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Atlas Oral Maxillofacial Surg Clin N Am 14 (2006) vii

Atlas of the
Oral and
Maxillofacial
Surgery Clinics

Preface

Implant Procedures

Michael S. Block, DMD
Guest Editor

This issue of the *Atlas of the Oral and Maxillofacial Surgery Clinics of North America* is designed to aid clinicians in several current techniques that promote efficient patient care while decreasing the traditional morbidity associated with major grafting procedures. The issue also focuses on techniques for enhancing the aesthetic result, taking into consideration preserving and creating bone in extraction sites as well as using adjunctive soft tissue procedures.

The first two articles represent the author's experiences with creating and preserving bone after tooth extraction, as well as the use of a minimally morbid technique to augment the thin alveolar ridge. These two procedures allow for in-office procedures without the need for deep sedation and provide a ridge that can receive an implant for the final restoration of the patient. The articles by Dr. Hisham Nasr and Dr. Jon Perenack demonstrate how soft tissue procedures on the alveolus and the lips can be used to enhance the final aesthetic appearance of restorations in the anterior maxilla. These procedures are extremely important for the patient's benefit. The aging process and loss of tissue support from loss of teeth can be reversed if careful treatment planning for the soft tissues is used. The article by Dr. Scott Ganz demonstrates the practical use of imaging to facilitate planning and rehabilitation of the patient with minimal incisions and minimal flap reflection. The use of imaging allows for preoperative fabrication of the final or provisional restoration, which is important to our patients. The edentulous maxilla is one of the most challenging sites to achieve a fixed or fixed/removable restoration, especially in the patient who may not desire or be a good candidate for extensive bone graft procedures. The use of recombinant protein or zygomaticus implants eliminates the need for autogenous bone grafts in selected patients. Once bone is formed or has been determined to be available, multiple implants can be used to provide an immediate provisional or final restoration.

The authors have spent considerable time and effort to submit articles that are thorough and well thought out, providing readers with an excellent reference source. I would like to thank the authors for their time and dedication to make this issue possible.

Michael S. Block, DMD
Department of Oral and Maxillofacial Surgery
Louisiana State University School of Dentistry
1100 Florida Avenue
New Orleans, LA 70119-2799, USA

E-mail address: mblock@lsuhsc.edu

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Atlas of the Oral and Maxillofacial Surgery Clinics

Techniques for Grafting the Extraction Site in Preparation for Dental Implant Placement

Michael S. Block, DMD*, Walter C. Jackson, DDS, MD

Department of Oral and Maxillofacial Surgery, Louisiana State University School of Dentistry, 1100 Florida Avenue, New Orleans, LA 700119-2799, USA

This article reviews the literature reporting materials to be placed into extraction sites in preparation for placing dental implants. The review of literature includes several materials that are not described in the technique section of this article because the techniques presented can be expanded to other materials. If there is a special technique for a specific material, the technique is mentioned and described in the text.

Uncomplicated healing of human extraction socket

The normal sequence of events of socket healing takes place over a period of approximately 40 days, beginning with clot formation and culminating in a bone-filled socket with a connective tissue and epithelial tissue covering. In the normal sequence of events of socket healing, controlled clinical studies have documented an average of 4.4 mm of horizontal and 1.2 mm of vertical bone resorption 6 months after tooth extraction. The sequence of healing involves a blood clot for the first 3 days, with the clot replaced by a provisional matrix by day 7. The provisional matrix is replaced by woven bone with 80% of the socket filled with mineralized material by day 30. By day 180, 85% of the site is bone marrow, with 15% of the volume filled with mineralized bone by volume.

Material considerations for grafting the extraction site

General considerations

The ideal situation is for an extraction site to heal with bone formation completely preserving and recreating the original dimensions of the bone when the tooth was present. Bone resorption is common after tooth extraction—thus the need to intervene with a method to provide ideal bone for implant placement and reconstruction with an esthetic and functional restoration. The materials chosen to graft the extraction socket should include the following qualities:

- The material should maintain space for bone to repopulate the graft and thus recreate the bone volume to close to original.
- The bone formed should have the density to allow for stabile placement of the implant; thus, the material placed should have exciting osteoconductive features to enhance bone formation.
- The material should be relatively inexpensive and readily available, without transferring pathologic conditions.

* Corresponding author.
E-mail address: mblock@lsuhsc.edu (M.S. Block).

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Based on the above criteria, the clinician should be able to choose which material is best for treating patient-related extraction site needs when planning implants into those areas.

Bovine mineralized bone

Bovine-derived bone is a xenograft. It is an anorganic, pathogen-free, deproteinized bovine, carbonate-containing apatite with crystalline architecture and a calcium/phosphate ratio similar to natural bone mineral in humans. The technique for using bovine particulate bone graft material is well described and is similar to the methods described for human mineralized bone, leading to bone formation and adequate bone support of implants 4 to 8 months after graft placement (Figs. 1 and 2). Bovine-derived cortical mineralized material has been shown to have excellent osteoblast adhesion. Klinge and colleagues implanted natural bone mineral (Bio-Oss) into experimental bone defects in rabbits and reported that this material, with similar size of inner macropores as natural cancellous bone, provided an ideal scaffold for new bone formation. Anorganic bovine bone has been shown to support osteoblastic cell attachment and proliferation. Over time, bone density in the grafted site increased to 69%, and by 12 months there was bone within the site. Bone density increased after 5 to 6 months. With time, bovine mineralized bone graft material becomes integrated and is slowly replaced by newly formed bone, although the resorption of the bovine material may take a longer time than initially reported. The use of deproteinized bovine bone in extraction sites does result in bone fill with an appearance similar to that of control sites, with bone filling the extraction site. This material is slow to resorb; the bovine cortical bone is present after 18 months. Therefore, when using the bovine mineralized bone material to graft an extraction site, 6 to 9 months may be necessary before placement of the implant, especially if the clinician plans to immediately provisionalize the implant.

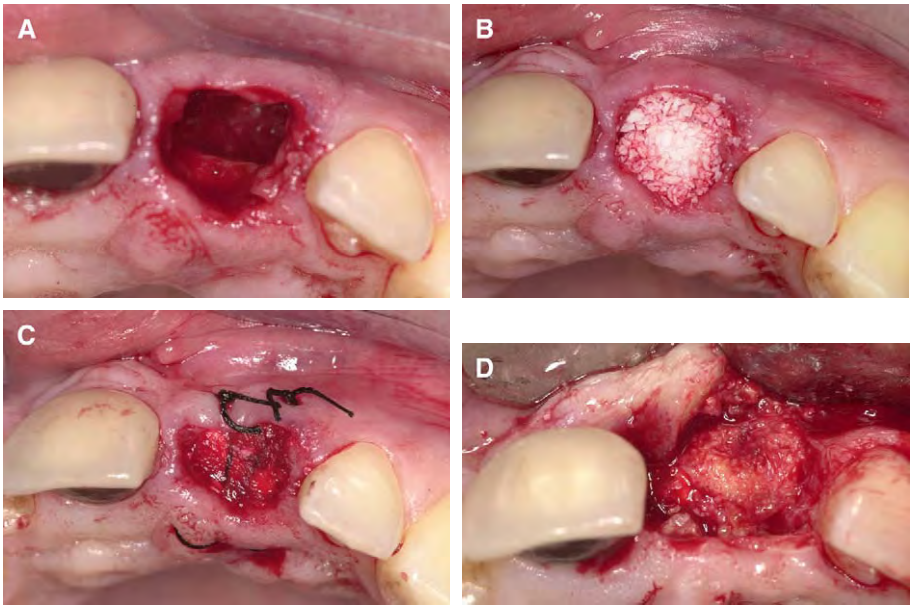
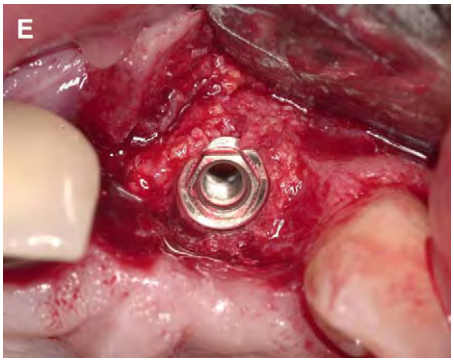
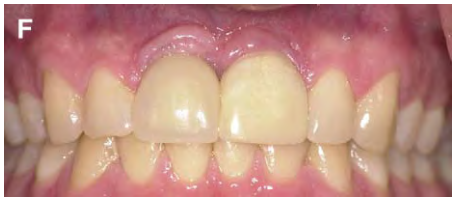


Fig. 1. (*A*) A central incisor was extracted with loss of a significant amount of labial bone. There was vertical palatal bone present but no labial bone superior to the nasal floor. (*B*) Bovine mineralized bone was compacted into the site to recreate the root prominence and to fill the space that was previously occupied by the root of the tooth. (*C*) A collagen material (Collaplug) was placed over the bovine graft. This was retained in position with two horizontal mattress silk sutures. (*D*) Four months after the graft was placed, a crestal incision was made and the gingiva reflected over the adjacent teeth. The previously placed bovine mineralized graft was present and was found to have recreated the space previously occupied by the tooth root. (*E*) A dental implant was placed into the bovine graft. This graft was soft, and the implant was placed with less than 20 cm torque. Therefore, the restoration was staged. (*F*) The final restoration. The implant was exposed 4 months after placement. Routine prosthetics was completed for the restoration of the maxillary left central incisor. (*G*) A 2-year follow-up radiograph showing excellent maintenance of bone levels.





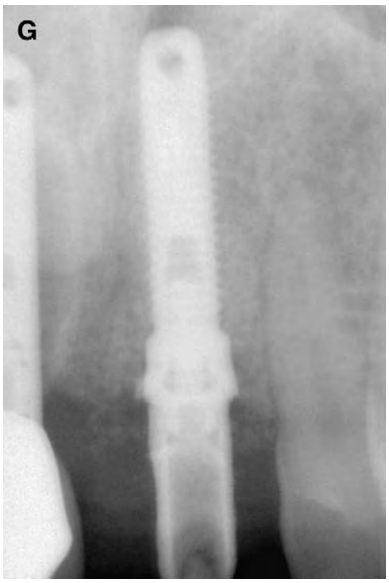
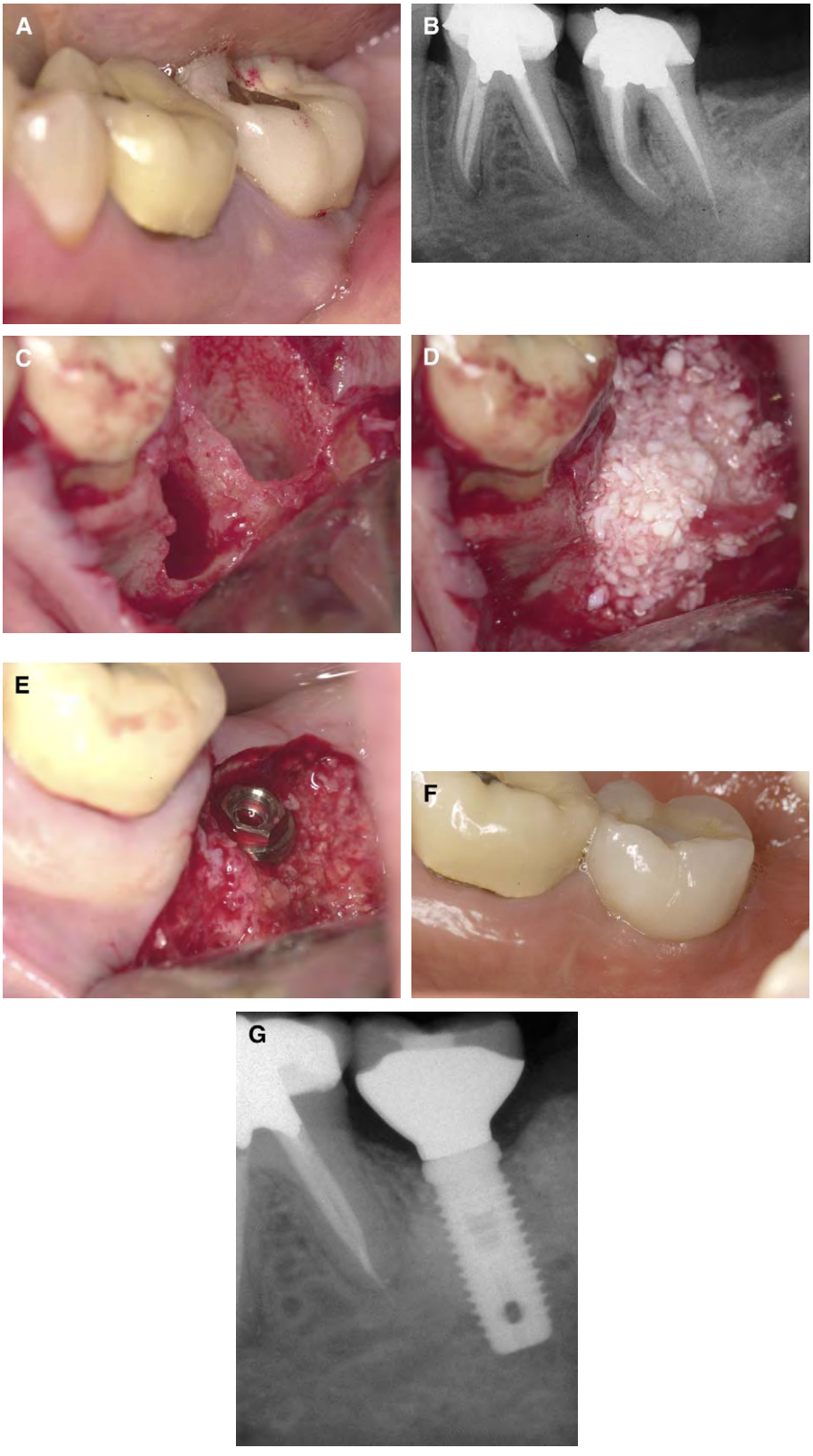


Fig. 1 (*continued*)

The advantage of the xenografts is that they maintain the physical dimension of the extraction socket because they resorb slowly. The source of the bovine bone is easier to obtain than human material. The disadvantage of this xenograft is that it is only osteoconductive and the resorption rate of bovine cortical bone is slow, with the bovine cortical bone often present after 18 months in situ.

Use of bovine mineralized bone graft with membrane placement for extraction site grafting

Fugazzotto and colleagues reported on 59 sites in 90 patients using membrane coverage of bovine bone-grafted extraction sites. They made a sulcular incision around the tooth to be extracted combined with buccal releasing incisions placed at line angles extending beyond mucogingival junction. Additional palatal sulcular incisions extended one tooth anterior and one tooth posterior to the tooth to be extracted. Full-thickness buccal and palatal flaps were reflected, followed by tooth extraction and defect debridement. A nonresorbable porous membrane was trimmed to appropriate size and secured buccally at the most apical aspect with nonresorbable fixation tacks. Bovine bone was mixed with sterile saline and placed beneath the membrane to fill the extraction site defect and any ridge defect present. The buccal flap closure was achieved after making horizontal releasing incisions at most apical aspects of the flap. On reentry, patients treated with resorbable membrane demonstrated bone regeneration but not reconstruction of an ideal ridge form. The morphology of the regenerated ridge was thin. However, patients treated with nonresorbable titanium-reinforced Gore-Tex membranes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demonstrated regenerated hard tissues mimicking an ideal ridge form, corresponding precisely to the space created beneath the secured titanium-reinforced membrane. Secured titanium-reinforced membranes were shown to be the most ideal means by which to ensure the final morphology of the regenerated hard tissues.

Mineralized bone allograft

Human mineralized bone in particulate form has been shown to preserve the site's bone bulk and volume in preparation for placement of implants. Several mineralized grafts are available. The advantages of using an allograft are that the graft material is available without the need for a second surgical harvest site and that the material is osteoconductive.

The common form of mineralized bone graft is particulate cortical or cancellous bone, washed with a series of ethers and alcohol, lyophilized, and sieved to the particle size necessary for a specific indication. The freeze-dried mineralized bone allograft is usually sterilized with gamma radiation. There are limited comparative reports involving different processing methods of mineralized bone and clinical results. The choice of which allograft to use should be based on ease of delivery, cost, consistency in appearance of the graft material, and quality of the bone bank.

One form of human mineralized bone for grafting is processed using the Tutoplast method, which results in mineralized human bone with the collagen matrix intact (Puros, Tutogen, Germany). This process involves multiple washes to remove fats, cellular material, and noncollagenous proteins. The washes deactivate and destroy any remaining proteins that may be pathogenic and presumably preserves inductive protein activity and the natural trabecular pattern of the bone. Cancellous bone is harvested from donors who are free of transmissible diseases. The bone is delipidized with acetone, and an osmotic treatment is performed to remove cells and lower the bone's antigenicity. An oxidative treatment destroys the remaining proteins and minimizes graft rejection by inactivating enzymes. The bone is then dehydrated by solvents, which remove water from the tissue and further disinfect the bone. The process is concluded by limited dose of gamma irradiation. The particulate bone is available from cortical or cancellous bone. It is believed that this human mineralized bone forms a scaffold that encourages osteoconduction within the grafted site. Histology has demonstrated viable bone formation around the mineralized human allograft particles at 5 months. There is no evidence that this material is osteoinductive. When cortical mineralized allografts are implanted into muscle, there is almost a total absence of new bone formation.

Time for replacement of mineralized allogeneic bone graft with bone

In an animal model, the mineralized allograft was found to remodel with osteoclasts at 4 weeks, with total replacement of the graft by 26 weeks. A human case report indicated that at 5 months after grafting with mineralized human bone, osteocyte nuclei were found within lacunae in an osteoid matrix that was appositionally deposited against nonvital graft bone. Nonvital bone graft particles were interconnected by cellular and vascular fibrous connective

Fig. 2. (*A*) Preoperative picture of a mandibular left second molar, which has a large bone lesion. The plan was to extract the tooth and graft the defect to reconstruct the loss labial bone, followed by a single tooth implant restoration. (*B*) A periapical radiograph shows a large area of bone loss adjacent to the fractured mesial root of the second molar. Note the large area of bone loss, which extends to the furcation on the tooth. (*C*) An incision was made around the neck of the tooth with vertical release posteriorly. The tooth was extracted. Note the large area of bone loss labial to the root site. (*D*) Bovine mineralized bone was placed into the extraction site to fill the voids of the roots and to aid in reconstruction of missing bone from the previous extraction. (*E*) After allowing 4 months for healing, a dental implant was placed into the site. The previously placed bone graft has maintained the vertical and horizontal width of the previously placed graft, and the site has been reconstructed. (*F*) The final crown in place. The crown is of appropriate proportions due to the restoration of vertical height by the graft. (*G*) A 2-year postimplant placement radiograph shows complete bone fill in the area of the previous tooth that had been extracted and maintenance of bone in the area of the previous tooth that had been extracted.

tissue exhibiting intramembranous bone growth. On visual inspection, minimal remnants of mineralized bone graft material are present at 4 months. Lamellar bone is observed at 6 months in maxillary and mandibular defects in a report of a case series of 28 patients. Piatelli reported evidence of osteoconductive activity at 6 months, with bone formation over the grafted particles away from the preexisting bone.

Time to supporting implant placement

After 4 months of healing in extraction sites grafted with human mineralized bone, implants have been successfully placed and often immediately provisionalized (Figs. 3–9). The bone density was sufficient to require greater than 25 N-cm of insertion torque to place the implants in 75% of the cases.

One goal for grafting the extraction site is retention and preservation of the original ridge form and maintenance of the crestal bone after the implants have been restored. Using no membrane at the time of extraction site graft, at 4 months, grafted sites seemed to be and felt bone-hard and seemed to be filled with bone. 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 0–1.27 mm) at final restoration. A measurement of 1.27 mm from the top of the shoulder of the implants correlated with the level of the first thread of the implant. Thus, bone heights were maintained with this material.

Grafting extraction sites and membrane placement

The combination of mineralized, freeze-dried, cortical allograft with a nonresorbable porous membrane has resulted in successful bone formation over an extraction site. When using a nonresorbable porous membrane, primary closure of the extraction site is mandatory. However, excessive mobilization of the gingiva can result in a deviation of gingival form and a suboptimal esthetic result in the anterior maxilla. If a nonresorbable membrane is intentionally left exposed, it needs to be removed 6 weeks after placement. Resorbable membranes, if exposed, may be able to be left in position, but usually a poor gingival morphology results due to the reaction of the gingival adjacent to a chronically infected and resorbing membrane.

Current technique advocates the 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 (Collaplug; Zimmer Dental, Carlsbad, California) that resorbs in less than 7 days. This technique is described in this article.

Disadvantages for using human mineralized bone allograft

Adverse cell reactions to implanted mineralized bone are not well documented but theoretically can occur. Human mineralized bone is difficult to obtain and must be treated with strict controls. Bone banks may vary and may have different quality control measures. Fears may be attributed to religious beliefs or to possible transmission of diseases from a cadaver. Accredited bone banks require screening and testing before donor selection. With stringent sterilization and processing, there is only a 1 in 2.8 billion chance of contracting HIV, and no known occurrences have been reported.

Autogenous bone

Clinicians feel that the ideal bone replacement graft material is autogenous bone. For grafting the extraction site, autogenous bone can be harvested from the symphysis, ramus, maxillary tuberosity, or by using bone removed during alveoloplasty. Bone can be scraped from

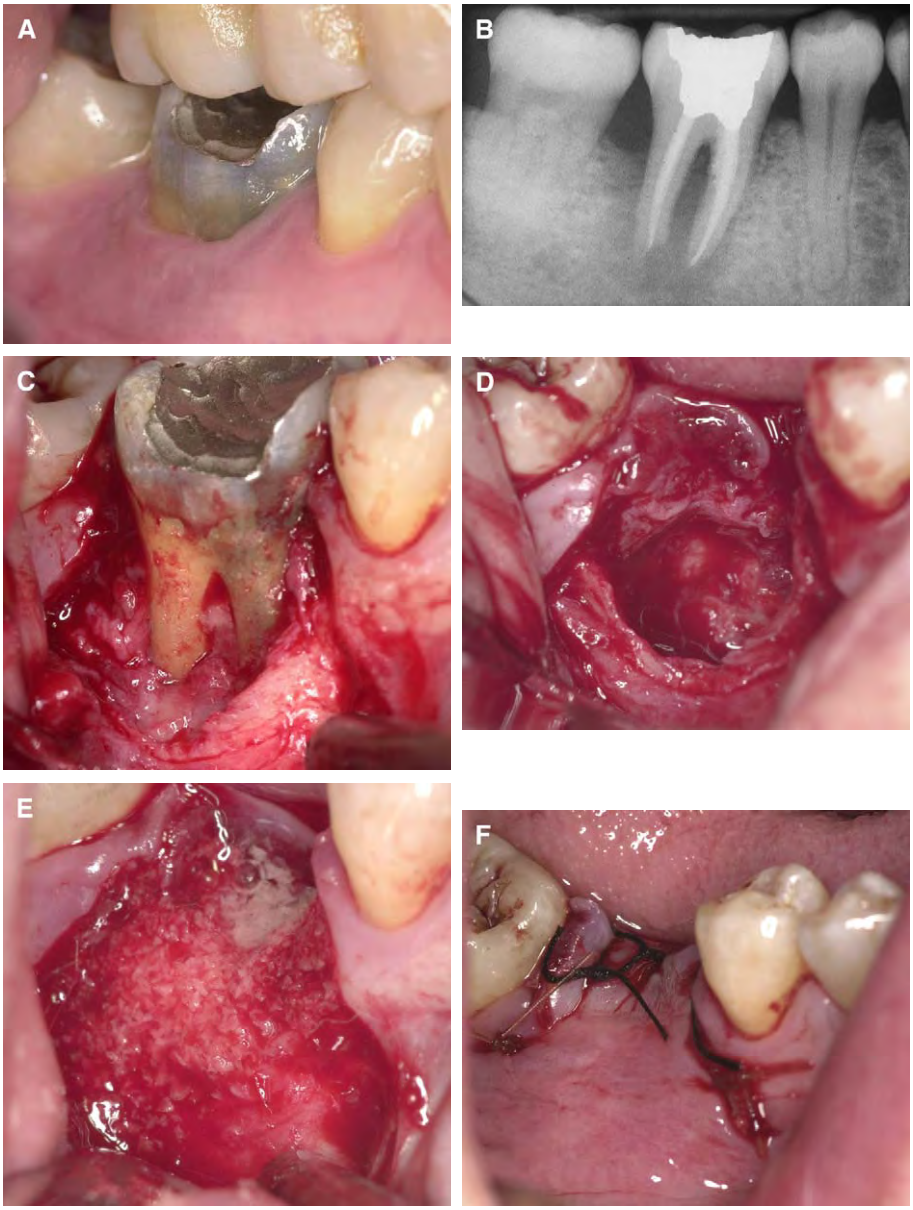

Fig. 3. (*A*) A patient with a mandibular first molar that is in need of extraction. The patient was on antibiotics and chlorhexidine rinses preoperatively to decrease the bacterial flora around this tooth. (*B*) A periapical radiograph of the tooth shows large areas of bone loss extending across the entire labial aspect of the tooth. (*C*) An incision was made around the labial surface of the tooth and linked with two vertical extensions. The vertical releasing incisions were made within the site of the first molar. Care was taken to avoid raising the attached tissues on the adjacent teeth. A full-thickness exposure was performed, exposing the lateral aspect of the tooth and the extensive amount of bone loss. (*D*) The tooth and a small amount of granulation tissue were removed. The area was irrigated thoroughly. The lingual plate of bone is intact with loss of the labial plate to the root apices. This defect has intact mesial and distal walls and an intact lingual plate; therefore, it can be characterized as a three-wall defect. (*E*) A graft of human mineralized bone is placed into the defect to reconstruct the height and width of the socket. After this is compacted, the area is primarily closed. (*F*) Photograph showing the primary closure of the wound with the keratinized gingiva, previously on the labial aspect of the tooth and 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 was scored to provide mobilization of the flap, which allows tension-free closure. (*G*) Photograph taken approximately 16 weeks after the graft, just before placing the implant. The keratinized tissue that had been advanced to the lingual aspect of the ridge is still present. There is excellent ridge form and height. (*H*) An incision was made at the junction of the keratinized tissue near the lingual mucosa to allow the keratinized tissue to be transposed labially. After a full-thickness reflection, the bone graft is seen, and the reconstructed width and height to the ridge is confirmed. In this case, a dental implant, a provisional abutment, and crown were placed. (*I*) Periapical radiograph taken approximately 3 years after restoration of the tooth. Note the restoration of bone in all aspects. (*J*) The final crown approximately 2 years after placement. Notice the gingival health on this tooth.

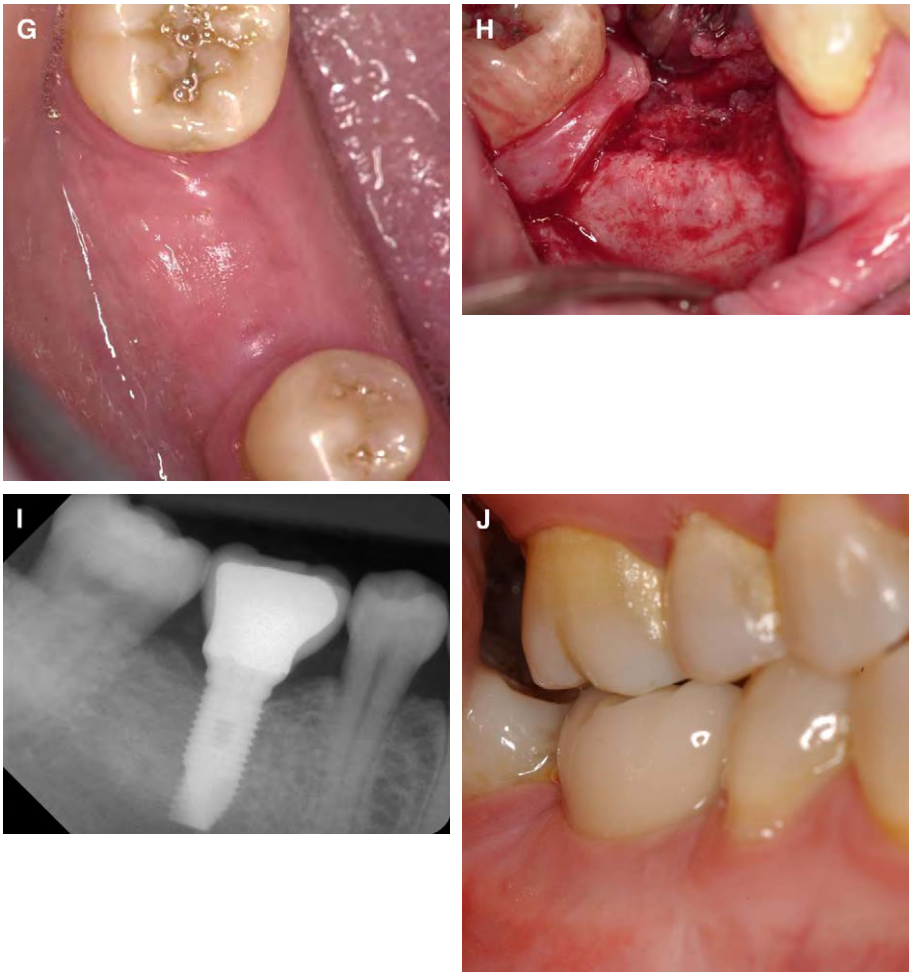

Fig. 3 (*continued*)

adjacent sites, collected in a sieve after shaving the bone with a bur, collected with a Rongeur forceps from adjacent sites or the alveolar ridge, or collected as a block from the symphysis or ramus/body region. The decision to harvest autogenous bone is usually made before extracting the tooth. Incision designs should take into consideration the need for subperiosteal tunneling or separate incisions to allow for harvesting bone. When extracting multiple teeth, 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 with a round bur in the chin or body/ramus regions.

Autogenous bone, when particulated and placed into the extraction socket, is osteoconductive and provides viable cells for phase osteogenic I aspects of bone graft healing. With barrier membranes, autogenous bone grafts had better osteoconductive properties during the initial healing period compared with allogeneic graft material. Nonvital autogenous bone particles are surrounded by new bone formation. Autogenous bone is resorbed and replaced by the host with bone.

Although the use of autogenous bone grafts beneath membranes is considered the gold standard because of unsurpassed biocompatibility and a more rapid course of regeneration of lost hard tissues, clinical studies and case reports are replete with evidence that comparable results may be obtained with appropriately used nonautogenous grafting materials beneath membranes.

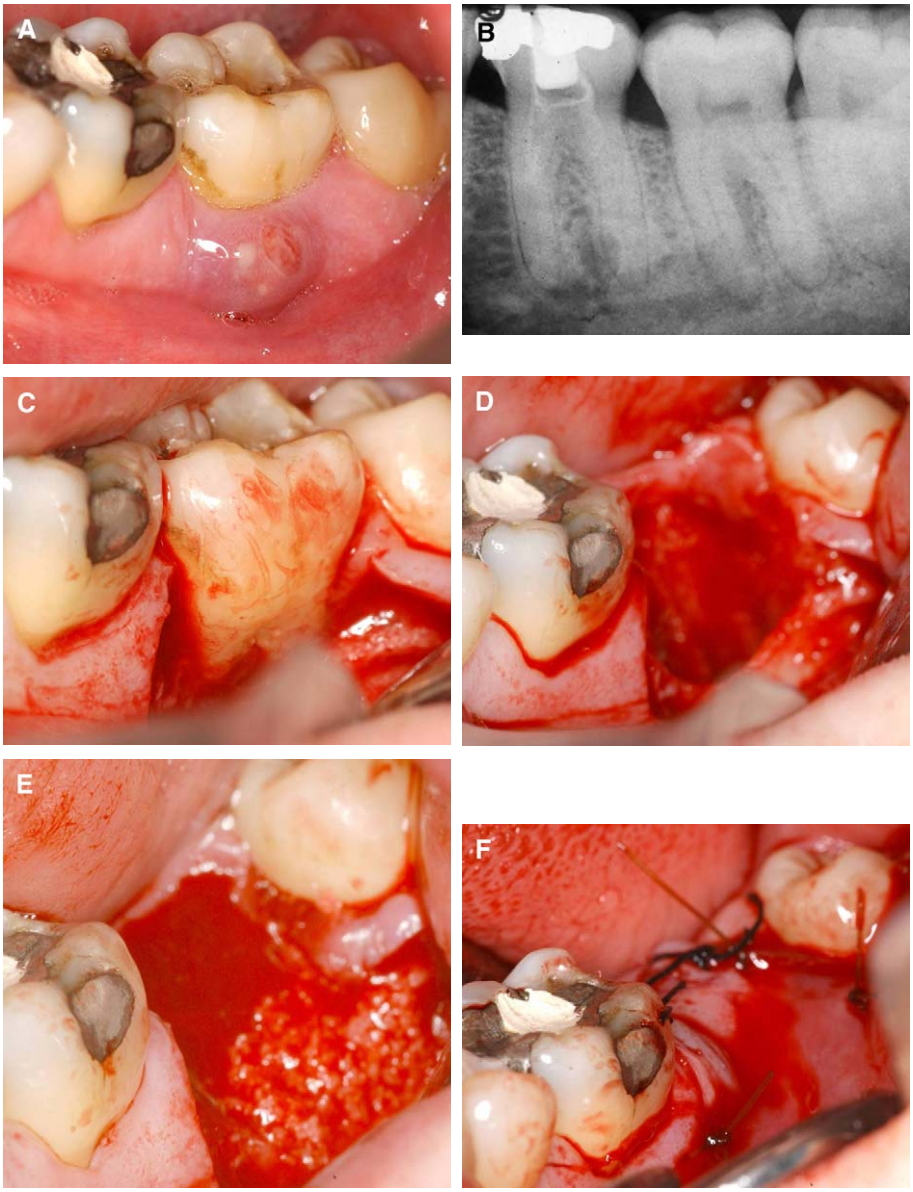

Fig. 4. (*A*) A patient with a mandibular second molar that has obvious abscess formation secondary to a fractured mesial root. The third molar posteriorly is healthy but malposed, and the first molar has a large restoration. (*B*) Periapical radiograph showing the large area of radiolucency on the labial aspect of the mesial root and the furcation area. (*C*) An incision was made around the neck of the tooth with two vertical releasing incisions and a full-flap reflection. The tooth was removed and was found to have a fracture extending to the end of the furcation. The tooth was removed atraumatically. (*D*) Extraction site. The lingual plate and the mesial and distal interproximal bone are intact. The labial bone is not prevalent. After irrigation and debridement of granulation tissue, the site was grafted. The periosteum was released before placing the graft to allow for tension-free closure. (*E*) A graft of human mineralized bone was placed into the molar site for reconstruction of height and width. (*F*) The flap was advanced to achieve primary closure. (*G*) The keratinized gingiva was mobilized to the lingual aspect of the crest. This is the ridge approximately 4 months after, just before the placement of the dental implant. Note the "banking" of the keratinized gingiva on the crest of the ridge. (*H*) Radiograph showing restoration of the bone in the second molar area before placing the implant. (*I*) An incision was made along the lingual aspect at the junction of where the keratinized tissue and lingual mucosa had been primarily reapproximated. The gingiva was reflected labially, exposing the healed bone graft. Sufficient bone was present to place an ideal wide diameter implant. (*J*) A 5-mm-diameter dental implant was placed. An abutment and provisional crown were also placed to immediately provisionalize the restoration because greater than 20 cm of torque was required to place the implant. (*K*) A 2-year post-restoration radiograph showing maintenance of bone around the implant. (*L*) Final restoration showing maintenance of excellent of tooth form and gingiva health.

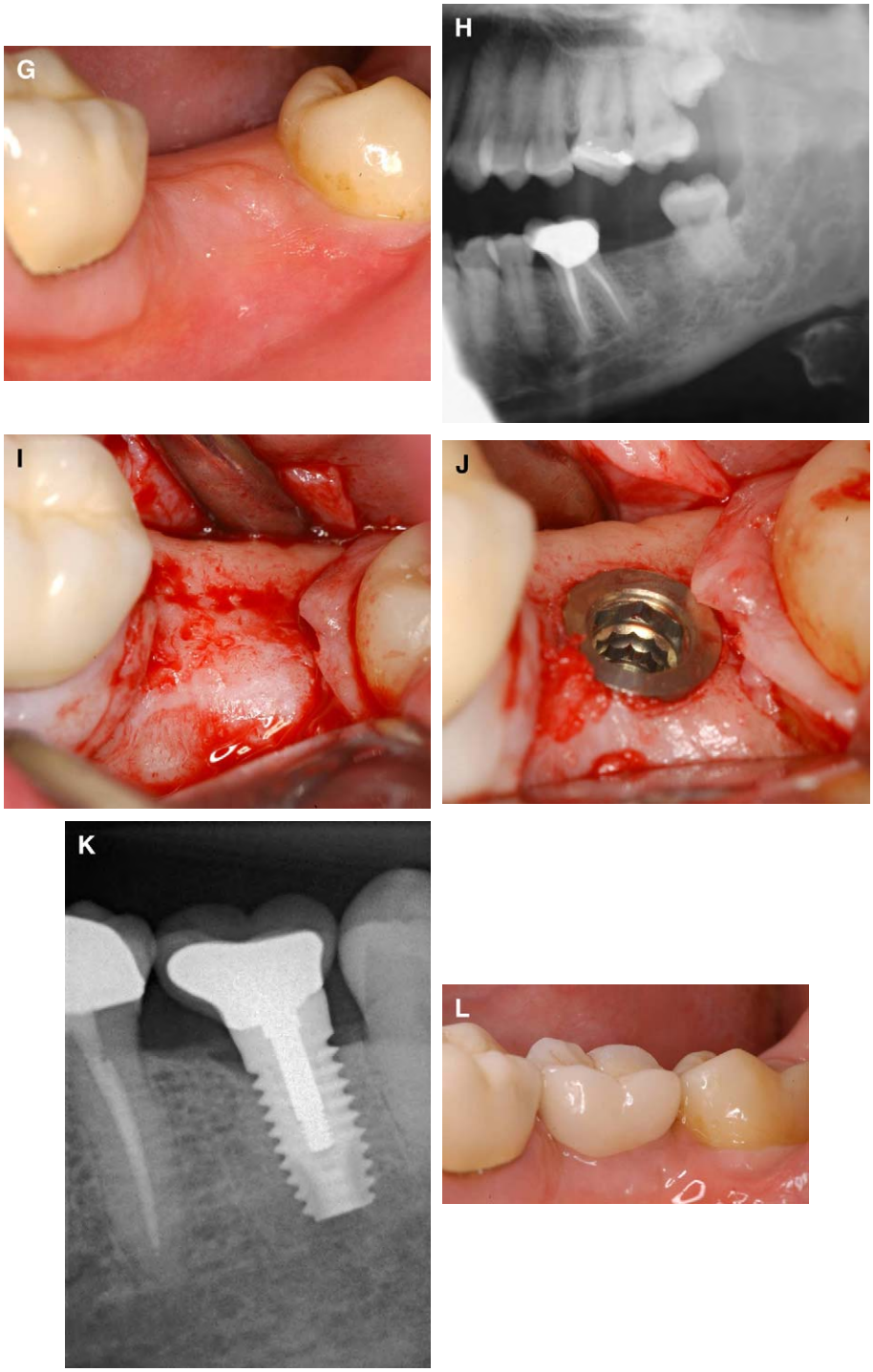

Fig. 4 (*continued*)

The advantage of using autogenous bone without a membrane when grafting an extraction site is that the bone material provides minerals, collagen, viable osteoblasts, and bone morphogenic proteins (BMP). The greatest disadvantage is that when it is used in extraction sites, there is concomitant morbidity when an additional harvest site is used. If the ideal criteria for an extraction site graft material are considered, the rapid bone turnover resulting in less space maintenance may decrease the final results; therefore, other materials may provide more

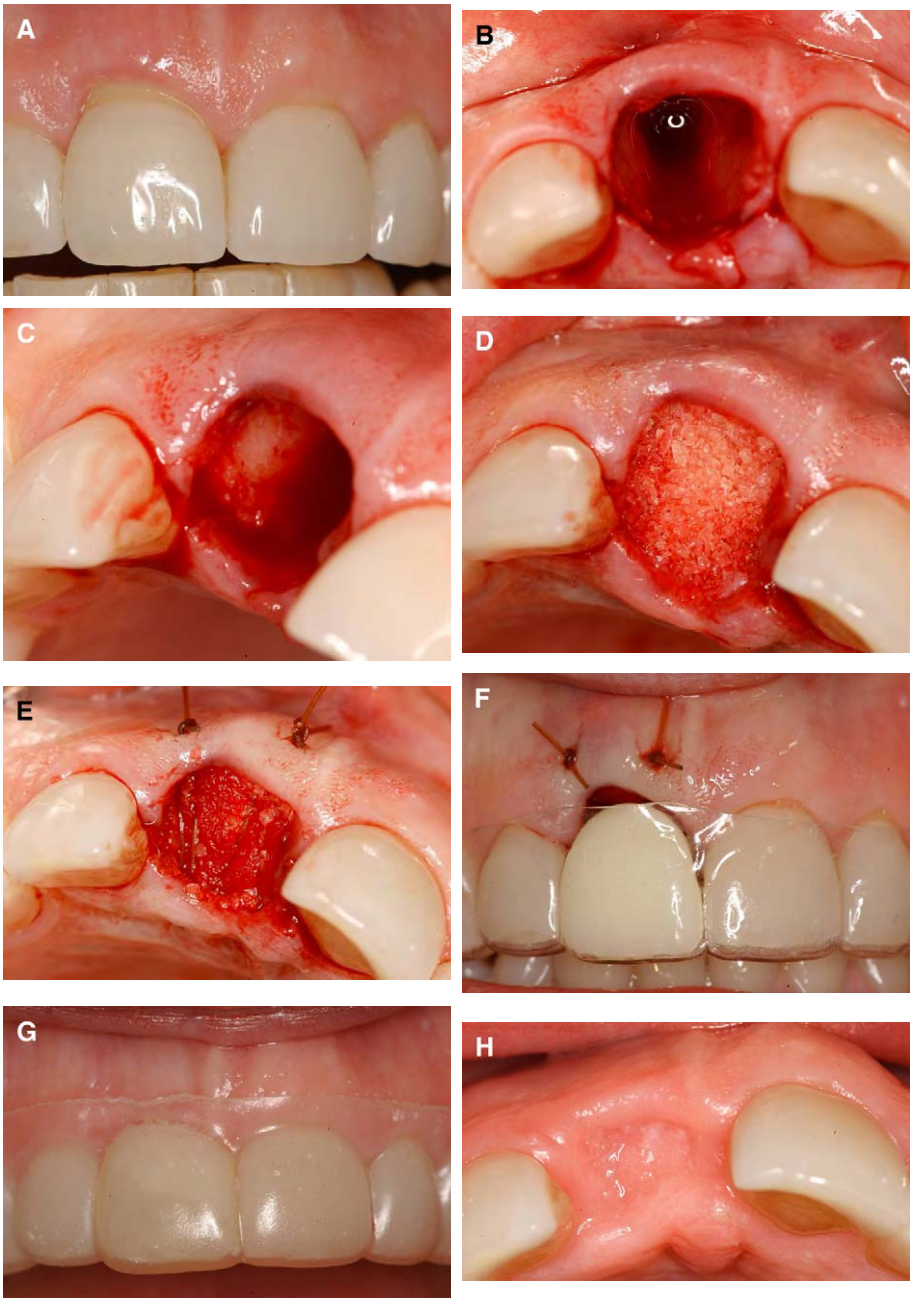

Fig. 5. (*A*) This patient had a right central incisor in need for extraction secondary to coronal fracture and composite repair. There was excellent interproximal bone between the lateral incisor and central incisor and in the interdental area between the two central incisors. However, there was 2 to 3 mm of labial bone loss over the facial aspect along the distal line angle of the tooth, with resultant gingival recession. (*B*) The tooth was extracted atraumatically with the use of osteotomes. Incisions were made only around the neck of the tooth. (*C*) The bone adjacent to the lateral incisor is present at the cemento-enamel junction (CEJ) of the lateral incisor. This is a good prognosticating sign for the final papilla. However, there was bone loss along the labial distal aspect of the tooth, as predicted from the initial preoperative examination. (*D*) Human mineralized bone was 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. (*E*) A piece of collagen was placed over the extraction site and was maintained in position with mattress chromic sutures. (*F*) A temporary prosthesis was placed with the temporary tooth in appropriate form, intentionally leaving a space between the tooth and the gingiva. (*G*) A new temporary was made to allow for the vacuform plastic material to extend over the labial aspect of the gingiva. This created a suction that guided the soft tissue to form underneath the right central incisor temporary. (*H*) Preoperative picture of the patient immediately before placing the implant, using a flapless technique, approximately 4 months after a graft placement. (*I*) The implant is in position using a flapless approach. At this point, the abutment and provisional crown were placed. (*J*) The final restoration in place showing maintenance of gingiva profile.

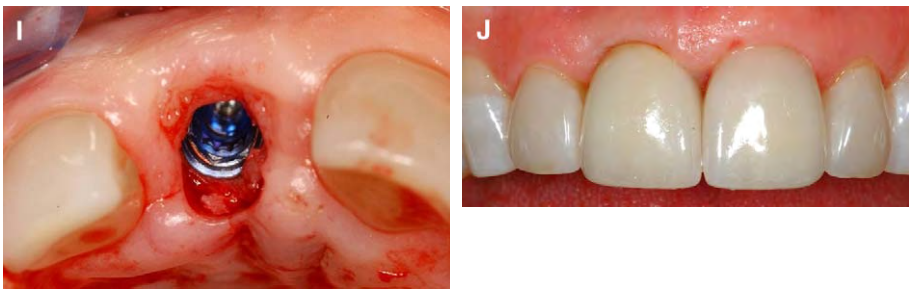

Fig. 5 (*continued*)

ideal results for implant placement, especially in larger defects, esthetic defects, and when the clinician desires to avoid the use of a membrane.

Demineralized freeze-dried bone allograft

Demineralized freeze-dried bone allograft (DFDBA) is derived from human bone whose donors have been screened, selected, and tested to be free of HIV and hepatitis. It is processed to eliminate diseases that might threaten the health of the recipient. The bone is immersed in 100% ethanol to remove fat, frozen in nitrogen, freeze dried, and ground to particles of various sizes depending on the specific graft indication. The lyophilization step allows for long-term storage and decreases antigenicity. One of the processing steps in demineralization is the use of 0.6 N hydrochloric acid or nitric acid, which tends to ensure its disease-free state. The HCl removes calcium and phosphate salts but retains collagen and theoretically exposes the BMP. After washing and dehydration, the material is radiated or cold sterilized in ethylene oxide. The use of radiation above 2.5 megarads is avoided to limit inhibition of bone formation. Studies indicate that cytotoxic compound formation can exist within the graft in the presence of lipids; therefore, removal of lipids is critical when washing the bone upon processing.

Demineralized bone grafts are osteoconductive and can act as a scaffold for bone formation within an extraction site. At 6 months, DFDBA particles are intact in the bone sites. At the edge of newly formed bone, DFDBA particles are active in the process of bone formation; however, the particles located at a distance from the newly formed bone show minimal mineralization or osteogenesis. Although some authors believe that DFDBA has osteoinductive characteristics, Becker showed that, at 7 months, borders of DFDBA bone spicules grafted to human extraction sites appear irregular and that lacunae are empty without evidence of osteoclastic or osteoblastic activity. DFDBA has been considered a space maintaining device. DFDBA seems to be the most frequently used graft material in combination with membranes for bone formation in bone defects. Because of the relative decrease in predictable bone formation, a mineralized bone allograft is preferred for extraction site grafting.

Among autogenous particulate bone and demineralized or mineralized bone allografts, all using a barrier membrane, the type of graft material did not affect the clinical success of the implants. This was the result of a retrospective study with 526 implants placed in regenerated bone followed from 6 to 74 months postloading of the implant. Eight implants failed, with a cumulative success rate of 97.5%.

Bone morphogenic proteins

Wozney suggested the possibility of placing recombinant human bone morphogenetic protein (rhBMP)-2 into extraction sockets to ''accelerate the time at which implants could be placed.'' Thirteen proteins have been identified that are osteoinductive compounds and encourage new bone formation. When used in extraction sites, a statistically significant linear dose-response relationship between rhBMP-2 dose and bone height response has been detected ($P = .007$, rank

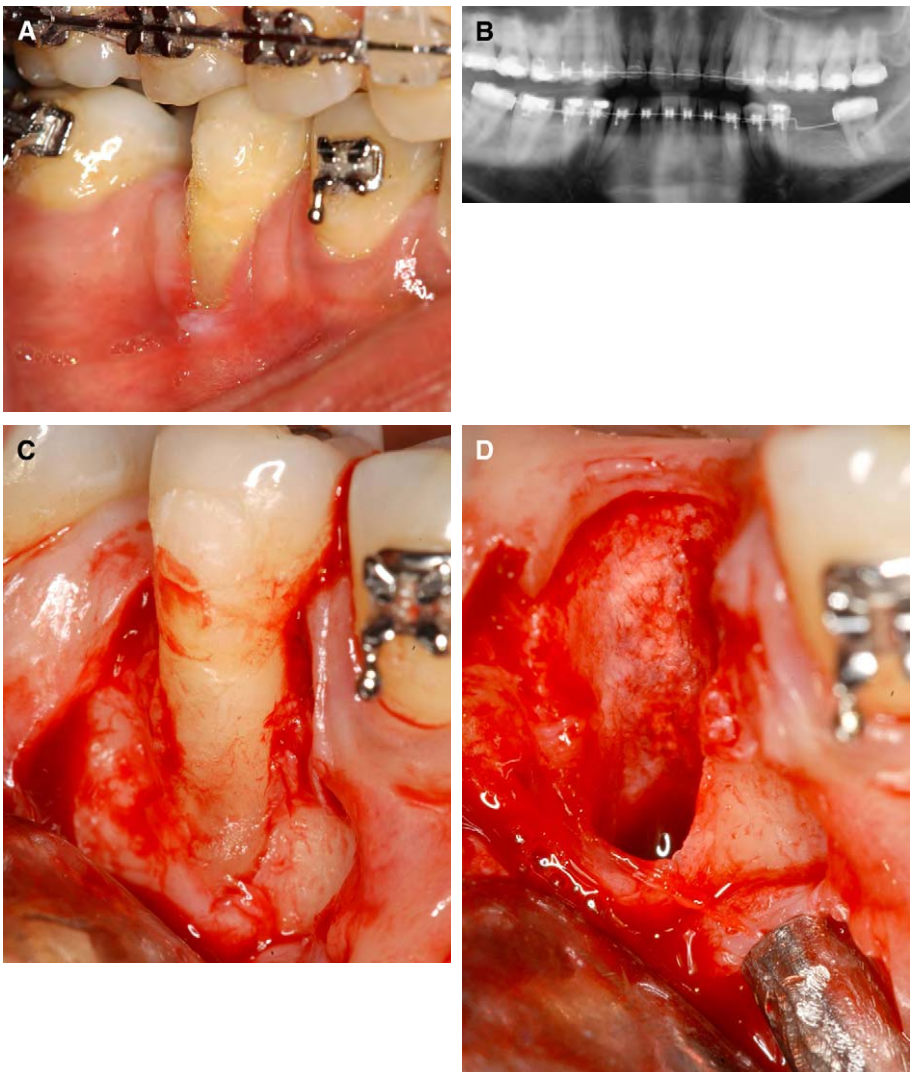

Fig. 6. (*A*) This patient has had orthodontic therapy to create space and to realign her dentition. The mandibular right second premolar has a large area of labial bone loss and soft tissue loss. (*B*) Panoramic radiograph showing the close approximation of the second premolar to the inferior alveolar foramen, just anterior to it, and the area of bone loss. (*C*) A vertical releasing incision was made after an incision made around the tooth, and a full-thickness reflection was performed. The labial root of the tooth was exposed from the bone. The interdental bone adjacent to the adjacent teeth was intact. (*D*) The tooth was extracted, leaving a large vertical labial gap. This patient needs restoration of height and width of the socket. (*E*) A graft of mineralized human bone was placed into the site and compacted firmly. The graft was formed to match the labial contour of the cortical bone. (*F*) The initial V-shaped gingival defect was deepithelialized. The periosteum was scored inferiorly. Care was taken to avoid the inferior alveolar nerve. The flap was advanced and sutured with a 5.0 chromic suture and a 6.0 chromic suture to achieve primary closure. (*G*) The ridge before the implant was placed. The defect healed with epithelium over the defect. (*H*) The interdental implant was placed into the grafted bone. The width of the grafted alveolar ridge allowed a 4-mm-diameter implant to be easily placed. (*I*) The implant in position on radiograph just after it had been exposed. (*J*) A fixed abutment was prepped in the lab and placed to restore this tooth. (*K*) A final restoration is placed over the previously compromised site.

