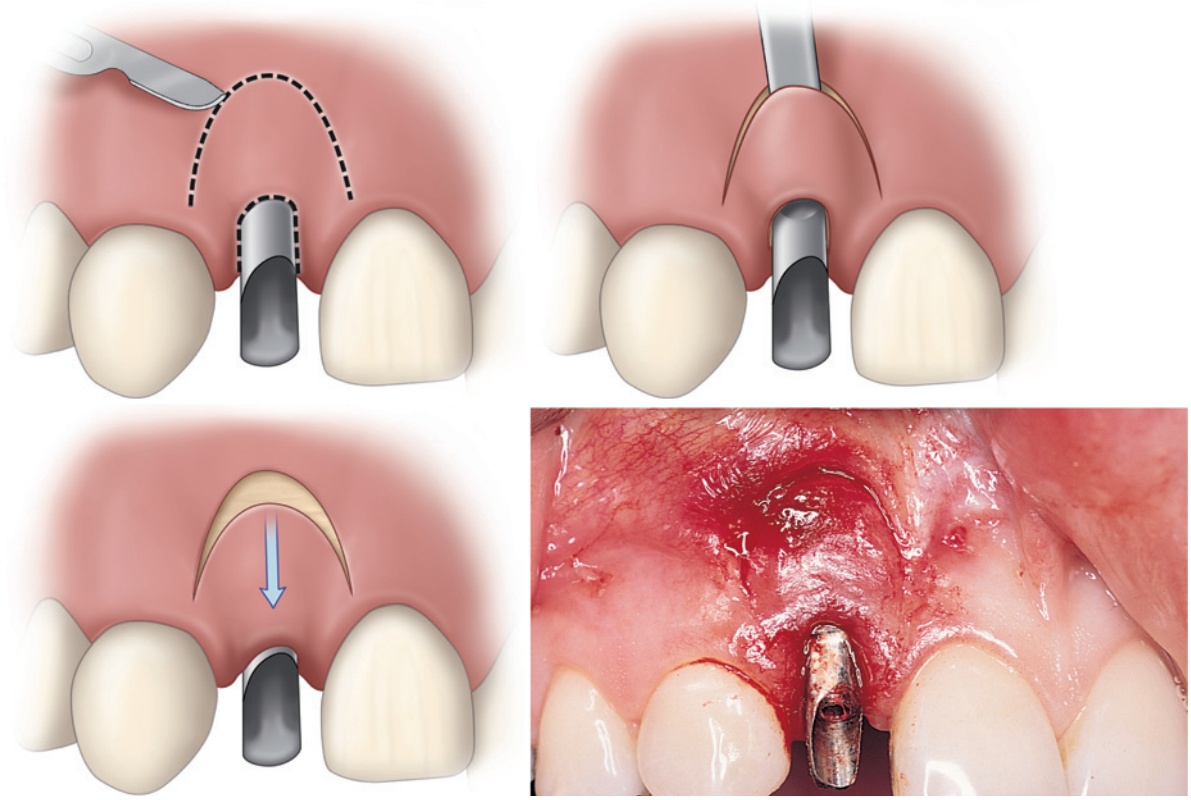
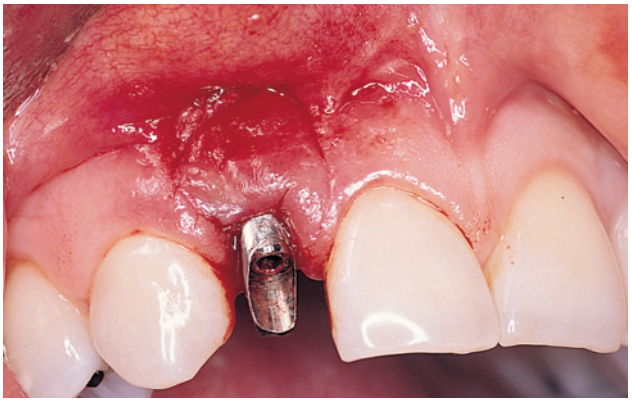
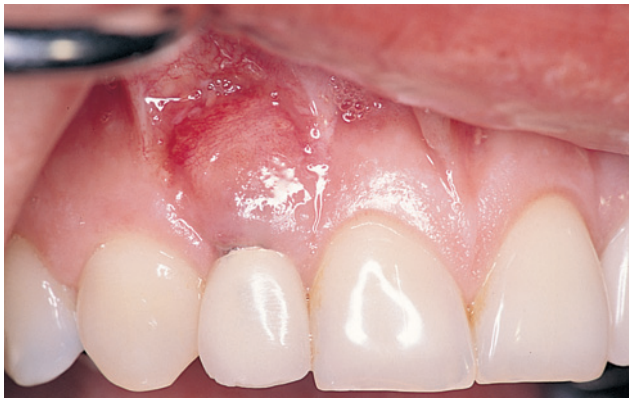