$P = .0063$) among the alveolar ridge preservation patients, indicating that patients treated with higher doses generally produced higher bone height responses as seen with CT scan processed sections.

In the above-mentioned study, the teeth were extracted under local anesthesia. The socket was debrided, and the bony walls were perforated using a one half round bur. The rhBMP/absorbable collagen sponge (ACS) device was implanted into the socket. Eight milliliters of a concentration of 0.43 mg/ml were evenly expressed onto the collagen sponge. The desired amount of the soaked sponge was cut with scissors to fit the socket site. Once the treatment

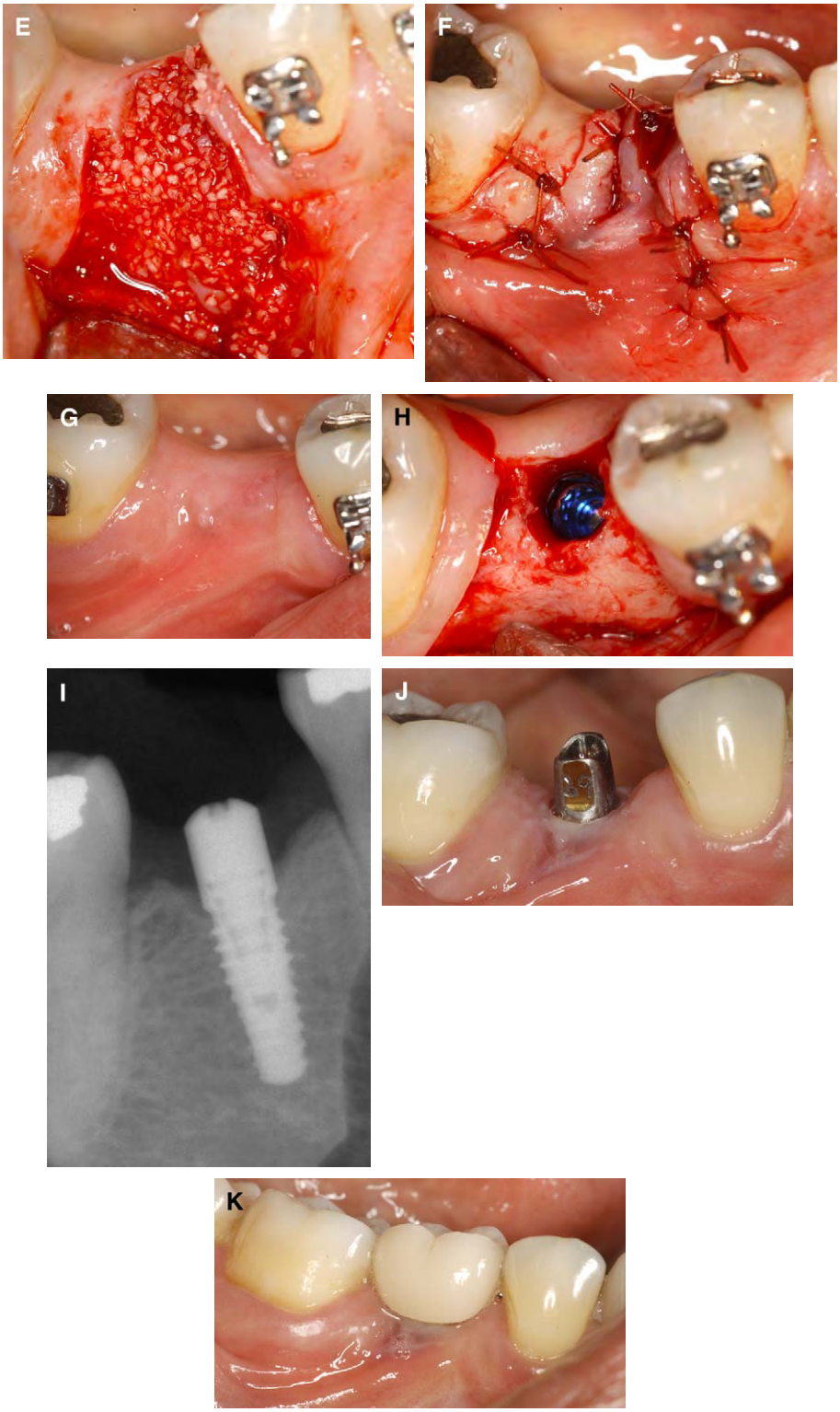

Fig. 6 (*continued*)

area had been rebuilt with layers of sponge, a larger piece of the sponge was positioned over the treatment area to fully fill the treatment site, and the gingiva was advanced to close the site. It was concluded that rhBMP/ACS treatment increased bone height greater than complete fill of the extraction socket. The mean height response indicated that bone formation equaled or

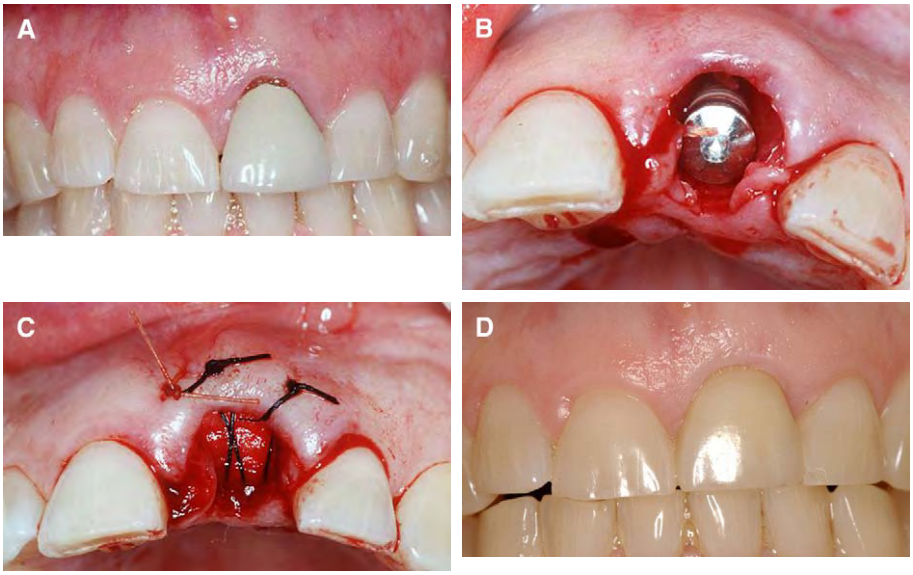

Fig. 7. (*A*) This patient needs a maxillary left central incisor removed. She desires implant placement. The gingival margin on the tooth before extraction is at a different level than the adjacent right central incisor. This case demonstrates that without extrusion of the left central incisor, or without crown lengthening of the adjacent tooth, the gingival margins of the final restoration are the same even though the area has been grafted. (*B*) The tooth was extracted, and the implant was placed. There was a labial defect between the labial surface of the implant and the labial bone. This was grafted. (*C*) A graft of bovine mineralized bone was placed in the defect between the implant and the labial bone. A collagen membrane was placed over the graft and implant and was secured in position with horizontal mattress sutures. A removable temporary was placed. (*D*) The final restoration. The final gingival levels are identical to the preoperative gingival levels. Even with grafting and advancement of the gingiva, the final gingival levels are limited to the level of the bone.

exceeded a complete fill of the extraction socket. However, in this study there was an absence of a negative control group, and there was a significant dose-response effect.

Implantation of rhBMP-2 results in bone formation in a manner similar to osteogenic bone extracts. Recruitment of undifferentiated mesenchymal cells followed by transient cartilage formation is observed. With the appearance of vascularity, cartilage maturation, removal, and bone formation is seen. The resulting bone ossicle becomes populated with bone marrow, and the bone continues to remodel. Thus, implantation of BMP can result in the entire bone formation at an ectopic site. Implantation of increasing amounts of rhBMP-2 results in increased intramembranous (direct transition of mesenchymal cells into osteoblasts) bone formation. The use of BMP recombinant protein in extraction sites to preserve and reconstruct bone deficiency is not well studied, but the preliminary work indicates the potential for this material to be successful in this application.

Surgical techniques

Anterior maxillary teeth

The following techniques discuss methods to graft 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 at least (1) the gingival margin position; (2) the level of bone on the adjacent tooth; (3) the presence or absence of root prominence; (4) the proportions of tooth to be replaced in regards to adjacent teeth; and (5) the levels of bone around the tooth to be extracted, to include apical bone, labial bone concavities, loss of labial or palatal cortical bone, and the presence of apical bone lucencies secondary to previous surgery.

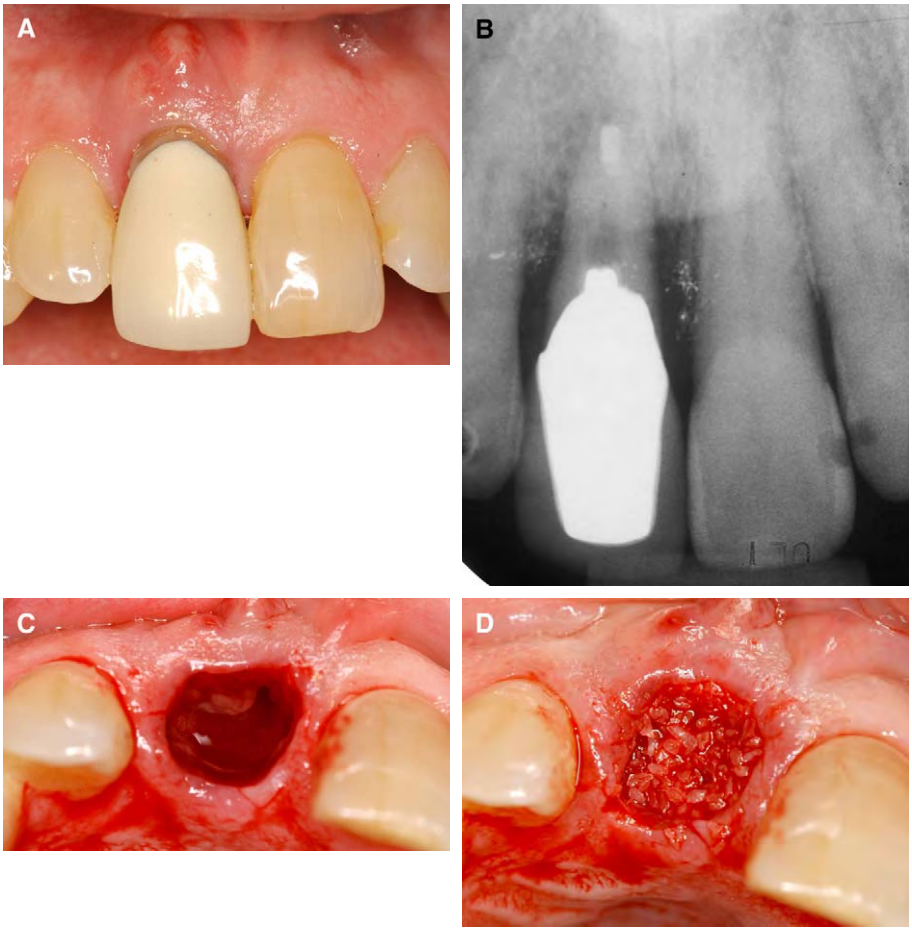

Fig. 8. (*A*) A 58-year-old man with a large area of bone loss over the maxillary right central incisor. The tooth was mobile and hds a draining fissure present over the labial surface of the tooth at the level of the apex of the tooth. (*B*) Periapical radiograph showing significant bone loss to approximately 3 mm from the apex of the tooth. This large restoration had been stable for 14 years before the current problem. The patient was placed on antibiotics and prescribed a mouth rinse to decrease the bacteria flora and was appointed for surgery. (*C*) The tooth was extracted easily after incisions were made around the neck of the tooth. After the tooth was removed, there was a large area of bone loss, extending 9 mm from the gingival margin. Even with the 9-mm pocket that was present on the labial aspect of the tooth, the gingiva form matched the level on the adjacent tooth. (*D*) A graft of human mineralized bone was placed into the defect and compacted to recreate root form anatomy and the labial aspect of the socket. (*E*) A piece of collagen was placed and retained by a horizontal mattress suture. (*F*) The area approximately 4 months after graft placement, indicating sufficient form of the gingiva and root prominence. (*G*) After a crestal incision and small reflection in the sulci of the adjacent teeth, there was sufficient amount of bone found for placement of a 4-mm-diameter implant. (*H*) The implant was placed approximately 3 mm apical to the adjacent gingival margin. After the implant was placed, bone harvested from the drills was placed over the labial aspect to further augment the site. (*I*) The site was closed with two vertical mattress sutures everting the interdental papilla and to advance the flaps coronally. (*J*) Radiograph showing the placement of the implant. (*K*) After 4 months, the implant was exposed with a tissue punch, and a temporary healing abutment was placed. The temporary fixed abutment that had been prepared is visible. Notice the appropriate contour of the root prominence even though the initial bone loss was significant. (*L*) Frontal view of the temporary fixed abutment for the provisional crown. The gingival margin is level with the adjacent tooth, as desired. (*M*) The temporary restoration in place before fabrication of the final restoration. Note the excellent symmetry with the adjacent tooth, which was achieved because of the grafting of the extraction site. (*N*) Notice the contour of the temporary crown, which mimics the natural crown.

Gingival margin position

If the gingival margin on the tooth to be extracted is apical to the ideal position for the planned esthetic restoration, then the tooth needs to be orthodontically extruded or the bone moved using distraction osteogenesis or interpositional osteotomies. Isolated labial bone defects can be grafted. However, if the tooth is extracted and the gingival margin is apical to the ideal

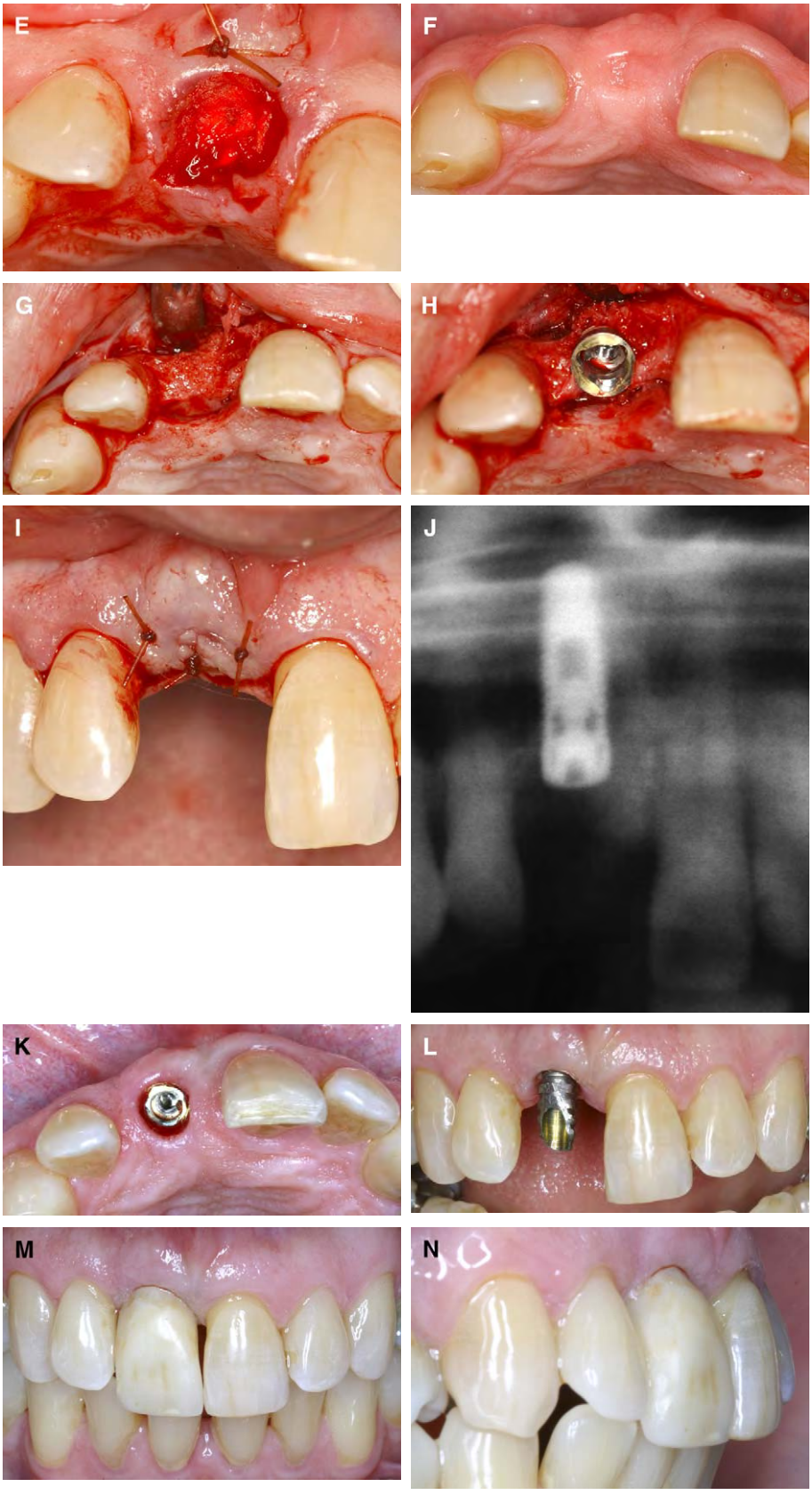

Fig. 8 (*continued*)

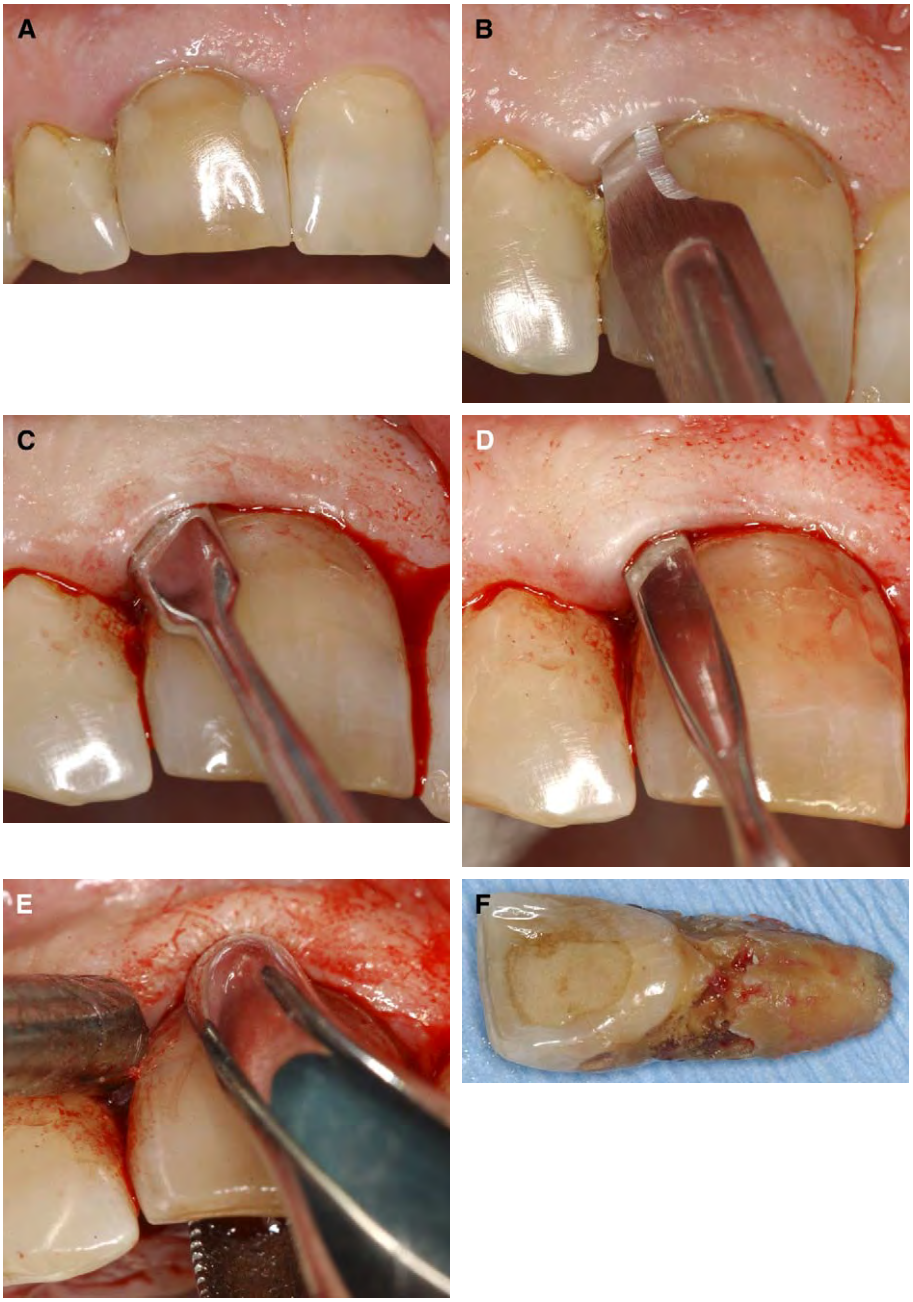

Fig. 9. (*A*) Preextraction view of right central incisor planned for extraction and graft secondary to lingual external resorption. (*B*) A 15c blade is used to incise the gingival attachments at the junction of the bone and tooth. (*C*) A Hershfeld #2 periosteal elevator is used to gently retract the gingiva limited to the junction of the tooth and bone, avoiding elevation of periosteum. (*D*) A periotome is placed at the junction of the tooth and bone and gently tapped to form a separation of the bone from the tooth. (*E*) After the periotome was used to create mobility of the tooth, a small forceps is used to extract the tooth, using rotary movements to avoid trauma to the labial bone. (*F*) The tooth is seen with lingual external resorption. (*G*) A spoon-shaped curette is used to remove granulation tissue, which had replaced the tooth structure that was resorbed from external resorption. (*H*) The tip of a 1-ml plastic syringe was removed, and the particulate graft was packed into the syringe. (*I*) The syringe was placed into the depth of the socket, and the particulate graft was condensed into the socket. (*J*) Gauze was used to absorb fluid expressed from the socket and to further compress the graft. (*K*) The graft was further compressed using the small end of a periosteal elevator or other blunt-ended instrument, such as a burnisher. (*L*) Scissors were used to cut a 3- to 4-mm–thick piece of Collaplug. (*M*) The Collaplug was compressed between fingers to form a thin disc that was placed over the compressed graft. (*N*) A 4-0 suture was placed first through the labial gingiva, superficial to the Collaplug, through the palatal gingiva, back through the palatal gingiva, and then again through the labial gingiva to form a horizontal mattress suture. (*O*) The suture was tied to gently approximate the gingiva to its original position. The temporary restoration was placed.

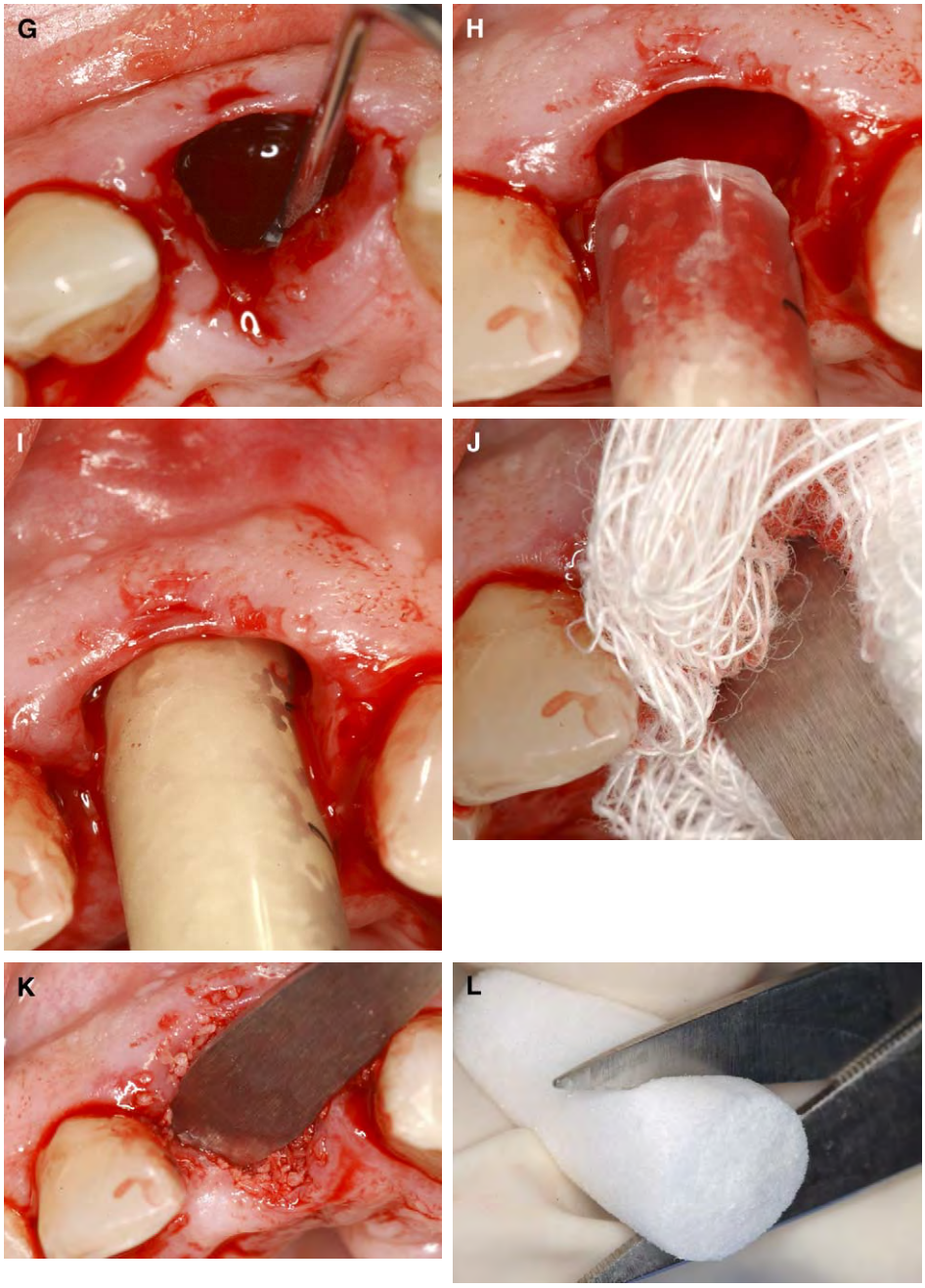

Fig. 9 (*continued*)

level, then the final restoration will have the gingiva at a compromised location. Grafting the extraction site does not usually correct gingival margin location problems. Adjunctive procedures to correct this may include gingival margin manipulation of the adjacent tooth, such as crown lengthening (Figs. 5, 7, and 8).

Level of bone on the adjacent tooth

Clinical evaluations by Tarnow and Ryser in separate publications indicate that the most important factor that predicts the presence of papilla between a tooth and 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.

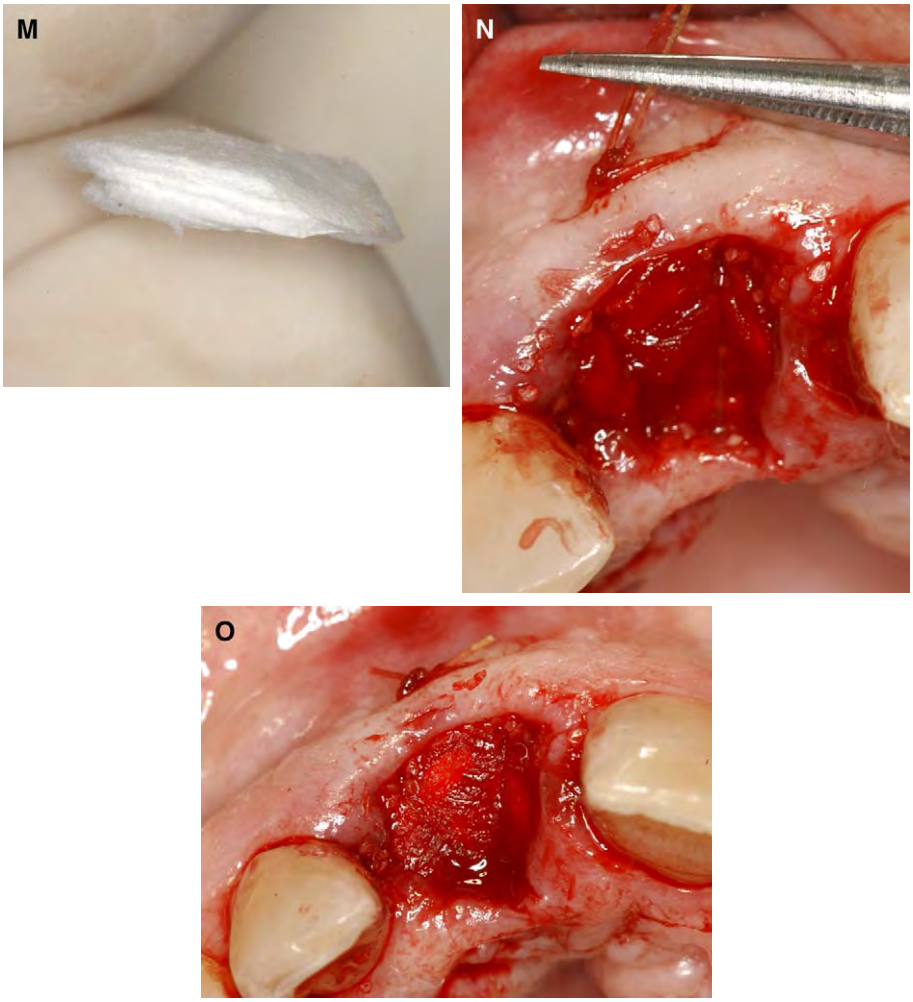

Fig. 9 (*continued*)

Thus, if the bone level on the adjacent tooth is at the cemento–enamel junction, then the papilla is likely to be adequate as long as the proportions of the final restoration are reasonable (Fig. 5).

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 that is known to be the root prominence. When a tooth is extracted and the site not grafted, there is labial bone loss to some degree that results 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 (Figs. 5, 7, and 8).

Proportions of tooth to be replaced in regards to adjacent teeth

In the preoperative evaluation of the patient, if the tooth to be replaced is longer or shorter than one to be extracted, then the implant position may be altered to compensate for planning for a gingival margin perhaps more apical than original. If the tooth proportions indicate that a more coronal positioning is indicated, then appropriate grafting may be necessary to achieve the desired result. If the implant is placed too superficially and the esthetic restoration requires lengthening the tooth without moving the incisive edge, then the resultant problem is the result

of improper vertical positioning of the implant. It is critical to place the implant with the final crown form determined from preoperative planning using ideal crown proportions.

Levels of bone around the tooth to be extracted, to include apical bone, labial bone concavities, loss of labial or palatal cortical bone, and the presence of apical bone lucencies secondary to previous surgery

If there have been previous surgical procedures performed on the tooth to be extracted, or if the tooth has a history of previous avulsion and replacement, then the bone around the tooth may have local deficiency. Apical procedures may result in concavities that have a direct effect on implant positioning and stability. If apical bone concavity or labial bone loss is expected, then at the time of the extraction grafting can be used to augment the site before placing the implant (Table 1 and Fig. 9).

Surgical method

For patients who are planned for extraction and graft without immediate implant placement, an Essix (clear thermoformed plastic material)-type temporary 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. Sixteen weeks after extraction and graft, the implant can be placed and immediately provisionalized if indicated.

Tooth extraction protocol

Local anesthesia is administered, including infiltration around the tooth for improved hemostasis. Sulcular incisions are made around the tooth to be extracted using a 15c-sized

Table 1
Surgical method: step by step—anterior teeth including premolars

Procedure	Comments
Make an incision in sulcus around tooth.	Use a small scalpel blade, and maintain all gingiva.
Use a small periosteal elevator (Hershfeld #2) to identify junction of tooth and bone.	The small periosteal elevator prevents trauma to the gingiva. Only dissect to identify by feel the bone–tooth junction without elevation of periosteum.
Use periotome instrument to separate the bone from the tooth.	Use gentle pressure or gentle mallet to allow preservation for 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 the granulation tissue from the socket.	Remove only the granulation tissue. Do not scrape the bone excessively.
Evaluate the levels of bone on mesial, labial, distal, and palatal aspects of the socket.	This provides insight into timing of future procedures.
Place particulate graft material into 1-ml syringe.	Reconstitute graft material as per recommendations of the tissue bank.
Place syringe into socket and firmly compress the graft into the socket.	Remove excess fluid with sterile gauze and pack the defects from within the socket to reconstruct the original bone morphology.
Cut and form a disc of Collaplug-type collagen material and place it over the graft site and tuck it under the edges of the gingiva. Place a 4-0 size suture in a horizontal manner to compress the gingiva to the site.	This material aids in retention of the graft during the first week and promotes reepithelialization of the site. Primary closure is Not achieved to avoid disruption of the gingival architecture.
Place a removable temporary.	The temporary may be tooth borne using an Essix type retainer or an removal partial denture (RPD) type. Place gentle pressure on the papilla and avoid pressure on the graft. Do not use plunging pontics. or you will lose a portion of the graft.

scalpel blade. Care is taken to minimize trauma to the gingiva. The scalpel blade should be angled to closely follow the curvature of the tooth without cutting the gingiva. A series of thin elevators, such as a periotome, are used to first separate the bone from the labial, interproximal, and palatal surfaces of the tooth to allow removal of the tooth without removal of 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 avoid 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 to reconstruct the osseous defects. Soft tissue remnants are removed from the socket with a dental curette, and the graft is 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 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 is mechanically placed into the syringe. The mineralized graft material used by this author is human mineralized cancellous or cortical particulate bone, 350 to 500 μm in diameter. The bone is provided in a sterile container that has been sterilized with radiation. Most extraction sites rarely require more than 0.5 ml of graft material to graft the socket.

The syringe with the graft material in it 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 is useful to aid in compaction of 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 material (Collaplug) 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 avoid elevation of the gingival from the underlying labial bone to preserve the blood supply to the thin labial cortical bone. One or two 4-0 sutures are placed in a horizontal mattress fashion to gently conform the gingiva 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. Thus, 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.

Techniques to graft the anterior maxillary tooth extraction site in the presence of large bone defects

When presented with an anterior tooth that has extensive bone loss usually over the labial aspect of the tooth, with the palatal bone intact, the surgical technique is similar to that described previously. Incisions are made around the tooth only, 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 space previously taken up by the tooth as the pocket of the graft. The tooth and roots are removed carefully. After removal, granulation tissue is removed. Teeth with large external resorption areas may have granulation tissue present taking up the volume lost by the tooth during the resorption process.

The particulate graft is placed with a 1-ml syringe and compacted to recreate the root form and volume of the tooth. Often the apical region is easily reconstructed from within the socket. A resorbable membrane can be used depending on clinician preference, although in the presence of low-grade infection membranes may be prone to infection. This author removes the tooth, grafts the site, covers the extraction socket with collagen material, and does not use a membrane.

Grafting molar extraction sites

If the treatment plan includes placement of an implant into a posterior tooth site, it is often advantageous to graft the molar site to allow for ideal bone volume for a wide-diameter implant. The goal is to have sufficient bone present for an appropriate-sized implant with regard to the molar-sized restoration. The following technique has been useful for grafting the posterior molar site (Table 2).

Incision design

The multi-rooted tooth, after extraction, leaves a large defect in the bone. When grafting the defect and socket with particulate material, the desired result is dependent on retention of the graft within the socket. To allow for primary closure of the site after placement of the graft, incision design is critical.

The incision design allows for advancement of the labial keratinized gingiva 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 to allow for full-thickness flap elevation to expose the lateral aspect of the alveolus and to allow for advancement of the flap over the site after grafting. When there has been extensive resorption of the labial or facial cortical bone, the flap elevation may be easier with sharp dissection. Care should be taken to avoid perforation of the labial gingiva. After the flap is raised, the periosteum is scored and relieved to allow for passive advancement of the flap.

Tooth extraction and graft procedure

The tooth is elevated gently and removed with minimal lateral subluxation. All attempts should be made to preserve the lateral cortical bone. The tooth can be sectioned to facilitate bone preservation. Granulation tissue is curetted. The site is irrigated gently with sterile saline, and the flap is tested to assure passive rotation to the lingual tissues.

Table 2
Surgical method: step by step—molar teeth

Procedure	Comments
Make an incision in thesulcus around tooth but limit only to labial gingiva without incising interdental region. Make releasing vertical incisions to avoid elevation of the interdental gingiva.	Use a small scalpel blade, and maintain all gingiva. The goal is to reflect a labial based flap without disruption of the adjacent interdental gingiva. The flap is 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. Avoid 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 mesial, labial, distal, and palatal aspects of the socket.	This provides insight into timing of future procedures.
Before placing graft material, score the periosteum at the base of the flap to allow passive advancement of the flap. Periosteal release may be necessary along the vertical release incisions.	The goal is to allow for tension-free closure. Keep the periosteal release limited to the periosteum and avoid dissection of the adjacent musculature. This limits bleeding and patient postoperative morbidity.
Place particulate graft material into a 1-ml syringe.	Reconstitute graft material as per recommendations of the tissue bank.
Place syringe into socket and firmly compress the graft 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.	The primary closure maintains the graft in position and is less prone to graft escape compared with using only Collaplug covering in the molar site.

The 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 a scalpel and forceps. The particulate graft is placed into the syringe and firmly compacted into the extraction site. The graft material is compacted with the aid of 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.

Usually, resorbable suture (4-0 chromic on a tapered needle) is used to approximate the edge of the keratinized labial gingiva 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 keratinized labial gingiva is "banked" toward the lingual aspect of the ridge and is transposed to the labial surface of the abutment after the implant is placed and exposed for restoration.

Postoperative instructions

Patients are given antibiotics and pain medication. Antibacterial rinses are started 1 to 2 weeks after graft placement. Soft diet instructions are given to the patient. The sutures are removed 7 to 10 days after graft placement. Three months after graft placement, radiographs are taken to evaluate the bone height for implant placement. Implants are placed 4 months after graft placement.

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Horizontal Ridge Augmentation Using Particulate Bone

Michael S. Block, DMD

Department of Oral and Maxillofacial Surgery, Louisiana State University School of Dentistry, 1100 Florida Ave., New Orleans, LA 70119-2799, USA

Thin alveolar ridges prevent dental implant placement. A variety of autogenous, allografts, xenografts, and alloplastic onlay grafts, alone or in different combinations, have been used to provide sufficient ridge width for proper positioning of endosseous implants.

Disadvantages with the iliac crest donor site include significant resorption, patient morbidity, and high costs due to hospitalization and general anesthesia. Early placement and loading under function of dental implants within iliac crest onlay bone grafts have shown to markedly decrease progressive resorption of the graft and maintain a significant quantity of bone and a high percentage of stable functional implants over the long term.

Symphyseal or ramus grafts from the mandible seem to undergo less resorption due to a thick cortical layer and rigid three-dimensional structure. Complications associated with harvesting symphyseal grafts include a limited amount of donor bone, damage to the anterior dentition, and sensory nerve disturbance in up to 10% of patients.

Barrier membranes placed over bony defects allow cells from the adjacent bone to populate the space under the membrane and generate bone under the membrane. Successful lateral ridge augmentation using a combination of block and particulate symphyseal or ramus bone in conjunction with barrier membranes has been reported. Complications with membranes include tissue dehiscence, membrane displacement, and membrane collapse reducing the volume of the graft. Long-term evaluation of osseointegrated implants in vertically regenerated bone using the principles of guided bone regeneration with autograft or allograft showed that the regenerate bone responds to implant placement similar to nonregenerated bone.

Particulate autogenous bone has been used to augment the mandible. Control of the surgically expanded soft tissue volume is believed to prevent resorption of graft material over the long term. With the procedure described by Marx, a full-thickness periosteal reflection of the bone is performed, and dental implants up to 15 mm in length are placed to create, control, and maintain the periosteum from the bone. Bovine bone mixed with autogenous particulate bone combined with tissue sealant (fibrin glue) has been reported as a successful method to augment the horizontal dimension of the ridge, using an open approach to place the material.

Hydroxylapatite augmented ridges are infiltrated with bone several years after ridge augmentation. This osteoconductive material, when placed under periosteum using a simple tunneling technique, is eventually infiltrated with bone. Implants have been placed successfully into hydroxylapatite augmented ridges 5 to 10 years after the ridges have been augmented.

Human mineralized cancellous bone can be used for preservation of ridge width after tooth extraction. By preserving the space that was previously maintained by the presence of the tooth, the particulate graft, after 4 months, has excellent ridge width and sufficient preservation to place wide-diameter implants. Severe labial bone loss was reconstructed at the time of tooth extraction with particulate material. The advantage of this material is that it is slowly resorbed

E-mail address: mblock@lsuhsc.edu

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and replaced with bone, maintaining space and the mineralized graft material's osteoconductive properties.

Based on our review of the literature, common themes persist. If the periosteum is raised and the space is maintained with an osteoconductive material, bone ingrowth into the space can occur. For dental implants, it is desired to have a high density of bone formation within the augmentation without excessive loss of volume during the remodeling phase of the augmentation material. The ideal ridge augmentation material for implant reconstruction has the following characteristics:

- The graft material should be able to maintain space for the time necessary to achieve bone ingrowth and implant healing. Bone ingrowth should be rapid and of sufficient density for implant stabilization.
- The resultant ridge augmentation should be stabile over the time for graft consolidation and implant integration, which may take 6 to 8 months.
- The resultant ridge augmentation should be stabile after the implants have been restored, without evidence of bone loss.
- The graft material should be able to promote osteoconduction of the neighboring cells to form bone within the augmentation.
- The bone augmentation material should be able to be remodeled into long-lasting bone based on the functional matrix theory.
- The material should have ease of placement to avoid patient morbidity.
- The material should have predictability, with an incidence of success at least equal to onlay grafts.

The technique used for horizontal augmentation is similar to the ridge augmentation methods described for hydroxylapatite augmentation of the edentulous ridges. Because of the bone ingrowth found within hydroxylapatite-augmented ridges, without the use of membrane barriers and the evidence of the osteoconductive nature and slow resorption found with mineralized bone particles, a subperiosteal tunneling approach with placement of the particulate graft material directly on bone is performed in patients whose alveolar ridges have sufficient height but insufficient width for implants. This graft technique results in bone formation sufficient to allow placement of at least small-diameter implants, with maintenance of the newly formed bone after final restoration.

Patients are selected for this procedure if they have satisfactory vertical height of the posterior alveolus superior to the inferior alveolar canal but less than 4 mm of bone width. The patients are warned that particulate grafts may resorb and may not result in sufficient bone for augmentation. If this happens, onlay grafting with ramus or symphyseal bone is performed. In a consecutive series of 35 patients by this author, onlay grafts were not required because the resultant ridge width was sufficient for the placement of at least small-diameter implants. However, there was a 2% incidence of implant failure in the grafts and a 5% incidence of isolated graft resorption adjacent to a natural anterior tooth near the incision that resulted in a ridge that was too thin for implant placement.

The patient who is a candidate for the proposed particulate onlay procedure should have adequate vertical height but lack horizontal width. In addition, the shape of the thin crest should widen as the ridge approaches basal bone, with the resulting thin ridge forming a medial wall and the wider inferior aspect forming a ''floor'' for the graft. This two-wall type defect is ideal for this procedure.

Surgical technique

Topical anesthesia is placed over the edentulous ridge. Up to 3.6-ml of 2% Xylocaine with 1:100,000 epinephrine is infiltrated into the edentulous ridge as a hydropic dissection, limited laterally to the external oblique ridge and posteriorly up to the retromolar pad, without violation of the peripheral muscle attachments (Fig. 1A). Ten minutes are allowed before starting the surgery.

The general principle for choosing the incision location is to keep the incision away from the planned tunnel and to allow for tension-free closure. If the incision is too close to a natural

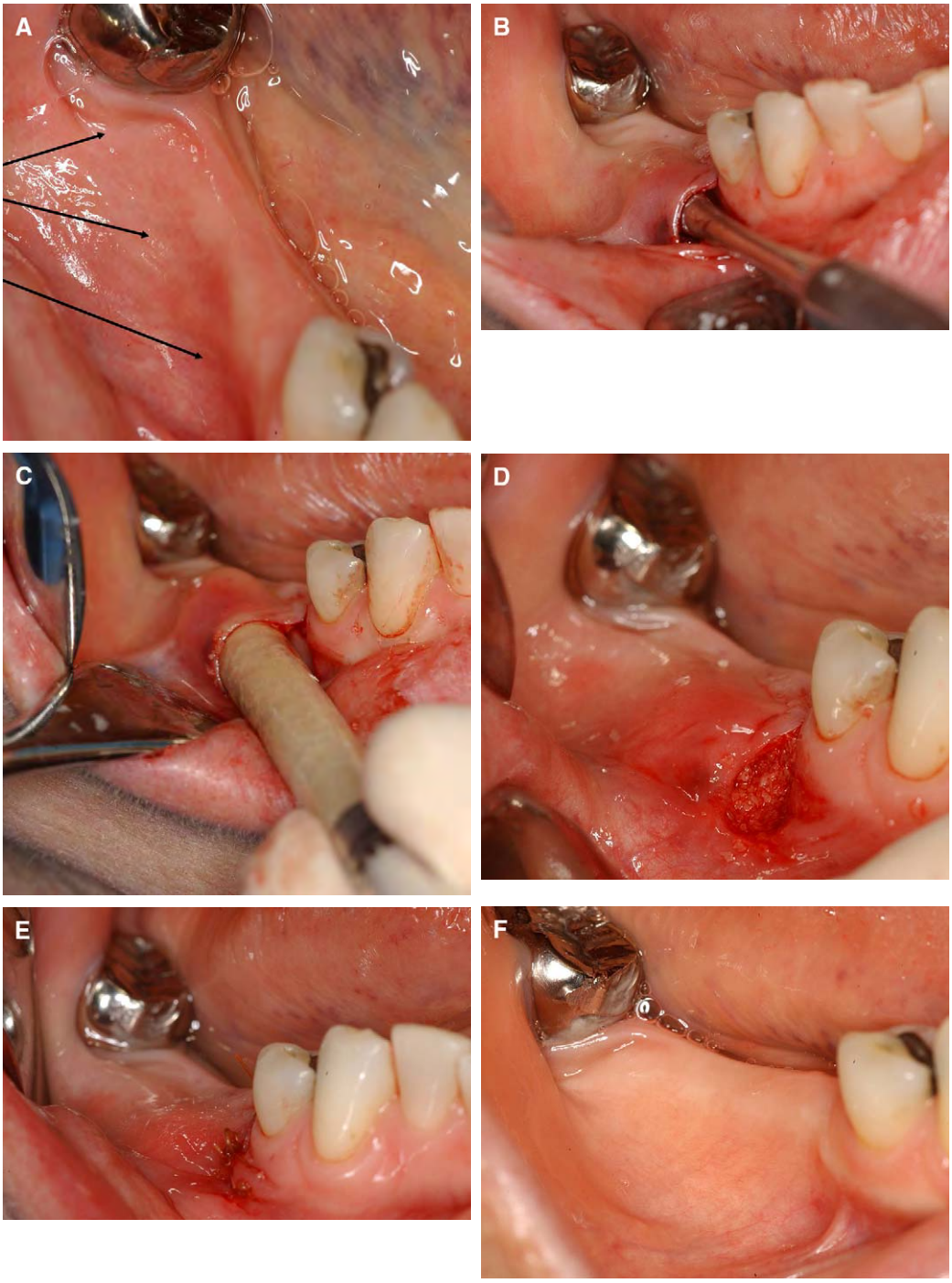

Fig. 1. (*A*) Patient presents with thin right mandibular posterior ridge with less than 3 mm width determined by probing. Treatment plan is for an implant-supported, three-unit prosthesis. The arrows point to the area of the planned augmentation. Local anesthesia is administered only in these areas to perform a hydropic dissection. (*B*) After administration of local infiltrative anesthesia, a small vertical incision is made, and a conservative subperiosteal tunnel is created. Care id taken to preserve lateral and posterior muscle attachments. (*C*) For this patient, 1-ml of human mineralized cancellous bone (350–500 μm diameter) was placed into a 1-ml syringe with the tip cut at a bevel. The graft was placed into the tunnel directly on the bone and compacted to form a firm augmentation. (*D*) The graft is compacted firmly into the tunnel. Note the graft augmenting the area adjacent to the premolar tooth. (*E*) Resorbable sutures were used to close the incision. Note the obvious augmentation. (*F*) After 16 weeks to allow for graft consolidation and bone formation, the patient returns for implant placement. The ridge palpates firm and resists penetration with a small needle. (*G*) The augmented ridge before placing the implants. Note the vascularity of the new bone. (*H*) The implants were placed requiring at least 35 N-Cm torque as per the drilling console. (*I*) A 2-year, post-restored radiograph showing excellent bone preservation at the implant sites. (*J*) The final prosthesis, fabricated after 4 months of healing of the implants in the graft.

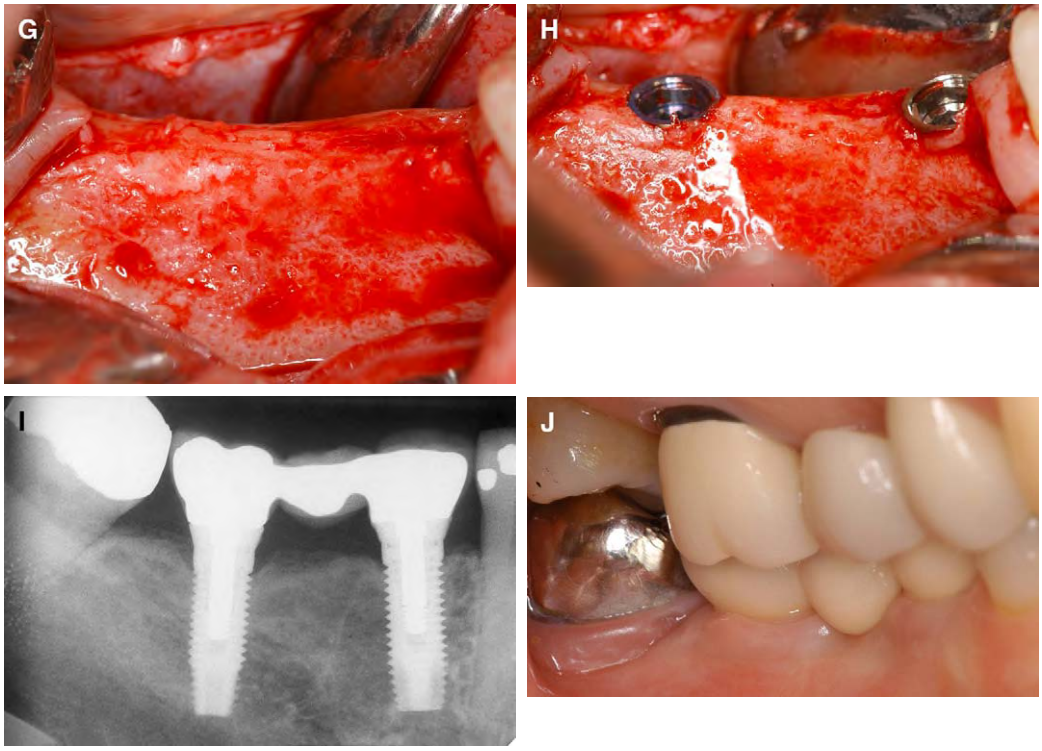

Fig. 1 (*continued*)

tooth, closure is difficult after the augmentation due to the tenting of the tissue from the graft. An anterior location may be useful.

The incision to access the thin ridge is made starting on the superior aspect of the crest running inferiorly in a vertical fashion (Fig. 1). The incision can also be placed inferior to the superior crest region but should not cross the attached tissue on the crest into the lingual mucosa. If the incision enters the loose lingual mucosa, then closure is more difficult, and incision breakdown may occur.

Using a small, blunt-ended periosteal elevator, a subperiosteal tunnel is developed posteriorly to create a well-defined pocket. Care is taken to avoid excessive dissection, keeping the dissection limited to the external oblique ridge and anterior to the retromolar pad without violating 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. It is critical to avoid excessive lingual dissection to maintain a well-defined tunnel for graft placement and to prevent migration of the particles after placement. At the site of the incision, the tissue is gently reflected anteriorly to allow for tension-free closure.

After the subperiosteal tunnel is formed, the particulate material, ranging in volume from 0.5-ml for two tooth sites to 1.5-ml for missing premolars and molars, is placed. Most posterior edentulous ridges require 1-ml of graft material. The tip of a plastic 1-ml tb-type syringe is removed at an angle to form a bevel; this is similar to the syringes used in the past for hydroxylapatite augmentation.

The human mineralized bone graft material is hydrated and mechanically placed into the 1-ml syringe(s). The particle size used by this author ranges from 350 to 500 μm. Smaller particle sizes tend to flow with the blood, and larger sizes can pierce the overlying mucosa due to sharp edges.

For larger (1.5-ml) augmentations, two syringes are used to facilitate the surgery. With the aid of gentle retraction using a small periosteal elevator, the syringe is inserted, bevel down, into the subperiosteal tunnel; care is taken to place it directly onto bone. The syringe is advanced to the most posterior aspect of the planned augmentation. With gentle pressure, the graft material is extruded from the syringe and firmly compacted in position, forming a dense graft. Digital

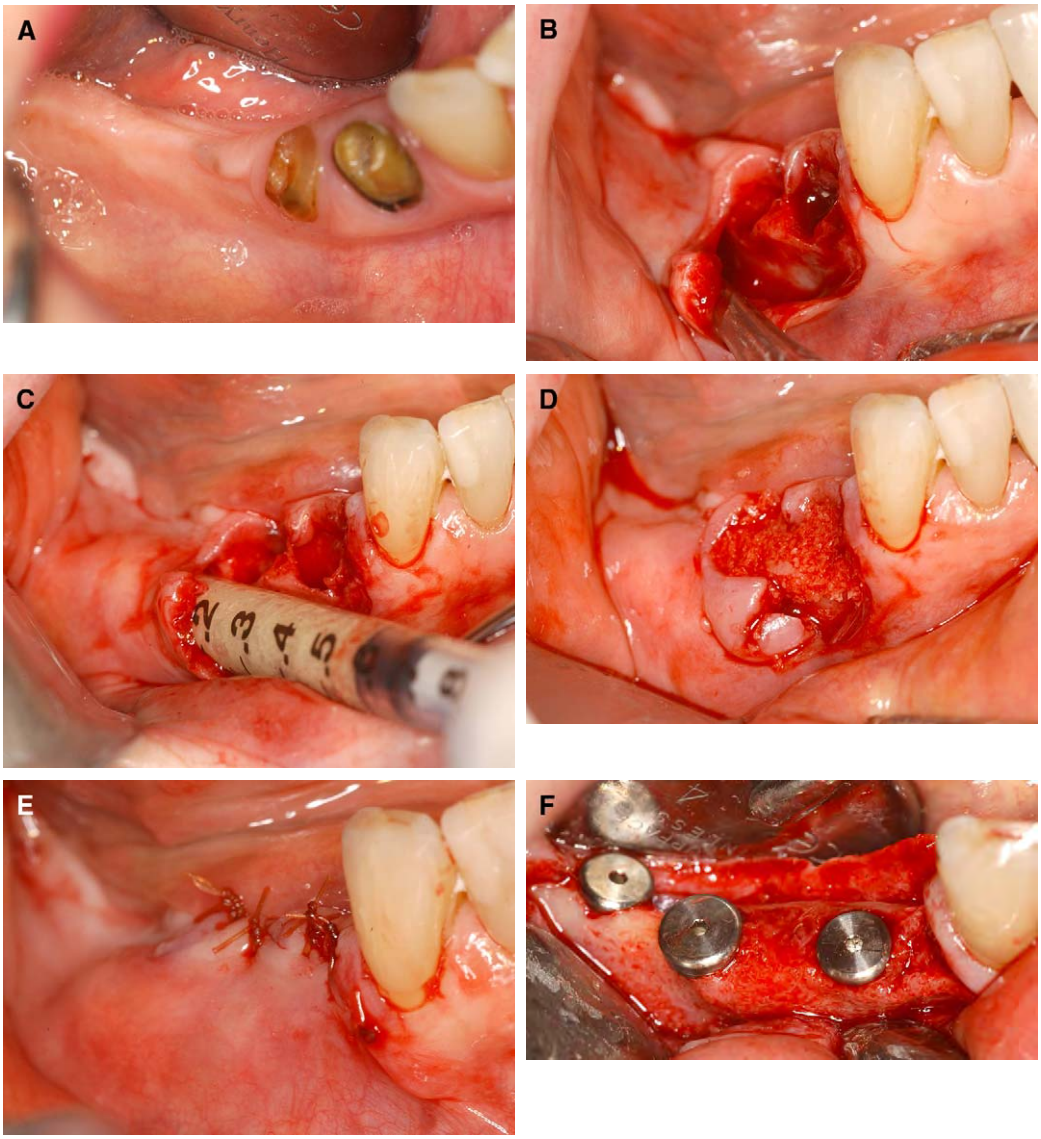

Fig. 2. (*A*) A 78-year-old woman with two premolars in need of extraction and a thin ridge posterior. The patient desires a fixed restoration in this quadrant. (*B*) A vertical incision was made anterior to the first premolar, combined with a sulcular incision around the necks of the two teeth planned for extraction. A subperiosteal tunnel was created for the posterior ridge augmentation. Care was taken to avoid excessive stripping laterally. (*C*) Approximately 1-ml of human mineralized bone was placed into a 1-ml syringe and compacted firmly into the posterior subperiosteal tunnel. (*D*) The graft has been placed into the extraction sites in preparation for placing implants after 4 months of healing. Note the posterior extent of the graft. (*E*) The periosteum has been scored to allow for a tension-free closure over the extraction sites. Note the clearly defined posterior extent of the graft. (*F*) After allowing 4 months for graft consolidation, a crestal incision was made to expose the graft site. Three implants have been placed. Note the clear demarcation of the graft, which is similar in position as seen in Fig. 2E.

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 using interrupted resorbable sutures.

Patients are placed on antibiotics and analgesics. No prostheses are allowed over the grafted sites for 4 months. The patients are instructed to ingest a soft diet without chewing on the grafted side and are followed weekly and then monthly.

Usually, the thin ridges have a 5- to 8-mm lateral ridge augmentation immediately after placement of the material, with subjective evaluation indicating maintenance of at least 50% of the augmentation 4 months later. A few patients may be prone to more resorption and a few to less resorption. The best results are in patients with obvious two-wall–type morphology (Figs. 2–7).

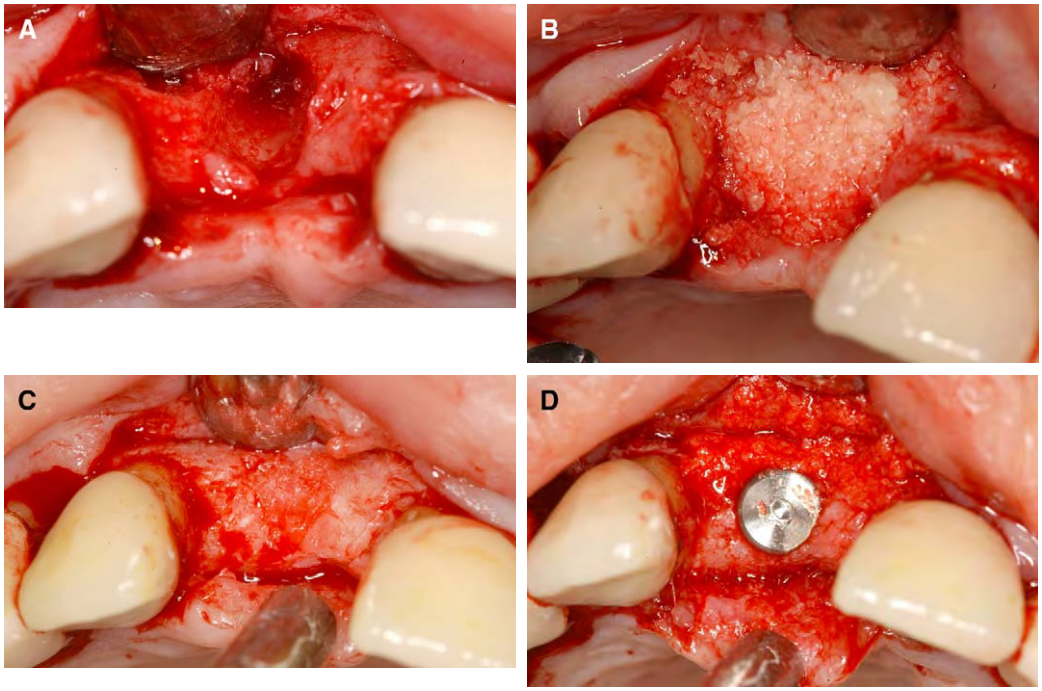

Fig. 3. (*A*) This patient had a central incisor removed, leaving a significant horizontal defect. There is insufficient bone present to place an implant. A crestal incision was combined with sulcular incisions to allow for creation of an envelope-type flap. (*B*) A particulate graft of human mineralized bone was placed to augment the thin maxillary bone. After the graft was firmly compacted in position, the flap was closed. (*C*) After allowing 4 months for bone consolidation, a crestal incision combined with sulcular incisions was used to expose the grafted site. Note the excellent consolidation of the graft. (*D*) The implant is in a proper position in relation to the adjacent teeth.

Summary of clinical results

Incision healing

The incisions heal uneventfully in 75% of patients, with small incision breakdown and loss of a small amount of the graft adjacent to the incision. The open incisions heal within 7 days by secondary intention. Open incisions are treated with gentle irrigation and the use of a gentle mouth rinse until the sites heal.

Ridge ''feel''

The ridges are firm to palpation within 2 weeks and are ''bone hard'' after 3 months. At 3 months, radiographs are taken, and the patients are scheduled for fabrication of the surgical guide stent and implant placement. After 4 months, graft resorption may occur, and the graft site can decrease in width, similar to autogenous grafts.

Implant placement observations

Four months after ridge augmentation, implants are placed into the grafted ridges. For implant placement, a crestal incision is made combined with anterior and posterior vertical release if necessary, followed by full-thickness periosteal reflection to expose the ridge. After confirmation of at least 5 mm of ridge width, implants are placed; the number and location are dependent on the prosthetic plan. In 10% of patients, the ridge was too narrow in the site immediately adjacent to the most anterior tooth (canine or premolar) secondary to loss of graft from incision dehiscence, but the ridge was sufficient two teeth distal from the adjacent tooth for implant placement. In these ridges, the anterior tooth in the posterior restoration is typically cantilevered forward based on two premolar- and molar-positioned implants.

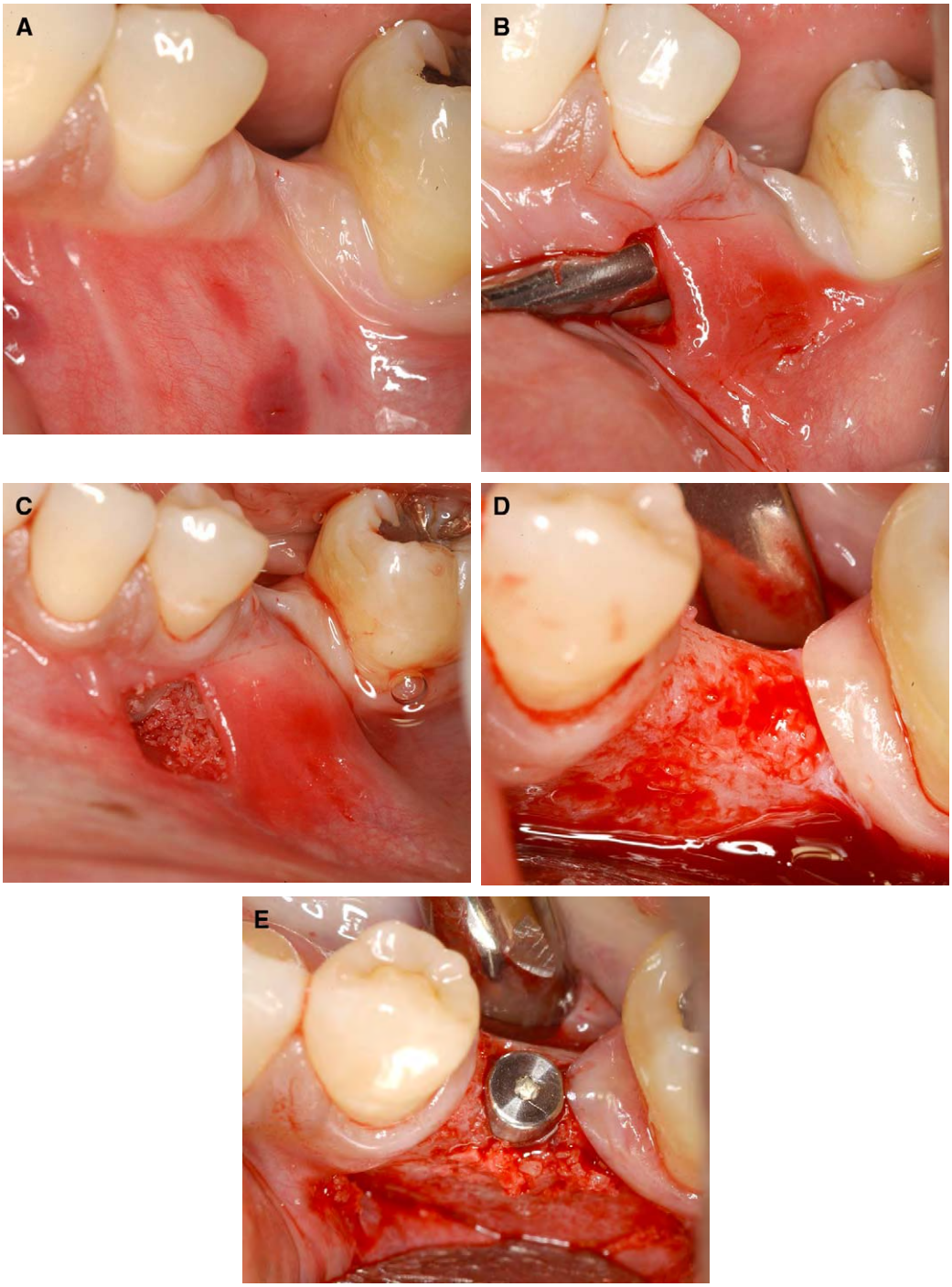

Fig. 4. (*A*) This photograph was taken after administration of local anesthesia. This ridge palpated to no greater than 2 mm in width. The treatment plan called for a graft and an implant for a single tooth restoration. (*B*) For the placement of the particulate graft, an incision was made under the adjacent tooth in the loose mucosa, and a subperiosteal tunnel was created over the labial aspect of the thin ridge. The previous concave ridge profile was easily converted into a convex profile by the periosteal elevator. (*C*) Approximately 0.5-ml of human mineralized bone was placed and compacted firmly to over-augment the ridge. The resultant graft created a ridge width approximating 6 mm. (*D*) Four months after the graft was placed, local anesthesia was infiltrated into the edentulous site, and a crestal incision was made to expose the grafted ridge. The resultant ridge measured 4.5 mm in width. (*E*) A 3.25-m diameter implant was placed with no implant dehiscence. Bone covered all of the implant and was solid during the placement process.

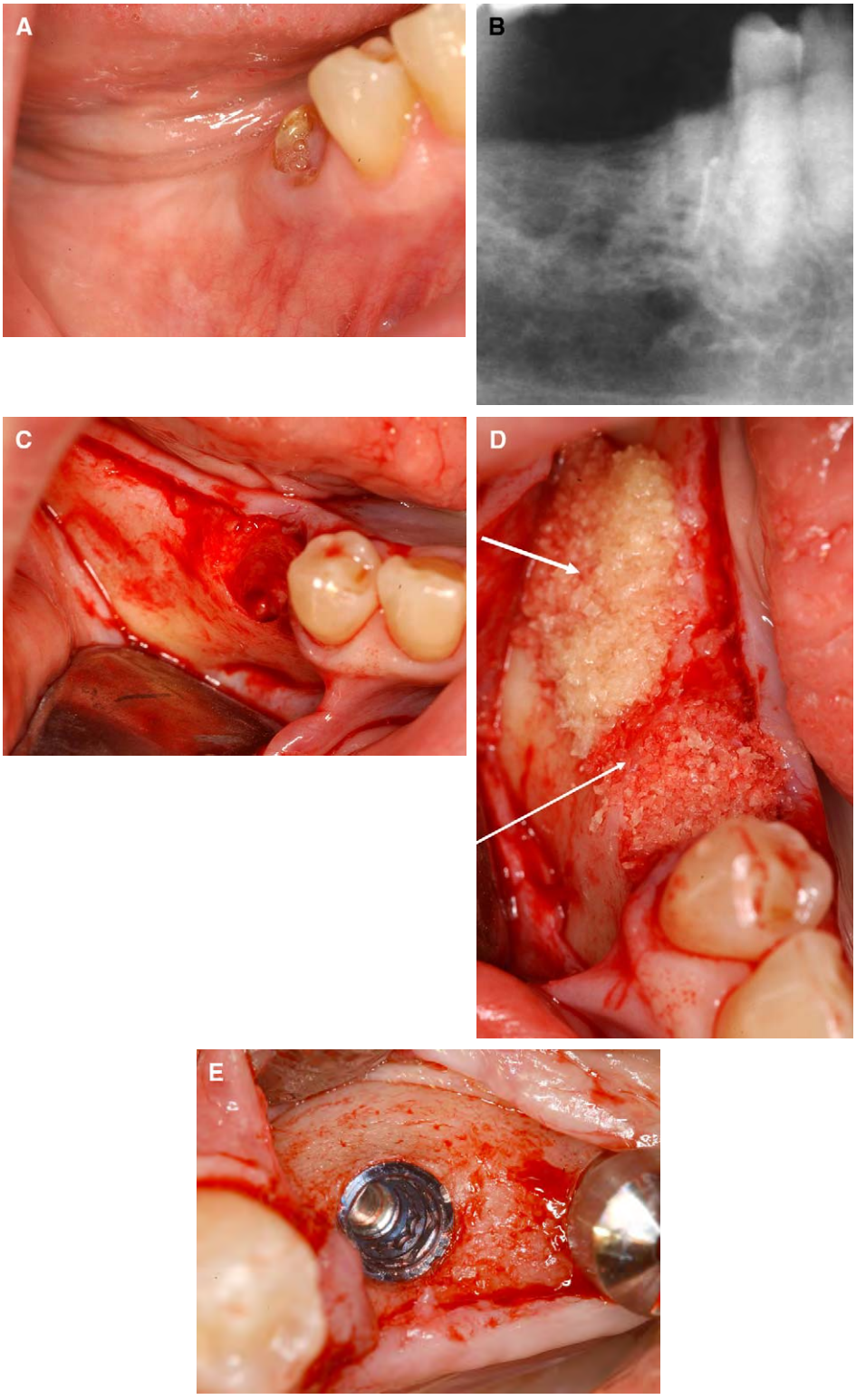

Fig. 5. (*A*) An 80-year-old woman was referred for extraction of the second premolar and augmentation of a thin posterior ridge and placement of three implants for a fixed restoration. (*B*) An enlarged panoramic radiograph showing the premolar root approximately 3 mm from the mental foramen. The surgical plan was to graft the extraction site and perform an open ridge augmentation posteriorly. (*C*) A crestal incision was combined with a vertical incision to expose the ridge. The tooth was extracted. (*D*) Particulate bone was placed to augment the thin ridge and to graft the extraction site (arrows). (*E*) After 4 months, implants were placed and then exposed 4 months later. Shown are the bone around the extraction site and one implant within the augmented bone.

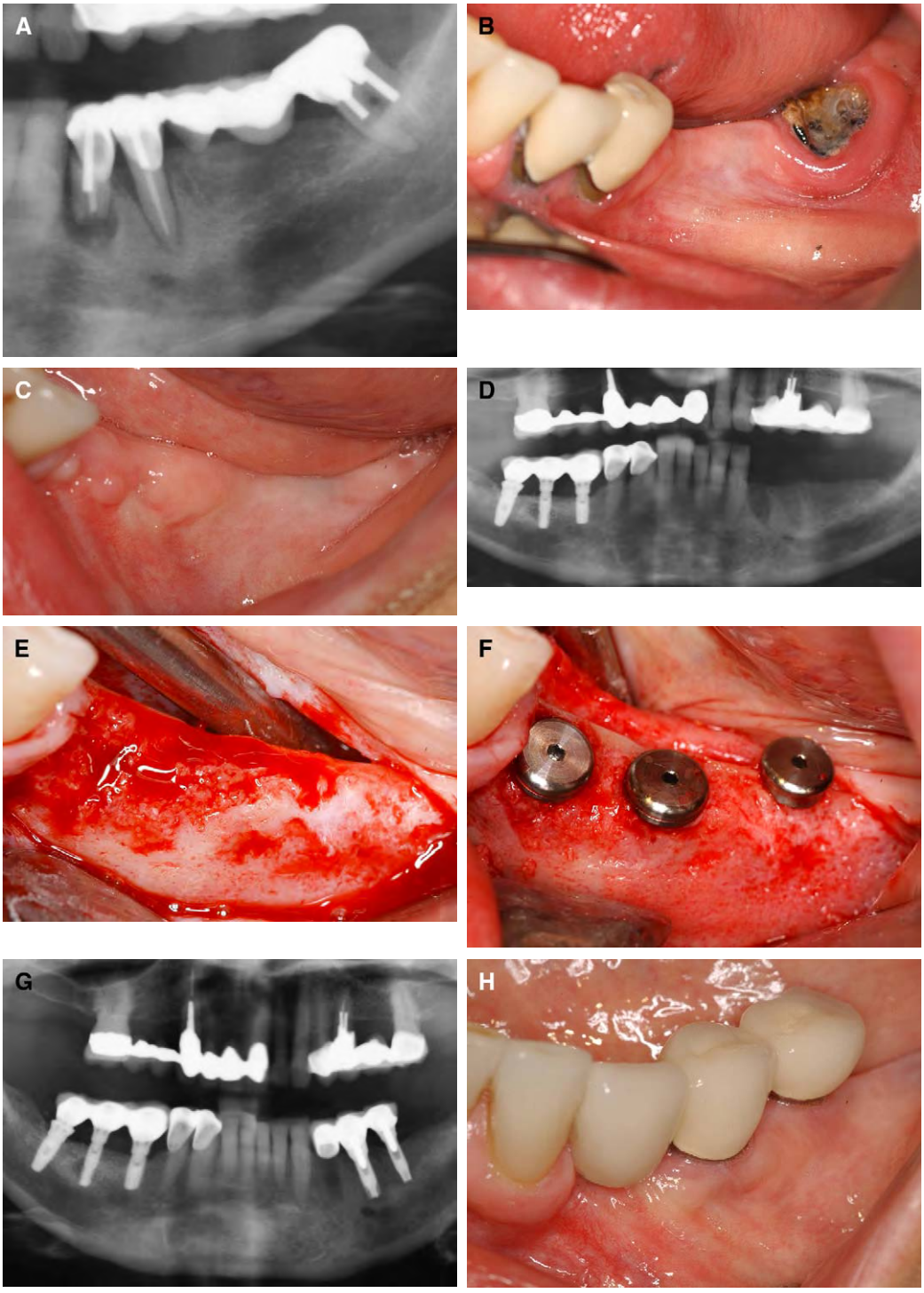

Fig. 6. (*A*) A 55-year-old woman was referred for extraction of the mandibular left two premolars and third molar, combined with extraction site grafts and horizontal ridge augmentation in the thin edentulous region. Note the extensive radiolucency in the site of the first premolar. (*B*) Clinical view showing the thin ridge in the edentulous region, to be later compared with the resultant ridge in Fig. 6H. (*C*) The teeth were extracted, and the sites and ridge were augmented. Shown is the augmented ridge 4 months after graft placement. (*D*) The panoramic radiograph was taken immediately before placing the implants. Note the lower radiodensity in the region of the first premolar. (*E*) The ridge was exposed and the augmentation seemed to be adequate for the placement of three implants. The bone at the anterior implant site was softer than the posterior two implant sites. (*F*) Three implants were placed. (*G*) At the time of implant exposure 4 months later, the anterior implant was found to have minimal integration and was removed. The final restoration was fabricated on the posterior two implants placed into grafted sites. (*H*) The final restoration with a pontic cantilevered anteriorly. Note the excellent ridge form and bulk in the area of the previously thin ridge.

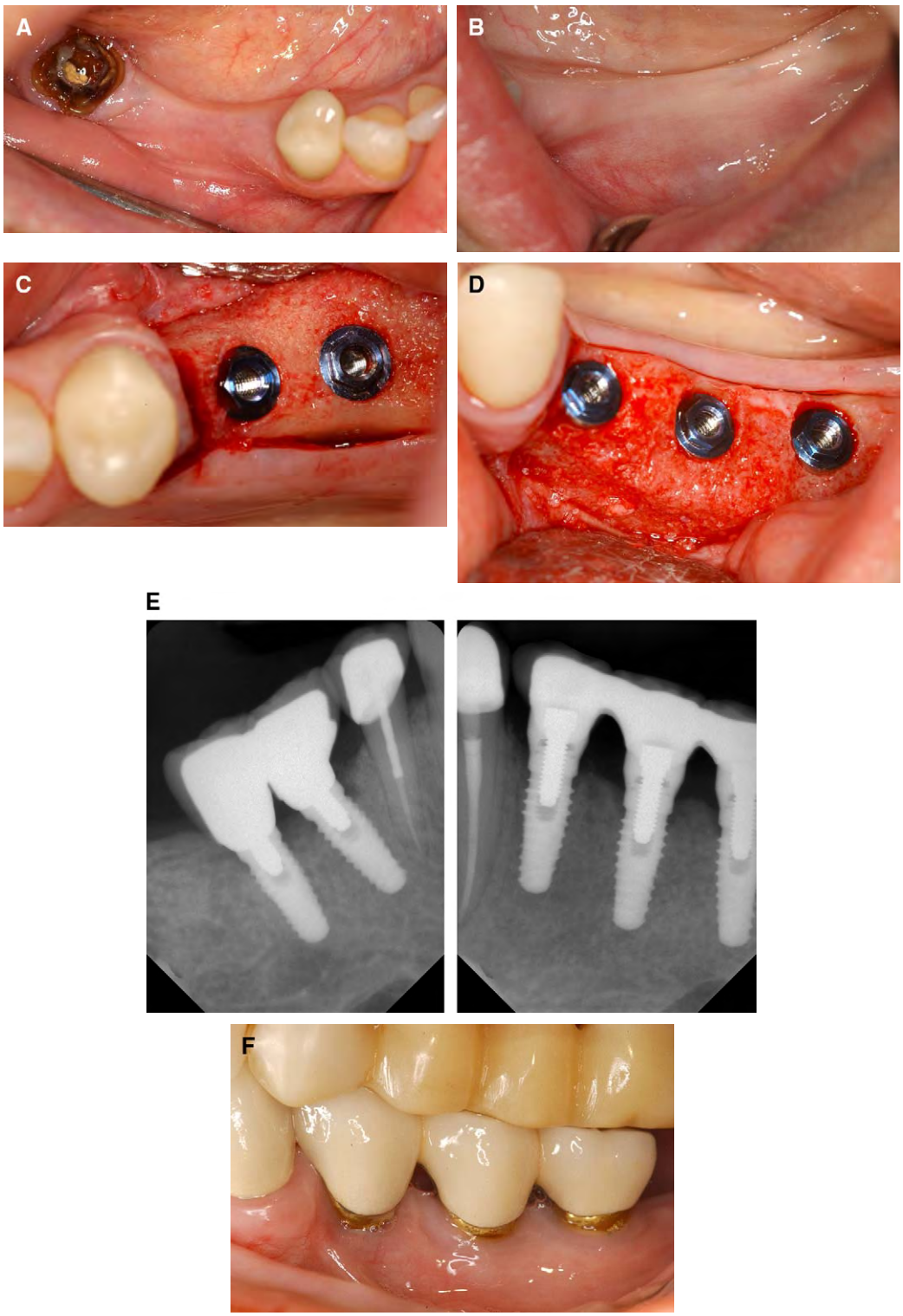

Fig. 7. (*A* and *B*) Right and left thin posterior ridges in a patient who desires fixed restorations rather than her removable partial denture. Bilateral ridge augmentations were performed placing 1-ml of particulate human mineralized bone into subperiosteal tunnels. (*C* and *D*) Four months after grafting, crestal incisions were made and implants placed, with two implants on the right and three implants on the left. Note the excellent bone width present around the implants. (*E*) Periapical radiographs 2 years after placement of the final restoration, showing excellent bone levels in the sites of the augmentation. (*F*) Final restoration. Note the excellent gingival response and ridge bulk.

Augmentation of the bone within 5 mm of the adjacent tooth is difficult to achieve because of the usual gradual decrease in ridge width from the tooth to the thinner part of the ridge and the difficulty maintaining the graft adjacent to a tooth (eg, the first premolar location adjacent to a canine). Patients took narcotic pain medication for up to 4 days, with a majority only needing non-narcotic medication.

The resultant augmentation has been sufficient for at least the placement of small-diameter implants. Implants are exposed after 4 months for integration. Failures have occurred in sites requiring grafts in large lytic areas of bone loss involving the lateral portion of the alveolus.

Follow-up examinations 2 years after restoration placement indicate stable facial bone levels as indicated by the pockets no greater than 3 mm in depth and pain-free function.

Summary

The successful use of onlay grafts using ramus or symphyseal bone is well known. However, these procedures carry with them a level of morbidity, which can be a negative for the patient and the referring restorative dentist. Our choice of which procedure to use is on the basis of which procedure can provide the necessary goal with less morbidity. The procedure described in this article is performed efficiently in the office setting with local infiltrative anesthesia and with minimal patient morbidity. If this procedure fails, then a conventional onlay graft can be performed.

A similar procedure has been reported using bovine bone combined with autogenous chips. The authors report using a fibrin glue product to retain the graft's form because they used an open approach to access the ridge. Our results are similar to those reported with bovine/autogenous bone product.

In our patient series, this procedure has been predictable and has allowed patients a less morbid alternative. It is anticipated that not all augmentations will be successful and that in the future other materials may prove to be excellent. Long-term follow-up is important to complete the evaluation of this method.

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Current Methods for Soft Tissue Enhancement of the Esthetic Zone

Hisham F. Nasr, DDS, MScD

The Perioclinic, 337 Metairie Road, Suite 301, Metairie, LA 70005, USA

The recent demand for esthetic dental procedures has brought about a new challenge for surgical specialists placing implants in the esthetic zone. Surgical attempts at restoration of soft tissue architecture, including marginal tissue and papilla levels, have been met with varying degrees of success and failure depending on the complexity of each clinical condition. Among the factors that limit restoration of an ideal soft tissue framework around implant restorations are the absence of a connective tissue attachment to titanium implants and their abutments and the loss of supporting alveolar bone after tooth extraction with subsequent loss of soft tissue volume and bone remodeling adjacent to dental implants.

In the case of inadequate available bone, several approaches have been developed to minimize such tissue deficits via bone grafting before or at the time of implant placement. When intact socket walls are present, immediate anterior implant placement and nonloaded provisionalization have been advocated on the basis of the clinical finding that the final definitive crown supports the gingival marginal tissues that have lost periodontal fiber attachment to the cervical root area after extraction. However, when patients present with a history of factors contributing to loss of the socket wall, such as external root resorption or root fractures, immediate provisionalization is not recommended, and other measures may become necessary. Although hard tissue augmentation procedures have been well researched and documented, soft tissue surgical techniques designed for enhancement of implant restorations in the esthetic zone have fallen short of providing a reproducible and predictable outcome that would simulate natural marginal tissue topography.

The connective tissue graft, initially advocated for soft tissue augmentation and root coverage, offers an attractive option for the improvement of the soft tissue framework around implant restorations. This article presents detailed techniques for enhancement of the soft tissue framework around implants placed in the esthetic zone using the connective tissue graft under different clinical scenarios.

Harvest of the connective tissue

Introduction of the double scalpel handle has facilitated harvest of the graft from palatal donor sites. This technique was used by the author for harvest of the connective tissue grafts shown in this article. It is briefly presented herein as an alternative approach to the original technique.

Two #15 or #15C scalpel blades are placed on the handle (Fig. 1A), which is available with interscalpel distances ranging from 1 to 3 mm, depending on the desired graft thickness. A stab incision is initiated approximately 2 to 3 mm from the palatal gingival margin opposite to the maxillary first molar (Fig. 1B). The handle is angled midway between the palatal soft tissue curvature and the underlying bone surface. A cadaver dissection study has shown that the anatomic

E-mail address: nasr@perioclinic.net

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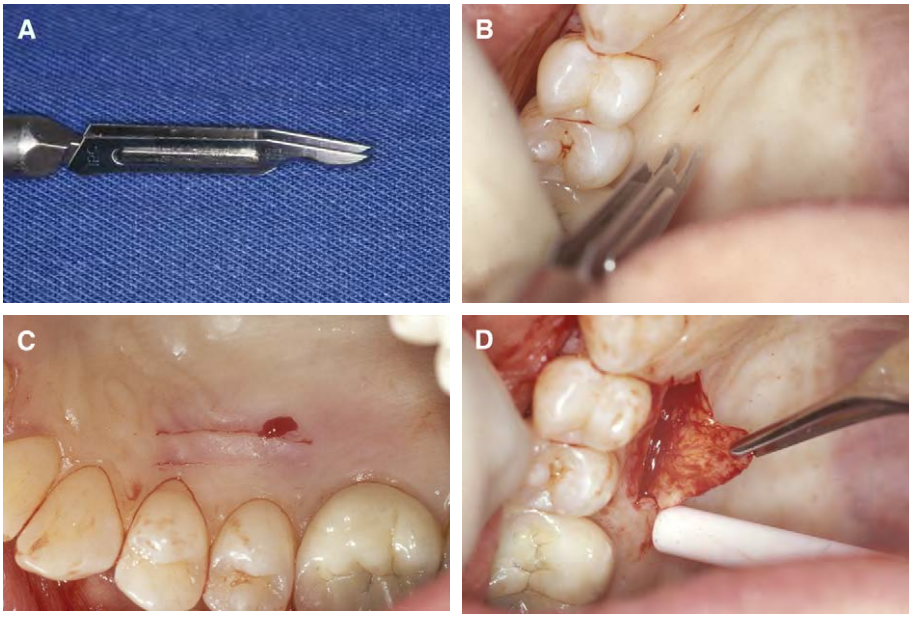

Fig. 1. (*A*) The double-scalpel handle with two 15C blades. (*B*) Initial stab incision at the palatal donor site. (*C*) Horizontal parallel incisions created by the double-blade scalpel. (*D*) Release of the connective tissue graft from the donor site.

location of the greater palatine neurovascular bundle ranges from 7 to 17 mm from the cemento–enamel junction, depending on the shape and height of the palate. The incision is carried opposite to the maxillary cuspid (Fig. 1C); then, a single #15C scalpel is used to make two vertical incisions within the created pouch, one on either end of the graft. These are connected by another horizontal incision at the apical extent of the graft, thereby releasing the connective tissue graft from the donor site (Fig. 1D).

Soft tissue enhancement for immediate implants with nonintact socket walls

When a diagnosis of root fracture or external root resorption has been made, it is prudent to anticipate an associated loss of adjacent alveolar bone. Although immediate implants may be considered in sockets with intact osseous walls, loss of bone in the form of large dehiscences or fenestrations may present a risk to successful osseointegration. Additionally, esthetic failure results if the osseous architecture is not reconstructed for support of desirable soft tissue morphology. Fig. 2A shows a patient in whom external and internal root resorption at the maxillary left central incisor resulted in alveolar bone loss due to a history of recurrent infection that has been controlled by systemic antibiotics. Tomographic evaluation indicated the presence of adequate bone volume at the apical and palatal areas for primary stabilization of an immediate implant. A flapless technique is followed, starting with an intrasulcular circumferential incision for release of the attached cervical periodontal ligament fibers. Careful atraumatic tooth extraction is a key factor in minimizing further bone loss or widening of the socket dimensions. Use of a periotome is the preferred technique. The periotome is placed at the disto-palatal or mesio-palatal line angle within the periodontal ligament space, and controlled pressure is applied in a back-and-forth motion until tooth luxation occurs. The periotome may be placed into the facial socket space for final removal of the intact tooth (Fig. 2B). In the case of more complex extractions, an alternative technique includes the use of high-speed diamond rotary instruments under copious irrigation to hollow out the root structure until a thin shell remains. This is collapsed internally with the periotome or thin elevators. A common sequela after extraction of a tooth with labial bone dehiscence is a more apical location of the gingival margin due to loss of cortical bone support (Fig. 2C). This soft tissue deficit must be corrected to avoid esthetic problems resulting from a final crown length that is not in harmony with the adjacent natural teeth.

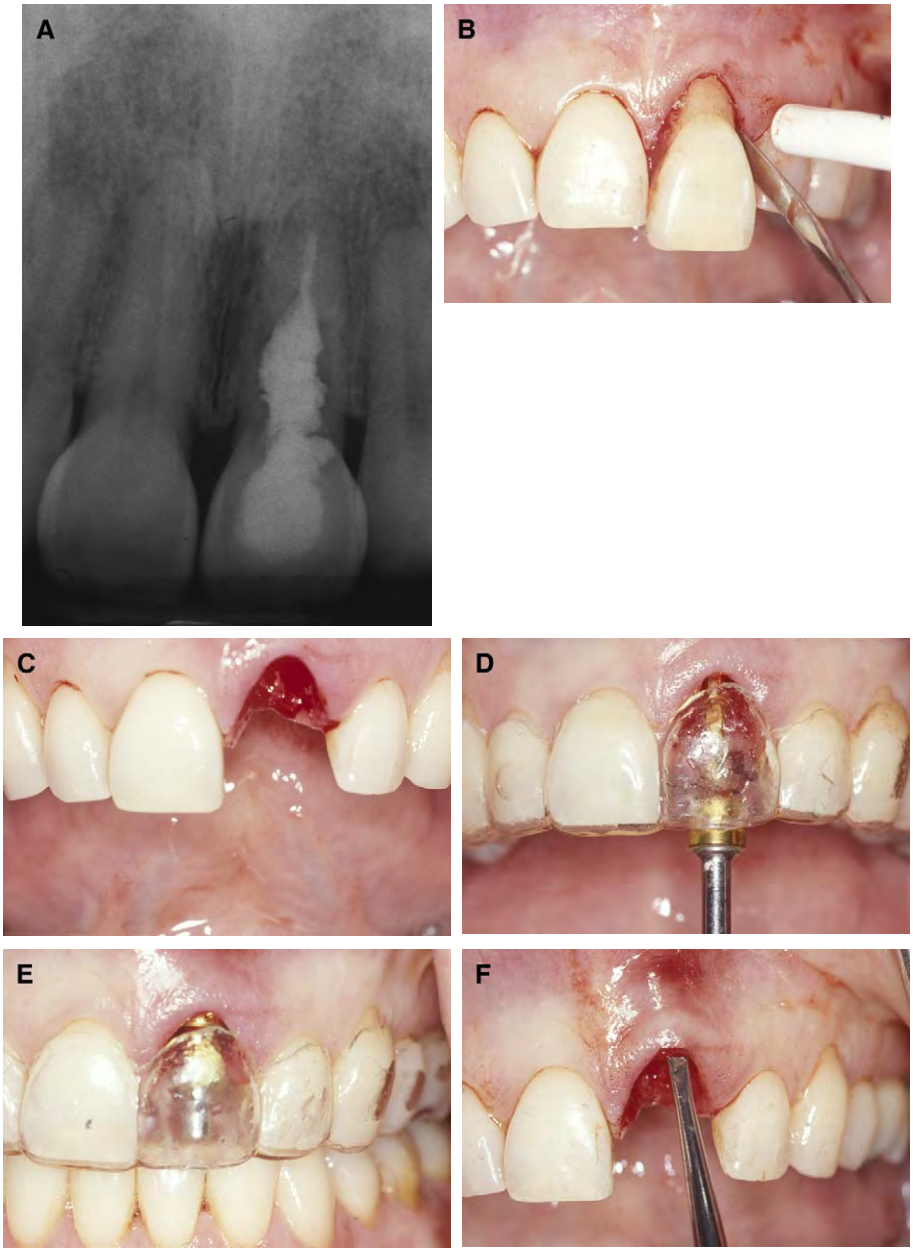

Fig. 2. (*A*) External and internal root resorption at maxillary left central incisor. (*B*) Periotome-assisted atraumatic surgical extraction. (*C*) Note the more apical location of the facial gingival margin after extraction. (*D*) Implant site preparation using surgical template guidance. (*E*) The implant emergence profile is within the confines of the future restoration as verified by the template. (*F*) Use of a small elevator to create a minimally reflected mucoperiosteal flap.

Before implant placement, meticulous degranulation and debridement of the socket must be performed to ensure absence of attached fibrous or granulomatous tissues that may interfere with successful osseointegration. If inadequate bleeding is present, intra-marrow penetration at the palatal socket wall may be performed using a small round bur for enhancement of the blood supply and potential introduction of natural bone growth factors into the socket space.

Surgical stent guidance is necessary for ideal three-dimensional implant positioning (Fig. 2D, E) to facilitate the final restorative phase. The implant drill should be directed just palatal to the apex of the socket for a slightly more palatal bodily positioning of the implant. This achieves optimal primary stability by engaging dense palatal bone and avoids erroneous emergence of the implant in a more labial position, which is one of the most common causes of esthetic failure. The requirements for vertical placement of the implant platform vary among implant

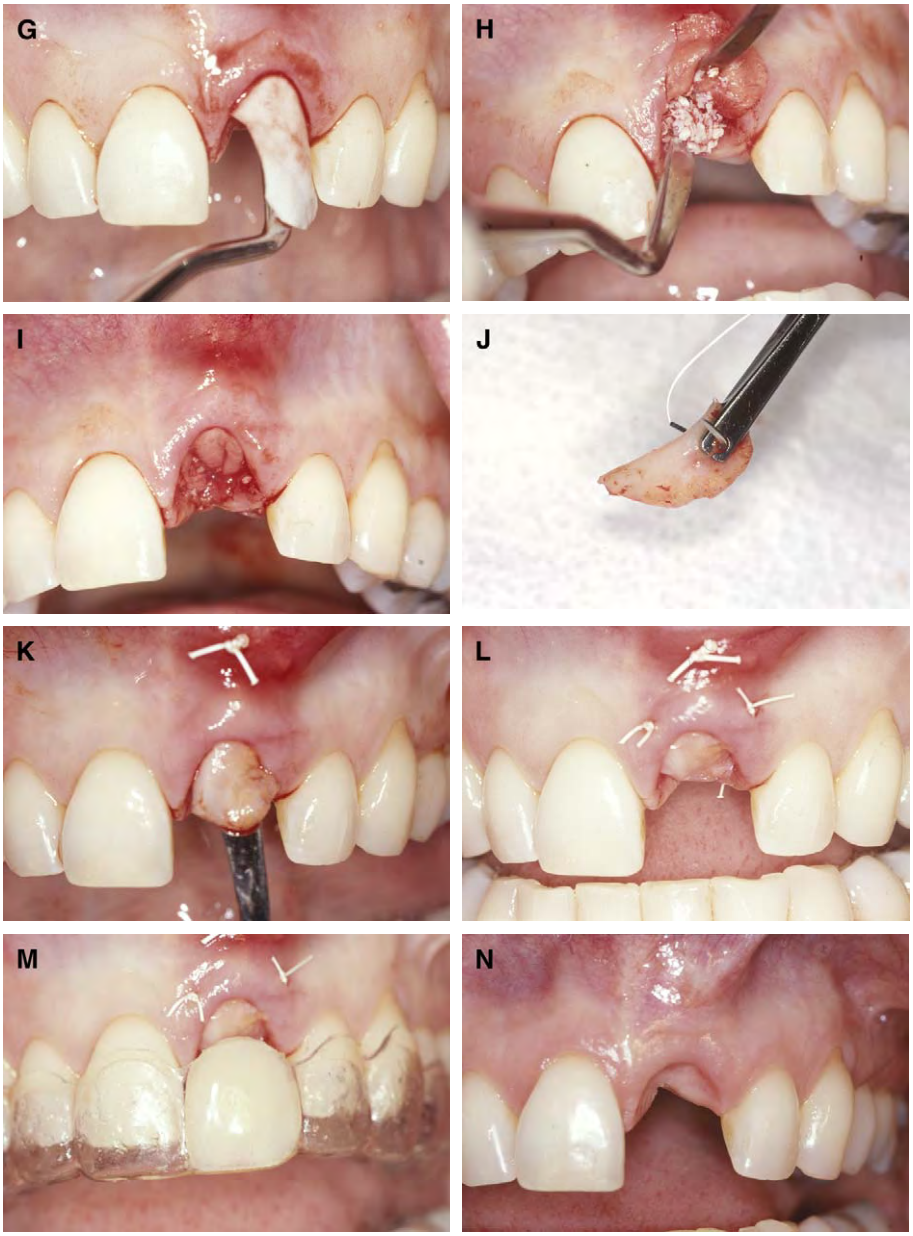

Fig. 2 (*continued*) (*G*) The resorbable collagen membrane is introduced into the labial pouch. (*H*) Particulate bone graft is placed into the residual socket defect. (*I*) The membrane is folded over the implant/bone graft area and is stabilized under the palatal soft tissues. (*J*) Corn suture pliers guide the needle through the connective tissue graft. (*K*) The graft is stabilized between the membrane and the labial soft tissues. (*L*) The socket is sealed with the connective tissue graft. (*M*) The natural crown is used as a temporary tooth. (*N*) Ideal soft tissue topography is reproduced at facial gingival margin and papillae in harmony with adjacent soft tissue levels.

systems; however, platform placement approximately 2.5 to 3 mm apical to the anticipated future facial gingival margin is considered optimal for two-stage implant systems. Although the remaining residual socket defect dimensions may not pose a risk to successful osseointegration, esthetic failure occurs if inadequate hard tissue is present for support of the labial soft tissues at the dehiscence defect. Guided bone regeneration with a resorbable collagen barrier membrane may be necessary.

A conservative mucoperiosteal reflection is performed by introducing a small periosteal elevator through the socket opening. A minimal dissection is carried just beyond the labial dehiscence bone margins (Fig. 2F) to provide a rest for the barrier membrane. Larger dissection

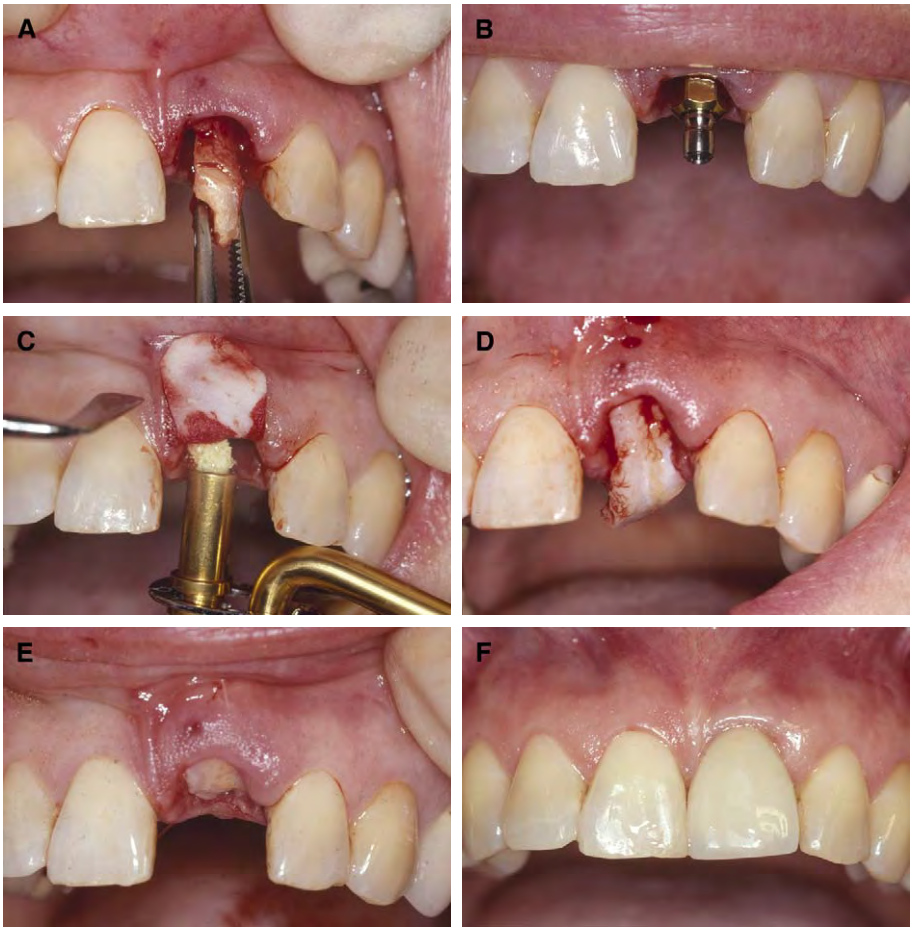

Fig. 3. (*A*) Extraction of the vertically fractured root at left central incisor. (*B*) Immediate implant placement with an optimal three dimensional angulation. (*C*) The resorbable collagen membrane is folded back to allow placement of the bone graft. (*D*) The connective tissue graft is introduced between the membrane and the labial soft tissues. (*E*) Complete coverage of the area of guided bone regeneration by the connective tissue graft. (*F*) The final restoration with an ideal soft tissue profile.

should be avoided to maintain periosteal blood supply to the delicate remaining intact portions of the labial cortical plate. A minimum of half the labial plate must be intact for application of this technique. A similar reflection is performed as necessary for membrane stabilization at the palatal aspect. The collagen membrane is trimmed to follow the labial, occlusal, and palatal bone anatomy and is introduced between the labial cortex and the labial soft tissues to rest passively on the intact bone margins of the dehiscence defect (Fig. 2G). The occlusal and palatal extension of the membrane is gently turned labially while particulate bone graft material is placed to fill the residual socket defect and rebuild the lost portion of the labial socket wall (Fig. 2H). The membrane extension is passed over the socket opening so the edges rest under the palatal soft tissues on the intact palatal bone, thereby containing the grafted material circumferentially around the implant (Fig. 2I). Although this approach offers the potential for improvement of bone volume around the implant, soft tissue augmentation is necessary for socket seal and for repair of the earlier recession associated with extraction and for circumferential support of the marginal tissues. The connective tissue graft is harvested from the palate as earlier described and used for the aforementioned purposes using vertical mattress sutures at the labial and palatal apical extents of the created tissue envelopes. A small elevator is placed between the labial soft tissues and the barrier membrane to guide the suture needle into the intervening space without disturbing the membrane position.

Corn suture pliers are used to introduce the suture through one end of the tissue graft (Fig. 2J), and the needle is passed back through the socket opening to guide the connective tissue

into the labial pouch and stabilize it on the labial aspect (Fig. 2K). A similar approach is followed to stabilize the graft on the palatal side. Additional sutures may be placed as necessary for socket seal and for complete coverage of the underlying membrane and for support of the marginal soft tissues circumferentially (Fig. 2L). If a removable partial denture is not provided by the restorative dentist, the natural crown portion of the extracted tooth may be used for provisionalization. This can be secured with composite resin bonding inside a vacuum-formed Essix-type clear appliance. This is fabricated from the pre-extraction cast and delivered as a temporary removable prosthesis until initial healing occurs (Fig. 2M). A removable partial denture with an ovate pontic design is later delivered and modified as necessary by the restorative dentist to create and maintain ideal marginal soft tissue anatomy before second-stage surgery (Fig. 2N). The ovate pontic design is critical to the final esthetic outcome, and its use further facilitates implant uncovery surgery, where a conservative punch-type incision may be performed within the created soft tissue concavity at the expense of the palatal tissues. A fixed provisional implant restoration is recommended at this stage because it may be modified to further enhance the soft tissue topography before placement of the final restoration.

Figs. 3A to 4E demonstrate clinical cases where soft tissue enhancement around single maxillary anterior implant restorations has been achieved using the described technique. In Fig. 4D, the use of this connective tissue graft technique has helped eliminate the persistent soft tissue sinus tract noted at time of extraction (Fig. 4A, 4B, 4E) and implant placement.