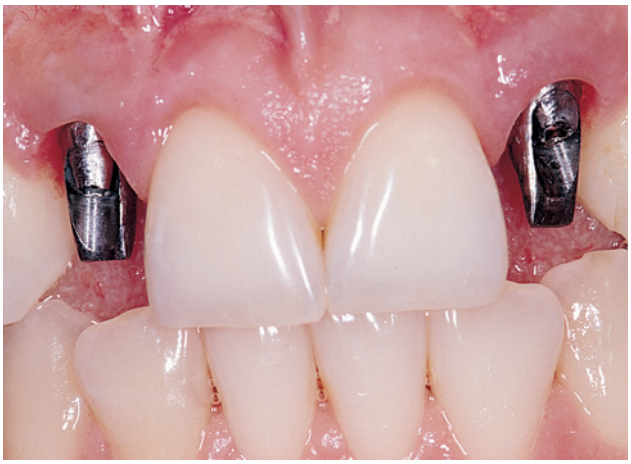
FIGURE 9-11 **M-P,** Using a 15b blade, a semilunar incision is made 10 mm superior to the gingival margin within the unattached gingiva, curving inferiorly 2 to 3 mm from the papilla. The



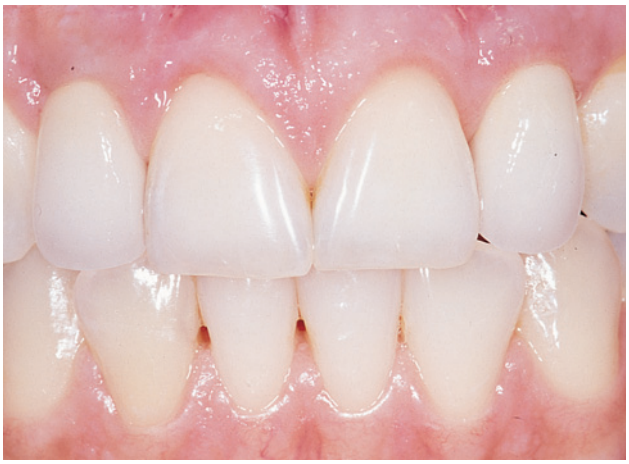
● **FIGURE 9-11** **Q,** Semilunar flap is positioned passively to the desired gingival location, with 50% excess planned because some shrinkage is expected. Light pressure is applied for 5 minutes to allow the development of a clot. The patient is instructed to keep gentle pressure on the site and to avoid vertical forces on the gingiva.



● **FIGURE 9-11** **R,** Semilunar flap 2 weeks after the procedure.



● **FIGURE 9-11** **S,** New abutments immediately before final placement of the implant crowns. Crown lengthening has been performed on the adjacent central and canine teeth.



● **FIGURE 9-11** **T,** Final restoration with symmetric gingivae. (Soft tissue surgery by Dr. Hishan Nasr and Dr. Michael Block; prosthetics by Dr. Thomas Salinas.)

after it has been mobilized and moved coronally. The ends of the semilunar flap should be brought to the end of the tooth, leaving at least 2 to 3 mm of tissue at the papilla. This 2 to 3 mm of papillary tissue serves as the blood supply for the semilunar flap.

After the semilunar incision has been made, the flap should be mobilized and brought coronally. Small residual tissue attachments may need to be further incised to allow adequate mobilization of the flap. The flap of tissue is moved coronally and held in place with slight pressure on moist gauze for 5 minutes. Depending on the clinician's preference, an adhesive may be used to "glue" the edge of the flap to the crown; however, this usually is not necessary. The coronal movement should be overcorrected by 1.5 mm, because shrinkage of the flap is expected secondary to scar contracture at the incision site.

Postoperative instructions include a soft diet for 14 days, minimal pressure when brushing the teeth using a roll technique and a very soft toothbrush, and antiplaque rinses for 2 months. After 8 weeks, the soft tissue has healed sufficiently to allow fabrication of the final prosthesis.

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