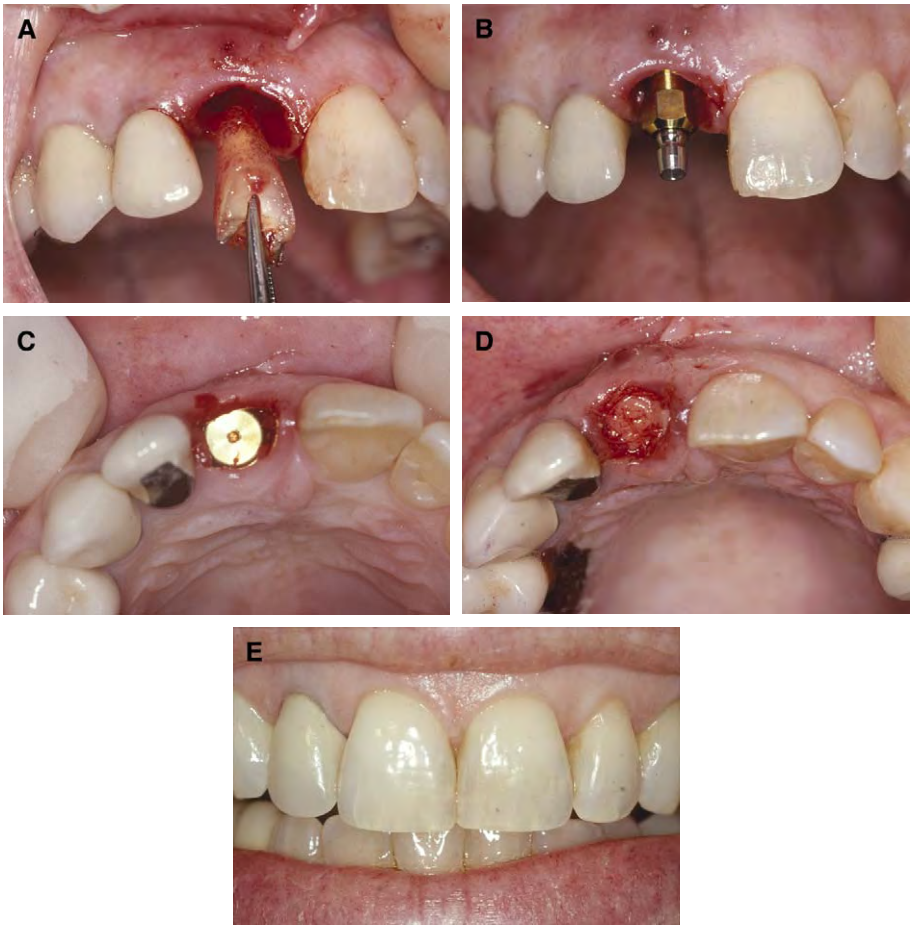

Fig. 4. (*A*) An obliquely fractured tooth is extracted atraumatically. (*B*) The immediate implant platform is approximately 3 mm below the facial gingival margin. (*C*) Labial bone dehiscence results in collapse of the facial soft tissue against the implant surface. (*D*) The connective tissue graft supports the marginal soft tissues while covering the guided bone regeneration area circumferentially over the implant. (*E*) The final restoration at the maxillary right central incisor is supported by an esthetically pleasing soft tissue topography that is visible in the patient's smile.

Soft tissue enhancement for delayed implants with minor ridge defects

The connective tissue graft may be used for correction of minor ridge defects in conjunction with delayed implant placement. The patient in Figs. 5A and B presented with a slight ridge deficiency associated with congenitally missing maxillary lateral incisors. The thin mucosal tissues would constitute an esthetic problem at the cervical area of the final restoration due to light reflection from the gray titanium implant collar and transmission through the thin marginal soft tissues resulting in a grayish hue. At the time of implant surgery, a connective tissue graft is placed over the labial cortical plate (Fig. 5C) to provide an adequate thickness of keratinized soft tissues that would reduce the dark color transmission and help with ovate site preparation (Fig. 5D). The result may be further enhanced by using tooth-colored abutments for support of the final all-ceramic restorations (Fig. 5E), which is particularly important when the patient has a high smile line, as noted in this case.

Soft tissue enhancement for delayed implants with large ridge defects

In cases with more advanced tissue loss, bone augmentation is necessary before implant placement. Fig. 6A demonstrates a patient with severe ridge deficiency after trauma to the anterior maxilla. Cortico-cancellous block bone grafts harvested from the mandibular symphysis or ramus areas may be used for reconstruction of lost bone volume. The block grafts are

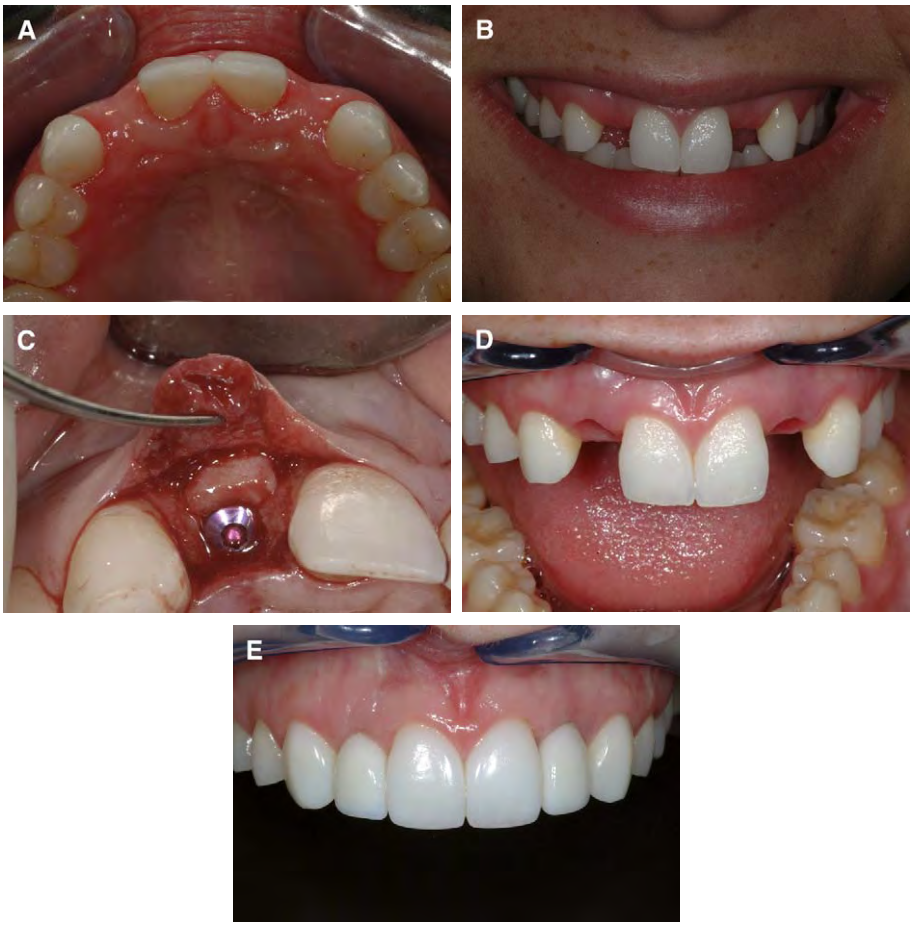

Fig. 5. (*A*) A patient with slight ridge deficiency due to congenitally missing lateral incisors. (*B*) The patient's high smile line constitutes an esthetic challenge. (*C*) Connective tissue grafts are placed on the facial aspect of each implant for soft tissue augmentation. (*D*) Soft tissue enhancement resulting from ovate designed provisional teeth. (*E*) Final implant restorations at upper lateral incisors.

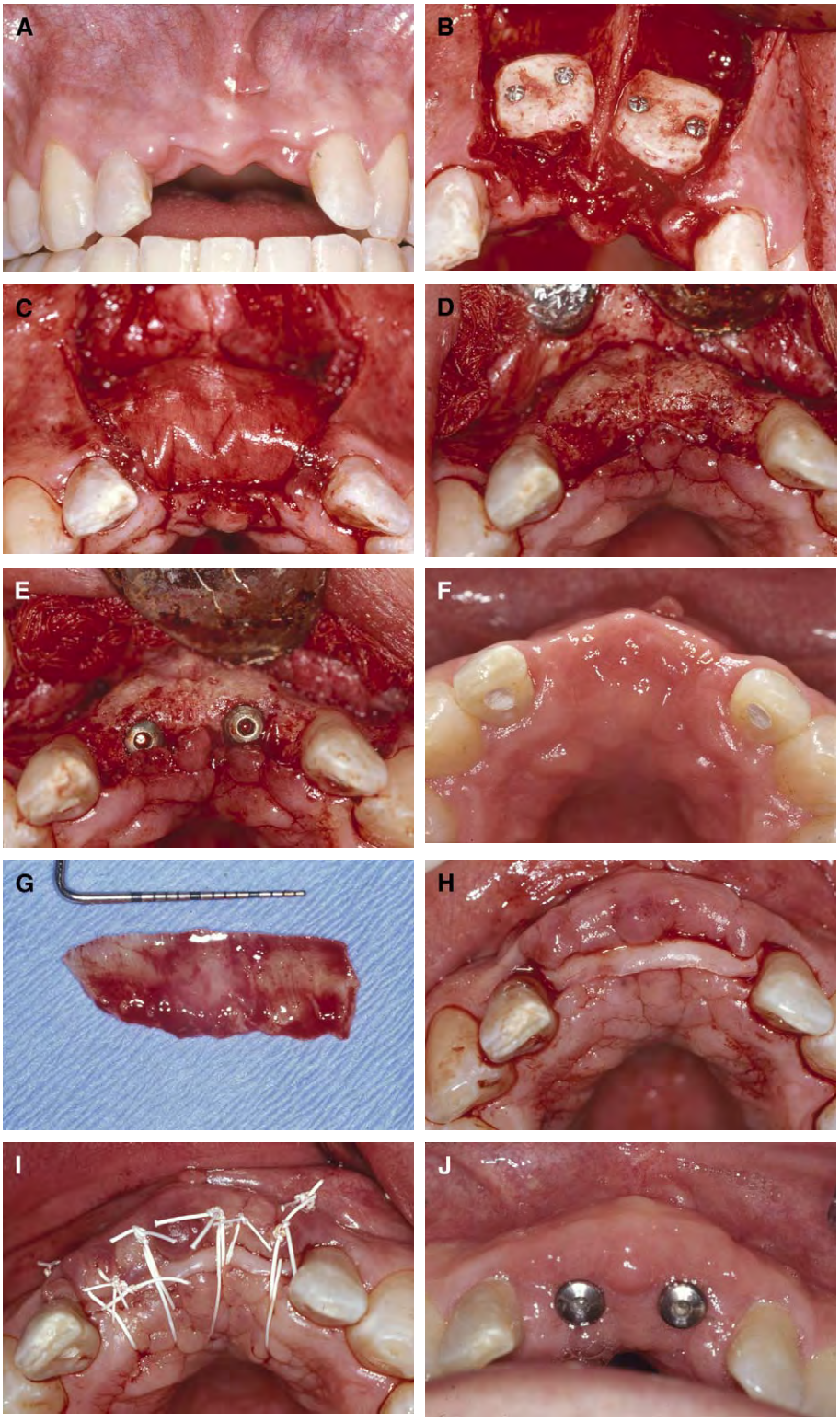

Fig. 6. (*A*) A severe residual defect is present after trauma to the anterior teeth. (*B*) Block bone grafts are secured in position for delayed implant placement. (*C*) A resorbable barrier is used over the bone graft area. (*D*) The ridge dimension is reconstructed to an ideal thickness. (*E*) Implants are placed within adequate supporting bone. (*F*) Bone graft resorption results in reduction of ridge dimension. (*G*) A large connective tissue graft is harvested from the palate. (*H*) The graft is placed in a partial thickness pouch labial to the implants. (*I*) Mattress sutures are used to stabilize the graft apically and occlusally. (*J*) Restoration of the lost ridge dimension is achieved after soft tissue maturation.

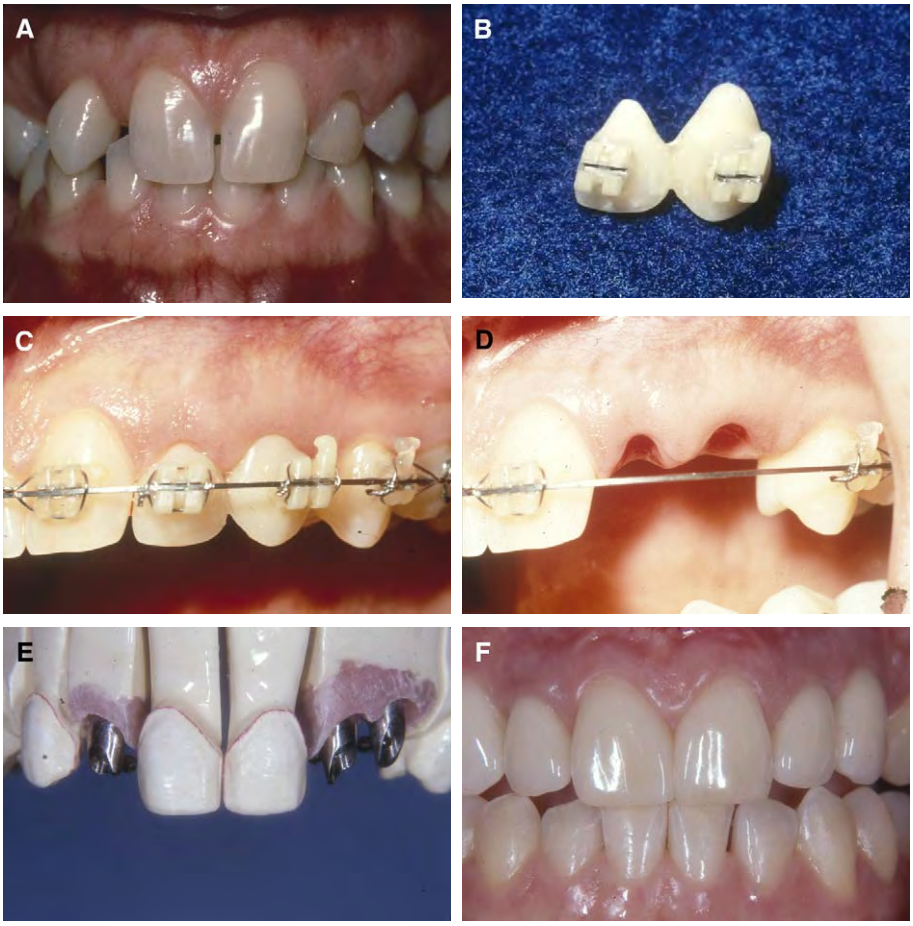

Fig. 7. (*A*) The patient presents with orthodontic problems, missing permanent teeth, and mobile deciduous teeth. (*B*) Orthodontic brackets are placed on the provisionalized teeth. (*C*) The ovate pontic design supports the soft tissue topography and is stabilized with orthodontic wire. (*D*) Maintenance of the interproximal papilla after implant placement. (*E*) Reproduction of the soft tissues on the working cast to assist the technician. (*F*) The final restorations. Note the gingival margin and papilla levels adjacent to each implant.

stabilized at the recipient sites (Fig. 6B), and the results may be enhanced by using a composite of autogenous cancellous bone chips mixed with mineralized particulate bone graft and covered by a resorbable collagen membrane (Fig. 6C). Although significant improvement in bone volume is predictably achieved for implant placement (Fig. 6D, E), a soft tissue problem is encountered in such cases due to the coronal repositioning of the mucogingival junction to achieve primary wound closure after periosteal releasing incisions. This places thin mucosal tissues at the future emergence site of the implant restorations. Additionally, a reduction in bone volume occurs due to remodeling and partial resorption of the block grafts (Fig. 6F). The connective tissue graft is used to compensate for this reduction in tissue thickness and to provide adequate keratinized tissues at the restoration emergence area (Fig. 6G). The graft is secured inside a partial-thickness soft tissue pouch created facial to both implants using apical and occlusal mattress sutures (Fig. 6H, I). This may be performed before or at the time of second-stage implant surgery. Fig. 6J demonstrates the significant improvement in tissue thickness with this technique.

Restorative and orthodontic soft tissue enhancement for delayed implants

The restorative dentist and laboratory technician must be cautioned against over-contouring of the implant restorations, particularly at the delicate labial gingival margin, to avoid iatrogenic labial soft tissue recession. On the other hand, an optimal contour supports the

interproximal papillary tissues and maintains proper form and fullness. The interproximal height of bone at the adjacent natural teeth has been shown to be a determining factor in the presence or absence of papillae adjacent to single tooth implants. Although the papilla height is approximately 5 mm between adjacent natural teeth, the interimplant papilla may be lost or may measure 3.4 mm in height on average. Therefore, placement of adjacent implants is the least desirable option in anterior tooth replacement, and measures must be implemented to reduce this problem.

In some clinical situations, papillae heights may be maintained nonsurgically. The patient in Fig. 7A presented with tooth malposition problems and congenitally missing permanent maxillary lateral incisors and left cuspid teeth. Mobility of the retained deciduous teeth dictated a restorative plan that includes orthodontic space management and implant replacement of the missing permanent teeth. Provisionalization with ovate pontic designs at extraction time would provide the needed support for the interproximal papilla (Fig. 7B, C). The orthodontic wire is used to support the temporary teeth and maintain papilla form during orthodontic therapy and through the osseointegration phase (Fig. 7D). A soft tissue cast is recommended to guide the technician during ceramic build-up for support of the delicate marginal tissues (Fig. 7E). Lingual set screws may also provide the fixed implant restorations with a retrievable advantage. Figure 7F demonstrates a good esthetic result achieved with a combination of implant-supported and laminate veneer restorations. Although the final outcome is esthetically pleasing compared with the preoperative situation, the interimplant papilla remains somewhat more apical to the desirable ideal papilla height noted at the papillae between the implants and the adjacent natural teeth.

Summary

The procedures presented in this article emphasize the role of the surgeon in reconstruction of ideal soft tissue contours around implant restorations. Implants placed in the anterior maxilla present a surgical challenge due to tissue limitations that are unique to dental implants compared with natural teeth. The connective tissue graft offers versatile approaches for enhancement of the soft tissue profile around esthetic zone implants. These procedures must be complimented by a good understanding of the restoration role in the maintenance of an esthetic submergence profile to support the marginal soft tissues.

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I thank Drs. Susan LeBon, Corky Willhite, Donna Palmisano, Gerard Chiche, and Basil Mizrahi for the restorative work presented in this article.

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Lip Modification Procedures as an Adjunct to Improving Smile and Dental Esthetics

Jon D. Perenack, DDS, MD*, Teresa Biggerstaff, DDS, MD

Department of Oral and Maxillofacial Surgery, Louisiana State University Health Sciences Center, 1100 Florida Avenue, New Orleans, LA 70119, USA

The perioral region provides a framework through which the observer views the dentition. Often, costly and time-consuming dental work remains hidden behind a less-than-optimal soft tissue window. In the young patient, efforts to improve esthetics in this region often involve optimizing lip volume, architecture, and eversion. In the aged patient, a more complex situation exists. Predictable changes that occur in the perioral region with aging include loss of lip volume and architecture, lip lengthening and inversion, and rhytid formation secondary to accumulated actinic damage and repeated muscle movements. These changes are progressive and are generally considered unaesthetic. For the patient who has undergone dental rehabilitation, in addition to facial rejuvenative procedures such as rhytidectomy (facelift) or browlift, inattention to this area is often the ''give-away'' of the patient's true age. This article focuses on techniques to optimize perioral esthetics with consideration to reconstructing the ideal lip–tooth relationship, including the use of augmentation materials to create or recreate lip volume and architecture, surgical techniques to optimize lip length and eversion, and a review of skin resurfacing techniques to reduce or eliminate actinic changes.

Evaluation and diagnosis

Treatment planning depends upon a thorough understanding of the normal lip anatomy and the expected changes that develop with age. The initial evaluation should include notation of the general skin characteristics of the patient and an assessment of the structure of the lips. Notation of overall pigmentation and sun-reactive type should be performed using a scoring system such as Fitzpatrick's scale; similarly, the presence and nature of rhytids should be recorded using a scoring method such as Glogau's scale or Hamilton's scale. In the perioral region, rhytids are assessed with regard to orientation (vertical, horizontal, or criss-crossing), effects of lip animation (eg, smile or pucker), and their depth. The presence of dyspigmentations, telangiectasias, or pathology (eg, actinic keratoses) should also be noted.

For treatment purposes, the normal lip can be considered to be composed of two types of structural elements: those that provide framework architecture and those that add volume to the lip. Framework elements provide sharp contrasts of lighting and demarcate the vermillion–cutaneous junction. To the observer, they convey the shape of the lip. In the upper lip, this is represented by the white line of the lip and the philtral columns. These anatomic elements are formed primarily by the interplay of muscle insertions of the levator labii superioris and the orbicularis oris. The orbicularis oris inserts into the ipsilateral and contralateral philtral column, and the levator labii superioris has insertions to the ipsilateral philtral column only (Fig. 1). The white line of the lip represents dermal insertion points of these two muscle groups.

* Corresponding author.
E-mail address: jperen@lsuhsc.edu (J.D. Perenack).

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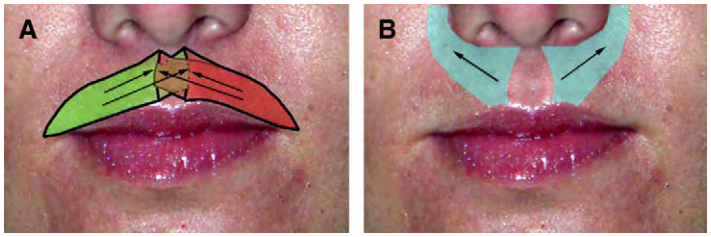

Fig. 1. (*A*) Insertions of orbicularis oris. (*B*) Insertions of levator labii superioris.

In the lower lip, the main architectural element is the white line of the lip, particularly in the central third. This is formed primarily by dermal insertions of the orbicularis oris muscle. The shape and size of the vermillion, or red, portion of the lip is related primarily to the volume elements of the lip. In the upper lip, this morphology is provided by the central tubercle and paired lateral extensions (Fig. 2). In the lower lip, two variations can be noted: a uni-lobed lip or a symmetric bi-lobed lip (Fig. 3). The red aspect of the vermillion is optically created by a thick vascular lamina propria viewed through a thinly keratinized squamous epithelium (Fig. 4). The relative area of the volume component of the lip compared with facial area has been shown to be important factor in aiding an observer determine if a face should be considered to be youthful or attractive. Bisson described that lip area, when viewed from the front, has profound effect upon ascribing an attractive "model" appearance. In his study, cover models from fashion magazines were found to display on average twice as much lip area as nonmodels. Similarly, assessment of the face into thirds and the lower face into proportional fractions for the "attractive, youthful" face has been described (Fig. 5). Upper incisal display is an important element in projecting a youthful appearance to the perioral area. Although there is natural variation in the length of the upper lip and maxilla in younger patients, generally a value of 3 to 4 mm for women and 2 to 3 mm for men of incisal display at rest, with the lips slightly parted, is associated with an unaged lip.

Age-related changes to the perioral area

With increasing age, a number of predictable changes that affect the display of dental esthetics occur in the perioral region. These changes relate to generalized loss of lip volume and architecture and lip lengthening with lip inversion. Surface changes also occur in the epidermis and dermis as a result of accumulated actinic damage. Decreased lip volume is the result of atrophy of muscle and fat. With atrophy of muscle, the youthful shape of the lips becomes visibly less distinct. This is particularly evident in the upper lip, where muscle insertions form the philtral columns, white line of the lip, and Cupid's bow (Fig. 6). As age-related attenuation progresses, these elements flatten and eventually are no longer present. The reduction of volume in the lower lip is mainly evident in the loss of "pout" that is present in the younger patient. Loss of tone in the orbicularis oris allows the gradual increasing display of the lower dentition at rest that is normally not visible at an earlier age.

Age-related lip lengthening is the product of the gradual weakening of fascial attachments that suspend the soft tissue of the lip and the loss of lip volume. Lip lengthening that occurs with

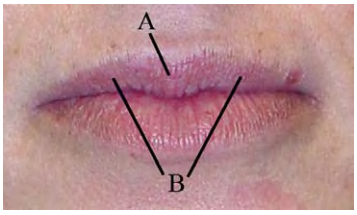

Fig. 2. Contour elements of the upper lip. (*A*) Midline tubercle. (*B*) Lateral lip extensions. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1635; with permission.)

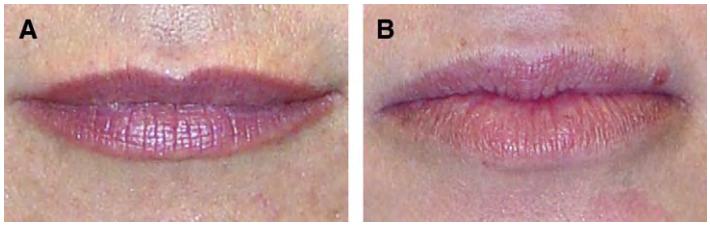

Fig. 3. Contour variations of the lower lip. (*A*) Uni-lobed. (*B*) Bi-lobed. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1635; with permission.)

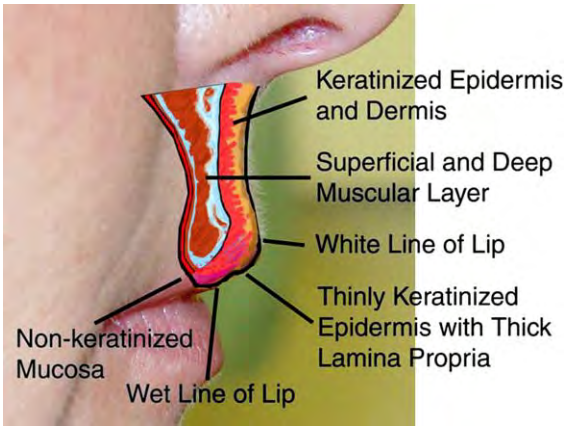

Fig. 4. Cross-sectional view of the lip.

Fig. 5. Ideal proportions of the lower face. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1635; with permission.)

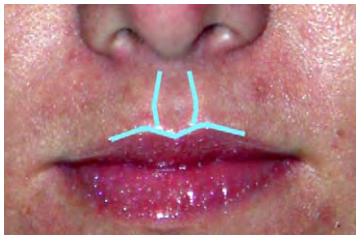

Fig. 6. Framework elements of the upper and lower lip. Philtral columns and the white line of the lip are shown. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1635; with permission.)

the loss of volume can be likened to the changes that occur in a balloon as air is removed (Figs. 7 and 8). Fibrous attachments between the superficial muscular layer of the lip and the base of the nose and melolabial folds involute and weaken with age and contribute to lip lengthening. In the upper lip, this lengthening tends to invert the lip, thus decreasing the amount of visible vermillion and further producing a ''thin-lipped'' appearance. Although variation exists, particularly in the ''long-faced'' patient, the upper lip is optimally 18 to 20 mm in length when measured from the naso-labial junction to the white line of the lip at the height of Cupid's bow. It is not uncommon for the senescent lip to measure 22 to 25 mm in length.

Evaluation of the patient with senescent lip should include attention to the frontal, profile, and three-quarter views of the face. Photographic documentation should be obtained. The frontal evaluation should include measurements of the upper lip from the nasolabial junction to the white line and an incisal display (or incisal masking) at repose and smiling. An estimate of vermillion display at rest is also noted. Attention is turned to evaluation of lip volume and architecture. The presence or absence of a prominent white line and philtral columns is evaluated. General bulk and morphology of the red portion of the lip is considered. The profile is evaluated for a prominent tubercle and lower lip pout. The silhouette of the upper lip should not show a ''double break'' (Fig. 9). Often it is useful to discuss the patient's expectations and goals using the photographic documentation as a reference point.

Effects of sun exposure to the perioral area

With an increase in age, the skin's cumulative ultraviolet light exposure also increases, causing changes in the epidermis and dermis. These actinic changes have been well documented. Histologically, with sun damage, the number of epidermal Langerhans' cells decreases. The epidermis can become atrophied and can show irregular distribution of pigment (solar lentigines) and cellular atypia. Dermal changes include accumulation of thick basophilic fibrous material in the superficial reticular dermis (elastosis). As this elastotic tissue accumulates, it pushes out collagen fibers and blood vessels, resulting in observable telangiectasias, erythema, decreased elasticity, coarse dry skin, and blotchy pigmentation. Initially fine vertical lines develop radially in the perioral region. With accumulated sun damage, these deepen, and eventually horizontal rhytids appear. In summary, actinic changes of the perioral region clinically include textural and pigmentary disturbances.

Treatment options

Lip augmentation procedures

A lip augmentation procedure can be considered to be any technique that adds new structure or the appearance of new structure to the lips. These techniques can be subdivided into those that create or recreate the architecture of the lips and those that add volume to the body of the lips.

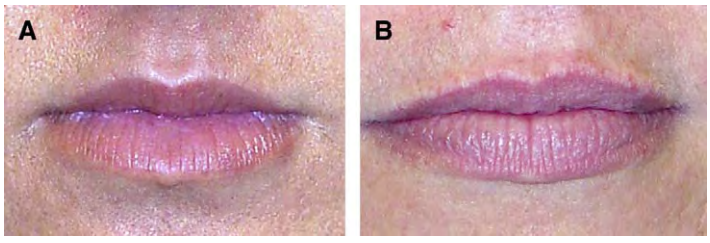

Fig. 7. Changes associated with age-related atrophy of the lip. Note the indistinct light reflex of the philtral columns and the white line of the lip in the aged subject (*B*) compared with the younger subject (*A*). (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1636; with permission.)

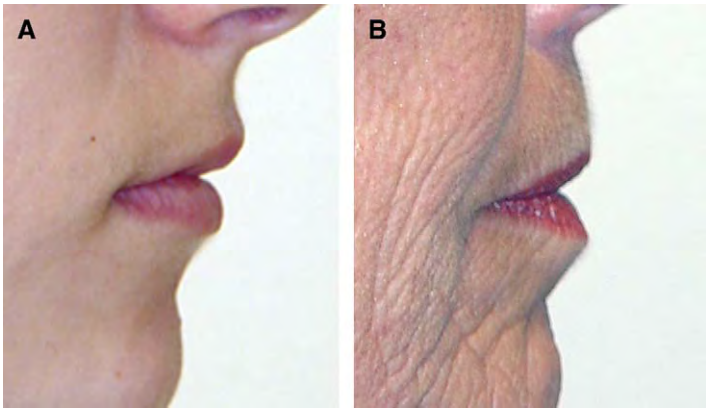

Fig. 8. Lengthening of the upper lip in an aged patient (*B*) with associated lip thinning and vermillion inversion in contrast to younger patient (*A*). (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1636; with permission.)

Technique for the creation or recreation of lip architecture

The creation or recreation of lip architecture requires the precise placement of a filler substance in the position of the philtral columns and the white line of the upper and lower lips. In the young patient this often represents adding substance to pre-existing, albeit subjectively hypoplastic, structure. In the aged patient with flat, featureless, atrophic lips, these structures may be absent. Due to the requirement for precise filler placement, this objective is best realized with a substance that can be readily injected into the dermal/subdermal plane using a small needle (eg, a 25-, 27-, or 30-gauge needle). At this depth, dense connective tissue prevents the filler from migrating, and tissue augmentation creating sharp demarcations of light reflection is possible. There are many injectable types of filler available to the surgeon; we recommend using an FDA-approved material such as stabilized hyaluronic acid or human collagen. Stabilized hyaluronic acid is available in animal-derived and non-animal–derived forms. The non-animal form offers the advantage of less tissue reaction and less potential for allergic reaction. Both forms boast a longer visible result than collagen, the most similar competitor. Results are typically 6 to 12 months in duration of effect, as compared with 3 months for collagen. Stabilized hyaluronic acid has the disadvantage of more immediate, prolonged tissue edema, usually lasting 3 days, as compared with minimal edema seen with collagen injection. Pain with injection is greater with hyaluronic acid and frequently necessitates local or topical anesthesia. Due to its profile of less postoperative edema, collagen has a role for the patient who requests a filler before an important social event that occurs

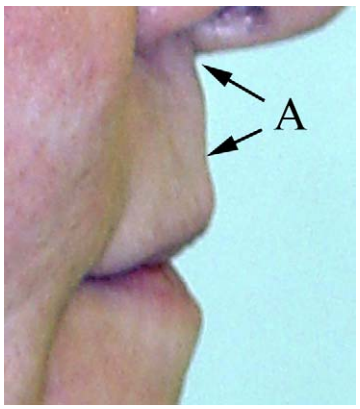

Fig. 9. Double break at points (*A*) in the profile silhouette of the upper lip. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1636; with permission.)

soon after its placement. The patient is always cautioned that unaesthetic edema, hematoma, or ecchymosis is a possibility.

Anesthesia. Local anesthesia to the area is usually required and consists of lidocaine blocks, with or without epinephrine, to the infra-orbital and mental nerves. Alternatively, topical anesthetic creams or ice can be applied to the area to induce desensitization.

Filler placement. The placement of the filler is typically performed in the dermal/subdermal plane. A threading technique with a 30-gauge, 0.5-in needle along the path of the white line and philtral columns is used (Fig. 10). For philtral column augmentation, each column is individually pinched between the thumb and forefinger with one hand while a cone of filler, with its base at the white line, is injected into the correct plane (Fig. 11). Attention is then turned to the white line of the lip. A 30-guage needle is typically threaded at or slightly inferior to the white line of the upper lip, and filler material is injected. In the lower lip, the injection is performed at or slightly superior to the white line. The lateral thirds of the white line of both lips are under filled relative to the central third. Typically, a volume of 0.5 to 0.8 ml of hyaluronic acid or collagen is required to optimize the architecture of both lips.

Treatment of radially oriented vertical lip lines. Correction of an atrophic white line in the aged patient also improves radially oriented vertical lip lines that have their origin at the vermillion–cutaneous junction. A common comment by patients is that colored lip liner does not ''bleed'' after white line augmentation. For patients who desire obliteration of residual vertical lines and are not seeking a resurfacing procedure, subdermal/dermal injection of filler at the depth of these areas is effective. In cases where a resurfacing procedure is planned but deep vertical lines greater than 0.5 mm are present, the patient should be counseled that for maximum correction a filler should be considered as an adjunct. This may be accomplished before or after the skin resurfacing.

Treatment for optimizing lip volume

When attempting to optimize lip volume in the young or aged patient, the practitioner has more options to achieve the desired result due to the slightly less precise requirements for filler placement. Filler materials that are appropriate for this purpose can be broadly considered to be those placed as an injectable material through a syringe and those that require surgical placement. Currently available materials along with their relative merits and risks are listed in Table 1. To minimize the risk of the filler being overtly palpable, it is typically placed 1.5 to 2 mm submucosally in the body of the red portion of the lip (Fig. 12).

Anesthesia. When lip volume augmentation is planned with injectable filler, lidocaine blocks or topical measures are adequate for patient comfort.

Injectable filler technique. A threading or multiple droplet technique can be used. With the threading technique, the injectable filler is placed into the body of the vermillion of the lip using

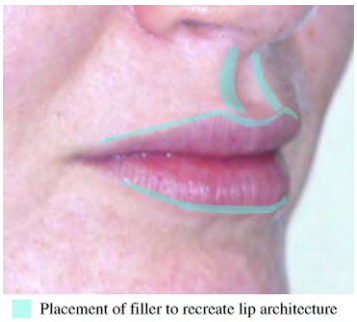

Fig. 10. Correct location of filler placement for augmentation of the architecture of the lip. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1637; with permission.)

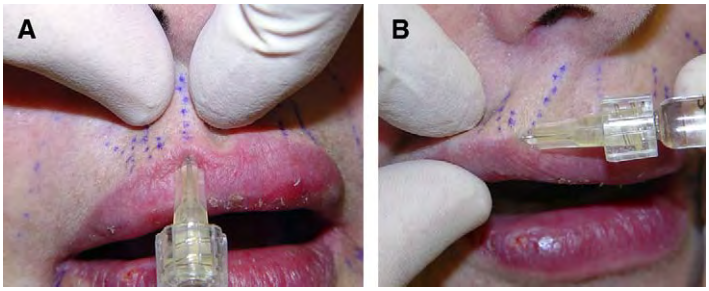

Fig. 11. Technique for filler augmentation of (*A*) the philtral columns and (*B*) the white line of the lip.

a long, 25-gauge needle. The needle is initially placed in each lip quadrant from the corner of the lip to the midline. As the needle is withdrawn, filler is injected in a continuous, controlled fashion. The droplet technique seeks to minimize filler migration by placing droplets of filler along multiple needle paths separated by living tissue. However, this occasionally results in palpable or visible nodules. In the upper lip, slightly more material may be deposited at the midline to simulate the tubercle. In the lower lip, the filler can be placed to create a bi-lobed or

Table 1
Various filler materials and properties used for augmentation of the lip

Material	Type	Placement	Duration of effect	Recovery time	Disadvantages
Bovine collagen (Zyderm, Zyplast)	Xenograft	Injection	2–3 mo	Short	Allergy testing, short duration of effect
Human collagen (from tissue bank) (Cosmoderm, Cosmoplast)	Allograft	Injection	2–3 mo	Short	Short duration of effect
Stabilized hyaluronic acid—nonanimal (Restylane)	Synthetic	Injection	6 mo	Short	Moderate duration of effect, increased recovery compared with collagen
Free-fat graft	Autograft	Large-bore injection	Variable; 3 mo with some permanency	Medium	Prolonged tissue edema (1 wk), variable efficacy, mostly nonpermanent
Fascia, SMAS—from patient	Autograft	Surgical	Variable; residual noted at 2 yr	Medium	Prolonged tissue edema (1–2 wk), mostly nonpermanent
Fascia, dermis—from tissue bank (Alloderm)	Allograft	Surgical	Variable; residual noted at 2 yr	Medium	Prolonged tissue edema (1–2 wk), nonpermanent
Poly-L-lactic acid (Sculptra)	Synthetic	Injection	Limited reports; repeat at 2 yr	Short	FDA approved for HIV-associated lipodystrophy only, granuloma formation
Polymethylmethacrylate microspheres in collagen base (Articol)	Synthetic/ allograft	Injection	Permanent	Short	Non-FDA approved, granuloma formation
Liquid silicone (Silikon 1000)	Synthetic	Injection	Permanent	Short	Granuloma formation, non-FDA approved
Expanded poly-tetrafluoroethylene (Advanta)	Synthetic	Surgical	Permanent	Medium	Prolonged tissue edema (1–2 wk), palpable graft, graft fracture, graft exposure

From Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1638; with permission.

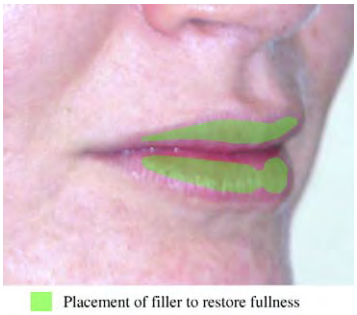

Fig. 12. Correct location of filler placement for augmentation of the body of the lip. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1638; with permission.)

uni-lobed appearance. Development of the tubercle in the upper lip should be performed conservatively because any asymmetry is evident.

Invasive lip volumizing technique anesthesia. Materials that require invasive surgical dissection through the lip for their placement (Table 1) benefit from conscious sedation, in addition to local anesthesia, to allay patient apprehension.

Invasive lip volumizing placement technique. These materials typically come in strips or tubes that are pulled through the lip. With the use of autologous fascia or submuscular aponeurotic system, the grafts are cut into the desired strip sizes.

Determining graft size. Required graft or synthetic material length should be measured individually for each lip in a circumferential fashion around a wide open mouth from commissure to commissure. The optimal width of the material is based on the desires of the patient but is typically from 3 to 5 mm in diameter in the center portion of the strip with gradual tapering to 2 to 3 mm at the ends.

Incisions and material placement. A small incision is made 1 to 2 mm from the corner of the mouth bilaterally, and a blunt trocar is passed through the lip at the desired depth. Once the trocar has been passed from incision to incision, it is withdrawn, and a small tendon passer is allowed to follow in the newly formed dilated passage (Figs. 13 and 14). The tendon passer in used to grasp the graft and pull it through the lip. The patient is instructed to open the mouth, and any excess graft is trimmed. The lip may be massaged to eliminate any clumping of the graft. Closure is generally accomplished through mucosa only without graft stabilization. In cases where the autologous graft lacks sufficient length to fill the entire lip, the entrance incisions are made at the most lateral extent of the graft when placed upon the stretched lip. The remainder of the procedure is accomplished in a typical fashion.

Selection of filler material. Selection of the filler material for the lip requires careful evaluation of the merits and disadvantages of each material. Duration of effect, recovery time, cost, risks, and adjunctive procedures concurrently planned that allow for harvest of the patient's own tissue for grafting are carefully discussed with the patient to obtain an informed decision and consent.

V to Y closure techniques for lip volumizing. Another surgical option for improving lip volume involves the use of single or multiple V to Y closures on the mucosal surface of the upper or lower lip. Oral and maxillofacial surgeons who regularly perform LeFort 1 osteotomies are well acquainted with this technique for preserving upper lip volume after surgery. A variation can be performed under local anesthesia augmented with intravenous sedation that "steals" tissue from the lateral lip and rotates it to improve lip pout and volume. Typically, two or three V to Y closures are completed on each lip to achieve an initially dramatic result. Disadvantages include

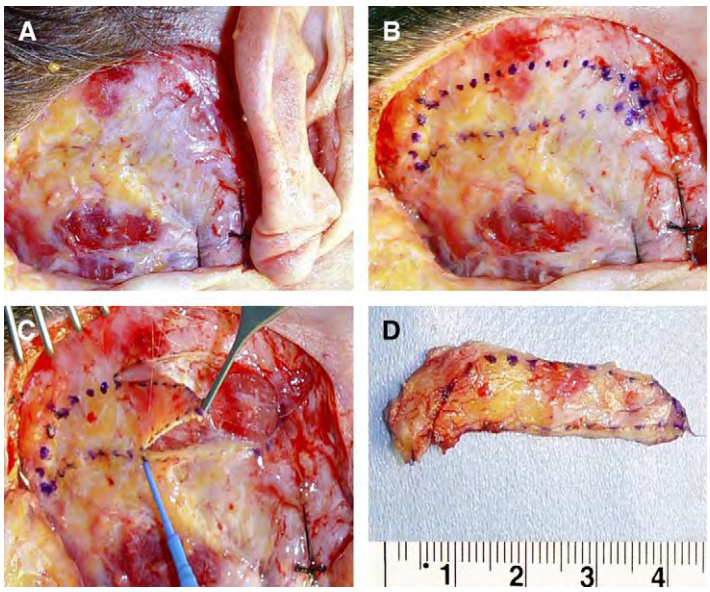

Fig. 13. Sequence for harvesting mastoid fascia graft. (*A*) Exposure of mastoid fascia via facelift incision. (*B*) The graft is measured and marked. (*C*) The graft is harvested. (*D*) The harvested graft is measured for shrinkage.

prolonged lip edema lasting 2 to 3 months, lip hypo- or dysthesesia, and often an equally dramatic relapse to a near presurgical appearance. For these reasons, coupled with the availability of less complication-prone procedures, the authors do not recommend this option unless it is planned in conjunction with a LeFort 1 procedure.

Adjunctive surgical procedures for optimizing lip length, eversion, and vermillion display

Treatment for the elongated, inverted lip

Two surgical procedures have been advocated for improving the elongated, inverted lip. With both techniques, shortening of the keratinized portion of the upper lip necessitates skin excision. The subnasal lip lift seeks to camouflage this excision by placing the incisions just inferior to the nasal sill. The vermillion excision technique places the excision at the vermillion–cutaneous junction. Table 2 lists the relative merits and disadvantages of each technique.

Subnasal lip lift

Indications. For the patient who exhibits inadequate upper incisal display coupled with a long upper lip and an acceptable Cupid's bow configuration, the subnasal lip lift is recommended. The subnasal lip lift involves excision of a wedge-shaped strip of skin and muscle from the upper lip immediately inferior to the nasolabial junction. As the tissue void is closed, the lip rotates and lifts superiorly. The lip is raised relative to the incisal edge of the upper teeth, and the vermillion is mildly everted to a more youthful appearance.

Contraindications. Relative contraindications for this procedure include a lip shorter than 18 mm, a history of forming hypertrophic scars or keloids, and the patient with excessively down-turned corners of the lips. An upper lip greater than 18 mm is generally required because an excision of at least 6 mm of skin is performed to achieve a noticeable result. A patient exhibiting less than 18 mm of upper lip length would be left with an excessively short upper lip. Hypertrophic scarring and keloid formation is possible in this location. Patients who exhibit this tendency are therefore excluded from this procedure. Austin has reported cosmetically undesirable results in the patient with down-turned lip corners. The lip lift often accentuates the "sad" appearance by raising the central portion of the lip. Although correction of this

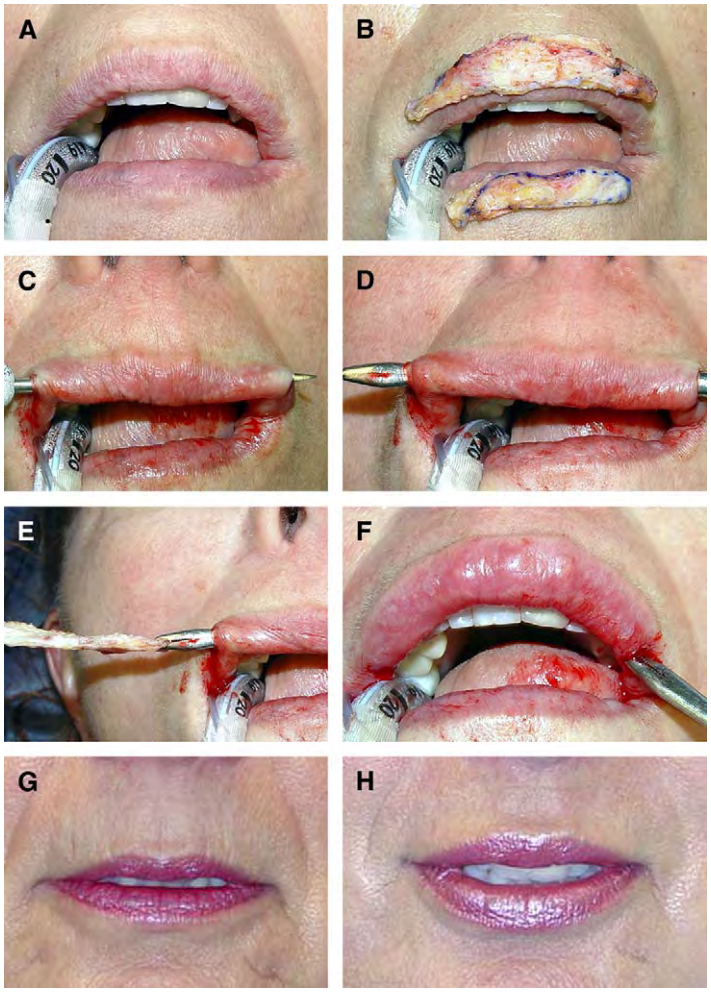

Fig. 14. Placement of mastoid fascia graft for volume augmentation of the lips. (*A*) Preoperative. (*B*) Grafts used to estimate placement of incisions. (*C*) Trocar creating graft recipient site within body of the lip vermillion. (*D*) Tendon passer inserted through graft recipient site. (*E*) Graft grasped by tendon passer. (*F*) Graft pulled through lip. (*G*) Preoperative perioral region. (*H*) Three months post lip augmentation with two-pass CO_2 laser resurfacing (Novapulse laser, 6 W, superpulse mode, 10% overlap, E16 pattern, using a pattern generator).

deformity is possible by simultaneously lifting the lip corners, this procedure has an unsatisfactorily high complication rate; therefore, the subnasal lip lift should be avoided in these patients.

Anesthesia. The lip lift can be performed under local anesthesia or with intravenous sedation. Lidocaine with epinephrine should be used to locally infiltrate the area to aid hemostasis. Care

Table 2
Comparison of subnasal lip lift and vermillion border excision techniques

Procedure	Advantages	Disadvantages
Subnasal lip lift	Good lip eversion	Potential changes to nasal sill
	Good lip shortening	Emphasizes down-turned "sad" lip corners
	Well-hidden scar	Unable to change shape of Cupid's bow
Vermillion border excision	Good lip eversion	Obliteration of white roll of lip
	Good control of shape of Cupid's bow	Visible scar
	Some lip shortening	Prolonged lip edema "Surgical" appearance

should be taken not to overinfiltrate the area with more than 1 ml of agent to avoid tissue distortion.

Incision markings. The superior extent of the excision is marked just inferior to the nasal sill extending from lateral ala to lateral ala (Fig. 12). The incision can be extended into the melolabial fold for more lateral lift, but this is rarely warranted. After the area has been anesthetized, it is useful to tattoo the markings with methylene blue. This is accomplished by applying tattoo "dots" every 2 to 3 mm with a sterile 30-gauge needle. The inferior extent of the tissue excision is marked by estimating how much of the lip must be removed to expose the desired incisal tooth display (Table 3). A 25% overcorrection is recommended to accommodate for relapse. Care is taken not to excise tissue so that less than 15 mm of upper lip is left intact.

Incision. A #15 blade should be directed perpendicular to the skin and should not cross the curvature of the nostril sill into the nasal vestibule. The tissue excision is typically wedge shaped viewed in cross-section extending to include orbicularis oris. For patients who require true vertical lip lifting, the excision encompasses more muscle. For patients needing mostly vermillion eversion, the excision involves mainly skin, with little muscle excision.

Closure. Closure is accomplished in layers. Typically, 3-0 polyglactin suture (Vicryl; Ethicon, Somerville, NJ) is used to close muscle, 4-0 monofilament chromic (Monocryl; Ethicon) is used to close subcuticularly, and 6-0 plain gut (interrupted) is used to meticulously accomplish skin approximation (Fig. 15). The resultant scar is generally well hidden in the nasolabial crease and easily camouflaged with make-up after 7 to 10 days. Fig. 16 demonstrates a patient immediately preoperatively and the typical presentation at the 2-week postoperative appointment. Plain gut sutures have been exfoliated, and the subnasal incision is well camouflaged. The increased incisal display is readily apparent.

Sequencing of techniques. The aged patient often presents with the triad of all three deformities: loss of lip architecture, loss of lip volume, and lip lengthening. The sequence of correction generally proceeds from lip architecture, to lip volume, to lip length. Other sequences often confound the operator by producing soft tissue edema, which makes accurate surgery difficult.

Fig. 17 displays typical results that can be expected with combined lip augmentation and lip lift procedures. At 3 months postoperatively, the upper lip has a more youthful fullness and eversion while allowing a pleasing display of the dentition at repose and when smiling. The lower lip displays a more attractive pout, which is associated with youth. The subnasal scar is almost invisible at 3 months.

Vermillion border excision technique

For the patient with an elongated upper lip, inadequate incisor display, and an undesirably flat Cupid's bow configuration, the vermillion border excisional technique represents a second

Table 3
Measurements and estimates of excision in lip lift surgery

	Desired post-op incisal display (DID)		Excisional height (EH)[a] (EH = 2 mm + DID − AID, Min. EH = 4 mm, Max. EH = 8–9 mm)	
Actual incisal display (AID)	Female	Male	Female	Male
+2 mm	+4 mm	+2 mm	4 mm	0 mm
+1 mm	+4 mm	+2 mm	5 mm	4 mm
0 mm	+4 mm	+2 mm	6 mm	4 mm
−1 mm	+4 mm	+2 mm	7 mm	5 mm
−2 mm	+4 mm	+2 mm	8 mm	6 mm
−3 mm	+4 mm	+2 mm	9 mm	7 mm
−4 mm	+4 mm	+2 mm	9 mm	8 mm

[a] EH = 2 mm + DID − AID; minimum EH = 4 mm, maximum EH = 8–9 mm.

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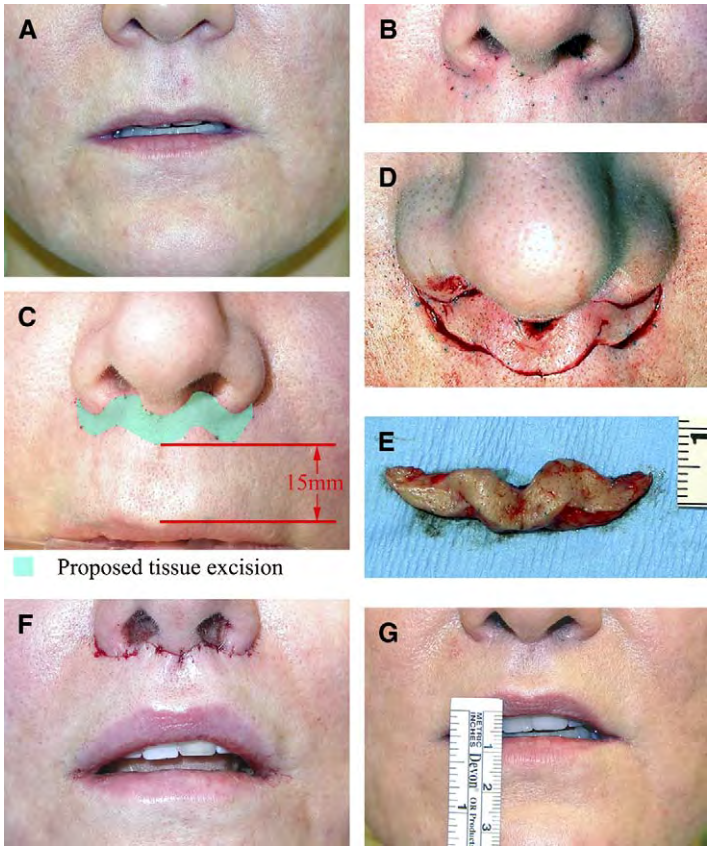

Fig. 15. Operative sequence for the lip lift technique. (*A*) Preoperative. (*B*) Preoperative markings. (*C*) Proposed excision area. (*D*) Incisional outline. (*E*) Excised skin and muscle. (*F*) Immediately postoperative. (*G*) Three months postoperatively. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1639; with permission.)

option (Fig. 18). This procedure is performed in a similar fashion to the subnasal lip lift, with the exception that the incision is placed at the vermillion–cutaneous junction (Fig. 19A and B). The main advantage of this variation is that the shape of the new Cupid's bow can be sculpted by the surgeon. Disadvantages of this technique include a more visible scar; obliteration of the white role of the lip, necessitating the placement of an injectable filler to recreate this structure; and a high propensity for the patient to obtain a "surgical" look in the perioral region (Fig. 20).

Postoperative care and complications

There are general postoperative instructions that are given to all patients undergoing a surgical lip procedure. The head should be kept in an elevated position for at least 24 hours to minimize swelling. For more invasive procedures, this period might be extended to 3 to 5 days. Ice to the affected area for the first 24 hours is effective in minimizing tissue edema. Patients are

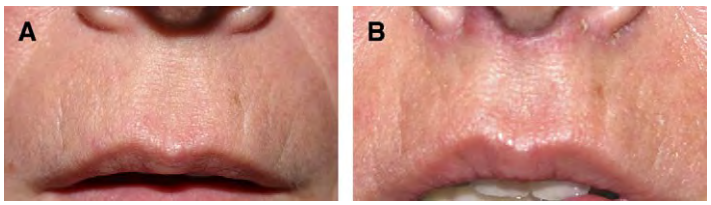

Fig. 16. Subnasal lip lift. (*A*) Preoperative. (*B*) Two weeks postoperatively.

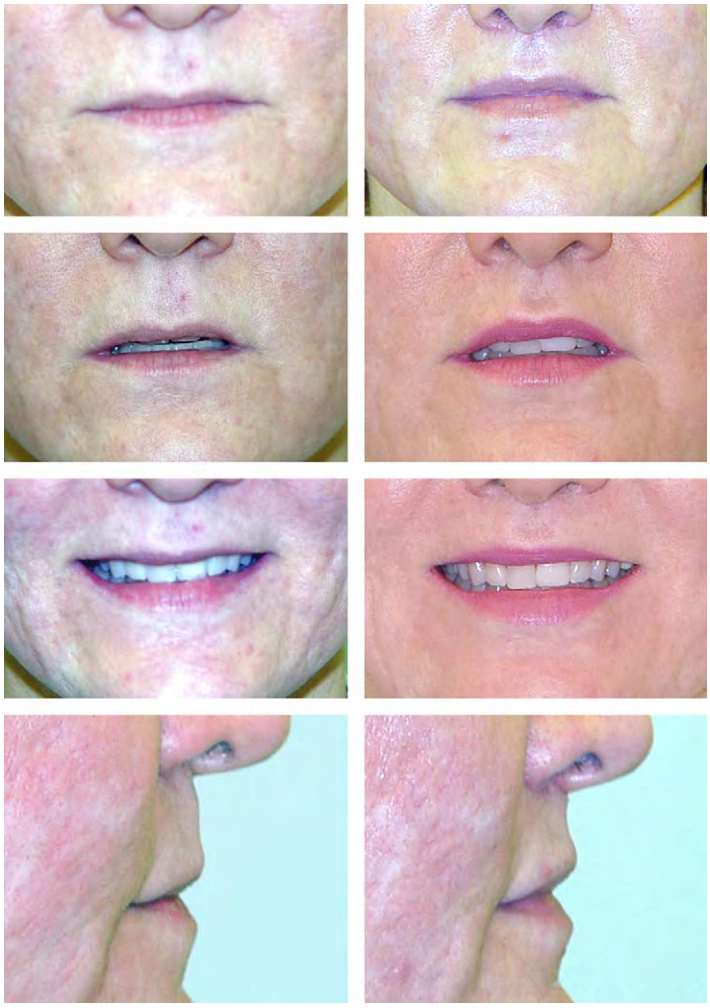

Fig. 17. Case study. Directed lip augmentation combined with lip lift procedure. Left column: preoperative. Right column: 3 months postoperatively. (*From* Perenack J. Treatment options to optimize display of anterior dental esthetics in the patient with the aged lip. J Oral Maxillofac Surg 2005;63:1639; with permission.)

generally cautioned not to manipulate or animate the lip area excessively for at least 48 hours. For lip lift and surgically augmented patients, this period is extended to 7 days. Incisions are covered with an antibiotic ointment for the first 48 hours and with a petroleum-based occlusive ointment until epithelialization is complete.

Complications are unusual but should be discussed with the patient before beginning treatment. Bruising and swelling are less likely in patients who require only filler injections but should be expected and figured into the patient's social calendar. Surgically placed fillers in the lips typically can produce profound, prolonged edema of the affected site. Preoperative counseling and frequent postoperative follow-up appointments are helpful in allaying patient anxiety. Hematoma is a possible complication but typically resolves with no treatment over a period of weeks. A large hematoma should be evacuated immediately in surgical patients; otherwise, aspiration at 7 days is recommended. Infection is unusual after lip surgery due the vascular nature of the area. For lip lift and surgically placed augmentation materials, oral antibiotics are prescribed for 7 days. Injectable fillers do not require antibiotic coverage. Visible scars are minimized with meticulous closure technique. In instances where the incisional scar seems to be developing objectionably, the site can be resurfaced with a CO_2 laser or dermabrasion. Optimal results are obtained if these measures are performed before 3 months postoperatively. Hypertrophic scarring or keloid formation is best avoided by identifying patients who are prone to this problem preoperatively and offering an alternative treatment. Occasionally,

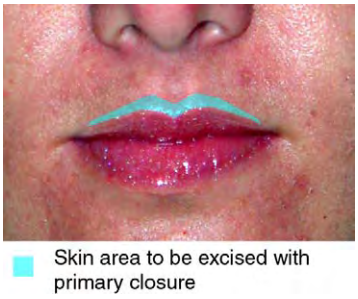

Fig. 18. Schematic of area of lip typically excised with vermillion border technique.

a patient is dissatisfied with a cosmetic result that is otherwise objectively adequate. This complication is best avoided by using preoperative counseling that can identify the patient's expectations as obtainable or unachievable.

Skin resurfacing and subsurfacing

Cumulative actinic damage to the perioral skin over time results in unaesthetic textural and pigmentary changes. These effects of sun-damaged and aging skin can be treated in a variety of ways, including chemical peel, laser resurfacing (ablative and nonablative), intense pulsed light, and nonablative radiofrequency. Dermabrasion is another ablative method that is not discussed in this article. Chemical peel and ablative laser resurfacing are considered to be invasive resurfacing methods due to the removal of epidermis with related dermal injury. Meanwhile, nonablative laser, intense pulsed light, and nonablative radiofrequency are considered noninvasive because the epidermis is theoretically not damaged. These noninvasive procedures are known as subsurfacing procedures because they inflict damage to the dermis only. Disadvantages to the invasive treatments include the 1 to 2 weeks needed for reepithelialization and postprocedure erythema, which can last for months. Other potential risks include postoperative pigmentary changes, scarring, delayed healing, and infection. The noninvasive procedures

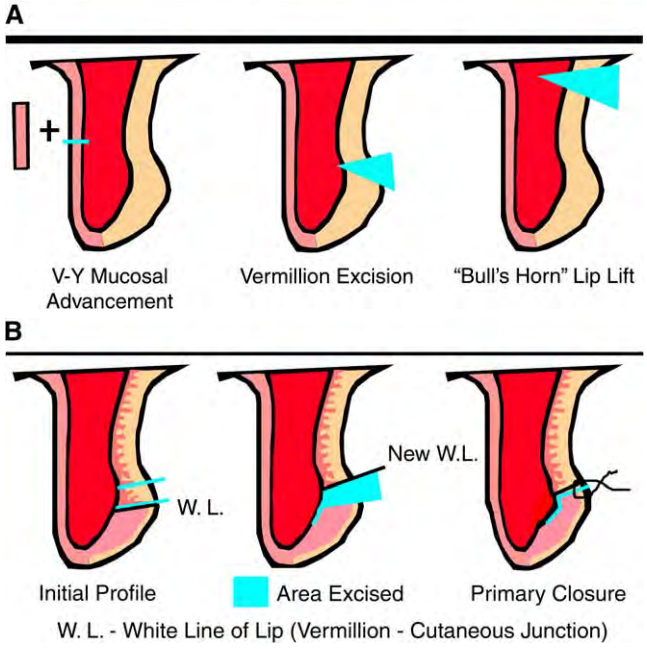

Fig. 19. (*A*) Schematic of effects of V to Y closure, vermillion border excision, and the subnasal lip lift. (*B*) Cross-sectional schematic of vermillion border excision procedure.

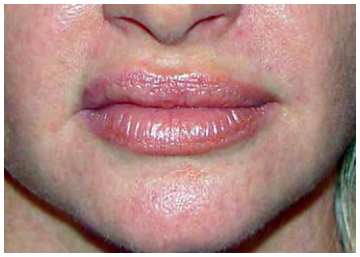

Fig. 20. Ten-year postoperative result of vermillion border excision. White roll has been maintained with collagen injections. Note surgical appearance particularly of right upper lip quadrant.

produce 2 to 3 days of post-procedure erythema, no epidermal damage, and little chance of dyspigmentation. However, the results of these procedures are less pronounced and less effective in severely photoaged skin. These noninvasive procedures seem to be best suited for patients who are unwilling to undergo a prolonged healing period or who possess a skin reactive type that precludes the use of more invasive procedures.

Skin resurfacing methods treat photodamaged skin by controlled injury. This injury removes the abnormal epidermis and stimulates collagen production in the dermis. There are three levels of resurfacing: superficial (to the papillary dermis), medium (to the upper reticular dermis), and deep (to the midreticular dermis). The modality with which to treat the skin is determined by the depth of injury needed to achieve the desired result. Mild photodamage may require a superficial injury, whereas severe photodamage may require a deep injury to produce satisfactory results.

Chemical skin resurfacing

Chemical peels have been a widely accepted method of skin resurfacing for many years. Several chemicals exist that can be used in facial resurfacing. The choice of chemical or combination of chemicals depends upon the depth of peel desired (Table 4).

Superficial exfoliative or resurfacing agents

For light or superficial (stratum corneum only) peeling, daily application of topical agents such as tretinoin, α-hydroxy acids, 5-fluorouracil, or salicylic acid can be used. Trichloroacetic acid (TCA) in concentrations of 10% to 20%, Jessner's solution (resorcinol, salicylic acid, and

Table 4
Chemical skin resurfacing

Characteristics	Very Superficial	Superficial	Medium	Deep
Agents	Tretinoin Salicylic acid 5-Fluorouracil α-Hydroxy acids TCA 10–20% one layer Jessner's one to three layers Glycolic acid 20–30%, 1–2 min	35% TCA one layer Jessner's four layers Glycolic acid 40–50%, 2–15 min	35% TCA plus Jessner's or glycolic acid 40% TCA 40–50%, one layer Glycolic acid 70%, 15–20 min	Phenol Phenol plus croton oil
Emergence of frosting	No frosting	15–20 s	5–10 s	5–10 s
Time to peel	Minimal flakiness in 2–3 d	3–4 d	7–8 d	10 d
Time to heal (reepithelialize)		4–5 d	7–10 d	10–14 d
Appearance of skin during application	No change or mild erythema	Diffuse erythema, light-white frost	Uniform light-white frost	Dense pure white frost
Layer of skin injured	Stratum corneum	Entire epidermis	Papillary dermis	Upper reticular dermis

lactic acid in ethanol) in one to three layers, and glycolic acid in 20% to 30% concentrations for 1 to 2 minutes produce light peeling. Superficial peeling (injury to the entire epidermis) can be achieved by using a single application of 35% TCA, four layers of Jessner's, or 40% to 70% glycolic acid for 2 to 20 minutes.

Medium-depth resurfacing agents

By combining agents used for superficial peeling, one can achieve a medium-depth (through epidermis to papillary dermis) peel. TCA (35%) combined with Jessner's or glycolic acid results in medium-depth peeling. TCA produces medium-depth injury in concentrations of 40% to 50%.

Deep-depth resurfacing agents

Deep peels are achieved by using phenol and combinations of phenol and croton oil. Medium depth agents can also unpredictably result in a deep depth peel when used aggressively.

Pre-resurfacing skin preparatory regimens

When planning a chemical peel procedure, the patient should be advised to use tretinoin 0.05% to 0.1% qid for 3 to 4 weeks before the procedure. Tretinoin gradually weakens keratin bonds and thin superficial keratin layers, resulting in a more uniform skin surface and even permeability to the chemical used for peeling. Patients who have darker-pigmented skin (Fitzpatrick III or IV) should be advised to use 4% hydroquinone bid for 3 to 4 weeks before and several weeks after peeling (starting after reepithelialization has occurred). Hydroquinone decreases the number of melanosomes in the skin and inhibits tyrosinase, preventing the conversion of tyrosine into melanin in the melanocyte and thus decreasing postinflammatory hyperpigmentation (Fig. 21). Darker-skinned patients may benefit from a longer pre-peel course of tretinoin. It is generally recommended to use a prophylactic antiviral to prevent a herpes outbreak even in patients who have no history of herpes. A typical course of an antiviral agent begins 1 day before resurfacing and continues for up to 2 weeks.

Anesthesia

Chemical peels (other than very light) should be performed under adequate sedation and analgesia if the entire face is being treating. If a limited area (eg, the perioral area) is to be treated, then local anesthesia (without epinephrine) or the application of ice to the area may be used.

Skin preparation

The area to be treated should be prepped with alcohol or acetone to remove oils and superficial debris from the skin. Eyes should be protected with lacri lube or wet gauze.

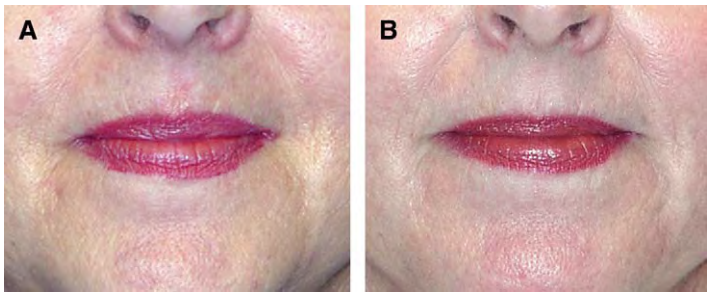

Fig. 21. Typical results obtained after 4 months of topical treatment with 0.1% tretinoin daily (0.5 in of gel to face and neck) and 4% hydroquinone twice daily (0.5 in of gel to face and neck). (*A*) Before. (*B*) After.

Agent application

The peeling agent can be applied using a cotton-tipped applicator, a sable brush, or gauze soaked in the agent. The agent is applied in rapid, uniform strokes. The practitioner must allow time for the emergence of skin frosting before the application of additional layers to avoid overtreatment. Stronger agents (40% TCA) produce a frosty look to the skin in as little as 5 to 7 seconds, whereas more dilute acid (20%) takes 15 to 20 seconds. When multiple coats of agent are applied to the face, the agent is ''feathered'' or diminished at the treatment area edges to aid in postoperative blending with areas of untreated skin.

Trichloroacetic acid chemical resurfacing

The most commonly used peeling agent is TCA. When using TCA, one can determine the degree of peel depth based upon the appearance of the skin during the application. Diffuse erythema with mild, light-white cloudy frosting results in a superficial peel. Uniform, light-white frosting is indicative of epidermal/dermal injury and results in a medium-depth peel (Figs. 22 and 23). Dense, pure white uniform frost is indicative of deep papillary-reticular junction penetration and results in a deep peel. Yellowish-gray frosting indicates reticular dermis injury and results in delayed healing and scarring.

Postoperative care

Postoperative care includes placing a moist occlusive dressing or ointment on the treated surface. Topical analgesics such as Xylocaine ointment or ice compresses can help with immediate post-peel burning. A bland moisturizer should be applied two or three times per day. Aluminum acetate solution soaks at day 4 to 5 can help induce separation of the superficial eschar. When reepithelization is complete, the patient should be encouraged to avoid sun exposure or to use sunscreen for up to 3 months.

Complications

Adverse effects of chemical peels include abnormal pigmentation, infection, scarring (especially with deeper peels), persistent rhytids, and patient dissatisfaction (especially with lighter peels).

Ablative laser resurfacing

Two ablative lasers are commonly used in skin resurfacing: the CO_2 laser and the Er:YAG laser.

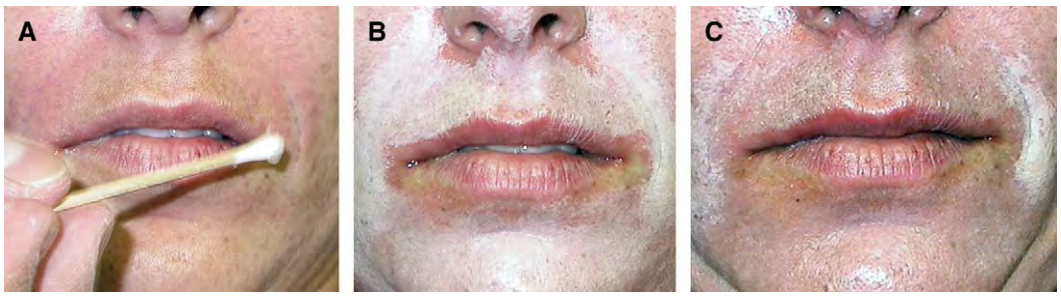

Fig. 22. Thirty percent TCA peel. (*A*) Application of initial coat. (*B*) Intra-operative frosting. Two layers of 30% TCA have been applied to melolabial folds. (*C*) Thirty minutes postoperatively. Pink frost in the perioral area is indicative of papillary dermal injury; denser white frost in the melolabial folds suggest papillary to midreticular dermal injury.

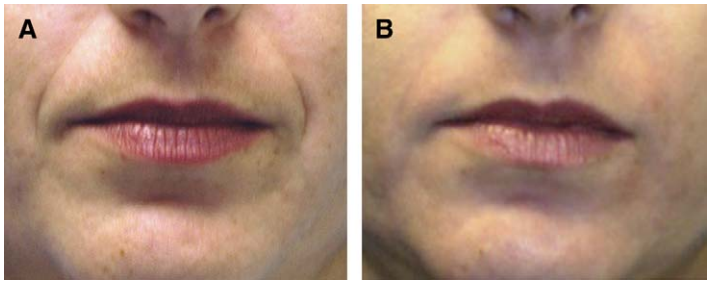

Fig. 23. (*A*) Preoperative appearance of patient from Fig. 22. (*B*) Three-month postoperative view after one-layer and selective two-layer 30% TCA peel with free fat injection to melolabial folds.

CO_2 laser resurfacing

CO_2 lasers are high-energy pulsed lasers that allow for higher-energy densities with safe exposure duration, which results in less risk for thermal injury to nontargeted tissues. The CO_2 laser targets water in epidermal cells, which are heated to 100°C and vaporized. The dermis responds to the conducted heat and produces a band of coagulation necrosis. The depth of this injury is determined by the energy of the laser and the amount of exposure time. Most systems have a computer-generated pattern to allow for simultaneous treatment of larger areas of skin. Indications for ablative laser resurfacing are actinic changes, rhytids, exophytic skin lesions, scars, and rhinophyma.

Anesthesia

Generally, conscious sedation combined with tumescent infiltration or blocks with local anesthesia provides adequate anxiolysis and pain relief. When acceptable to the patient, general anesthesia provides the most optimal pain control, particularly when multiple passes with the CO_2 laser is planned. General anesthesia is also recommended if combining laser treatment with other procedures. If treating a small area (eg, laser scar revision) local anesthesia is sufficient.

Prelaser skin preparation

It is recommended that patients be pretreated with tretinoin, although there is little scientific support for such treatment. Perioperative antiviral prophylaxis is always indicated. Postoperative hydroquinone is more useful than preoperative because the skin's melanocytes are vaporized with the first pass of the laser. Melanocytes that newly migrate to the reepithelialized skin post-treatment are the targets for hydroquinone treatment.

Laser treatment strategies

Laser energy and treatment time varies with the surface being treated. Periorbital areas require less energy and exposure time, whereas perioral areas and cheeks require more energy and more exposure due to the thicker skin. Each brand of system varies slightly from the next, but in general it is recommended that treatment consist of at least two passes of the laser to prevent pattern imprinting on the face.

Depth of ablation

Typical settings for the CO_2 laser are super-pulse mode, 6 watts, at 0% to 30% overlap. Settings vary depending upon the brand of laser. The first pass has the greatest effect due to the high water content in the epidermis. Before laser resurfacing, the skin must be adequately dried to prevent unexpected energy absorption. When the epidermis has been vaporized, it becomes white. This white layer of vaporized epidermis is generally removed to reveal a pink papillary dermis. The pink color of the dermis indicates minimal or no coagulation of the papillary dermis. With a second pass, the dermis takes on a more tanned look, indicating some degree of coagulation necrosis. The importance of removing desiccated tissue, or char, with wet gauze between passes is questionable. As more passes are made, the dermis begins to turn yellow; when this happens further, resurfacing leads to scarring. The practitioner must pay close attention to the color of the treated area to ensure treatment that is adequately deep but not so deep that scarring occurs.

Postoperative care

Postoperative care is similar to the care required after chemical peel. Wound protection can be achieved by a semiocclusive dressing or occlusive ointments until reepithelialization occurs. Antibiotic ointments are not recommended due to the increased chance of contact allergic dermatitis. Postoperative oral antibiotics are routinely prescribed. Oral analgesics are recommended, especially if a semi-occlusive dressing is not used. Patients should be instructed to avoid sun or to use sunscreen for approximately 3 months and to judiciously return to a simplified skin care regimen after reepithelialization. Fig. 14 demonstrates a patient who benefited from CO_2 laser resurfacing in conjunction with mastoid fascia autografting to add lip volume.

Contraindications to ablative laser resurfacing

Ablative laser treatment is contraindicated in patients who have skin adnexa abnormalities, such as patients who have a history of radiation therapy or a history of taking isotretinoin in the past 2 years. Ablative skin resurfacing in a patient who has a history of keloid formation or hypertrophic scarring and regional resurfacing in a darker-skinned patient (Fitzpatrick IV–VI) should also be cautioned against.

Complications

Complications include prolonged erythema (weeks to months), infection, hyperpigmentation, milia, acne, scarring, and hypersensitivity to sun damage for up to 2 years.

Er:YAG laser resurfacing

The Er:YAG laser was introduced as an alternative to the CO_2 laser with the hope of maintaining a similar clinical benefit profile while limiting the side-effect profile. The Er:YAG laser targets water at a wavelength of 2940 nm. The absorption coefficient of this laser is approximately 16 times higher than the CO_2 laser. Its optical penetration depth is about one twentieth that of the CO_2 laser. This superficial penetrance leads to effective tissue ablation with minimal thermal damage. Decreased thermal diffusion results in less coagulation necrosis, but it also results in less effective hemostasis and tissue contraction. A benefit of this laser's superficial absorption and relatively little thermal damage is less postoperative erythema. Manual removal of desiccated tissue between passes of the laser is also generally regarded as unnecessary.

Preoperative care

Pre- and postoperative care regimens are similar to those of the CO_2 laser.

Depth of ablation

The Er:YAG laser requires three or four passes to achieve penetration similar to the CO_2 laser. Overall clinical results for treatment of deeper rhytids and atrophic scars are less impressive with the Er:YAG laser than with the CO_2 laser; however, it produces modest improvement with a shorter recovery time.

Complications

Complications associated with the use of the Er:YAG laser are similar to those seen with the CO_2 laser but are generally less severe, less frequent, and of shorter duration. Many clinicians attempt to harness the relative benefits of the Er:YAG and CO_2 lasers by using them sequentially in a two-pass skin resurfacing technique.

Resurfacing adjuncts

For the patient with deep radial furrows, a filler is recommended in addition to the resurfacing procedure (Fig. 24).

Intense pulsed light

Intense pulsed light sources are nonlaser, nonablative, noncoherent, broadband flashlamp devices that emit light between the wavelengths of 500 and 1200 nm. Longer wavelengths can be

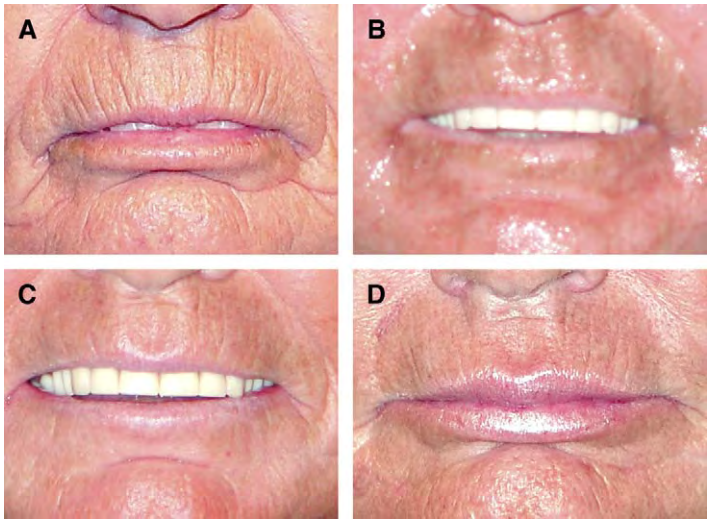

Fig. 24. Recovery and results after three passes with CO_2 Novapulse laser (6 W, superpulse mode, 10% overlap, E16 pattern with pattern generator). Injectable hyaluronic acid to deep furrows and lips was performed. (*A*) Preoperative. (*B*) Two days postoperatively. (*C*) Three months postoperatively. (*D*) One year postoperatively. Note mild hyperpigmentation from continued sun exposure. The patient refused the use of hydroquinone to correct this problem.

achieved by using appropriate filters (ie, cutoff filters) that block the shorter wavelengths. It is these longer wavelengths that cause dermal damage and subsequent dermal remodeling. The wavelength determines the absorption behavior and the penetration depth of the light. Wavelength can be adjusted with cutoff filters to be adapted to the patient's individual skin type (higher filters reduce melanin absorption and can be used to prevent adverse effects in patients who have darker skin types).

Indications

Initially, intense pulsed light sources were found to be effective in the treatment of vascular and pigmented lesions of the skin and for hair removal. Several studies show that intense pulsed light is effective in the treatment of rhytids and sun-damaged skin. Indications for this treatment include wrinkling, irregular pigmentation, telangiectasias, coarse skin, and diffuse erythema.

Treatment regimens

Most authors report good results when using intense pulsed light in a series of three to six treatments (based on the extent of photoaging) administered at 2- to 3-week intervals. Energy (fluence) can vary between 10 and 50 J/cm^2. Patients seem to tolerate double-stacked pulses better than triple-stacked pulses.

Anesthesia

Using a cooling system (cooling gels, ice gels, contact spray cooling, or a cooling handpiece) is recommended to prevent the epidermis from being burned. In most cases, topical anesthesia is not necessary.

Complications

Complications are rare and are minor. Postoperative erythema is the most common adverse event reported and can last from 2 to 48 hours. Some patients experience blistering of the skin, transient darkening of lentigines, or transient purpura. Patients who have severe or widespread

actinic damage may not benefit as much from this procedure as they would from an invasive resurfacing procedure.

Nonablative lasers

Several nonablative lasers are used in the treatment of aged and sun-damaged skin. These lasers use epidermal surface cooling in combination with deeply penetrating wavelengths that selectively target water-containing tissue, resulting in selective heating and subsequent thermal injury to the dermis. Examples include the Nd:YAG, pulsed-dye, and diode lasers.

Nd:YAG laser

The Nd:YAG laser was the first laser used as a nonablative skin rejuvenation tool. The 1064-nm Nd:YAG targets melanin, hemoglobin, and, to a lesser extent, water.

Treatment regimens

The Nd:YAG laser is used at an energy level between 2.5 and 5.5 J/cm^2 in a series of three or four treatments at 1- to 4-week intervals. The Nd:YAG laser is delivered freehanded by a handpiece with a 5- to 7-mm spot size. Treatment areas should be slightly overlapped, and the edges of the treatment areas should be feathered. The 1320-nm Nd:YAG laser is delivered in similar fashion but at energies between 30 and 40 J/cm^2.

Indications and outcomes

Nd:YAG and pulsed-dye lasers show similar outcomes in the treatment of photoaging and rhytids. Patients who have mild to moderate photoaging and rhytids respond better to treatment with this laser than do patients who have severe photoaging and rhytids.

Pulsed-dye and diode lasers

The pulsed-dye laser emits yellow light with a wavelength of 585 nm. This wavelength selectively targets hemoglobin and melanin.

Treatment regimens

The treatment energy range for the pulsed-dye laser is 2.4 to 6.5 J/cm^2. It has a pulse duration of 0.35 to 0.45 milliseconds. The laser handpieces vary from 4 to 10 mm spot size. This laser has been shown to be effective at treating mild wrinkling, telangiectasias, and photodamaged skin.

980-nm diode laser

The 980-nm diode laser targets hemoglobin, melanin, and water; using longer pulse durations favors the heating of water.

1450-nm diode laser

Several studies have shown that the 1450-nm diode laser is effective in treating mild to moderate rhytids. Three or four consecutive treatments at 3- to 4-week intervals are recommended.

Complications

The adverse effects of the noninvasive lasers are transient erythema, transient purpura, and, in one study, hyperpigmentation (thought to be due to the cooling system rather than the laser beam). These lasers are useful for mild to moderately photoaged, wrinkled skin in patients who cannot tolerate a prolonged healing period.

Nonablative radiofrequency

Radiofrequency tissue tightening is a relatively new alternative to nonablative laser technology. The radiofrequency device currently marketed (ThermaCool TC; Thermage, Hayward, CA) delivers electricity at 6 Mhz, which causes the movement of charged particles. The tissue's resistance to the flow of electrons generates heat, which causes collagen shrinkage and new collagen deposition. This system uses a concurrent built-in cooling system to prevent epidermal damage. The application of heat is uniform due to a capacitor membrane at the treatment tip. Several studies have shown improvement in the appearance of facial rhytids. Ruiz-Esparza recommends focusing treatment over the preauricular area, which provides an anchoring point to stretch the skin distally to it. Results are evident after just one treatment.

Anesthesia

Topical anesthesia without sedation is usually sufficient for pain control. Topical anesthetic gel or cream should be placed on the treatment areas for 45 minutes to 1 hour before the procedure. Most authors recommend placing an occlusive dressing over the lidocaine for the duration. After the allotted time, the anesthetic should be wiped off thoroughly with dry gauze.

Treatment area

The treatment area should be marked in a grid pattern of contiguous squares measuring just slightly larger than the area of the tip (ThermaCool = 1 cm^2). A radiofrequency return pad should be placed on the patient's back to create a return path for radiofrequency travel. Coupling fluid should be spread over the treatment area to enhance thermal and electrical contact with the tip. Each grid square should be treated individually with the radiofrequency tip, which can provide more than 100 applications depending on the treatment area size. Each treatment area is automatically precooled with cryogen and simultaneously heated and cooled and then post-cooled. The energy delivered can vary based on the thickness of the skin and the location of the skin (thicker skin needs higher energy). The energy level can be adjusted according to the pain experienced by the patient. Higher energy levels have been associated with a higher incidence of burns.

Complications

Postoperative complications include erythema and edema (which resolve within 72 hours), blistering, and scabbing.

Discussion

Creation of a more attractive soft tissue perioral window compliments the results of skillful dental restoration. In the young patient, efforts should be directed toward optimizing lip fullness and architecture and incisal display. The aged patient requires particular attention to correcting the loss of lip volume and architecture, lip lengthening, and the changes associated with accumulated sun damage. These goals can be met through relatively simple procedures that can be performed under local anesthesia. The key to satisfying the patient often rests with the first appointment when an adequate diagnosis of all perioral problems should be done. A comprehensive treatment plan should be offered, along with an explanation of each procedure offered and an attempt to integrate a skin-care regime. Patients are often unaware of the complexity of solving their particular esthetic concerns. Fig. 25 provides an algorithm to direct treatment planning of the perioral region. If a soft tissue filler is required, then discussion of material options with risks, benefits, and duration is important. If the filler used is nonpermanent, patients need to be kept in regular recall to maintain results. Reinjection or replantation of filler materials should be tailored to the resorption profile of the substance used. Stabilized hyaluronic acid should be used every 5 to 6 months. Collagen injections need to be repeated every

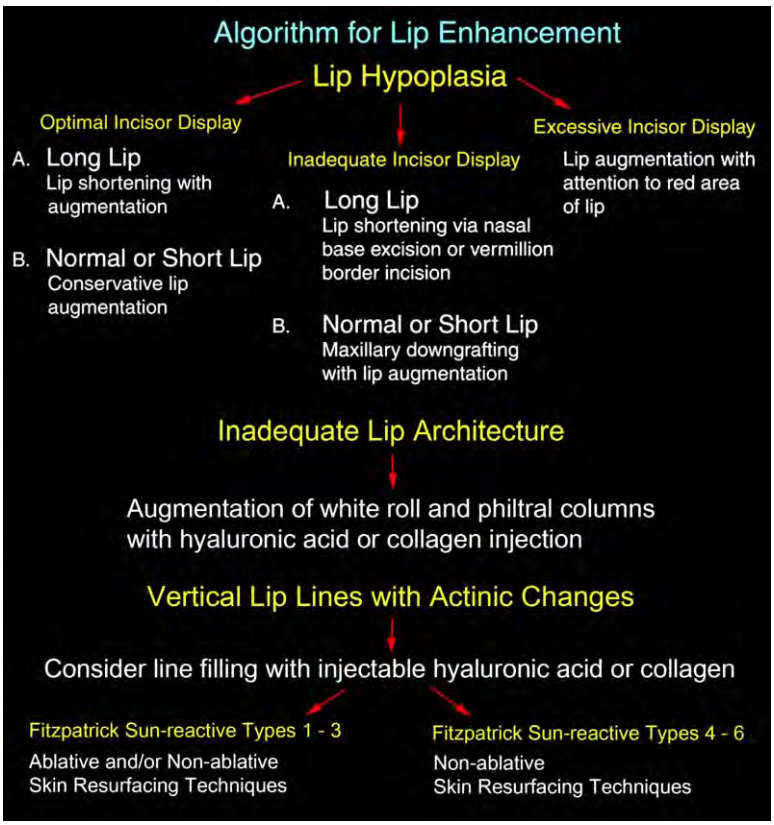

Fig. 25. Algorithm for lip enhancement.

2 to 3 months. Although this may affect patient acceptance of the treatment plan, often it merely requires the surgeon to explain the problem in terms similar to oral hygiene recall. A related problem can surface in the patient who undergoes simultaneous lip lift and moderate to severe lip volumizing. Dramatic lip volumizing often lowers the inferior border of the upper lip. If the lip lift has been planned to the new lip margin, an excessive tooth display is possible as the filler material resorbs. Although this phenomenon is theoretically possible, it is rarely of any significance. The question is occasionally raised as to the duration of the effect of the lip lift procedure. Although there is limited research on the subject, anecdotally there seems to be roughly a 10% to 20% immediate relapse noted within the first 3 months postoperatively. Long-term follow-up results from this point on suggest that the result is exceptionally stable.

Sequencing for the patient who requires a resurfacing procedure in addition to lip lift surgery is also important. Ideally, the lip lift is accomplished first, with the resurfacing timed at 1 to 3 months after the surgery. This creates an optimal situation to resurface the lip lift scar and minimize its final appearance. For patients requiring volume or architecture fillers in addition to resurfacing, both procedures can be performed simultaneously or separately at the patient's convenience.

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Techniques for the Use of CT Imaging for the Fabrication of Surgical Guides

Scott D. Ganz, DMD[a,b,*]

[a]*Department of Prosthodontics and Restorative Dentistry, University of Medicine and Dentistry of New Jersey, New Jersey Dental School, 110 Bergen St., P.O. Box 1709, Newark, NJ 07101-1709, USA*
[b]*Hackensack University Medical Center, 30 Prospect Avenue, Hackensack, NJ 07601, USA*

Implant dentistry has evolved into one of the most predictable treatment alternatives for partially and completely edentulous patients. The initial excitement about successful osseointegration has allowed clinicians to offer an extended set of treatment alternatives that include single tooth replacement to full mouth reconstruction. Pioneering protocols of the early 1980s relied on a two-stage surgical approach that allowed for the biological aspects of osseointegration to be achieved at the cellular level, insuring long-term success. These procedures often required extended periods of time to complete. Through strategic marketing and word of mouth, demand for implant-related treatment continues to grow and has compelled clinicians to search for new and improved methods to deliver such care within a shorter time period without sacrificing accuracy. As treatment protocols have progressed, implant manufacturers have met the challenge of providing surgical and prosthetic components to maximize outcomes in function and esthetics. However, as with any surgical intervention, problems can arise. Often, difficulties related to poor surgical or prosthetic outcomes can be directly linked to the diagnostic and treatment-planning phase.

Proper treatment planning should consist of a thorough assessment of the intraoral hard and soft tissue via direct examination, periapical and panoramic radiography, mounted study models, and (when required) a diagnostic wax-up of the desired result. Most dental students who were trained during the last 25 years in the United States were not taught how to adequately diagnose or plan a dental implant case. Other available diagnostic tools for preoperative assessment can include two-dimensional cephalometric or tomographic films (analog or digital), tissue- or bone-mapping techniques to assess underlying bone geometry, and drilling into stone models to simulate intraoral implant positioning. Recently, emphasis has shifted from relatively arbitrary implant placement in good available host bone (assessed by the surgeon at time of surgery) to placing implants with consideration of the final prosthetic outcome, soft tissue management, emergence profile, and tooth morphology. The goal of implant dentistry is not the implant; it is the tooth that we replace. To facilitate accurate translation from the desired plan to the surgical reality, templates or surgical guides should be used.

Conventional template design

When a single missing tooth needs to be replaced, the surgeon can free-hand the drill without a prefabricated template and hope to align the osteotomy perfectly between adjacent teeth in all

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* 158 Linwood Plaza, Suite 204, Fort Lee, NJ 07024.
E-mail address: sdgimplant@aol.com.

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directions (mesial, distal, facial, and lingual). The implant is positioned based upon the surgeon's idealized vision of the fixture within the bone, which may differ from the restorative needs of that particular site. In the fully edentulous arch, orientation and bone topography can vary greatly, creating an atmosphere whereby implants can be misaligned or worse. Templates can be created by various methods to help guide the surgical specialist or implantologist during the surgical placement of the implant, leaving most of the decision-making process at the presurgical level, whether in partially edentulous or completely edentulous presentations. In its elementary form, a template (the word "stent" is a misnomer) is fabricated based upon information of the final tooth form, not the bone. A template design based upon conventional prosthodontic protocols, including tooth morphology, emergence profile, occlusion, contacts, and embrasures, guides the implant placement in the position that best allows for proper restoration.

The first step required to fabricate a basic template are impressions of the patient's existing dentition, which yield plaster or stone models that can be articulated and analyzed in terms of the desired occlusion and tooth morphology. A diagnostic wax-up or placement of denture teeth onto the stone model demonstrates the desired restorative replacement, which can be translated to the surgeon through a simple vacuum formed matrix or a laboratory-processed acrylic prosthesis (Figs. 1 and 2). This vital information helps the surgeon to visualize the restorative requirements during the surgical procedure and can often lead to satisfactory results. An all-acrylic template that indicated the desired tooth position facilitated the placement of four implants, which led to successful restoration in the anterior mandible as illustrated by the postoperative panoramic radiograph in Fig. 3. Basic templates made entirely of acrylic or with cut-out windows are less accurate than those that incorporate a metal sleeve or tube to help stabilize the drill during the osteotomy. Using drills of similar diameter to the actual implant, a hole is created in the stone model that corresponds to the diameter of the implant to be placed. The appropriate implant analog is placed into the cast at the desired angulation and at a vertical depth approximately 3 to 4 mm below the cemento-enamel junction (CEJ) of the adjacent teeth. Using a long screw attached to the analog, a stainless steel tube can be dropped into position. A light- or heat-cured acrylic material captures this position and insures that the plan is easily transferred to the patient (Fig. 4). The steel tube should be slightly wider that the drill to prevent accidental deviation. The tube should be of a known height, and the acrylic should be relieved so that the head of the drilling unit is not impeded (Fig. 5).

Many solutions have been presented to help solve the dilemma of translating the restorative requirements from the laboratory to the patient at the time of surgery. Recently, an innovative thermoplastic template kit was introduced that allowed clinicians or laboratory technicians to quickly create a surgical guide without the use of a vacuum former (EZ-Stent, Mountain View, California). First, using the included drill, a hole is drilled into the stone model at the ideal position and trajectory. A guide pin of similar diameter is inserted into the hole, and any angle correction can be done at this time (Fig. 6). The thermoplastic template is placed in hot water until it turns translucent. It is then slid into position over the guide pin, and the softened material is adapted to the surrounding teeth. As it cools, the EZ-Stent returns to a hardened state

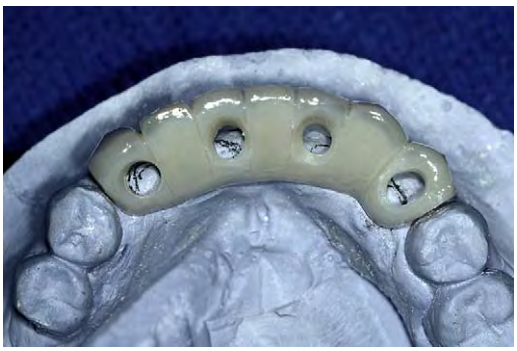

Fig. 1. A processed acrylic template indicating desired implant position on the master cast. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];60; with permission.)

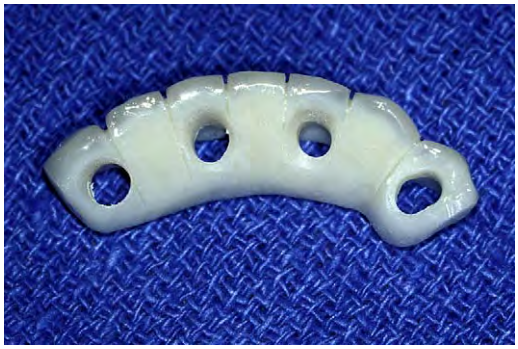

Fig. 2. The holes in the occlusal/lingual surface are used to start the osteotomy preparation. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];60; with permission.)

Fig. 3. The postoperative, panoramic radiograph revealing successful implant placement that supported a six-unit ceramometal restoration. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];60; with permission.)

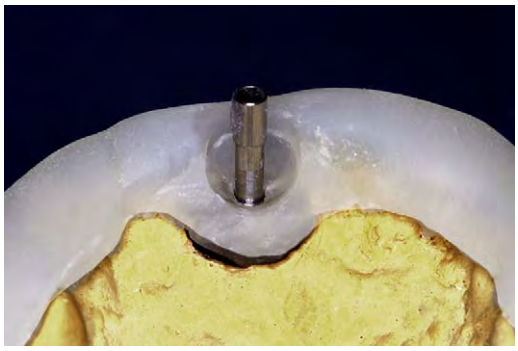

Fig. 4. A hole was drilled into the stone model, the appropriate analog was placed, and a surgical stainless steel tube was dropped over a long fixation screw to facilitate acrylic template fabrication over the remaining teeth. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];61; with permission.)

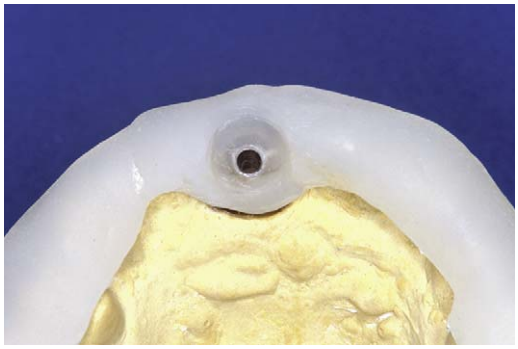

Fig. 5. The stainless steel tube allows for greater accuracy when drilling into the underlying bone. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];61; with permission.)

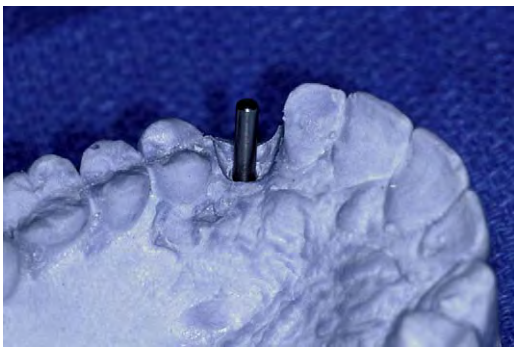

Fig. 6. Another method involved drilling into the bone with a special drill followed by placement of a steel post (E-Z Stent). The angulation and position should be carefully evaluated. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];61; with permission.)

that is strong and retentive (Fig. 7). The template is removed from the stone cast and placed into cold sterilization before the surgical procedure (Fig. 8). After anesthesia, the template can be placed intraorally over the adjacent teeth, allowing the stainless steel tube to help guide the drill into the bone (Fig. 9). If the original planning is correct, the result is a well-placed implant, as evidenced by the positioning of the Tapered Screw-Vent (Zimmer Dental, Carlsbad, California) illustrated in Fig. 10. These techniques (drilling into the stone model without three-dimensional [3-D] CT guidance) do not afford clinicians with reliable information relating to the underlying bone.

Advances in diagnostic imaging, such as tomography, digital radiography, and CT scan film, allow for a more accurate presurgical evaluation. Conceivably the most important technological advancement to enhance the clinician's ability to visualize bone anatomy has been the CT scan. CT scans have been used for medial imaging since 1973. It was not until 1987 that CT scans became available for dental applications. Even today, the most common method for obtaining CT scan data is through a referral to a radiologist in a radiology imaging center or hospital setting. From the CT machine, specially formatted diagnostic images can be created from scan data for diagnostic purposes. The resultant radiographic films offer true, undistorted, 3-D visualization of the maxillary or mandibular bone to determine potential receptor sites for the placement of dental implants in three or four views: (1) axial, (2) cross-sectional, (3) panoramic, and (4) 3-D reformatted images. Despite the advanced imaging techniques, the potential for linking the visualization on film is limited if there are no indicators for the ultimate position of the tooth or a final restorative goal. Radiopaque CT scan templates that incorporate some information as to tooth position, usually in the form of gutta percha radiopaque markers, incorporated into a patient's existing denture or via some type of barium coating give new

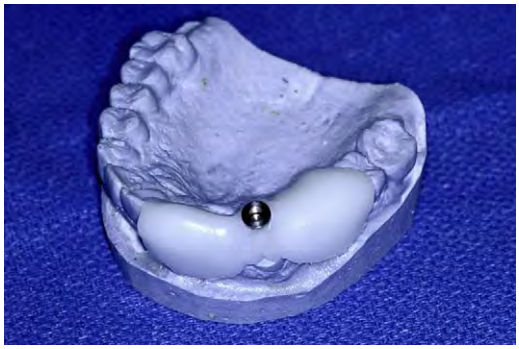

Fig. 7. A special thermoplastic material softened in hot water envelopes the stainless steel post and the surrounding dentition for support. This provides an innovative solution to easy template fabrication. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];61; with permission.)

Fig. 8. The tooth-borne template comes packaged with the integrated tube. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];62; with permission.)

information that could be viewed in relationship to the underlying bone. However, it is not an easy task to transfer the identified sites to the patient.

Weinberg and Kruger tried to overcome these limitations in developing a concept for 3-D presurgical planning based upon CT scan film data and using surgical drill guide tubes. A radiographic guide constructed of vertically placed titanium pins marked the central fossa of each tooth where and implant was desired. The patient wore the guide during the scanning process. Data were collected and transferred to a working cast using the guide to drill osteotomies in the stone. A set of special drills was developed to facilitate the surgery; using the drill guide tubes created from the interpreted CT scan data. A dual axes table was developed to help with the positioning osteotomies in the cast. This was a tedious and time-consuming task, but it offered a link between the CT film and the patient.

The inherent limitations of CT scan film were overcome in July 1993 when an innovative software program was introduced. SIM/Plant for Windows (Materialise-CSI, Inc., Glen Burnie, Maryland) was introduced as an intuitive, user-friendly, interactive, computer-based interface that revolutionized the world of diagnostic imaging for dentists by helping to translate the power of CT technology for the creation of accurate presurgical plans for their implant patients. SIM/Plant for Windows enabled the clinician to examine the CT scan data in an environment that surpassed the limited information afforded by CT scan film alone. Film cannot relate information on bone density, which is an important factor in determining an adequate location for osseointegration to occur. Since the development of SIM/Plant, other similar applications have been introduced in the marketplace for the purposes of making CT scan technology available to clinicians. To achieve predictable results and to enhance communication, these advanced imaging techniques are advocated for the surgeon and the restorative members of the implant team to help anticipate and deliver definitive implant-supported restorations.

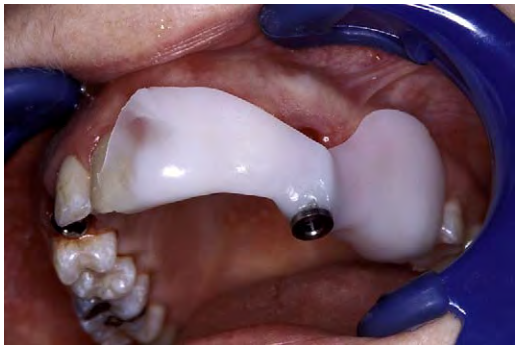

Fig. 9. The E-Z Stent thermoplastic material is positioned in the maxillary arch to facilitate proper implant placement. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];62; with permission.)

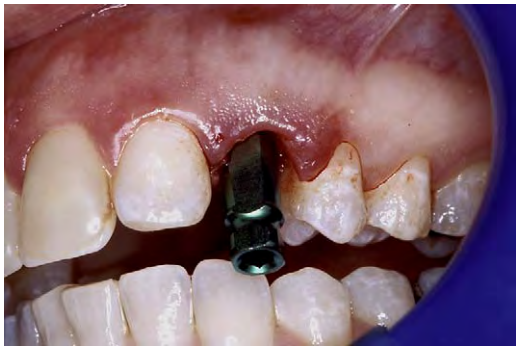

Fig. 10. Based upon the presurgical planning transferred by the template, the implant was surgically placed in the desired position. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];62; with permission.)

CT scan simulation

Using computer software to visualize potential implant receptor sites has revolutionized the manner in which imaging data are assimilated. The cross-sectional image relates the height and width of available bone, the thickness of the cortical plates, and the overall shape of the residual ridge. Bone density values can be obtained for various potential sites using intuitive tools, taking guesswork out of the equation. Interactive software applications permit simulated placement of the implant and restorative abutment to help plan the most ideal position based upon the restorative needs of the site. Fig. 11 illustrates a cross-sectional image representing a maxillary site where an implant has been virtually situated. An imaginary triangle can be drawn over the cross-sectional image where the base is at the widest aspect of the apical bone, and the apex of the triangle is positioned at the midline of the ridge. If there is ample bone within the triangle, then an implant can be placed that would bisect the triangle of available bone gaining increased bicortical stabilization in many cases. The ''Triangle of Bone'' concept was originally developed by the author to help diagnose potential receptor sites and, for instances where the bone was inadequate, to identify sites that required hard or soft tissue regeneration. Initially, the simulated implants were represented as cylinders that had the same dimensions as the implants to be used, based upon implant manufacturers' specifications. Recent software updates permit the clinician to place realistic computer-aided design (CAD) images from an implant library, slice, or section through the virtual model (in cross-sectional or axial planes) for enhanced visualization of the 3-D information with advanced diagnostic tools (Fig. 12).

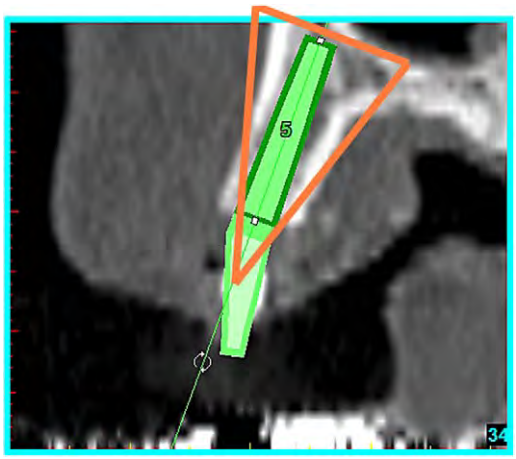

Fig. 11. A cross-sectional image showing the simulated placement of an implant within the ''Triangle of Bone,'' a concept that defines the existing available bone. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];63; with permission.)

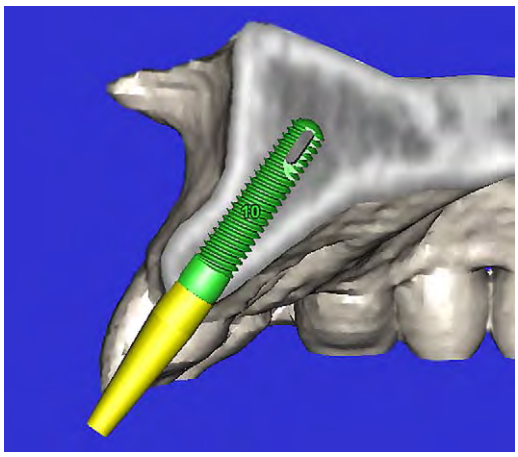

Fig. 12. CT scan technology has improved diagnostic and treatment planning capabilities with interactive 3-D implant positioning, enhanced CAD implant libraries, and new sectional 3-D views. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];63; with permission.)

CT-derived tooth-borne templates

Additional revealing and sometimes dramatic information can be achieved by removing or hiding the bone from view, leaving 3-D representations of the underlying roots of the natural teeth. Evaluation of adjacent tooth roots can be helpful when positioning implants to avoid proximity issues near vital structures. Congenitally missing lateral incisor teeth present many potential hazards that can be avoided with careful diagnosis and planning. CT scan imaging or volumetric tomography can be helpful in this regard. The minimally required space between teeth is often compounded by convergence of the adjacent tooth roots, limiting access for an implant. Fig. 13 represents a 3-D image where the bone has been removed to better appreciate root morphology and spacial location. Sufficient room was found for the placement of two implants. Using the manufacturer's supplied implant library, two Tapered-Screw Vent implants (seen in green) were virtually positioned with the abutments (in yellow) extending out to help verify proper trajectory and inclination (Fig. 13). The implants are to scale, are CAD versions of the real implants, and can be rotated and tilted interactively within the virtual 3-D model. The ability to visualize the physical shape, contour, taper, thread pattern, and antirotational features is helpful when choosing an ideal receptor site.

Once planned using SIM/Plant the data were sent electronically via e-mail to Materialise, Inc. (Lueven, Belgium) for the fabrication of templates to be used at the time of surgery. The surgeon must indicate the type, length, and diameter of each implant to be used and must provide the

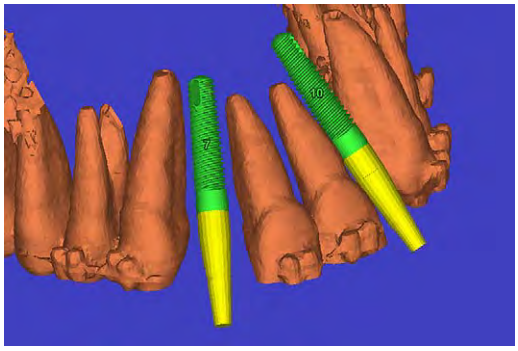

Fig. 13. Advanced software applications allow for the removal of the virtual bone so that the root morphology and implant orientation can be evaluated. In this example, two Tapered Screw-Vent implants are simulated with true CAD representations. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];64; with permission.)

drill sequence for the specific procedure. Because this was to be a tooth-borne template, a plaster cast was created from an alginate impression and sent separately to Materialise (Fig. 14). Using the CT data and treatment plan, a series of templates was fabricated, one for each drill diameter in the sequence of osteotomy preparation (Fig. 15). The templates fit accurately on the working cast, preventing movement during surgery (Fig. 16). The tooth-borne template is an essential tool that guides the drill sequence accurately, allowing for precision placement of the implants intraorally while avoiding contact with adjacent structures (Fig. 17).

Stereolithography and CT-derived, bone-borne template designs

To facilitate parallel implant placement in the anterior mandible, CT scans can provide the information to construct accurate surgical guides. A further advance in the evolutionary development of this imaging modality involves the use of stereolithography. Stereolithographic models are created from the CT scan data set through rapid prototyping technology and serve multiple purposes in medicine and dentistry. The ability to hold an acrylate model of the patient's mandible or maxilla in hand is an invaluable tool for learning anatomy, diagnosis, treatment planning, and template fabrication, which may evolve further into the fabrication of the transitional and final restorations. Fig. 18 reveals a stereolithographic model of the mandible with a surgical template (SurgiGuide; Materialise, Inc.) that was fabricated from the planning data. Implant receptor sites were chosen based upon the restorative requirements, bone contours, bone density, and path of the inferior alveolar nerve. A close-up view reveals the six embedded stainless steel tubes designed to guide one diameter of the sequential drills used to create the osteotomies (Fig. 19).

The partially edentulous mandible presents challenges because the overall contours and bone volume may differ from the contralateral side. A panoramic radiograph can be taken as an initial scout film to help determine potential implant sites and the location of vital structures. However, the inherent distortion factor of a panoramic radiograph can be as much as 7.5 mm, which can result in paresthesia, perforation, or other surgical complications if not recognized. The height of bone can be estimated, but there is no information related to the width of bone, thickness of the cortical plates, density between the cortices, or the 3-D position of the inferior alveolar nerve as it travels through the mandible and exits at the mental foramen (Fig. 20). Changes in the mandibular morphology cannot be detected without the use of cross-sectional and 3-D imaging. Variations in bone contours and location of important anatomy that can be assessed in multiple dimensions enable the clinician to accurately determine the best treatment plan. Careful analysis of the undistorted reformatted axial CT image revealed potential receptor sites for five implants of various lengths and diameters (Fig. 21). The anatomic permutations revealed in three cross-sectional images illustrate how the bone is dramatically different

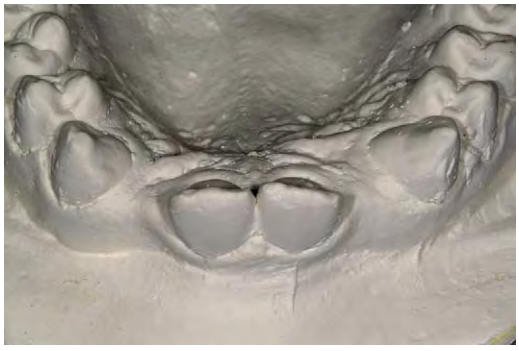

Fig. 14. The data from the software application SIM/Plant is sent to Belgium via e-mail. A plaster cast model of the patient's dentition is also sent. From this information, a tooth-borne template can be fabricated. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];64; with permission.)

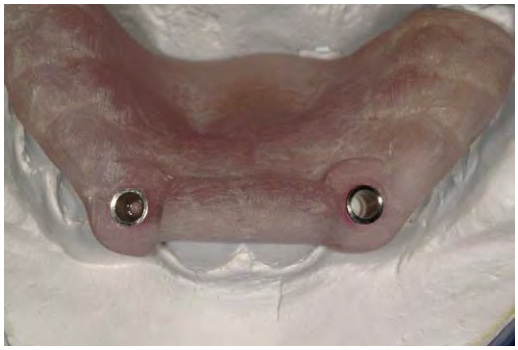

Fig. 15. A tooth-borne template with the incorporated surgical stainless steel tubes for accurate drill guidance. Each tube is 0.2 mm wider than the sequential drills to be used. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];64; with permission.)

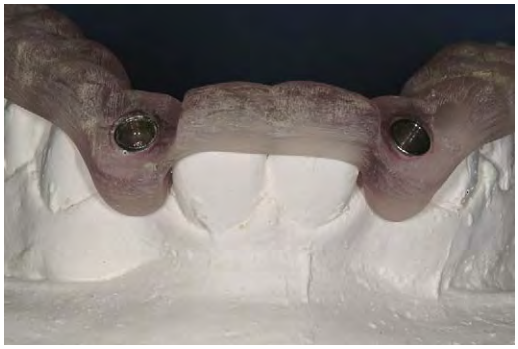

Fig. 16. The facial view of the tooth-borne template seated over the working cast. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];64; with permission.)

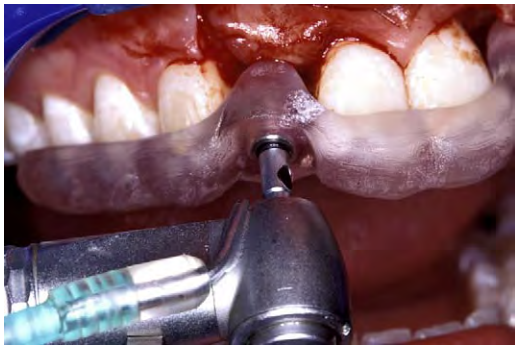

Fig. 17. The template snaps over the adjacent teeth, and with great stability the osteotomies can be created based upon the virtual plan. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];65; with permission.)

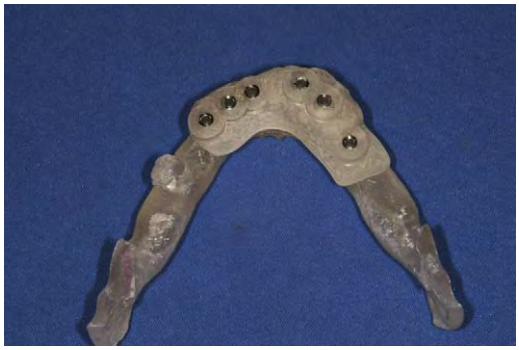

Fig. 18. A stereolithographic model of the patient's mandible with a template for the placement of six implants. The template is fabricated from the CT scan data and treatment plan. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];65; with permission.)

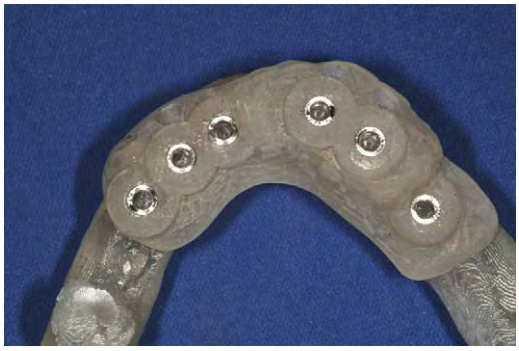

Fig. 19. Close-up view of the six embedded stainless steel tubes of the anterior mandibular template. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];65; with permission.)

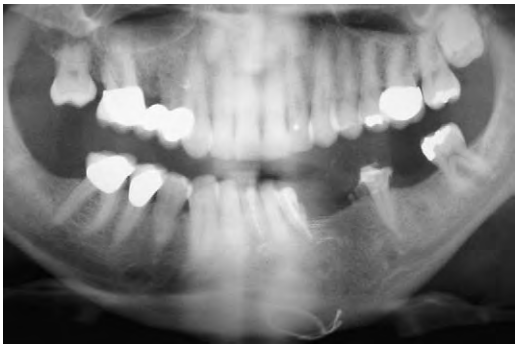

Fig. 20. A preoperative panoramic radiograph reveals the left mandibular partially edentulous areas where the patient desires a fixed restoration. It is difficult to assess the 3-D topography of the mandible or path of the inferior alveolar nerve. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];65; with permission.)

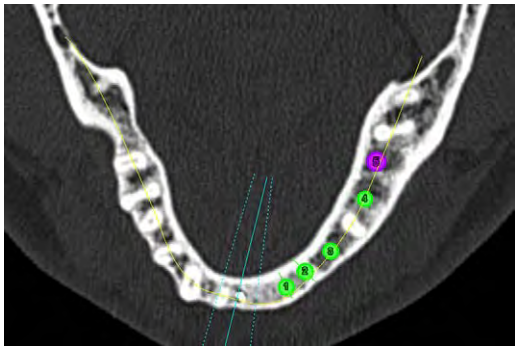

Fig. 21. The reformatted axial CT view allows for the individual implant receptor sites to be chosen based upon the restorative needs of the patient if the underlying bone anatomy and nerve position are favorable. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];66; with permission.)

within a short distance between three adjacent consecutive implants. There is a fenestration noted in the cortical bone in Fig. 22A, with the apical portion at a distinct facial angle from the crest of the bone (slice 79). A few slices posterior (slice 84), the bone contours change again (Fig. 22B) and then again (slice 91) for the third implant site (Fig. 22C). Once identified, the implant positions can be "tweaked" for parallelism and ease of restoration (Fig. 23). The best opportunity to accurately assess the implant placement is when the 3-D reconstruction is evaluated. The virtual model and the implants can be individually rotated or tilted in various positions to determine the trajectory of each implant in relation to the other and nearby vital structures within the envelope of the desired tooth position (Figs. 24 and 25).

Once the plan has been verified, the information can be transferred for the creation of a stereolithographic model. An appreciation of the variations in bone morphology is evident in occlusal and side views (Figs. 26 and 27). From the data set determined through software planning, the surgical templates can be fabricated to easily guide the placement of each implant with manufacturer-specific sequential drills. The bone-borne templates fit securely on the alveolar crestal bone during the surgery (Fig. 28). In this clinical presentation, an access hole was created to adapt the template over the existing natural premolar (Fig. 29). With the plan, the stereolithographic model, and the series of templates, the patient is prepared for the surgical procedure. An intraoral preoperative occlusal view indicates variations in the soft and hard tissue but does not provide as much information as CT imaging (Fig. 30). Due to the speed, efficiency, and accuracy of the sequence of templates provided by the virtual plan, osteotomy preparation is highly accurate and leads to less patient morbidity. Five Tapered Screw-Vent implants were placed as planned, using a one-staged approach, at the correct depth and trajectory, avoiding adjacent and proximal structures (Fig. 31). After 8 weeks of healing, impressions were taken to transfer the intraoral position of each implant to a soft tissue model (Fig. 32). Upon close inspection, the working cast exhibits excellent parallel positioning of the implant analogs, enabling a smooth

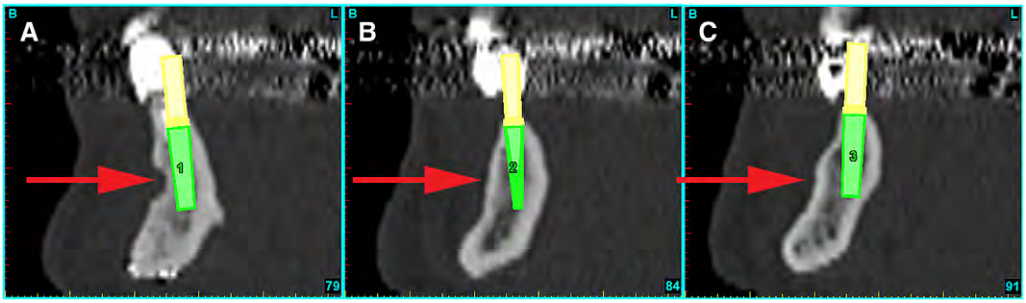

Fig. 22. Cross-sectional views show that over a short span, the bone geometry can change dramatically. Note the facial bone defect in the area where the first implant was planned and how the mandibular bone differs in shape for the second and third sites. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];66; with permission.)

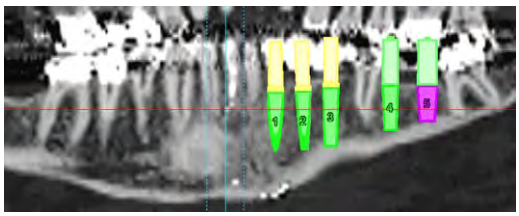

Fig. 23. The reformatted panoramic radiograph reveals the presurgical planning of five implants. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];66; with permission.)

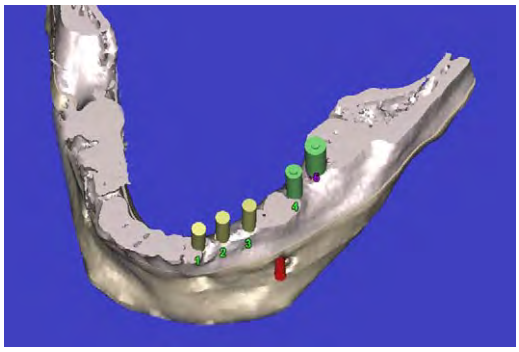

Fig. 24. A virtual 3-D model allows the clinician to interactively plan for the placement of the five implants and to evaluate interimplant distances, implant-to-tooth relationships, and overall parallelism, which affect the final restorative result. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];67; with permission.)

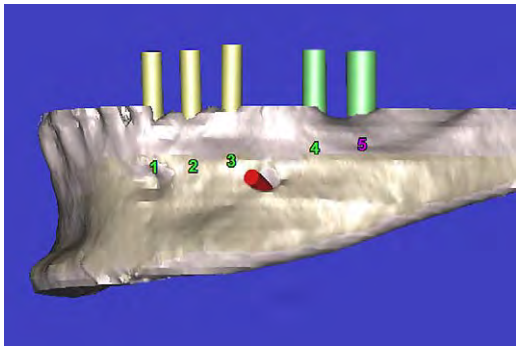

Fig. 25. A lateral view of the 3-D model reveals the path of the inferior alveolar nerve and the extensions in yellow and green of the simulated path of the abutment trajectories on top of the implants. The data set from this plan is transmitted via e-mail for the fabrication of the templates. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];67; with permission.)

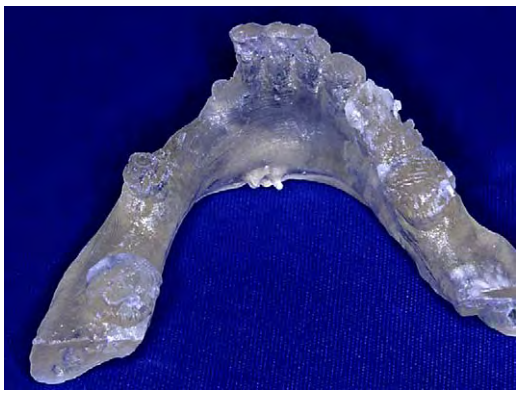

Fig. 26. An occlusal view of the stereolithographic model of the mandible that allows for a close inspection of the 3-D anatomy. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];67; with permission.)

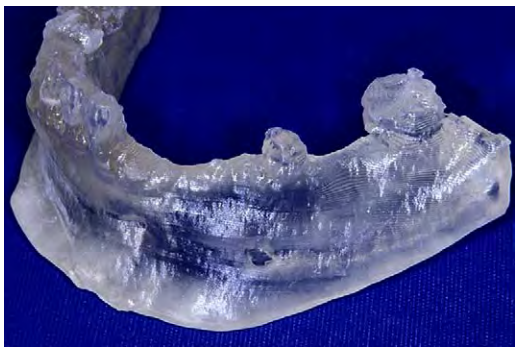

Fig. 27. The lateral view demonstrates the changes in bone topography position of the natural teeth and reveals the location of the mental foramen. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];67; with permission.)

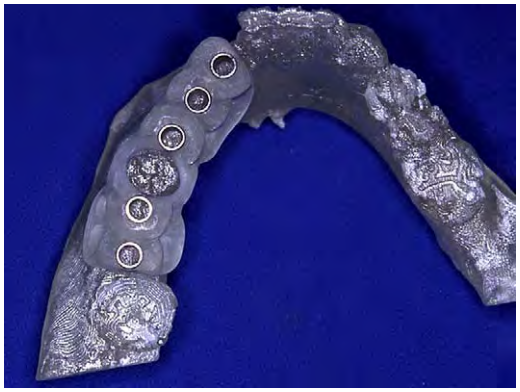

Fig. 28. The surgical templates fit over the bone and transfer the virtual plan to the patient. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];68; with permission.)

Fig. 29. The lateral view shows how the template fits over the natural remaining premolar tooth while giving guidance for the five implants to be placed. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];68; with permission.)

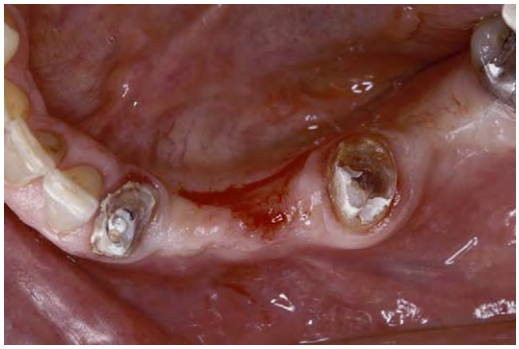

Fig. 30. Occlusal view of the intraoral clinical site. Note the volumetric change of the ridge in the edentulous areas. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];68; with permission.)

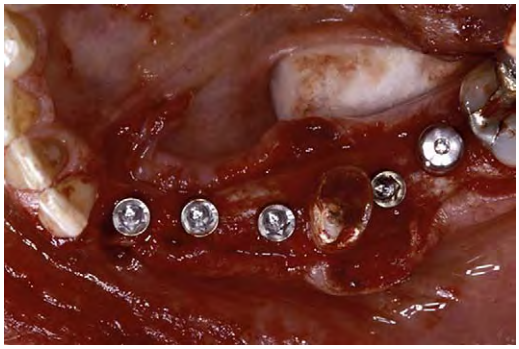

Fig. 31. Five implants successfully placed with sequential drilling techniques and sequential templates. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];68; with permission.)

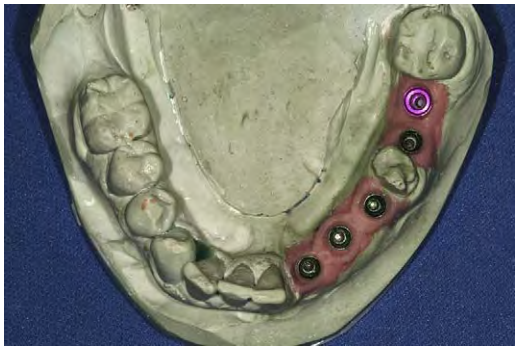

Fig. 32. A fixture level impression taken at 8 weeks postinsertion allow for an accurate soft tissue model. The implants are seen as parallel, simplifying the restorative phase. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];69; with permission.)

and often accelerated laboratory and restorative phase (Fig. 33). The postoperative panoramic radiograph illustrates the final restorative result, which returned the patient to form and function (Fig. 34). The implants avoided the superior aspect of the inferior alveolar canal and adjacent tooth roots.

Stereolithography for ridge reduction and immediate loading protocols

Clinicians are often faced with irregular patterns of bone resorption in the maxillary or mandibular arch. Planning for an immediate load case with irregular bone height or width is difficult at best, even with CT scan imaging. Additionally, it is difficult to achieve accurate implant placement without guidance if the relationship between the desired tooth position and the underlying bone is not known or appreciated in advance. Many planning obstacles can be overcome with the use of sophisticated software tools and stereolithographic models. A female patient presented with a problematic complete mandibular denture. The anterior section was painful during mastication due to the thin remaining crestal bone (Fig. 35). After clinical evaluation, the patient was referred for a CT scan of the mandible. After processing and reformatting by SIM/Plant, the 3-D image revealed the extent of the narrow bony spin on the superior aspect of the mandible (Fig. 36A). The higher anterior segment was found to be too narrow for implant placement. To facilitate the placement of dental implants, it was determined that the anterior ridge would be reduced to an adequate width (Fig. 36B). Using interactive features of the software, five simulated implants and abutments (yellow extensions) were to be placed

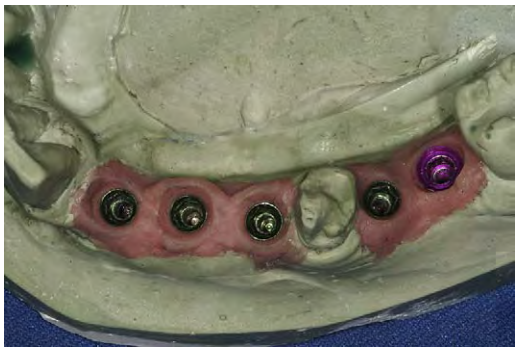

Fig. 33. Close-up occlusal view demonstrating surgical accuracy achieved with template guidance. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2];69; with permission.)

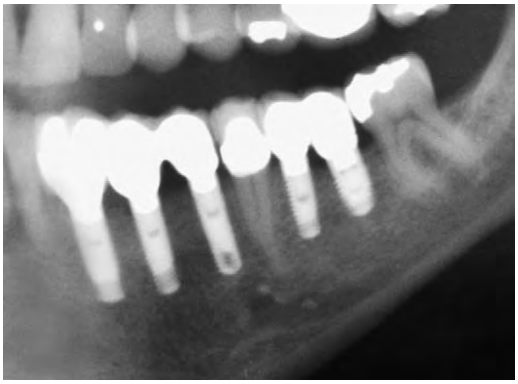

Fig. 34. Postoperative panoramic radiograph showing completed restorations for the five implants and single natural tooth in harmony with the remaining dentition. Note the avoidance of the vital structures in the area. (*From* Ganz SD. Presurgical planning with CT derived fabrication of surgical guides. J Oral Maxillofac Surg 2005;63[Suppl 2]; 69; with permission.)

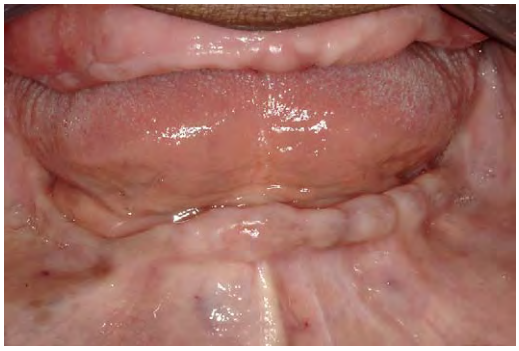

Fig. 35. Retracted view of patient with a fully edentulous mandible. Note the thin, severely resorbed anterior ridge.

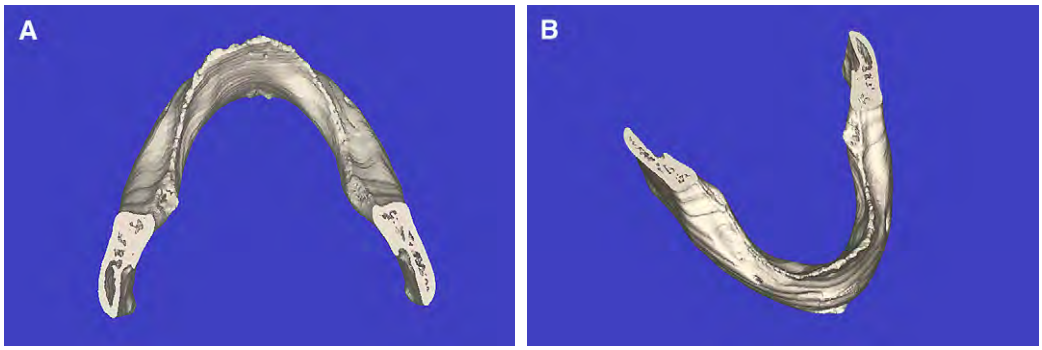

Fig. 36. (*A*) The CT scan revealed the extent of the thin bony spin on the superior aspect of the mandible. (*B*) The higher anterior segment was found to be too narrow for implant placement.

after the anterior ridge was reduced, as illustrated by the transparent segment in Fig. 37. The five implant receptor sites were found to be acceptable for length and fixation required for immediate loading.

A stereolithographic model was fabricated in advance to allow for better presurgical planning of restorative and surgical phases (Fig. 38A). The lateral view reveals the knife-edged aspect of the residual ridge, concavities, and other anatomic aspects of the mandible (Fig. 38B). To accurately transfer the simulated plan to the patient, four templates were fabricated. The first was to be used as a bone reduction template to aid the surgical modification of the bony ridge to the desired configuration for ideal implant placement. Three additional surgical templates were to be used to place the implants into the newly flattened ridge (Fig. 39). The three bone-borne templates allow the clinician to follow the manufacturer's sequential drilling sequence for the (1) pilot, (2) intermediate, and (3) final sizing drills. Each stainless steel tube has a diameter of 0.2 mm greater than the drill, leaving little room for error. Based upon the presurgical virtual planning as transferred to the surgical intervention, the case proceeded to completion with complete confidence. The reduction template seated on the stereolithographic model indicated the amount of bone to be sectioned from the anterior mandible (Fig. 40A). The distance from the desired level of bone to the height of the alveolar crest was 10 mm (Fig. 40B). Once the bone was properly removed from the stereolithographic model, the surgical implant guide fit securely (Fig. 40C).

At the time of surgery, a full-thickness mucoperiosteal flap was raised to expose the underlying ridge. The reduction template was seated on the anterior residual ridge indicating the amount of vertical bone to be removed (Fig. 41A). Vertical cuts were made at the level of the reduction template (Fig. 41B), and the bone was removed until the ridge was flattened to the desired dimensions (Fig. 41C). The implant placement guide (SurgiGuide) was firmly seated onto the bone with embedded tubes to guide the implant drilling sequence (Fig. 42B).

Before the surgical procedure, a simulation was performed on the stereolithographic model fabricated from the CT scan data. Osteotomies were accurately cut into the stereolithographic models using the templates as seen in Fig. 40C. Five Tapered Screw-Vent replica implants were successfully placed into the model as per the CT scan plan (Fig. 43A). Because the implants were planned to be parallel in the SIM/Plant plan, the simulated implants guided by the templates also achieved parallelism, as noted by the fixture mounts in Fig. 43B. As an important aid to the prosthetic reconstruction, the five implant replicas were placed at the same vertical height (Fig. 43C). Using five titanium tubes and screw abutments, the fixed-detachable prosthetic solution was planned in advance to be delivered at time of surgery (Fig. 43D). After the implants were placed, the five titanium screw–retained abutments were attached, and soft tissue closure was achieved (Fig. 44A). Using a rubber dam pickup technique to protect the underlying tissue and sutures, the prosthesis was seated over the abutment and secured with acrylic (Fig. 44B). The fixed detachable hybrid restoration allowed for immediate loading of the implants and increased function for the patient using techniques that significantly reduced surgical time. Within minutes, the prosthesis was finished, polished, and delivered to the patient, with the screw-access holes covered with a light cured material (Fermit; Ivoclar-Vivadent, Amherst, NY) (Fig. 45).

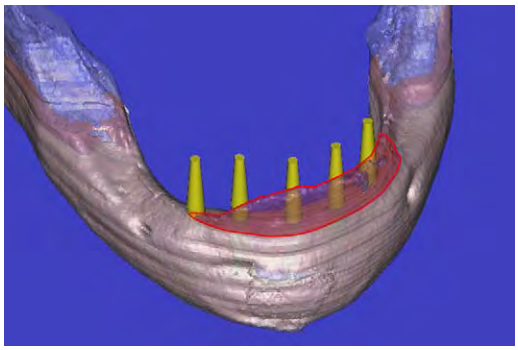

Fig. 37. Using interactive features of the software, five simulated implants and abutments (yellow) were to be placed after the anterior ridge was reduced, as illustrated by the transparent segment.

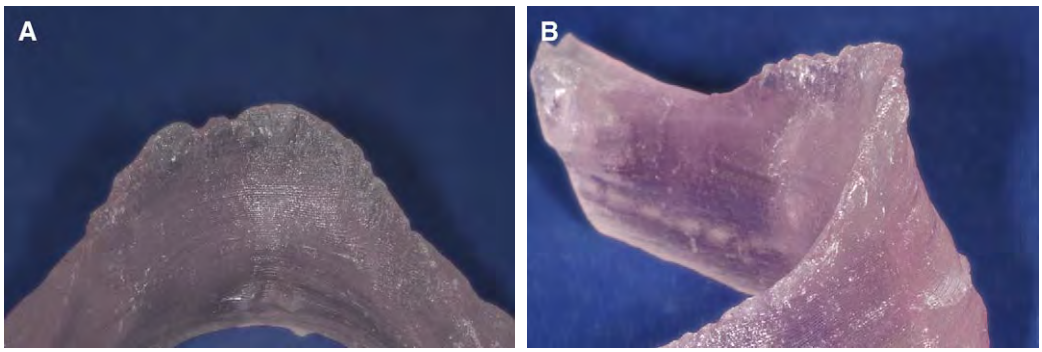

Fig. 38. (*A*) The stereolithographic model was fabricated to allow for presurgical planning. (*B*) The lateral view reveals the knife-edged aspect of the residual ridge.

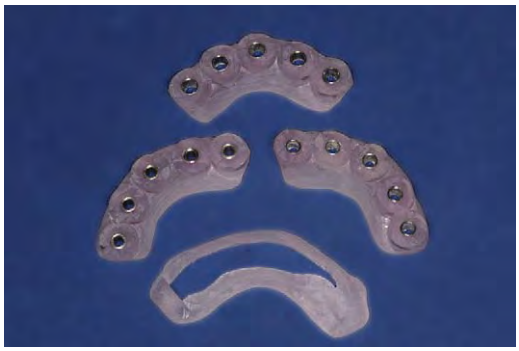

Fig. 39. To accurately transfer the simulated plan to the patient, four templates were fabricated: one as a reduction template and three to place the implants on the flattened ridge.

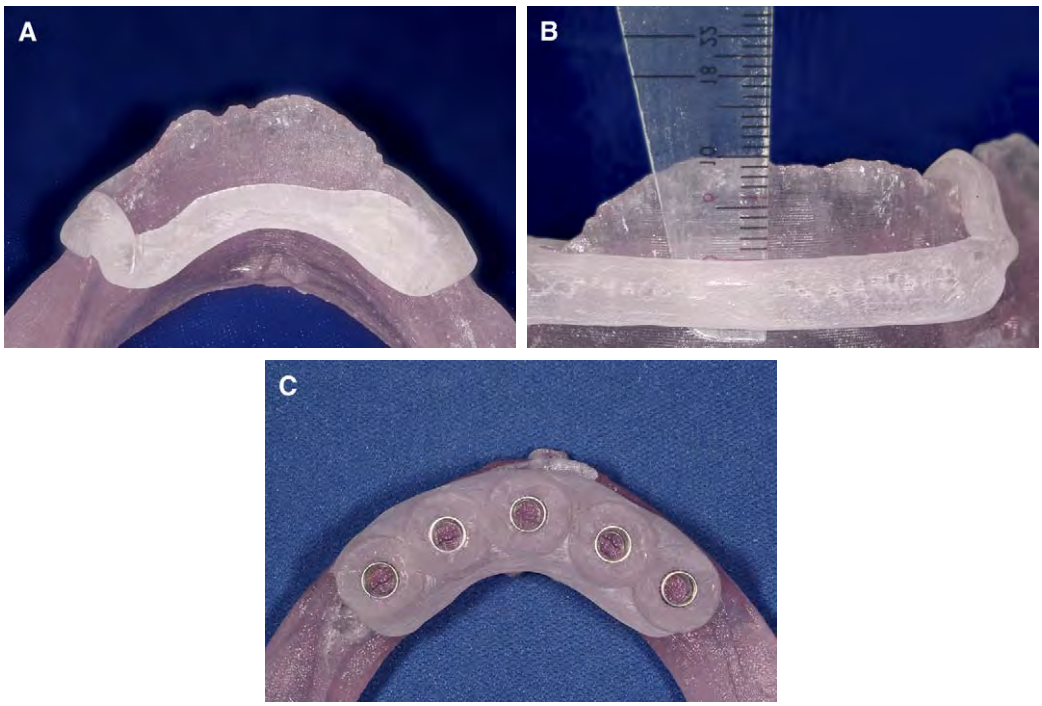

Fig. 40. (*A*) The reduction coping seated on the prereduced stereolithographic model. (*B*) Ten millimeters of bone height was to be removed to facilitate implant placement. (*C*) The surgical template adapted after bone of the stereolithographic model was reduced.

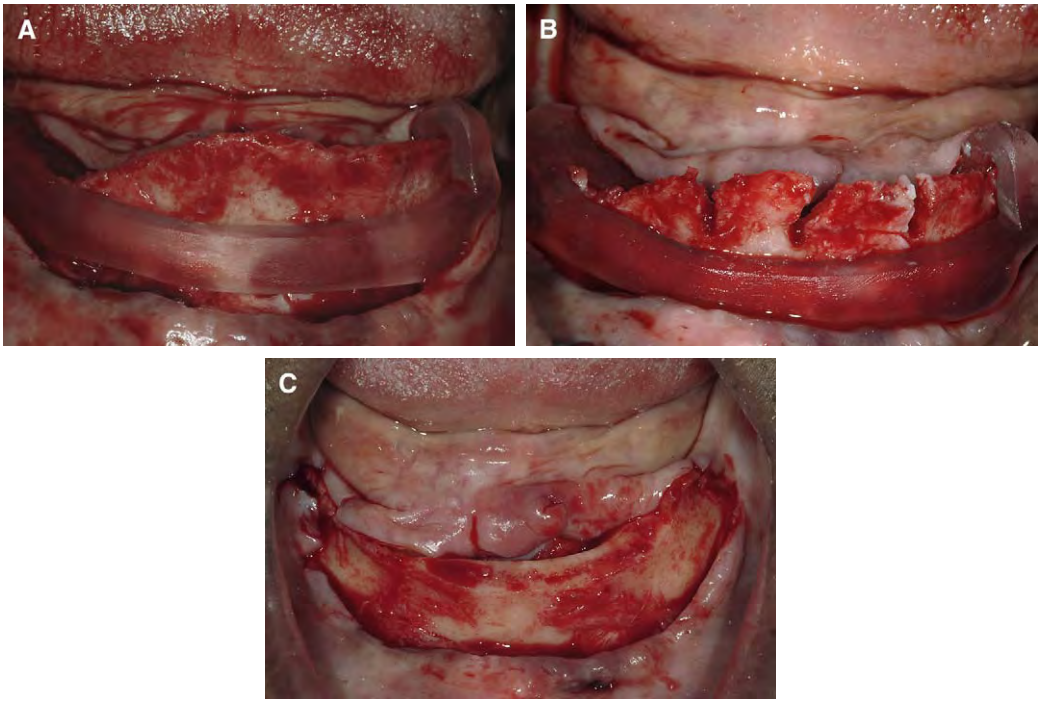

Fig. 41. (*A*) The retracted view of the reduction template seated on the anterior residual ridge. (*B*) Vertical cuts were made at the level of the reduction template. (*C*) The completed ridge flattened to the desired dimensions.

The use of presurgical planning and stereolithography enabled the prosthetic solution to be designed in advance on an irregular ridge (in height and width) that required reduction before implant placement. The use of a CT-derived bone reduction template and surgical implant templates facilitated the surgical aspect, increased accuracy, reduced operatory time, and helped accomplish a successful immediate load protocol with parallel implants.

Discussion

Implant dentistry is a proven, highly predictable method for replacing missing natural teeth. The advent of advanced imaging tools has enabled clinicians to expand their view into the third dimension. The ability to obtain a CT scan for a patient is only one part of the equation. Simply stated, ''It is not the scan, it is the plan,'' describes the most crucial aspect of the process. Interactive software applications help to visualize the CT scan data and plan for functional, esthetic, and predictable outcomes before the ''scalpel ever touches the patient'' (Ganz, 1995.)

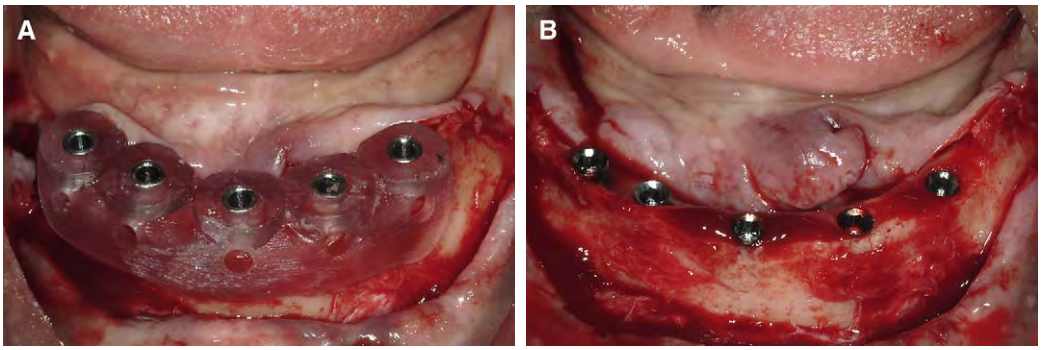

Fig. 42. (*A*) The surgical template seated on the reduced ridge. (*B*) Five Tapered Screw-Vent implants successfully placed as per the CT scan plan.

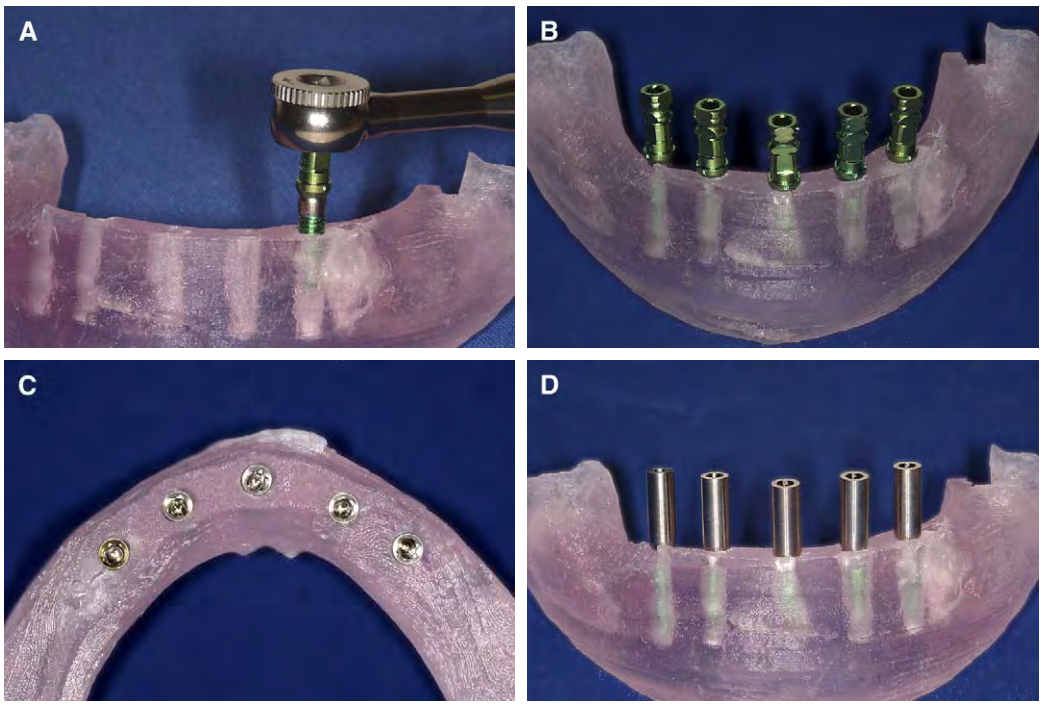

Fig. 43. (*A*) Using the template, osteotomies were cut into the stereolithographic model to allow for the placement of the five Tapered Screw-Vent implants. (*B*) The implants fully seated, with the fixture mounts indicating parallelism. (*C*) The five implants placed at the same vertical height aiding the prosthetic reconstruction. (*D*) Using five titanium tubes and screw abutments, the prosthetic solution was planned in advance.

Assimilating the CT data for purposes of correct diagnosis and treatment planning may be the most critical step in transferring accurate information to the patient at the time of surgery. Once the plan has been established and accepted by the patient, the template can be fabricated. The template is the link between the plan and the execution of the plan. Templates have been proven to be far more accurate than the traditional free-hand method of implant placement. Although templates can be fabricated without CT, it is the intention of the author to illustrate how important it is to understand the underlying anatomic structures so that the implant receptor sites can be located without infringing upon nerves, sinus cavities, or adjacent tooth roots. The plan should therefore be based on a sound understanding of the bone anatomy as it relates to the restorative needs of the patient, taking the guesswork out of the equation. The definitive simulation can be translated into a precision surgical template that insures successful treatment outcome.

As implant dentistry turns its focus to be driven more and more by the restorative requirements and as traditional protocols shift to accelerated immediate or delayed loading techniques, advances in template design will continue to improve out of necessity. Klein and

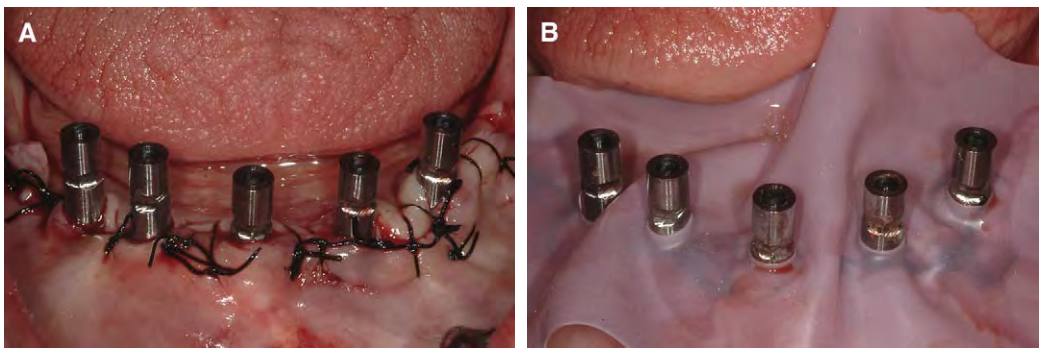

Fig. 44. (*A*) The five implants with the titanium screw–retained abutments attached and soft tissue closure. (*B*) Using a rubber dam technique, the prosthesis was seated over the abutments and secured with acrylic.

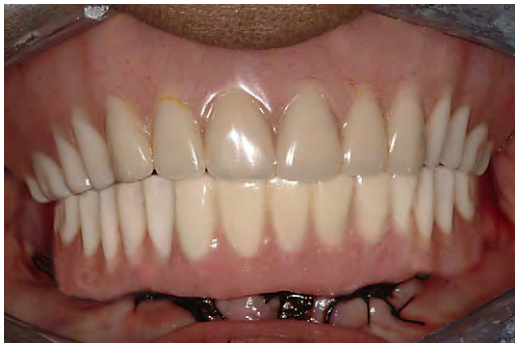

Fig. 45. The fixed detachable hybrid restoration allowed for immediate loading of the implants and increased function for the patient using techniques that significantly reduced surgical time.

Abrams [28] developed a link between the CT data and template fabrication by sending the 3-D coordinates of the SIM/Plant plan to a five-axis computer numerical-controlled milling machine. The drill guide system is incorporated into the milled surgical template in basic or advanced designs (Compu-Guide Surgical Template System; Implant Logic Systems, Cedarhurst, NY). This was followed by the incorporation of a CT-based surgical template that could be converted into a tooth-colored, temporary, acrylic, fixed-provisional restoration (Compu-Temp).

The use of stereolithographic models expands the clinician's ability to understand the patient's anatomy, create accurate surgical templates, manage simple and complicated cases, and link this to the restorative phase, as described by Ganz in 2003. The ability to visualize potential implant receptor sites as correlated to the final tooth position via CT imaging and advanced software applications has been illustrated as the first step toward the goal of restoring the patient to proper function and esthetics. Linking the virtual plan to the patient at time of surgery was also illustrated by the clinical presentations contained in this article. Although the use of a bone reduction surgical guide has been demonstrated in the literature, it was for a specific system (Novum; Nobel Biocare, Göteborg, Sweden) and was based upon understanding the vertical dimension of occlusion required for the procedure, using standard prosthetic protocols and diagnostic work-up to create the surgical guide. The bone is reduced, with the guide placed intraorally several times until the correct vertical dimension of occlusion is achieved, as judged by posterior vertical stops becoming completely engaged. Because the original cast surgery without CT now seems primitive, the novel reduction template as described in this article represents an evolutionary step whereby the exact amount of bone removal was determined in advance by the use of CT imaging combined with stereolithographic models. The reduction template, as seated over the mandible, guided the surgeon in accurately removing the proper amount of bone so that a secondary template fit on the prepared site. The secondary template was used to guide the osteotomies for implant placement. This type of accuracy has not previously been within the reach of all clinicians.

Summary

This article illustrates the advantages of using CT scan–based templates but does not attempt to cover all available methods for fabrication or review navigational or robotic technology, which, although innovative, may not be at the point where they are practical or efficient solutions. Even with CT imaging, clinicians have labored to link the information from the scan data to the surgical site, transferring angles and positions manually. This is overcome with interactive software applications that provide this information seamlessly. Based upon information contained within, templates derived from CT-scan planning data, which embed stainless steel tubes, are highly accurate and easy to use in bone-, tooth-, or soft tissue-borne (not shown) configurations. It is simple to place the drill through the tube and precisely drill into the bone, creating the desired osteotomy when all of the planning and decision-making is done

in advance of the procedure. Procedures were illustrated for single and multiple tooth applications in mandibular and maxillary arches.

Computer-guided surgery is here to stay. With the acceptance and proliferation of new in-office cone-beam CT machines, the technology will become more accessible as the benefits become more apparent to the growing number of clinicians who are performing implant surgical procedures. Additionally, many new solutions continue to be developed to help clinicians plan cases more accurately. CT-derived surgical templates allow for clinically significant improvements in accuracy, time efficiency, and reduction in surgical error, benefitting the patient, the surgeon, the restorative dentist, and the laboratory. Using CT imaging to assess bone anatomy and to determine implant receptor sites allows for improved techniques for flapless surgical procedures (when appropriate), which can be performed with greater levels of confidence and are less invasive. Novel CT-derived bone reduction templates allow surgeons to reduce irregular bony crests for purposes of accurate implant placement, thereby achieving results with more predictability and with greater efficiently than with conventional methods. However, the template is only as good as the planning. Achieving five or six well-fixated and parallel implants cannot be achieved with a free-hand surgical approach. Predictability can be enhanced only by thorough presurgical diagnosis and treatment planning using the information obtained from the CT imaging devices, which is then translated into accurate surgical guides. Continued improvements in the state-of-the-art software applications that enable enhanced planning give clinicians the vision necessary to deliver the desired results while serving as an excellent communication tool between all members of the implant team.

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Atlas of the Oral and Maxillofacial Surgery Clinics

Bone Morphogenetic Protein for Sinus Augmentation

Michael S. Block, DMD*, Ronald Achong, DMD, MD

Department of Oral and Maxillofacial Surgery, Louisiana State University School of Dentistry, 1100 Florida Avenue, New Orleans, LA 70119-2799, USA

Bone morphogenic proteins (BMP) are members of the family of transforming growth factors. Fifteen different BMP have been identified, all with varying degrees of cellular activity, including cartilage- or bone-inductive properties. Two recombinant proteins are available: recombinant human bone morphogenetic protein (rhBMP)-2 and rhBMP-7. These products have been investigated as alternatives to autogenous bone grafts in a variety of clinical situations, including spinal fusions, fracture repair, treatment of bone defects, and reconstruction of maxillofacial conditions. Reconstruction in the maxillofacial region includes alveolar ridge augmentation, mandibular reconstruction, and maxillary sinus augmentation.

Recombinant bone morphogenic protein administration

The BMP product is packaged as a lyophilized powder in a sterile vial. At the time of surgery, the powder is reconstituted with sterile water and applied to the carrier. rhBMP-2 or rhBMP-7 is delivered to the bone grafting site in 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 bonding the BMP to the carrier material. Carrier systems have included inorganic material, synthetic polymer, natural polymers, and bone allograft. The current collagen sponge carrier does not have significant mechanical strength to maintain a specific form. For interbody spinal fusion, the BMP delivery system is an interbody fusion cage.

Two rhBMP-associated carrier/delivery systems have received approval from the US Food and Drug Administration. Osteogenic protein-1 (OP-1) consists of rhBMP-7 and bovine collagen (Stryker Biotech Hopkinton, Massachusetts), which is reconstituted with saline to form a paste. The addition of carboxymethylcellulose forms a putty. The InFuse system (Medtronic Sofamor Danek Warsaw, Indiana) consists of rhBMP-2 on an absorbable bovine type I collagen sponge carrier. The labeled indications (as of May 2005) for these devices are summarized below:

- OP-1 Implant is indicated for use as an alternative to autograft in recalcitrant long bone nonunions where the use of autograft is unfeasible and alternative treatments have failed.
- OP-1 Putty is indicated for use as an alternative to autograft in compromised patients requiring revision posterolateral (intertransverse) lumbar spinal fusion, for whom autologous bone and bone marrow harvest are not feasible or are not expected to promote fusion.
- In conjunction with an LT-cage lumbar tapered fusion for spinal procedures in skeletally mature patients who have degenerative disk disease at one level from L4 to S1 (ie, labeled indication for InFuse)

* Corresponding author.
E-mail address: mblock@lsuhsc.edu (M.S. Block).

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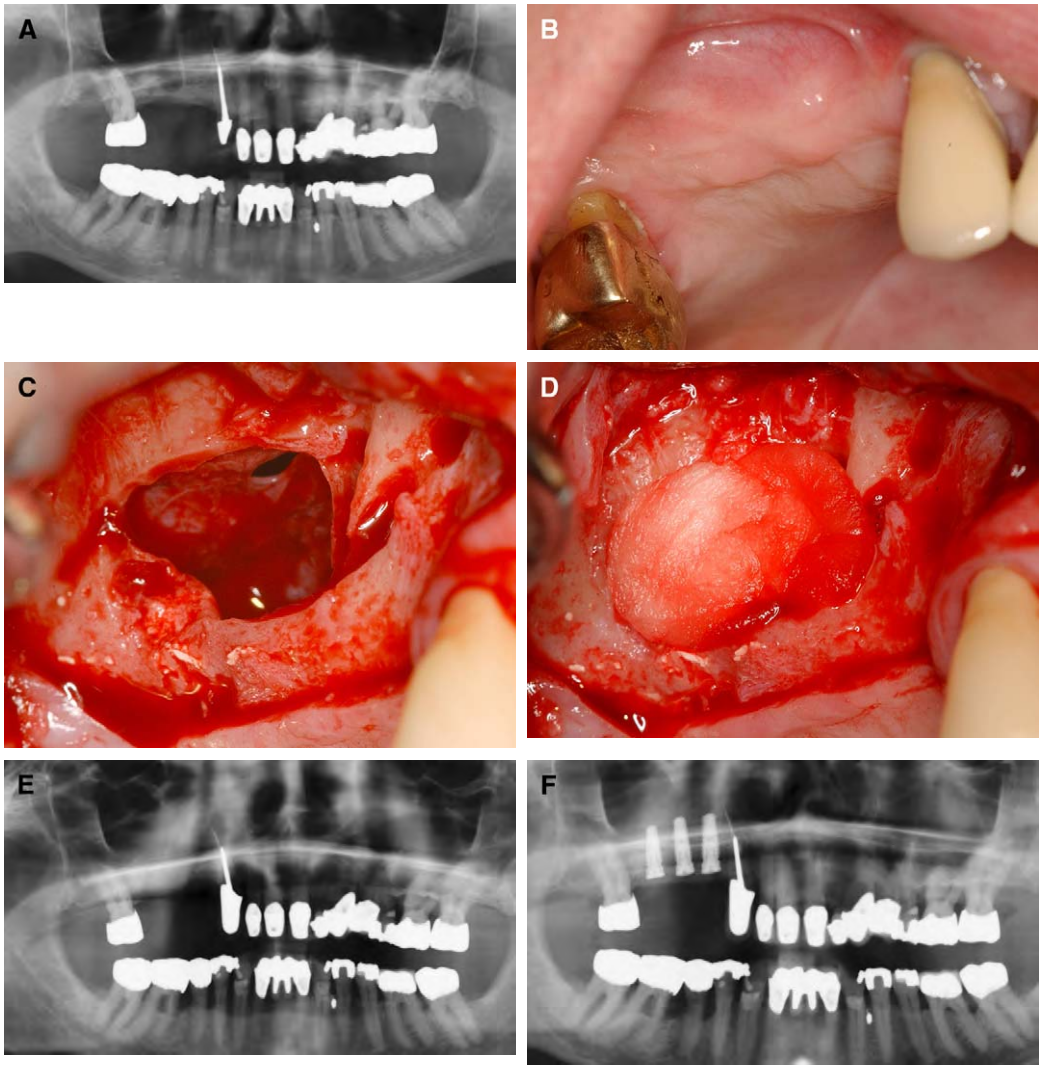

Fig. 1. (*A*) Preoperative panoramic radiograph showing edentulous region in right maxilla with less than 4 mm of bone available for implant placement. (*B*) Preoperative photograph showing flat ridge before graft. (*C*) A crestal incision was combined with anterior and posterior vertical release incisions to allow for exposure of the lateral wall of the maxilla. The lateral wall of the sinus was rotated medially with membrane reflection. A small perforation was present. (*D*) Approximately 12 mg of rhBMP-2 was placed on a collagen sponge (large kit), and the collagen sponge was placed into the sinus previously exposed in (*C*). (*E*) Panoramic radiograph showing excellent bone formation in the sinus 6 months later. (*F*) Panoramic radiograph just before exposing the implants. A three-unit fixed restoration was placed. There have been 2 years of uncomplicated follow-up.

- For the treatment of acute, open fracture of the tibial shaft (ie, labeled indication for InFuse)

The use of BMP is considered investigational for all other indications, including the following:

- As an alternative to autograft in compromised patients requiring revision posterolateral intertransverse lumbar spinal fusion, for whom autologous bone and bone marrow harvest are not feasible or are not expected to promote fusion (ie, labeled indication for OP-1)
- Treatment of spinal fusion or spinal fusion in the thoracic or cervical vertebrae
- As an alternative or adjunct to bone grafting in other locations, including craniomaxillofacial surgeries

rhBMP-2 and rhBMP-7 are contraindicated for patients who have known hypersensitivity to rhBMP-2 or -7 or to components of the formulation. These proteins are not recommended for use in the vicinity of a resected or existent tumor, in patients who have active malignancy or

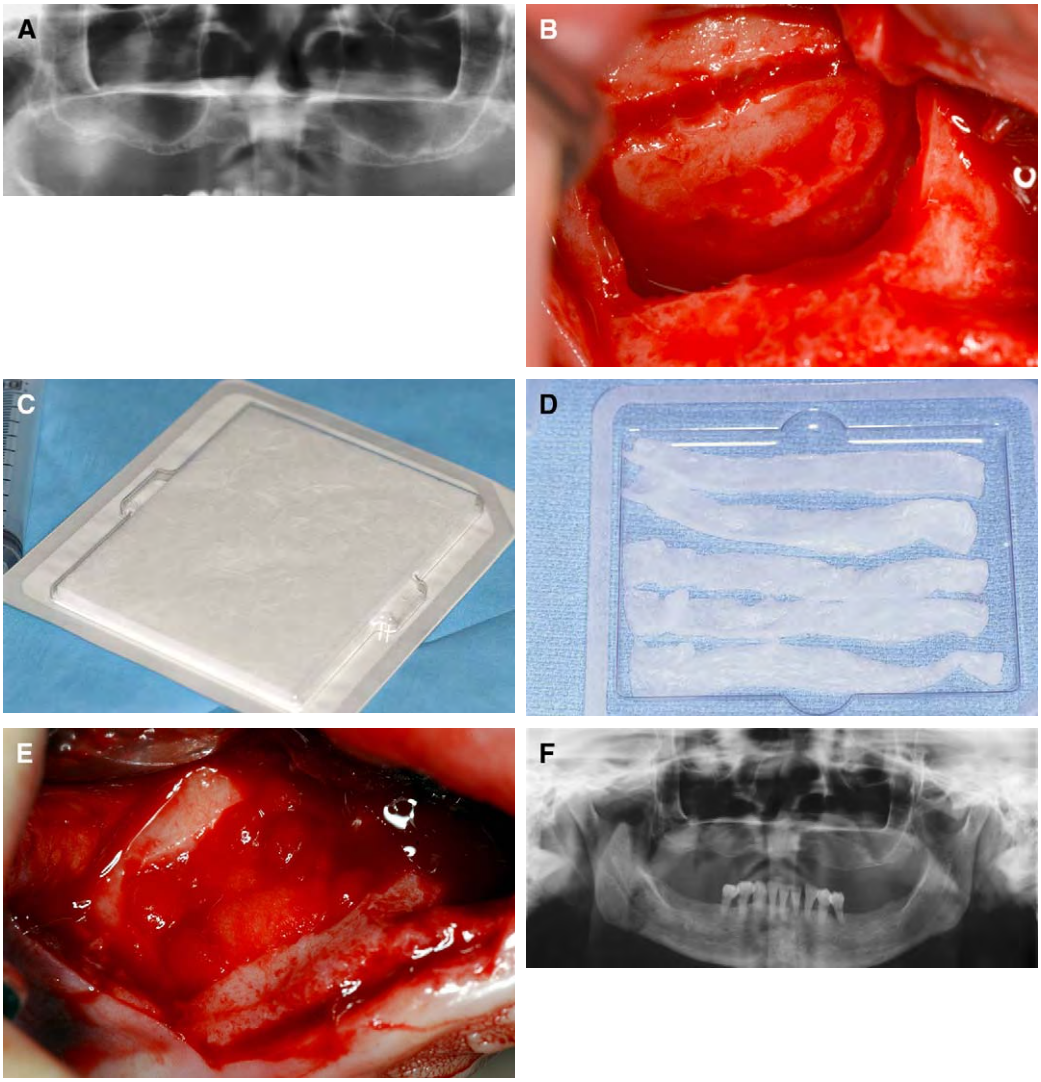

Fig. 2. (*A*) This patient wanted a fixed restoration placed in the maxilla. This preoperative panoramic radiograph shows extremely atrophic maxillary bone with anterior bone available only anterior to the canine locations. The treatment plan included bilateral anterior sinus grafts in preparation for a CT-generated stent and titanium milled hybrid prosthesis ad modem (Teeth in an Hour; Nobel Biocare, Goteborg, Sweden). (*B*) Bilateral sinus membrane elevation was performed to allow placement of approximately 7.5 mg of BMP on each side of the maxilla. (*C*) After the sinus membrane elevations were completed, verifying that the graft was performed, the BMP was reconstituted and evenly distributed on the collagen sponge. The collagen sponge before application of BMP is shown. (*D*) After the BMP was placed onto the collagen sponge, the sponge was cut into five or six strips to facilitate placement in the sinus membrane elevation sites. (*E*) The BMP-impregnated collagen was placed to graft the sinus. (*F*) Six-month panoramic radiograph showing excellent bone formation in the sinus. Implants were placed, and the maxilla was immediately reconstructed with the Teeth in an Hour method.

patients undergoing treatment for a malignancy, in patients who are skeletally immature, in pregnant women, or in patients who have an active infection at the operative site.

Antibody formation to rhBMP-2 or its influence on fetal development has not been assessed. The safety and effectiveness of this device has not been established in nursing mothers. Women of child-bearing potential should be advised to not become pregnant for 1 year after treatment with this device.

Literature review

There are a limited number of studies involving maxillary sinus augmentation using BMP. Boyne and colleagues were one of the first groups to augment the maxillary sinus with

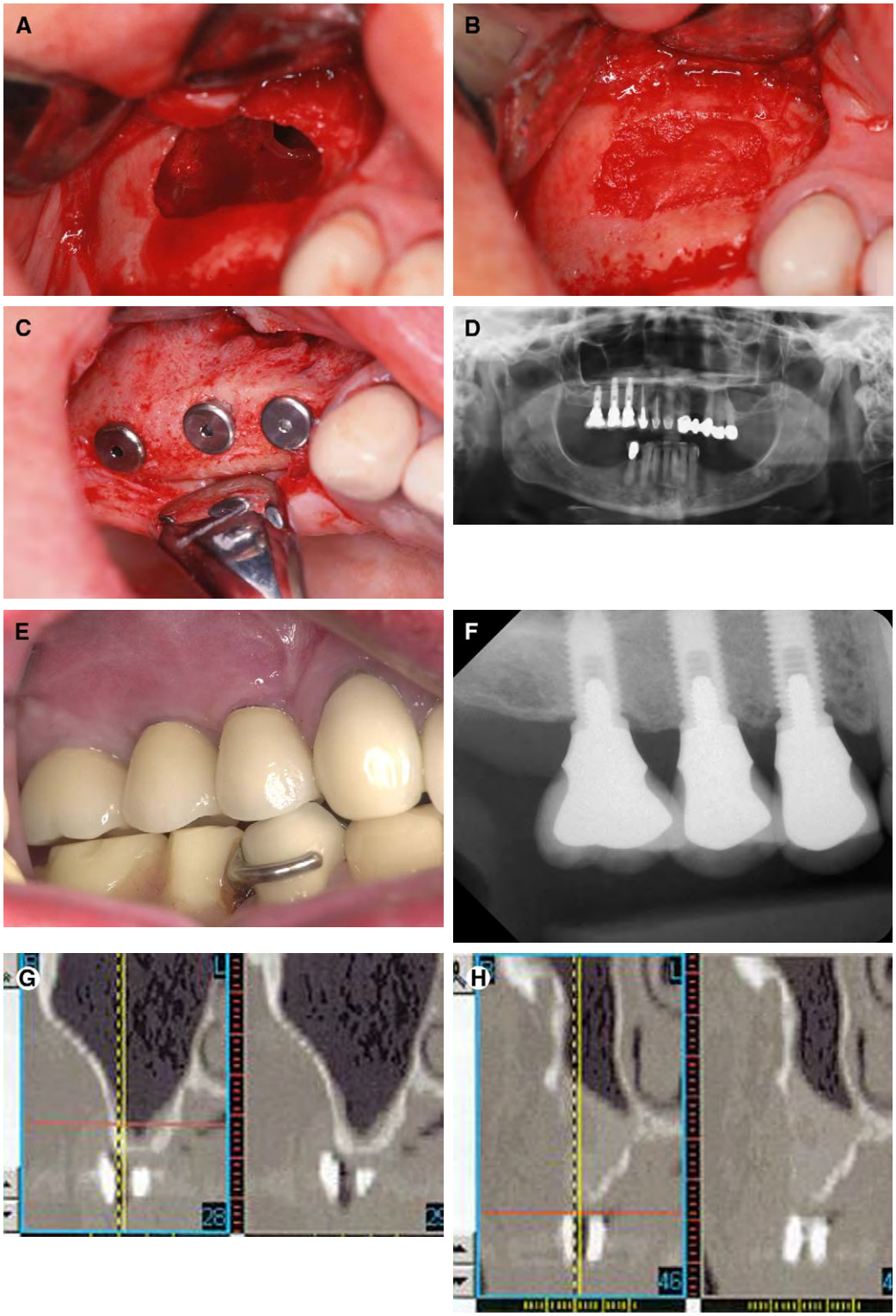

Fig. 3. (*A*) This 65-year-old woman was treatment planned for sinus grafting in preparation for implant placement and a fixed restoration in the posterior right maxilla. The sinus membrane was elevated with the patient under local anesthesia. (*B*) The BMP-impregnated collagen membrane was placed into this normal-sized sinus. BMP (12 mg) was used in this sinus. No membranes were used to cover the sinus graft site. (*C*) Six months later, three implants were placed. Note the excellent bone formation over the previously made window. (*D*) Immediate post-restoration panoramic radiograph showing bone formation at the apical portion of the implants. (*E*) Three-year post-restoration photograph demonstrating excellent soft tissue reaction to the implants. (*F*) Three-year post-restoration radiograph of the implants showing dense bone formation in the grafted sites. (*G*) Preoperative reformatted CT scan in area to be grafted with BMP. (*H*) Six-month post-BMP grafted sinus showing bone formation.

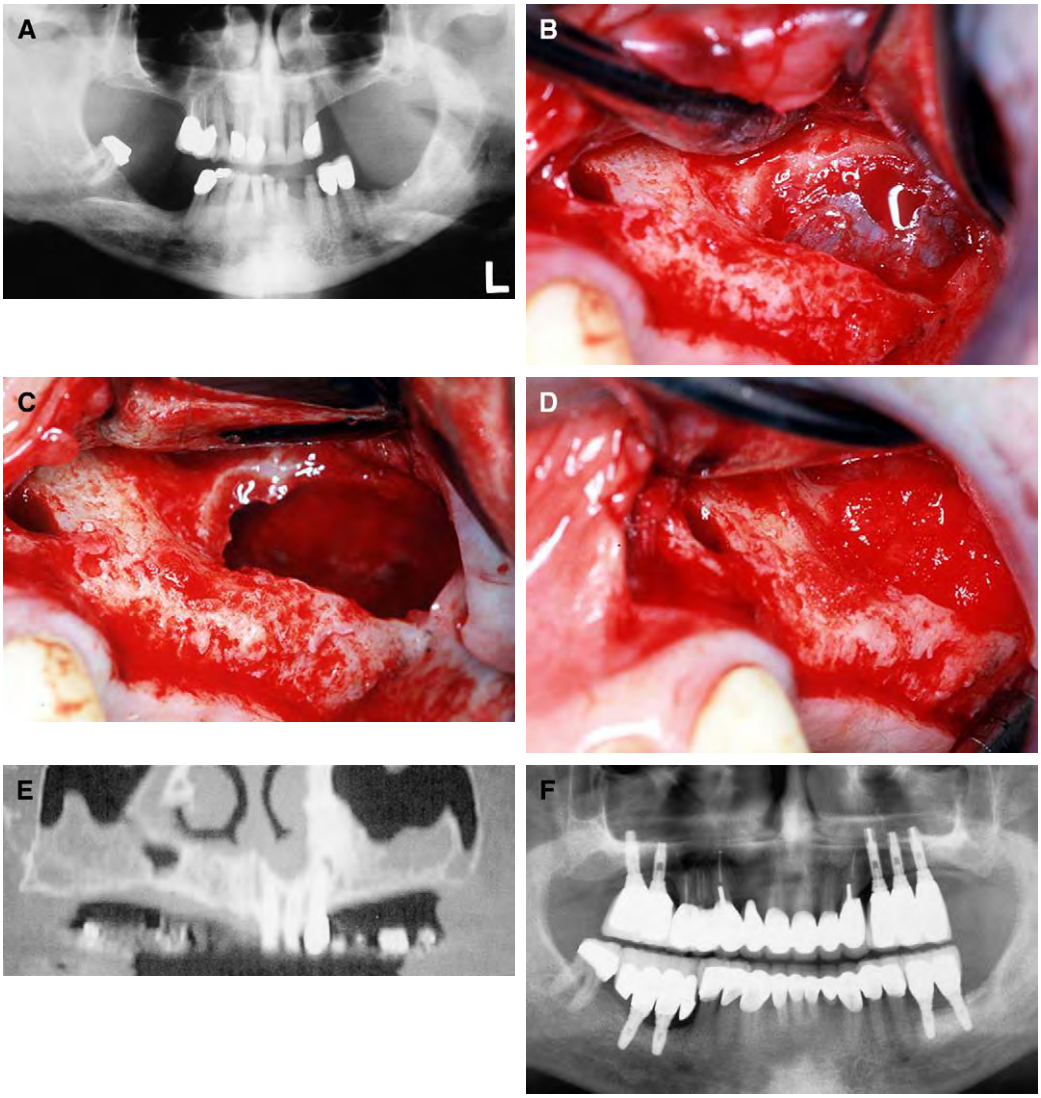

Fig. 4. (*A*) Preoperative panoramic radiograph showing minimal bone for implant placement bilaterally in the posterior maxilla. (*B*) A crestal incision was made with anterior and posterior vertical releasing incisions to allow for exposure of the lateral maxillary wall. The bone was removed over the sinus membrane, which can be easily seen before elevation. (*C*) The sinus membrane was elevated without perforation. (*D*) The collagen sponge strips were placed into the space between the membrane and the bony floor of the sinus. (*E*) Reformatted CT scan of this patient's 6-month post-BMP grafts to the sinuses. (*F*) Three-year postgraft panoramic radiograph showing bone maintenance on the implants in the BMP-grafted sinuses.

rhBMP-2/ACS in humans. Twelve patients underwent maxillary sinus augmentation, with total delivery doses of implanted rhBMP-2 (Genetics Institute, Cambridge, MA) varying from 1.77 to 3.4 mg (mean 2.89 mg) per patient. Significant bone growth was documented by CT. The overall mean height response for the maxillary sinus floor augmentation was 8.51 mm after 16 weeks (95% confidence interval 6.07–10.95). The most frequent adverse effects were facial edema, oral erythema, pain, and rhinitis. Of the 11 patients, eight 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 the time of dental implants revealed moderate to large amounts of osseous trabecular bone. Several other studies have been published in nonhumans.

Hanisch and colleagues performed sinus augmentation in four cynomolgus monkeys using rhBMP-2 (0.19 mg per implant)/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 exhibited a trabecular pattern indistinguishable from

residual bone. Polarized light microscopy suggested that the new bone was predominantly lamellar. Bone implant contact to the titanium implants was similar in newly formed bone and residual bone. There was a statistically significant difference in mean vertical bone gain between rhBMP-2 (6.0 $\pm$ 0.3 mm) and control sites (2.6 $\pm$ 0.3 mm; $P < .002$). Cancellous bone density within newly formed bone averaged 14.4 $\pm$ 2.9% and 13.9 $\pm$ 4.6% for rhBMP-2 and control sites, respectively, with no significant differences.

Maxillary sinus augmentation comparing rhBMP-2/ACS (12.5 μg) with iliac crest particulate cancellous bone (control group) with subsequent dental implant placement was performed in 30 rabbits. After 12 weeks of subantral augmentation, titanium dental implants were placed and allowed to osseointegrate for 3 months. There was comparable histologic and histometric evidence of bone formation between both 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 between the rhBMP-2 and the control group were similar. The rhBMP-2–induced bone seems to be of similar quality and as suitable for osseointegration as the residual bone.

Roldan and colleagues evaluated the benefit of platelet-rich plasma (PRP) in sinus grafting compared with rhBMP-7 using anorganic bovine bone as an osteoconductive medium in five miniature pigs. In this experiment, 420 μl rhBMP-7 was used. The mean bone–implant contact using rhBMP-7 was 45.8% and was 5.7% under PRP ($P = .002$). The mean height of newly mineralized bone in the augmented area using rhBMP-7 was 8.3 mm and was 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 as compared with the use of PRP. Terheyden and colleagues performed a similar study and reported comparable results. Margolin and colleagues evaluated the healing response and bone formation stimulated by three doses of recombinant human OP-1 (rhOP-1) of 0.25, 0.6, and 2.5 mg OP-1 per gram of collagen matrix, natural bone mineral, or collagen matrix alone (control) placed in the maxillary sinus of adult chimpanzees. Sinus augmentation with natural bone mineral or 2.5 mg OP-1 per gram of collagen matrix induced comparable radiographic and histologic evidence of bone formation. McAllister and colleagues showed that 2.5 mg OP-1 per gram effectively stimulates bone formation in the maxillary sinus in chimpanzees. Van den bergh and colleagues looked at three patients (total five sinus sites) and performed 2.5 mg of rhOP-1 and collagen carrier versus autogenous iliac crest bone grafts. One patient's core biopsy showed mature lamellar type of bone. In the second patient, no bone was found. The third patient had bilateral maxillary sinus augmentation (histologically similar to normal bone) and had successful implant integration.

Technique

The technique described in this article is that for BMP2 applied to a resorbable collagen sponge. Sinus grafts with recombinant BMP-2 are performed in a similar manner as other sinus graft procedures (Figs. 1–4). However, the data available are for the use of BMP placed through a lateral maxillary wall window and not through an intra-alveolar "socket" approach.

After the infiltration of local anesthetic (typically 1% or 2% Xylocaine with 1:100,000 epinephrine to the maxilla and vestibule), a crestal incision is made combined with appropriate vertical release to allow for 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 avoid or minimize membrane tears. Preservation of the lateral wall of the maxilla or maintaining it as the roof of the sinus floor graft is based on clinician preference. This surgical team does not obdurate membrane tears with membranes.

The BMP is supplied as a lyophilize 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 applied to the collagen sponge (Fig. 2C, D).

In an organized manner, liquid drops are applied to the sponge to equally distribute the BMP to the sponge. The entire BMP liquid is placed onto the sponge. At least 15 minutes are allowed for the BMP in solution to bind to the collagen sponge. After 15 minutes has elapsed, the sponge is cut into strips approximately 15 mm in width. The sponge strips are placed into the sinus

between the bony floor and the elevated membrane (Figs. 1D, 2E, 3B, 4D). After the sinus has received the sponge, the incisions are closed with appropriate suture, typically silk or chromic.

Postoperative instructions are similar as with any sinus graft. The patient should avoid Valsalva 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 shows bone formation in preparation for implant placement 6 months after graft placement.

When placing implants into a sinus grafted with BMP, the bone may feel soft or hard, depending on the density of bone that was formed by the patient. We allow 4 to 6 months for implant integration based on the density of bone felt at the time of implant placement.

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Delivery of Full Arch Restoration Immediately after Implant Placement Surgery: Immediate Function

Peter K. Moy, DMD

West Coast Oral & Maxillofacial Surgery Center, 11980 San Vicente Boulevard, Suite 503, Los Angeles, CA 90049-6603, USA
Implant Dentistry, UCLA School of Dentistry, 10833 Le Conte Avenue, Los Angeles, CA 90095-1668

Early studies of endosseous implants placed into immediate function focused on totally edentulous mandibles. The implants were placed anterior to the mental foramina in dense bone, and patients were provided with provisional prostheses. Promising results of implants placed into immediate function in other regions of the jaw were later published, and the feasibility of an immediate-function protocol for the maxilla was confirmed for single-tooth restorations and fixed partial prostheses. Olsson and colleagues also showed that early loading could be applied for cross-arch dental bridges in the maxilla, although in a limited number of patients.

The most important prerequisites for successful immediate-function procedures seem to be achieving initial implant stability and controlling the immediate loading forces directed to the implant. The initial stability is achieved through biomechanical interlocking of the implant in the surrounding bone and is needed to avoid micromotion at the interface during early healing. The implant's surface properties are believed to influence the bone healing and implant stability over time. To optimize the initial bone healing, especially in situations with less dense bone, a modified implant surface was developed (Fig. 1A and B) This surface (TiUnite; Nobel Biocare, Yorba Linda, California) has been shown to enhance establishment of primary implant stability and achieve secondary stability earlier than machined surfaces through heightened bone response to the TiUnite surface.

Encouraged by the reports indicating that earlier and even immediate loading can result in osseointegration, a new approach to placing implants through a surgical guide into the completely edentulous arch and placing the implants immediately into function was developed by van Steenburghe and colleagues at the Catholic University of Leuven in Belgium. Using CAT, surgeons and restorative specialists are able to perform virtual implant surgery on the computer (Fig. 2A and B) and plan the optimal placement for each implant. Using the Oralim software program (Nobel Biocare AB, Goteberg, Sweden), the surgeon and restorative dentist may assess the available bone in three dimensions directly under the pontic crown (Fig. 3A and B), thus determining the proper angulation and ideal positions for the implants (Fig. 4). Once the planning is completed, the data are sent via the Internet to the Procera laboratory (Nobel Biocare AB, Goteberg, Sweden) to convert the data and produce a stereolithographic cast of the edentulous jaw with the implants placed (Fig. 5A and B). This permits the technician to fabricate a precise and accurate surgical template, along with the definitive prosthesis (Fig. 6). The implants are placed during a single flapless surgical session, with the prosthesis attached immediately afterward (Fig. 7).

This approach dramatically condenses the time required for implant surgery and subjects the soft tissue to minimal trauma while yielding excellent esthetic results and a high degree of

E-mail address: drmoy@titaniumimplant.com

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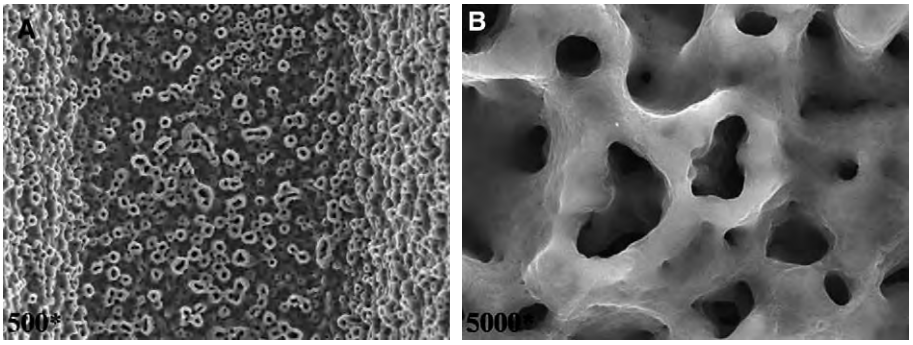

Fig. 1. (*A*) The TiUnite surface showing the porosity of new enhanced surface. (*B*) A higher magnification of the TiUnite surface.

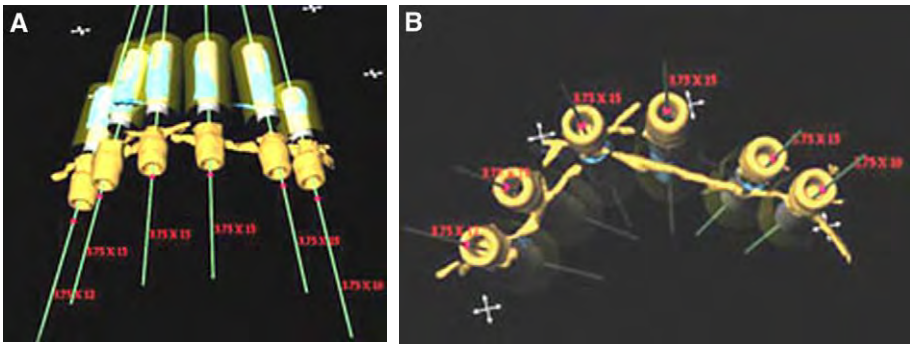

Fig. 2. (*A*) A planning scene from the original Oralim software program showing the positions of implants and abutments. (*B*) The same planning scene rotated three dimensionally to view the occlusal aspect, allowing for inspection of the proximity of components.

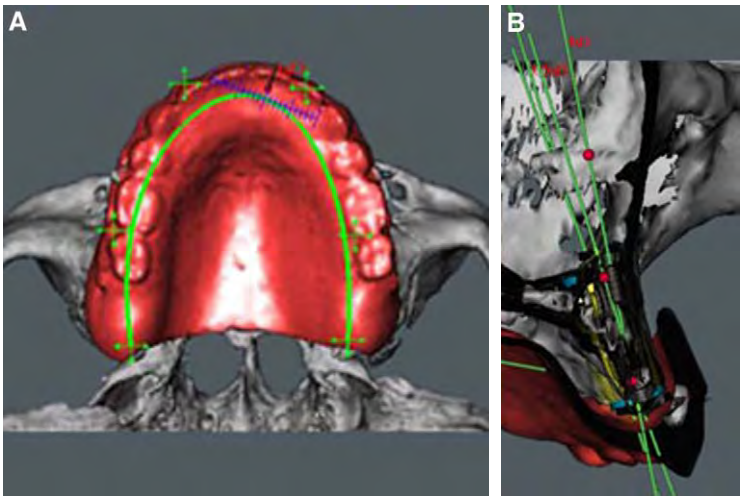

Fig. 3. (*A*) An occlusal view illustrating the prosthesis and the relative position of the denture to the osseous tissue. (*B*) An axial view showing the three-dimensional picture of the alveolar ridge in relationship to the denture teeth of the prosthesis.

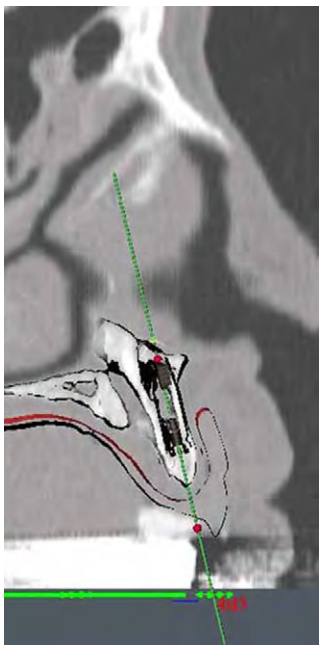

Fig. 4. An implant has been placed and angulated to the ideal relationship to the tooth in the prosthesis on the flat axial view.

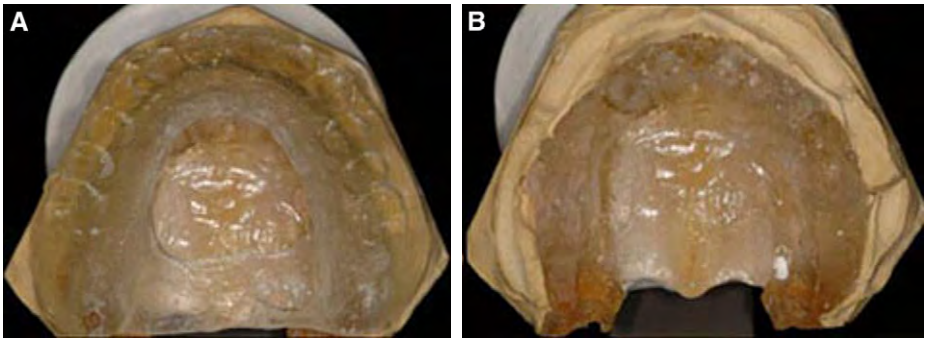

Fig. 5. (*A*) A CADCAM-generated, rapid prototype model with the replica of prosthesis attached to the model. (*B*) The same model with the prosthesis removed, showing the positions of implants.

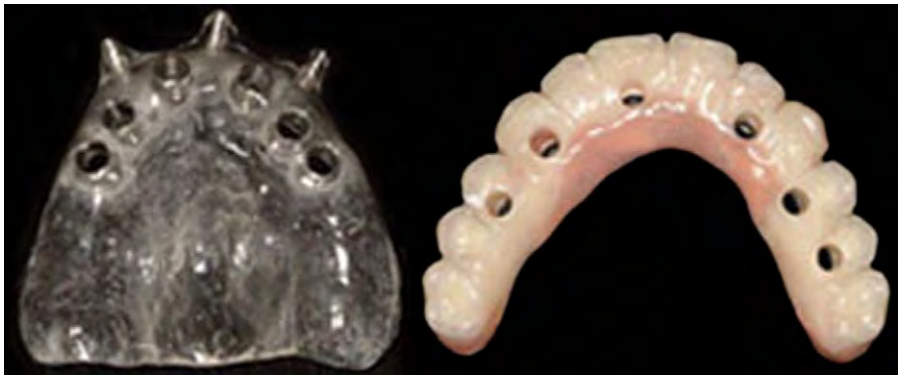

Fig. 6. A surgical template generated from the prototype model and the definitive prosthesis generated on the prototype model fitting exactly to the implant locations.

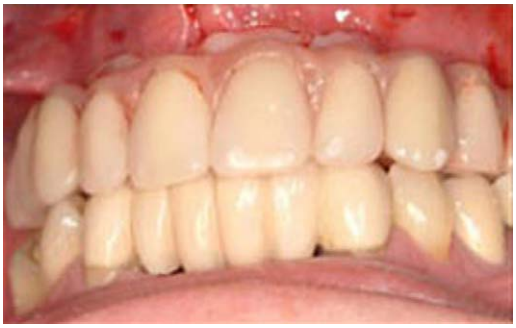

Fig. 7. The definitive prosthesis inserted and in occlusion.

patient satisfaction by providing the patient with immediate function using a fixed prosthesis (Fig. 8). Teeth-in-an-Hour differs from other techniques and surgical approaches by conserving the surgeon's and prosthodontist's time and minimizing the chair time required for the patient. Other techniques, such as the Novum technique, require the restorative specialist to spend a significant amount of time after the implants are placed providing the patient with the fixed restoration. This may be daunting for the patient, especially after having undergone a surgical procedure. Teeth-in-an-Hour prevents the need for this by having the restoration fabricated before the placement of implants. The surgeon may deliver the prosthesis immediately after the surgical procedure. Box 1 lists the advantages of Teeth-in-an-Hour, and Box 2 lists requirements for using Teeth-in-an-Hour.

System description

The Teeth-in-an-Hour system uses dual CT-scanned images taken at 0.5 mm cuts to create a highly accurate computerized model of the patient's oral anatomy and complete denture containing radiopaque markers (Fig. 9). A proprietary software program, Procera Software Planning Program, converts the CT data and allows the implant surgeon to plan the appropriate implant position and angulation in the available bone and directed by the prosthetic requirements of the pontics (Fig. 10A, B). This surgical treatment plan is captured in a high-precision surgical template (Fig. 11), which is produced on a reformatted, stereolithographic cast generated from the CT data. Based on the dual scanning of the patient's edentulous jaw and the actual denture alone, the soft tissue thickness throughout the arch is replicated on the stereolithographic cast (Fig. 12). A soft tissue cast is used to determine the customized height

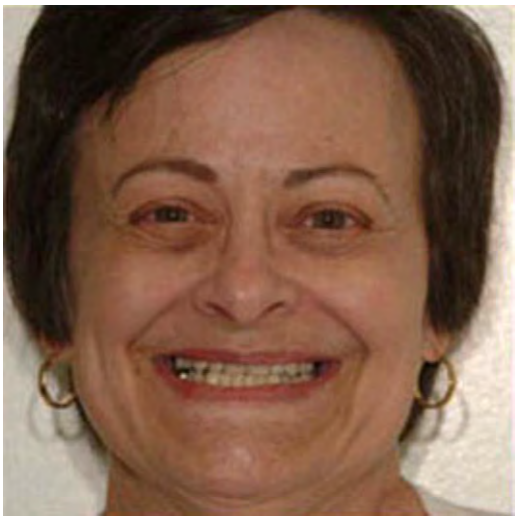

Fig. 8. Patient immediately after delivery of the fixed, definitive prosthesis.

Box 1. Advantages of the Teeth-in-an-Hour concept compared with other immediate-loading concepts

- Reduced surgical time due to flapless surgery
- Reduced healing time, postsurgical swelling, and discomfort
- Reduced prosthetic chair-side time after implant placement
- Elimination of the need for a temporary prosthesis
- Immediate esthetics because the delivered bridge is identical to the shade and mold of denture teeth in the original denture
- A total system that provides a complete oral reconstructive solution for dentists

and form of the restorative framework and to generate a highly accurate surgical template. The surgical template is secured during the surgery with horizontal anchor pins and template abutments attached to the first two implants (Fig. 13). All implants and the surgical template are placed in a flapless procedure (Fig. 14).

The surgery typically takes approximately 30 minutes and is followed immediately by installation of the permanent bridge (Fig. 15).

Patient selection

The system was originally designed for use in the completely edentulous jaw. With improvements of the software program and continued development of the surgical instrumentation, the partially dentated and single missing tooth situations may be treated with NobelGuide. The patient's general health should be uncompromised, and any positive medical findings should be well controlled. Any precautions taken for conventional implant surgery should also be used for Teeth-in-an-Hour procedure (eg, cessation of smoking).

Adequate alveolar ridge bone must be present to permit the placement of a 7-mm implant or longer. At least 40 mm clearance must exist between the top of the ridge crest and the incisal edges of the opposing teeth or edentulous ridge in the anterior region due to the extended length of the surgical components, such as the twist drills and drill guides. This inter-ridge clearance is necessary to perform the surgical procedure unimpeded.

The current denture in the jaw planned for treatment must have an optimized occlusion, teeth set-up, and mucosal fit. If not, a new denture should be fabricated, establishing ideal occlusion

Box 2. Important requirements for using the Teeth-in-an-Hour treatment modality

- Complete edentulism (mandibular, maxillary, or both arches)
- Access to a broadband Internet connection (high-speed DSL or T1 line)
- Working knowledge of the Procera Software Planning Program
- A computer with adequate speed and memory to download information and run the software program (system requirement: Pentium IV processor with 1.6 GHz speed or higher, 512 MB Ram or more, 40 GB disk or more and a high-end graphics card)
- The alveolar ridge must have at least 10 mm of bone height available for optimal results (implants shorter than 7 mm are not recommended for immediate loading situations).
- The surgeon must have specialized surgical instrumentation specifically designed for Teeth-in-an-Hour technique.
- The company recommends using the Branemark system or Replace system because the surgical and prosthetic components are designed for this particular external hex-top or triangular internal-connection implants.

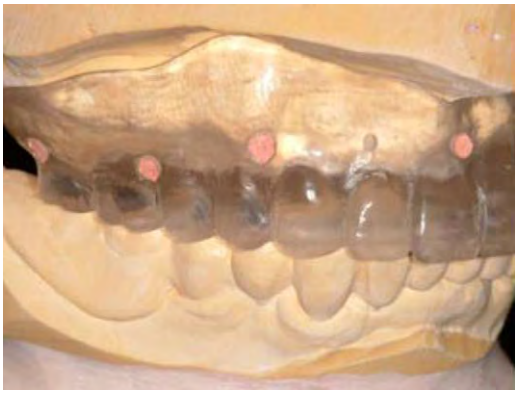

Fig. 9. A radiographic template generated by duplicating patient's denture and insertion of radiopaque (gutta percha) markers.

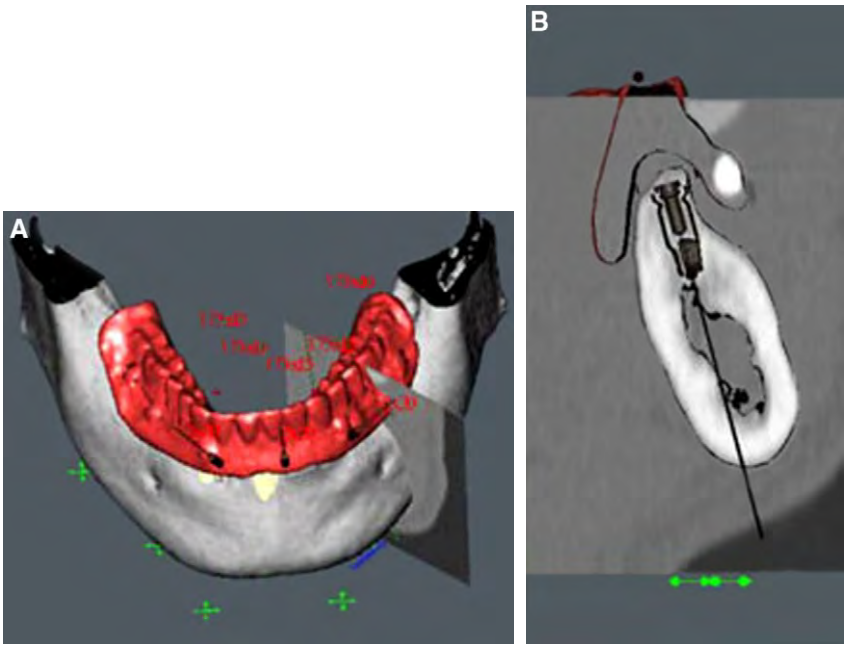

Fig. 10. (*A*) The planning software program permits visualization of the prosthesis and the relationship of the pontic teeth to the osseous anatomy to permit the ideal positioning of the implant. (*B*) An axial view showing the proper vertical and horizontal positioning of the implant and the implant's relationship to vital anatomy and the buccal-lingual dimensions of the pontic.

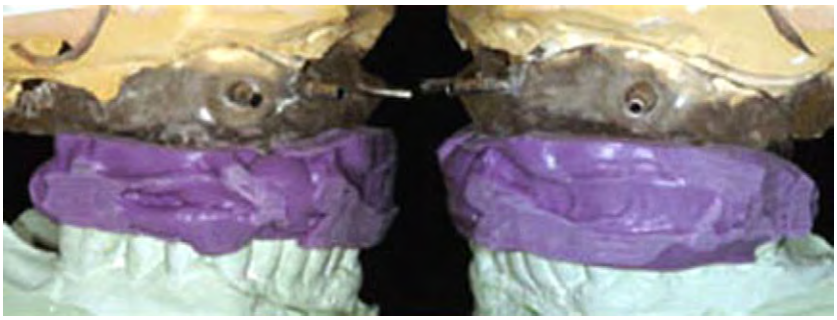

Fig. 11. The surgical template seated on laboratory-fabricated, mounted models to generate the surgical index, which is used to seat the surgical template intraoperatively.

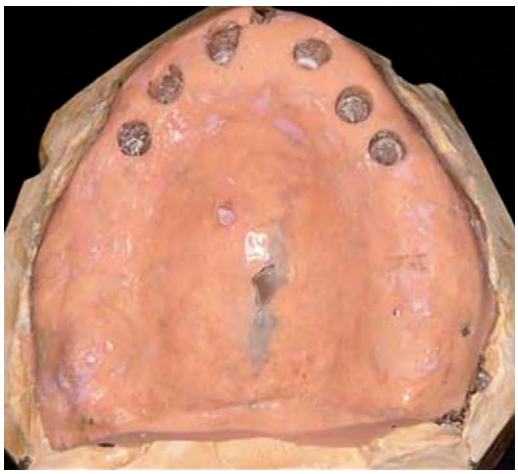

Fig. 12. A soft-tissue cast fabricated on the CADCAM generated model to match the contours and thickness of mucosal tissue.

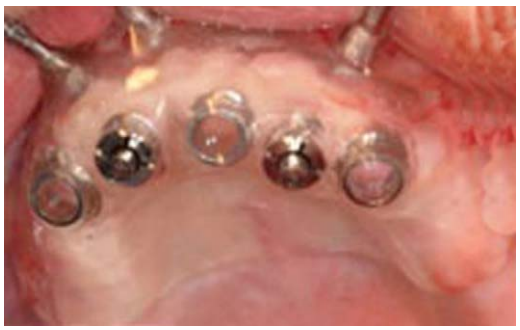

Fig. 13. The surgical template seated and secured with three horizontal stabilization pins and two stabilization implants.

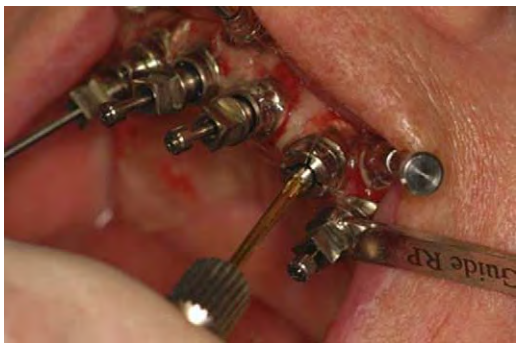

Fig. 14. An intraoperative view of the flapless procedure.

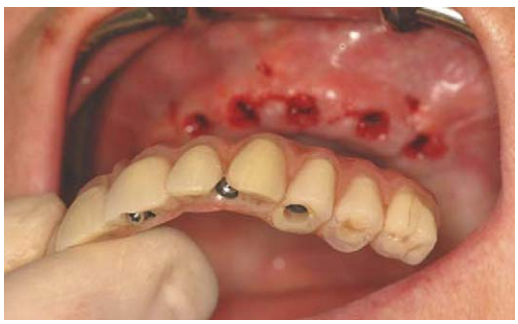

Fig. 15. Insertion of the definitive prosthesis immediately after the removal of the surgical template.

and teeth positions for the CT scanning. The fit of the intaglio (tissue-side) surface of the denture is important to the accuracy of the scan and consequently the accuracy of the Teeth-in-an-Hour bridge.

Presurgical/prosthetic steps

1. Make an impression of the opposing jaws using standard impression material (eg, alginate), and create an interocclusal index in a rigid material (silicone) (Fig. 16).
2. Record the shade and teeth molds to inform the laboratory technician.
3. Send all pertinent laboratory information (such as tooth shade, teeth mold, clinical photographs of the prosthesis in and out of the mouth) and an interocclusal index to the dental laboratory. The casts of the maxillary and mandibular arch should be mounted on a semiadjustable articulator and sent to the lab, along with the information regarding the shade and teeth molds.
4. Have the laboratory fabricate a replica of the denture in clear acrylic. The clear acrylic denture replica or the patient's actual prosthesis must be worn by the patient while the dual CT scan is being performed.
5. Prepare the prosthesis replica or the denture, placing two radiopaque reference markers on the lingual/palatal denture flange anterior to the canines, two in the buccal vestibular region of the premolars, and two in the molar region bilaterally (Fig. 17). The reference points must occupy different levels in relation to the occlusal plane (eg, offset or tripoding).
6. Send the patient to the scanning facility to obtain a spiral CT scan. During the double-scan procedure, the patient must wear the interocclusal index to keep the prosthesis or denture replica in the proper position. This assures the scans contain accurate data on the position of the denture teeth in relation to the available bone in the alveolar arch. (For details on the scan requirements, see the Nobel Biocare Teeth-in-an-Hour Concept and Planning Manual.) The scanning facility sends the CT data to Belgium to be uploaded and transferred into the Oralim program. With the Procera Software Planning program, it is possible for the clinician to convert the CT files and upload into the planning program on their own computer.
7. Using the planning software, determine the optimal sites for implant placement, taking into account anatomic constraints and prosthetic and esthetic considerations. Abutment lengths are planned during this process, along with the positioning of anchor pins to stabilize and correctly position the surgical template during the implant installation (Fig. 18).
8. Send the completed planning file via modem to a dental laboratory with the capability of using the Procera System, along with casts of the maxillary and mandibular arch mounted on a semiadjustable articulator and the patient's teeth, shade and mold instructions, the teeth set-up, interocclusal index, and any other pertinent information for the laboratory technician to fabricate the fixed prosthesis.
9. The dental laboratory produces a semifinished surgical template and orders the necessary clinical and laboratory components and instruments.
10. The implants recommended for use are Branemark System or Replace System implants with TiUnite surface and may be ordered directly from Nobel Biocare.
11. Nobel Biocare sends the laboratory the semi-finished surgical template, the interocclusal index, and the carbon-fiber or Procera implant bridge framework.

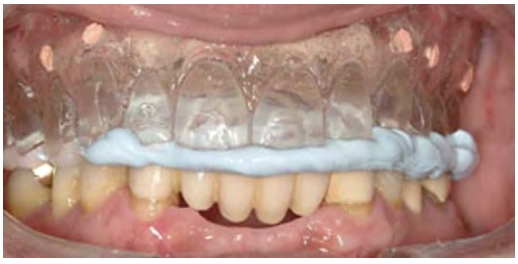

Fig. 16. Fabrication of the interocclusal, surgical index.

Fig. 17. Illustration of required positions of radiopaque markers.

12. The laboratory completes the preparation of the surgical template and manufactures a stone model with soft-tissue cast to complete the fabrication of the fixed bridge (Procera Implant Bridge or a carbon-fiber bridge) and a surgical index for positioning the surgical template during the implant placement procedure (Fig. 19).
13. The laboratory sends the finished bridge and surgical index to the surgeon.
14. The surgeon checks the Operation Information sheet to ensure that the data are correct and that all the components and instruments necessary to complete the surgery have been delivered before the surgical appointment (Fig. 20).

Surgical procedure

1. Visually inspect and compare the patient's intraoral anatomy, the model, and the Operation Information sheet.
2. Ensure the surgical index that accompanies the surgical template fits together and the surgical template indexes with the opposing jaw on the patient when occluding. This step ensures that the surgical template is correct (Fig. 21).
3. After administering the local anesthetic, prepare and drape the patient. Intravenous sedation or general anesthesia is not necessary, nor is it recommended due to the need for the patient to cooperate during the insertion of the surgical template to establish the proper vertical position of the surgical template.

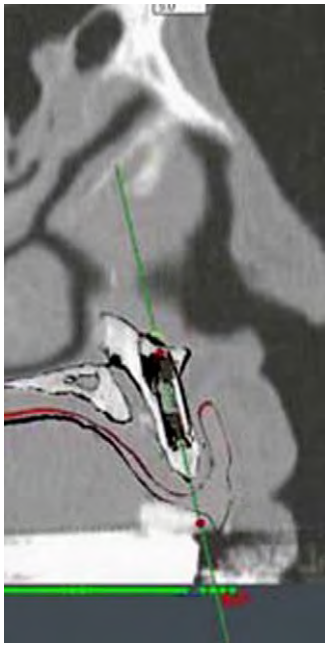

Fig. 18. An axial view of planning software program, permitting the proper placement of all surgical components.

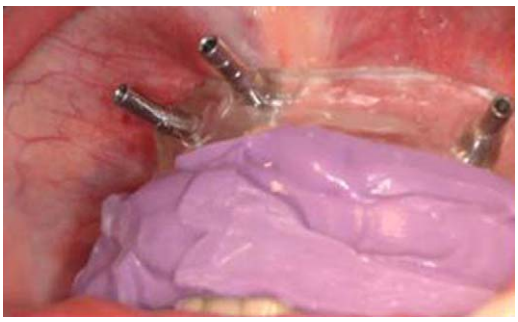

Fig. 19. The use of the surgical index to seat the template into proper position and establishing the appropriate vertical dimension of occlusion.

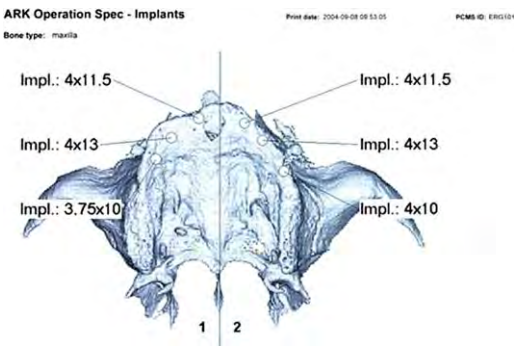

Fig. 20. Laboratory and surgical reference and work sheet for identification of positions, size of implants, and length of abutments.

4. Position the surgical template over the ridge using the index while occluding against the opposing dentition or denture (Fig. 22).
5. Once the template is correctly positioned and secured, start the drilling procedure with a 1.5 × 20 mm disposable twist drill in the horizontal template sleeves in the surgical template (Fig. 23). Drill a hole through the soft tissue and into the jawbone. To avoid fracture of the small diameter twist drill, avoid placing any lateral pressure on the drill.
6. Secure the surgical template using an anchor pin (Fig. 24).
7. Repeat the procedure for the two remaining anchor pins.
8. Select two vertical template sleeves on either side of the arch to start the implant insertion procedure. Typically, the next to the most distal implant site is used, bilaterally.
9. Placing the combination tissue punch/counterbore drill (Fig. 25A, B) in the vertical template sleeve. Drill to the stop indicator on the tissue punch/countersink drill. Soft tissue, along with crestal bone, is completely removed. A hand-held mechanical tissue cutter may be needed to remove additional mucosal tissue.

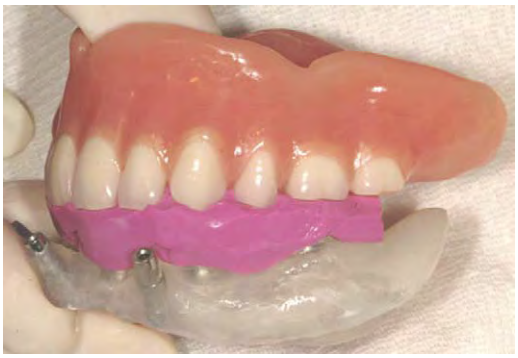

Fig. 21. Confirming the accuracy and fit of surgical index to surgical template and opposing occlusion.

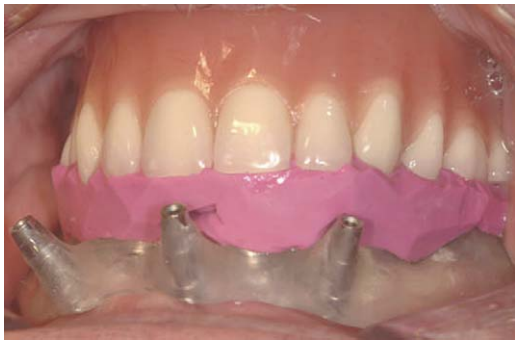

Fig. 22. Positioning of surgical template intraorally.

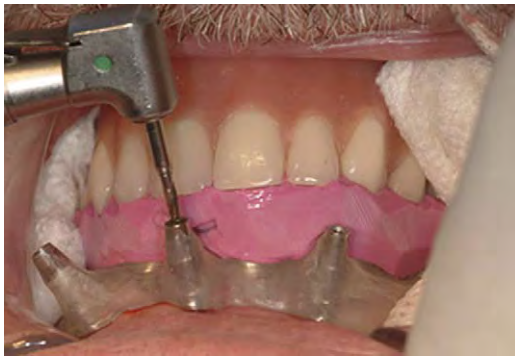

Fig. 23. Preparing to place the first horizontal stabilization pin using a 1.5-mm-diameter twist drill.

10. Place the 2-mm drill guide in the same vertical template sleeve and use the 2-mm twist drill to the desired depth under copious irrigation. Use the drill guide for directional guidance (Fig. 26).
11. Repeat Step 10 using the 3-mm drill guide and 3-mm twist drill (Fig. 27).
12. When the bone is extremely dense and hard, a 3.15-mm twist drill together with the 3.15-mm drill guide may be used.
13. Place the first implant, using the customized implant mount and implant guide sleeve (Fig. 28).
14. Remove the implant mount and screw a template abutment to engage the implant, thus applying vertical compression to the surgical template and mucosal tissue (Fig. 29).
15. Select a second template sleeve on the contralateral side. The next to the most distal implant site is most frequently used.
16. Place the second template abutment and screw in the same manner as the first, anchoring it to the surgical template.

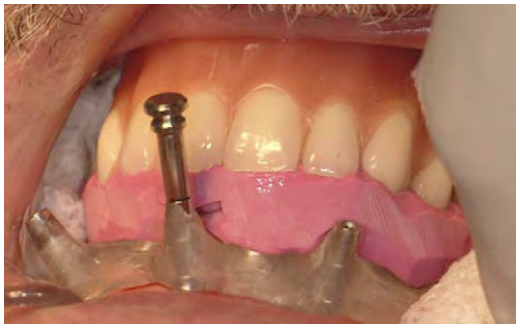

Fig. 24. A horizontal stabilization pin seated into position to hub.

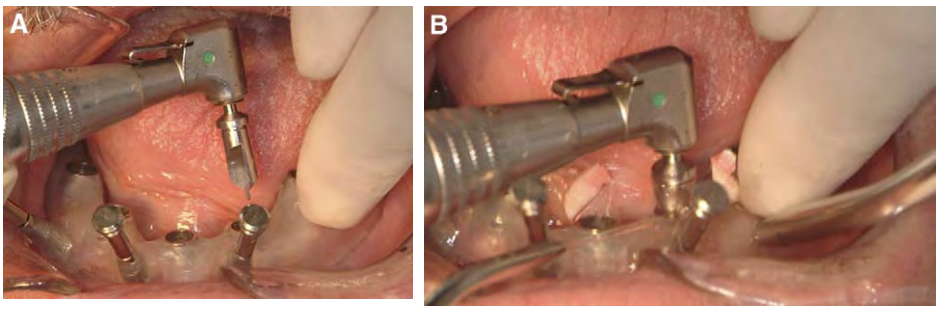

Fig. 25. (*A*) The first drill is a combination tissue punch and counterbore placed directly into vertical guide sleeve of the surgical template. (*B*) The first drill is taken down to the drill stop (flange).

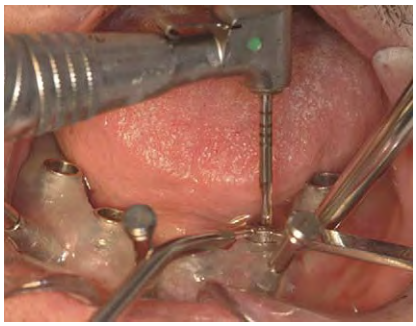

Fig. 26. The second drill is a 2-mm-diameter twist drill placed into a 2-mm drill guide.

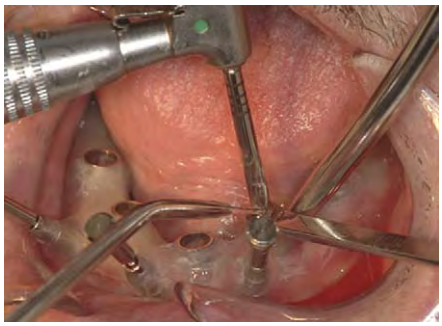

Fig. 27. The third drill is a 3-mm-diameter twist drill placed into a 3-mm drill guide.

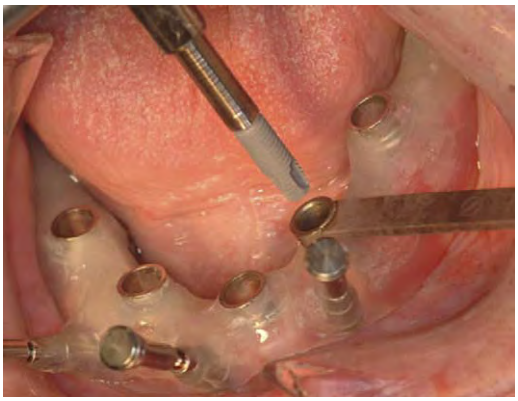

Fig. 28. Delivery of the implant with a custom implant mount to account for the increased length necessary to place implant through the vertical guide sleeve and the implant guide.

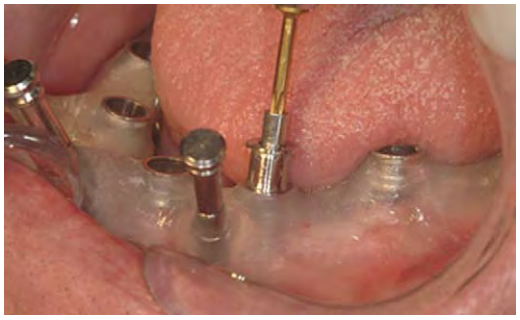

Fig. 29. A template abutment is used to apply even compression on the mucosal tissue by engaging the stabilization implant and placing the compressive forces on the surgical template.

17. Prepare the remaining implant sites and insert the implants. Because there is only one implant guide, the implant mount must be removed, the implant guide removed, and the mount replaced back onto the implant. This prevents the soft tissue from collapsing back over the implant while the other implant sites are being prepared.
18. Once all the implants have been properly inserted, remove the three horizontal anchor pins.
19. Using a gauze pack as a throat screen to prevent components from falling into the back of the throat, loosen the two template abutments and all implant mounts (Fig. 30).
20. Remove the surgical template with all template abutments and implant mounts.

Postimplant insertion/prosthetic steps

1. After the bridge has been thoroughly disinfected, place the sterile adjustable abutments in the bridge in accordance with the Operation Information sheet (Fig. 31).
2. Position the bridge over the implants as quickly and smoothly as possible to prevent the soft-tissue from collapsing on top of the implants, which would impede the complete seating of the bridge.
3. While the patient bites gently to balance the bite relationship, use the Unigrip screwdriver (Nobel Biocare USA, Yorba Linda, California) to hand-tighten the abutment screws until resistance is felt.
4. For final tightening, use the manual torque wrench and prosthetic Unigrip screwdriver to tighten the abutment screws to 35 N-cm (Fig. 32).
5. Check the occlusion and adjust it if necessary. Be especially cognizant of lateral interferences and eliminate these contacts.
6. Cover the screw access holes with a filling material.

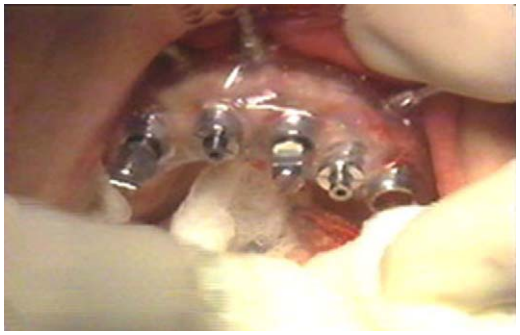

Fig. 30. When all implants have been inserted, the surgical template is removed. A throat screen is recommended to prevent loose components from falling into the back of the throat.

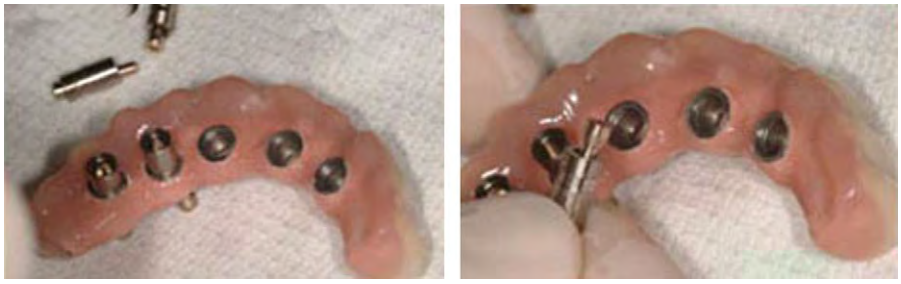

Fig. 31. All adjustable abutments are inserted into the definitive prosthesis before delivering the prosthesis.

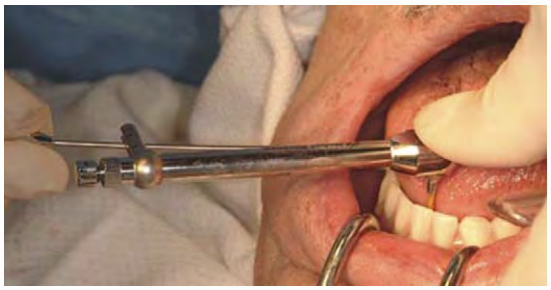

Fig. 32. When the adjustable abutments and prosthesis have been adequately seated into position, the abutment screws are tightened to 35 N-cm using the Nobel Biocare torque driver.

Postoperative patient instructions

The patient is instructed to remain on a soft, nonchewing diet for 1 week. Typical postsurgical instructions are given (eg, the use of ice to minimize swelling, warm saline rinses, and oral hygiene instructions).

Further readings

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Atlas of the Oral and Maxillofacial Surgery Clinics

Treatment of the Severely Atrophic Fully Edentulous Maxilla: The Zygoma Implant Option

Edward B. Sevetz, Jr, DMD

Department of Surgery, Section of Maxillofacial Surgery, University of Florida School of Medicine, 2140 Kingsley Avenue, Orange Park, FL 32073, USA

People who are missing teeth can be compromised or handicapped in chewing efficiency, speech problems, facial appearance, and self-confidence in social situations. This is not news to the dental profession. However, because dentistry was the first health care profession to benefit from the discovery of osseointegration by Per-Ingvar Brånemark when he first placed implants into the mouth in 1965, it has become generally accepted treatment to offer patients who have lost teeth the implant option for their replacement.

A sufficient quantity and quality of bone must be anatomically present for the successful insertion of implants for osseointegration. When teeth are lost, there is a normal physiologic process that causes the remaining alveolar bone to shrink over time. This can lead to significant problems for the retention and stability of removable prostheses and collapse of vertical dimension, adversely affecting facial appearance and dramatically lowering chewing capabilities. If patients do not receive the benefits of osseointegrated implant anchorage to replace lost teeth, time will rob them of adequate bone for implant placement. Bone graft reconstructions have long been used in attempts to reverse the shrinking alveolar base. When the posterior maxilla is involved, these attempts have come in the form of sinus grafting with autogenously harvested bone or alloplastic and xenoplastic materials. Other attempts have involved autogenous corticocancellous composite grafts to be placed onto the shrinking maxillary alveolus or interpositional LeForte 1–type grafting. These techniques result in varying survival rates of implants, ranging from approximately 60% to 90%. Tolman concluded that so many different attempts to solve the prosthetic problem of the severely atrophic fully edentulous maxilla indicate ''that no single solution has universal application.'' The surgeon must also consider that many of these options involve increased morbidity because of operations at harvesting sites along with increased cost to the patients.

With these considerations in mind, Brånemark embarked upon an alternative treatment option to help patients attain their prosthetic goals with increased predictability and with decreased morbidity, treatment time, and cost. Initially, he began using the zygoma as an implant anchoring site in patients who were missing portions of their maxilla due to cancer resections and in patients who had clefts. He found the zygoma to possess the quality of bone similar to the anterior mandible, which is widely known to have a high success rate of implant survival and to be of sufficient quantity. The goal of using the zygoma as an implant anchoring site was to provide predictable posterior anchorage for the restoring dentist's prosthetic efforts (Fig. 1). It was found to greatly decrease the number and size of grafting procedures required.

All patients in the initial series for this treatment option failed one or more previous attempts at reconstruction with grafting and implants. Despite the selection for inclusion of patients who had documented previously failed attempts, the survival rate of the zygoma implants placed into them, with follow-up of up to 10 years, was 94%. Ninety-six percent of the patients had prostheses anchored to implants at the end of that study. A world-wide, multicenter, prospective

E-mail address: drsomfs@bellsouth.net

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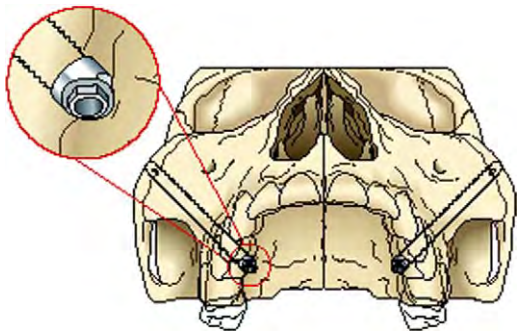

Fig. 1. Typical position of occlusal end of zygoma implant relative to prosthetic teeth. (Courtesy of Nobel Biocare; with permission).

study of consecutively placed zygoma implants in patients was initiated in late 1997. The zygoma implant survival rate in this prospective study was 96.3%.

Indications

Anchoring implants into the zygoma has been done primarily in fully edentulous arches to give posterior anchorage. Cross-arch stabilization by a passively fitting, solid framework enables all implants to share in the distribution of the occlusal load. Some have been placed in partially edentulous situations, and because so few have been done and followed, it should be considered experimental in the partially edentulous arch. Zygoma implants may be considered in patients with discontinuity defects in the maxilla or moderate to advanced atrophy and resorption to the degree that posteriorly positioned short implants might be expected to have a lower chance of long-term survival and often to preclude the need for bone-grafting procedures.

Zygoma implants have been used primarily in situations in which other anterior implants can also be placed so that once the framework is attached to the abutments, the long zygoma implants are not able to be placed under a bending moment of torque. More recently, two zygoma implants have been placed into each zygoma with and without additional implants anteriorly or posteriorly. This has further reduced the need for bone grafting. These treatments should be considered experimental until further studies have been done.

Contraindications

In addition to any known implant placement contraindications, patients who have active maxillary sinus disease should have that condition treated before zygoma implants are placed. The surgeon should consider if the patient can open their mouth widely enough to access the posterior regions and if an existing lower dentition may also hamper access.

Preoperative work-up

After a thorough prosthetic work-up is done to choose a goal that can be achieved with the help of osseointegrated implants, radiographic evaluation of the prospective candidate for zygoma anchorage is indicated. Studies are done to rule out active maxillary sinus disease and to evaluate the volume of bone in the zygoma. These studies may include panoramic films, P-A and lateral cephalometric films, and CT scans from the orbital floor down through the residual maxilla (these can be done in axial cuts about 2.5 mm apart and computer reformatted into coronal projections). When reviewing the coronal reformatted "slices," the zygoma implants usually come into the arch at about the second premolar area and just palatal to the residual alveolus. From that second premolar area, one can measure on the CT scan the distance to the incisura of the frontozygomatic notch, which is approximately where the superior end of the implant can be positioned (Fig. 2).

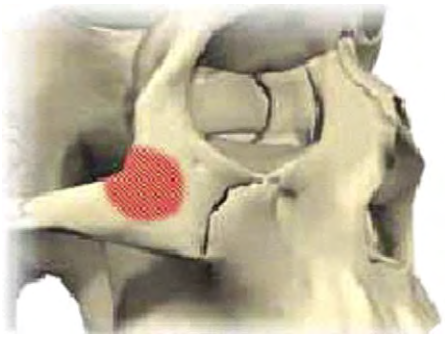

Fig. 2. Typical position of apical or superior end of zygoma implant relative to the zygoma and fronto-zygoma notch. (Courtesy of Nobel Biocare; with permission).

The lengths that are commercially available for the zygoma implants range from 30 to 52.5 mm. The axial "slices" tell if any other areas of the residual alveolus might be a candidate for a shorter implant. Most commonly, two or more anterior implants are placed at the time of zygoma implant placement to prevent torque to the framework and implants. Even in fairly atrophic maxillae, there can remain a small volume of bone adjacent to the incisal foramen or in the canine area on up superiorly into the combined wall between the lateral aspect of the nose and the medial wall of the maxillary sinus. Study of the tuberosity/pterygoid areas may reveal that implants may be placed there as well, with a mesial axial inclination to facilitate placement of impression copings and screws. In patients who have hypoplastic maxillary sinuses, the zygoma implants may be positioned outside of the maxillary sinuses.

Surgical technique

Once the patient has been appropriately worked up from the medical, dental, and maxillofacial anatomy perspectives, they are usually brought to the operating room for general anesthesia and nasoendotracheal intubation. Brånemark describes the initial incision as at the LeFort 1 level in the maxillary labial mucobuccal fold (Fig. 3), although others use a crestal incision on the residual maxilla, with relaxing incisions as needed, anteriorly and posteriorly (Fig. 4).

Although the zygoma implant has greatly decreased the need for simultaneously placed bone grafts, if one is planned, the incision design might have to be altered accordingly.

The palate area should be exposed to plan the entrance of the drilling (Fig. 5). The dissection should continue subperiosteally superiorly and toward the frontozygomatic notch. Care should be taken to identify and avoid the infraorbital nerve (Fig. 6).

When the zygoma is exposed, there may be a few fibers of muscle to be detached from anterior-most aspect of the arch. Some surgeons have advocated that to ensure that the frontozygomatic notch has been correctly identified, the posterior approach to the zygoma can be subperiosteally dissected to arrive at the notch from the posterior aspect and the anteriorly identified approach to the notch (Fig. 7). A custom-designed zygomatic notch retractor can be placed, and the surgeon can then visualize the anatomic pathway the implant might take from the exposed palatal aspect of the residual alveolus on up to the frontozygomatic notch (Fig. 8).

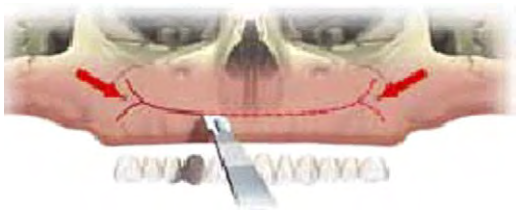

Fig. 3. Level of labial incision if using the Leforte 1 approach. (Courtesy of Nobel Biocare; with permission).

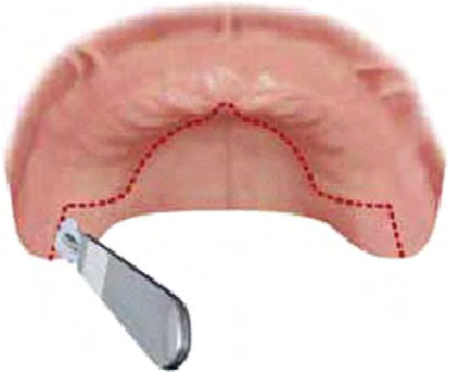

Fig. 4. Option of choosing crestal incision for approach. (Courtesy of Nobel Biocare; with permission).

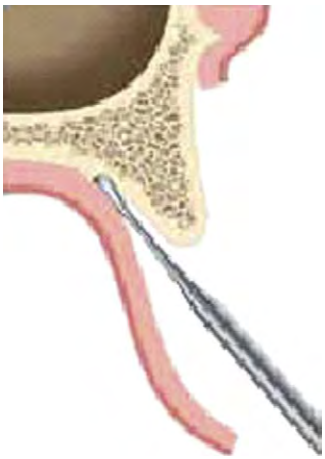

Fig. 5. Elevation of full-thickness mucoperiosteal flap for access to begin drilling. (Courtesy of Nobel Biocare; with permission).

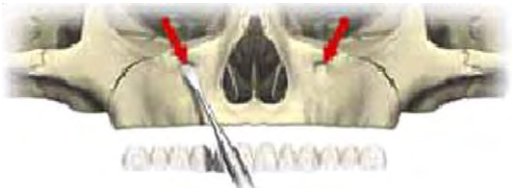

Fig. 6. Locate and avoid the infraorbital nerve. (Courtesy of Nobel Biocare; with permission).

Fig. 7. The fronto-zygomatic notch must be correctly identified. (Courtesy of Nobel Biocare; with permission).

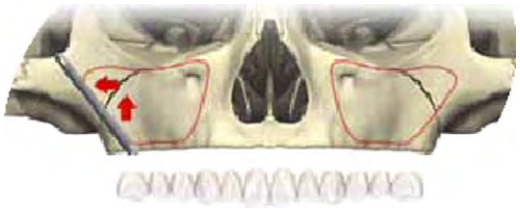

Fig. 8. Visual orientation is provided by a correctly positioned custom fronto-zygomatic notch retractor. (Courtesy of Nobel Biocare; with permission).

Usually, the surgeon is positioned at the operating table on the side opposite of the proposed zygoma implant placement. This facilitates the dissection, drilling, and visualization/orientation in the limited size field. The surgeon may choose to move to the other side of the operating table to place a zygoma implant into the second side of the procedure. Once orientation has been achieved in the surgeon's "mind's eye," a boney window is made through the anterior aspect of the maxillary sinus. This is done under cooling saline irrigation and may be done with a round bur or a fissured bur. Brånemark originally stated that a 5 mm × 10 mm boney window could be cut and that the sinus membrane need not be kept intact (Fig. 9). However, if it is kept intact, it can be easier to dissect and reflect medially with less bleeding (Fig. 10).

The boney window is made to visualize the bone where the surgeon drills, under cooling irrigation, and to assure that the sinus mucosal lining is not pushed into the zygoma wrapped around the implant, thereby decreasing successful osseointegration. The anterior maxillary sinus wall thickness is usually <1 mm in these patients, so keeping it intact is not required for strength of the mid-face. Not uncommonly, this window can be made longer than 10 mm, in a superior-inferior direction, to allow the surgeon to mechanically clean the mucosa off the floor and roof of the maxillary sinus where the drills will go through (Fig. 11).

If the sinus membrane keeps getting in the way of drilling, it may be moved medially by packing the sinus with iodoform gauze or other sterile packing. The gauze packing is removed before closure. With the frontozygomatic notch retractor in place, the sinus window opened, and important areas cleaned of sinus lining membrane, the surgeon visually lines up the path for the first drill, which is a 2.9-mm-diameter round bur. Once the retractor has been positioned by the surgeon, it is good practice to palpate the frontal process of the zygoma and make certain that the notch retractor is lateral to it and not in the floor of the orbit. It is also good practice to have this palpated by a surgical assistant for confirmation of the retractor's proper position (ie, lateral to the orbit). The entrance point for drilling is in part dictated by how widely the patient's mouth can be opened without damage to the TMJ. It is helpful to have the patient paralyzed while under the general anesthesia. This helps in placing the entrance for the zygoma implant as far posteriorly as possible. It usually enters the resorbed alveolar area in approximately the second premolar region, although this can vary depending upon patient anatomy. The initial opening should be as close to the medial aspect of the residual alveolus as possible. All drilling should be done with copious saline irrigation for cooling. It is usually easy to penetrate the thin residual maxilla as the round bur moves superiorly. The custom notch retractor has a line on its surface that can be seen easily when the surgeon positions it where it is desired. When drilling up into the zygoma, it is easy to see if the drilling direction is right or left of this retractor line and therefore going "off the planned course." The surgeon can see whether the bur is becoming too anterior or too posterior by visualizing it as it pierces the inferior aspect of the body of the

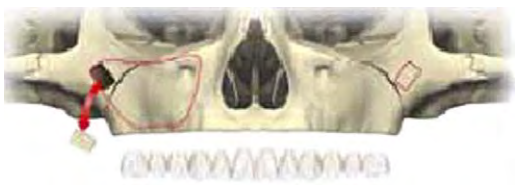

Fig. 9. A boney window is made in the anterior wall of the maxillary sinus. (Courtesy of Nobel Biocare; with permission).

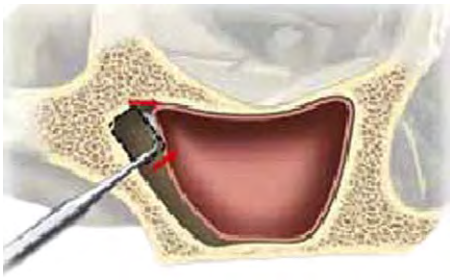

Fig. 10. The sinus membrane lining is reflected off of the proposed drilling sites. (Courtesy of Nobel Biocare; with permission).

zygoma. If it comes out too anterior, it does not use as much of the zygoma bone as is available for osseointegration. If the drilling orientation is too posterior, muscle and vessels such as the maxillary artery may be inadvertently encountered. The goal is to pierce the frontozygomatic notch or be slightly anterior to it (Fig. 12). The round bur pierces the inferior aspect of the zygoma but does not go not much farther due to its relatively short length (Fig. 13).

This is followed by use of the longer 2.9-mm-diameter twist drill. This twist drill is long enough to drill through the entire zygoma. Once the drilling enters the inferior aspect of the zygoma, the irrigating cooling saline is sprayed onto the drill/bone interface and is moved superiorly as the twist drill is about to emerge. Once it emerges, the notch retractor is touched by the twist drill. The retractor protects the deep side of the face, shielding the facial nerve and other vital structures. A sleeve is available to slide onto the drills so that they do not irritate or damage soft tissue along the way while the surgeon's attention is focused on the apex of the drill. Care must be taken by the surgeon to avoid leaning on the twist drill as it proceeds superiorly. Doing this might cause damage at the inferior opening, widening it beyond the intended dimensions. This could be a cause for failure later if the tissues are not sealed around the portion of the implant that extends from the mouth into the maxillary sinus. It is good practice to stay "on line" while drilling from inferior to superior openings because as the implant is placed later in the sequence, the surgeon might find that they cannot get the apex of the implant to enter the drilled opening in the inferior aspect of the zygoma unless the same orientation, in three dimensions of space, is maintained between the opening in the maxilla up through the opening into the zygoma. The next drilling component is a pilot drill, which precisely widens the opening into the zygoma from 2.9 mm in diameter to 3.5 mm in diameter without altering the chosen path. It has a noncutting tip with a diameter of 2.8 mm, which fits into the opening drilled by the 2.9-mm twist drill and guides a cutting portion to start the 3.5-mm-diameter drilling (Fig. 14). This can be used through much of the zygoma and is followed by a 3.5-mm-diameter twist drill to complete the drilling through to the notch retractor (Fig. 15).

A depth gauge approximately 3.5 mm in diameter can now be placed to measure the distance from the alveolus opening through to the exit of the zygoma. Each twist drill has markings on it to indicate the possible length of the implant to be placed later in the sequence (Fig. 16).

Fig. 11. The length of the window can be extended to facilitate mucosal reflection. (Courtesy of Nobel Biocare; with permission).

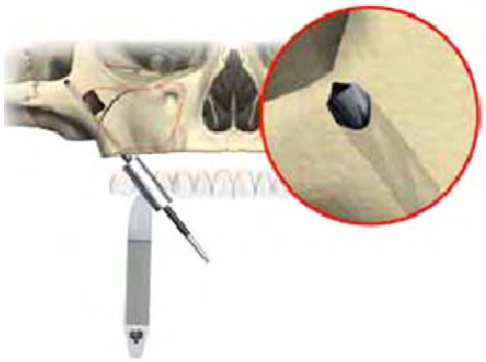

Fig. 12. The ideal site the apex or superior end of the zygoma implant is at or slightly anterior to the fronto-zygomatic notch. (Courtesy of Nobel Biocare; with permission).

Fig. 13. The round bur's length enters only the inferior portion of the zygoma. (Courtesy of Nobel Biocare; with permission).

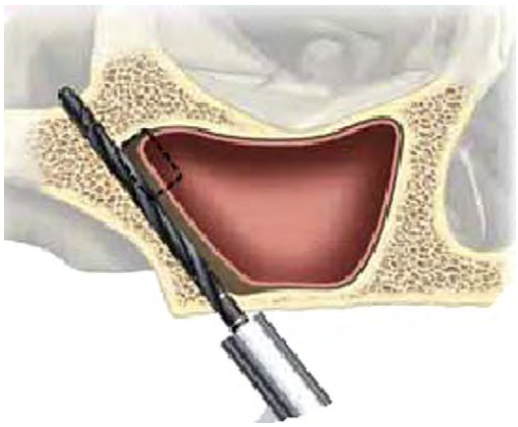

Fig. 14. The pilot drill guides and widens the site for the 3.5-mm-diameter drill. (Courtesy of Nobel Biocare; with permission).

The zygoma implants are available in 2.5-mm increments from 30 to 52.5 mm (Fig. 17). The apex is slightly conical in shape, which facilitates positioning, and the surgeon may plan to have this apex emerge from the superior exit hole 1 or 2 mm. This brings more of the wider portion of the implant into contact with the prepared hole in the zygoma, but if the implant protrudes too far in a patient who has relatively thin facial tissues, the patient may be able to palpate that apex later. The twist drills come in different lengths to facilitate use in more posterior openings through the residual maxilla compared with more anterior openings. Once the measurement

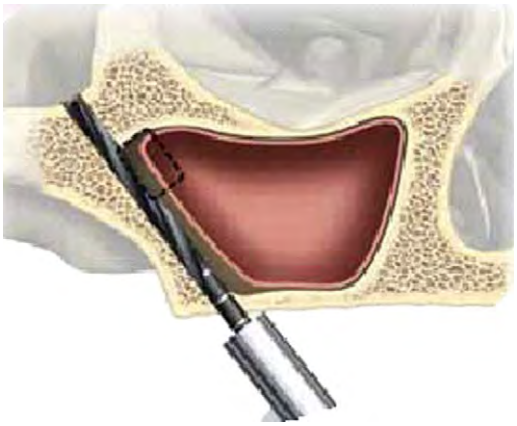

Fig. 15. The 3.5-mm-diameter drill length reaches through the zygoma. (Courtesy of Nobel Biocare; with permission).

has been taken and the desired length implant has been selected, it can be machine-placed after switching to slow speed and under saline irrigation (Fig. 18).

The implant's diameter is 4.0 mm for the majority of its length and 4.5 mm diameter near where it emerges through the residual maxilla. If the bone at the inferior opening is thick and dense (which rarely occurs), only then is the countersink drill used to slightly widen the opening before placing the implant in a controlled manner. Cooling irrigation should be used on the portion of the implant that enters the inferior aspect of the zygoma. If the surgeon, looking through the sinus window as the implant progresses toward the opening in the inferior aspect of the zygoma, sees that the apex of the implant is not going to line up with the opening, it is time to take a corrective step. Preferably using a titanium instrument and not touching a portion of the implant that will enter the zygoma, but farther down along the mid-portion of the implant shaft, the surgeon can apply slight pressure or lift to the shaft of the implant to guide it into the opening in the zygoma. This misdirection problem may occur if the surgeon uses a different orientation of the long axis of the implant as it enters the inferior opening in the residual maxilla than the one that lines up with the inferior opening in the zygoma. To aid the surgeon in visualizing the correct orientation to follow, just before placing the implant, the surgeon can place the 3.5-mm-depth gauge through both openings and see the correct orientation in three dimensions of space to enter both openings with one continuous, long implant. The surgeon should be aware that due to the density of the zygoma, the drilling machine frequently stops, even on its highest insertion torque setting, before the implant is fully seated. When it does, there

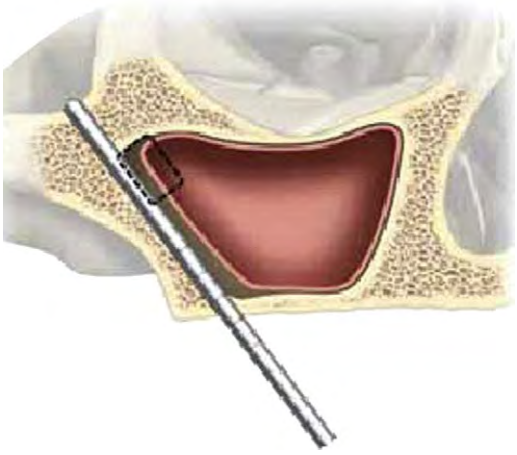

Fig. 16. The depth gauge allows the selection of the final zygoma implant length. (Courtesy of Nobel Biocare; with permission).

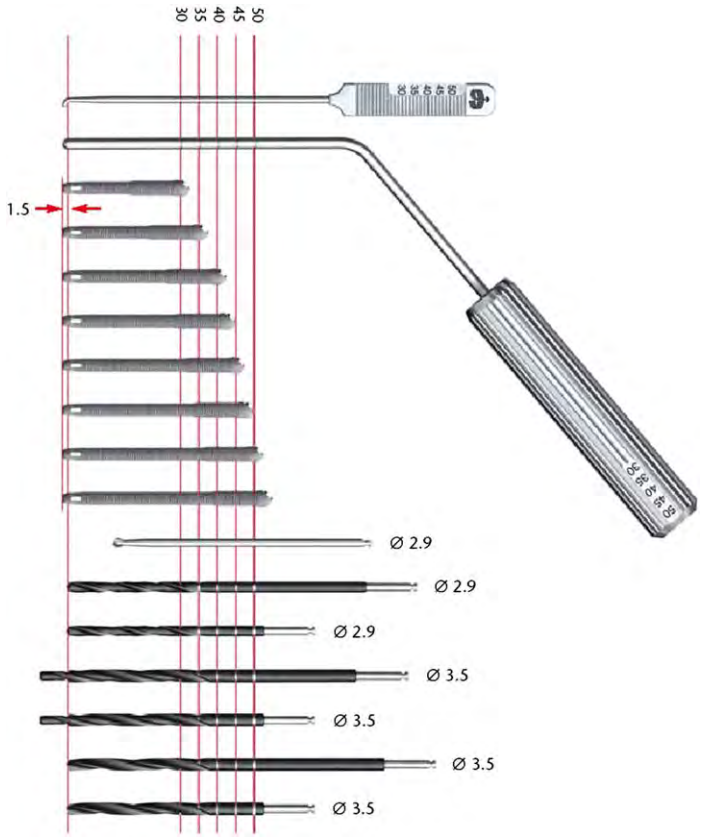

Fig. 17. Sizes of various components and zygoma implants. (Courtesy of Nobel Biocare; with permission).

is a hand instrument that fits onto the implant mount to allow the implant to be fully inserted by clockwise hand-twisting the implant into place under cooling irrigation (Fig. 19). This may occur more commonly in the future if the surface of the titanium implant is roughened by any commercially available proprietary process (Fig. 20).

A small suction tip should be used to suction out the sinus of all irrigation fluids and any blood before closure. At this point, previously placed packing is removed. Inserting the implant's head as close as possible to the medial aspect of the residual alveolus makes less of a buccal extension for the prosthetic portion of the case and makes the abutment less noticeable to the patient's tongue. The final orientation of the implant is critical for the prosthetic phase of

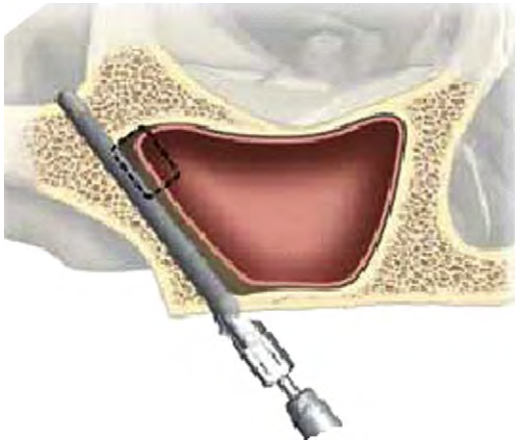

Fig. 18. Insertion of the zygoma implant. (Courtesy of Nobel Biocare; with permission).

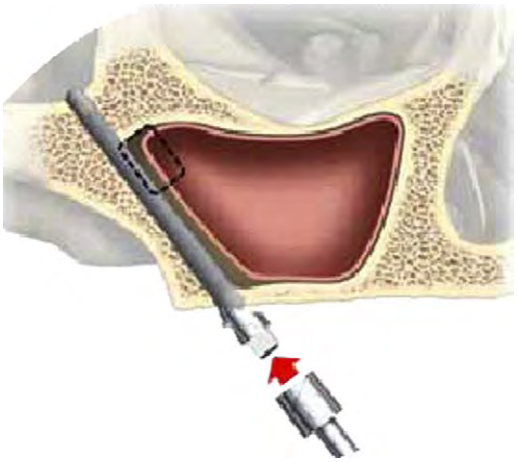

Fig. 19. Hand instrument to complete the placement of the zygoma implant in dense bone. (Courtesy of Nobel Biocare; with permission).

treatment that follows. Obscured by the implant mount is the hex head of the implant. It is oriented at 45° relative to the long axis of the implant. It must be oriented toward the desired plane of occlusion to accept an abutment and later prosthetic framework (Fig. 21). The way to insure that the head of the implant is pointed in the correct direction is to place a small screwdriver or driver bit into the screw which secures the mount onto the implant. The inserted device should point toward the desired plane of occlusion and can be so oriented by turning the hand torque device on the mount (Fig. 22). After the mount is removed by backing out the screw, the hex-head of the implant will be properly oriented (Fig. 23).

If the mount is prematurely removed by the surgeon, it can be remounted, but with difficulty. Most commonly, additional anterior implants are placed at the same time as the zygoma implants. Once all implants and cover screws are placed (Fig. 24), measurements should be taken from some fixed point, such as the maxillary midline, to every implant. This aids in finding them at the uncovering procedure. Six months is allowed to elapse before uncovering for the majority of these implants. In experimental work ongoing now, this time is shortened, at times significantly. Proper long-term follow-up is required before any shorter periods can be recommended before uncovering the implants.

Closure of the initial surgery should be done meticulously to prevent communication between the open sinus window and the mouth or around the inferior opening through which the implant was inserted. Most commonly, a vertical mattress suturing technique is used. The window into

Fig. 20. Zygoma implant configuration may have a proprietary roughened surface. (Courtesy of Nobel Biocare; with permission).

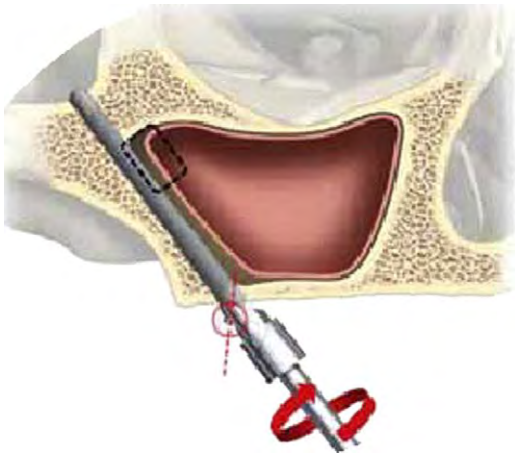

Fig. 21. Hand-torque insertion instrument used to adjust the orientation of the occlusal end of the zygoma implant. (Courtesy of Nobel Biocare; with permission).

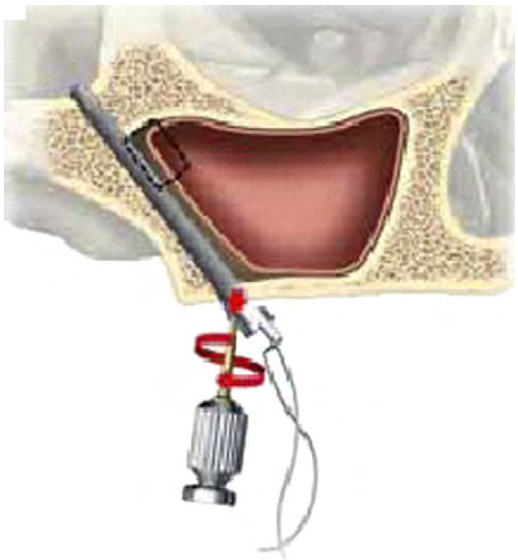

Fig. 22. A screw driver can aid in checking the orientation of the occlusal head of the zygoma implant. (Courtesy of Nobel Biocare; with permission).

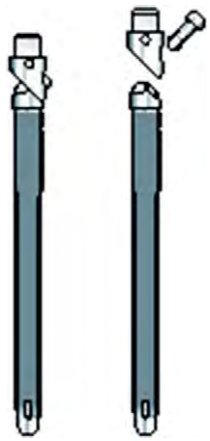

Fig. 23. Implant mount screw secures the mount to the hex head of the implant and points in the same direction as the hex head. (Courtesy of Nobel Biocare; with permission).

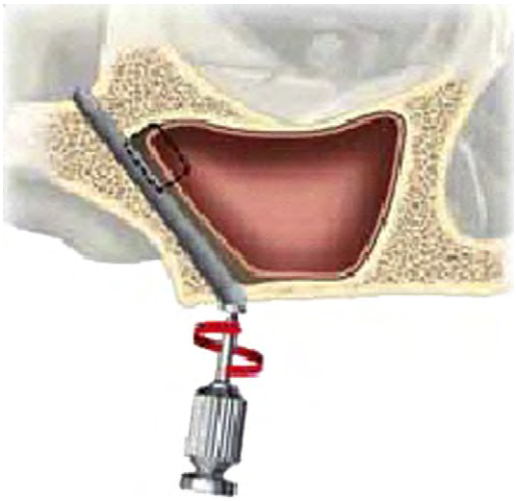

Fig. 24. Cover screw placed with a screw driver. (Courtesy of Nobel Biocare; with permission).

the sinus need not be closed. In the rare instance that a gap is found around the opening drilled into the residual maxillary alveolus, it may be grafted with a small amount of bone with or without a membrane or with titanium mesh. Antibiotics are commonly given perioperatively and continued postoperatively as determined by the surgeon. The denture that the patient had been wearing preoperatively is not put back into the mouth for at least several days or, according to the original Brånemark work, for up to 2 weeks postoperatively. Before allowing the patient to use it, the denture is soft relined to avoid pressure on the cover screws. Relines are checked every few weeks and replaced as needed to maintain the appropriate softness. Patients are cautioned against blowing their nose or smoking because these activities may have a deleterious effect on the outcome and success of the procedure. A soft diet should be considered for several weeks postoperatively, and the patient should sleep with the head slightly elevated. Rarely, patients may experience nose bleeding, originating in their sinuses, for which they should apply nasal pressure and rest. In extremely rare instances, the anterior nasal area may be packed for hemostasis.

Uncovering procedure and prosthetics

The uncovering procedure is done in an office setting under local anesthesia. It should be coordinated with the restorative office so that the patient can go directly there after uncovering and abutment placement. The palatal mucosa is the thickest in the mouth and usually has to be surgically thinned overlying the zygoma implants. Abutments are placed in the usual manner and should be done by the surgeon in most cases because soft tissue adjustments are often required. This uncovering usually takes longer than for the usual case for shorter implants due to the added care for the zygoma implants. The zygoma implants are essentially only supported in the bone of the zygoma, and little or no support is given to them by the residual maxillary alveolus. It is recommended that all abutments be connected with a temporary rigid bar as quickly as possible and that the denture not be worn until the temporary bar is placed. With careful coordination between the surgical and restorative offices and the dental lab, the temporary bar can be fabricated in one day (Fig. 25). The patient stays on a full liquid diet until the splinting bar is placed. This may be accomplished as simply as soldering gold cylinders onto a gold bar (Fig. 26).

The denture is relieved and relined before reinsertion. This temporary bar does not become part of the final framework. The remainder of the prosthetic work is routine. Cantilevers are kept to a minimum, and the occlusal table is commonly from first molar to the contralateral first molar in a fixed prosthesis. The labial flange is built up sufficiently to give the desired amount of lip support and to prevent air escape. Although this almost certainly prevents oral

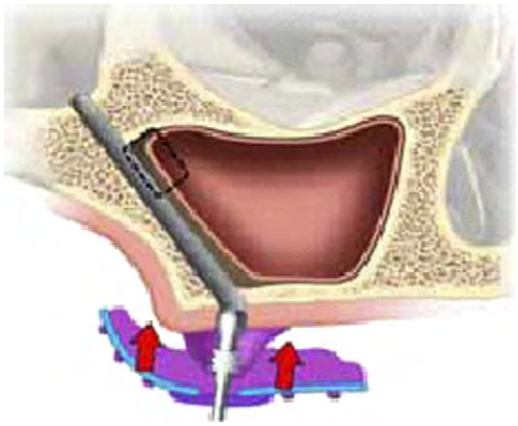

Fig. 25. Impression-taking with coping in place. (Courtesy of Nobel Biocare; with permission).

hygiene access from the labial, these patients seem to do fine if the palatal aspect of the prosthesis is kept approximately 2 mm off the palatal mucosa so that they can flush under there with a water-Pik device. In the rare instance that abutments later seem to have some inflammation around them, patients respond well by self-wiping around those abutments with q-tips dipped in chlorhexidine solution, daily.

Biomechanical considerations and analysis

Biomechanical engineers Skalak and Zhao analyzed the zygoma implant and short implant loading system mathematically and found that the system could withstand proper physiologic loading of occlusion, even without support from the residual maxilla around the zygoma implants, by load-sharing if the rigid framework was passively properly fitting, and lateral rotational bending force moments were avoided with the help of the additional shorter implants (Fig. 27). Unilateral use of the zygoma implant system has not been studied sufficiently to recommend its routine use. No implants have been reported as fractured while in use.

Maxillary sinus considerations

Although implants that had small projections into the nasal cavity and maxillary sinuses had been found not to have caused problems, the fact that the zygoma implant would traverse the entire sinus was new territory when Brånemark's work on this project began. Dr. Bjorn Petruson, the chief of Ear-Nose-Throat surgery at Sahlgrenska University Hospital in Sweden, was asked to co-follow these patients by Brånemark. He followed 14 of the patients for years by looking into their sinuses with sinoscopy through a small opening he surgically made in their inferior meatus area. He took photographs and made videotapes. He found that some of

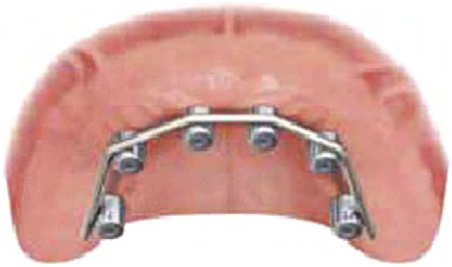

Fig. 26. Splinting of all implants together for stability and force distribution. (Courtesy of Nobel Biocare; with permission).

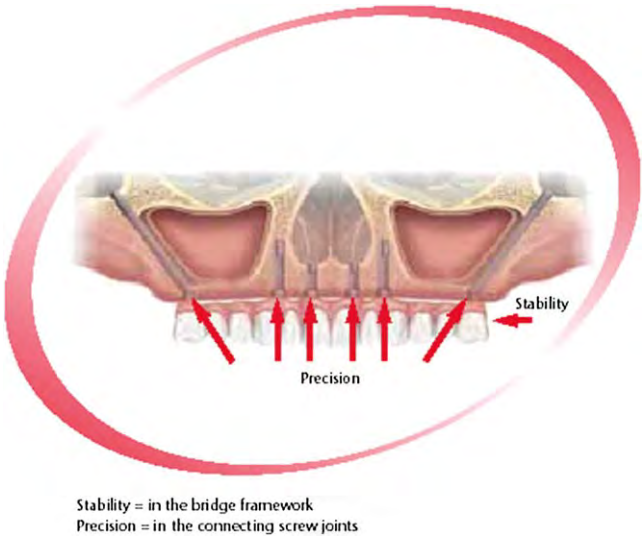

Fig. 27. Additionally placed implants aid in force distribution and load stabilization by further securing the framework. (Courtesy of Nobel Biocare; with permission).

the zygoma implants were covered with sinus membrane, some were not, and some were partially covered. He concluded that there was no increased risk of inflammatory reaction in the normal nasal and maxillary mucosa in the regions where titanium implants passed through the mucosa. In the rare instances that patients developed sinusitis after the zygoma implant procedures (a few patients had a history of repeated sinusitis before zygoma implant placement), his recommendation was to make a permanent opening in the inferior meatus region between the maxillary sinus and the nasal cavity. The added passageway seems to have prevented recurrent bouts of sinusitis. Petruson did not recommend the removal of an osseointegrated zygoma implant as treatment for the sinusitis.

Follow-up by the surgeon

Although implant dentistry is a team approach, each team member is likely to follow different aspects of the care. The surgeon should radiographically evaluate the fit of the framework once it is placed and annually re-evaluate the whole system, along with the soft tissue response to the prosthesis and abutments. If inflammation around the palatal abutment of the zygoma implants is found during follow-up visits, discussing hygiene care with the patient and the restorative office may be helpful. Chlorhexidine may be wiped around the abutments with q-tip applicators.

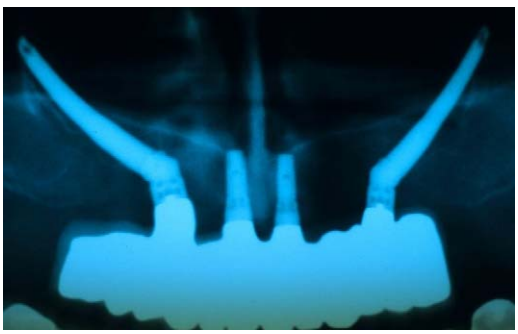

Fig. 28. Panoramic radiograph of typical fixed prostheses on two zygoma implants and two anterior shorter implants.

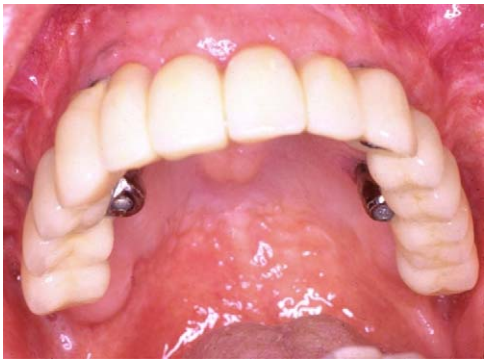

Fig. 29. Intra-oral view of fixed prostheses on four implants: one in each canine site and bilateral zygoma implants in the premolar regions.

Informed operative consent

There are routine risks that any surgeon might face with mid-face surgical procedures, including swelling (although there is usually less edema seen in these cases than one would expect given the extent of the dissection even if steroids are not routinely used; facial ice packs may be helpful postoperatively), infection (consider using antibiotics perioperatively), sinusitis (may require the inferior antrostomy procedure recommended by Petruson), pain (less intense than one would expect), bleeding with need for additional treatment (eg, nasal packing), bruising (not as much as one might expect), numbness (may be of the infraorbital distribution and should be temporary, unless the nerve was avulsed), paralysis of facial muscles (not reported in the routine protocol), loss of implant due to infection or failure to osseointegrate (rarely seen, but one might consider placing another zygoma implant after removal of the failed one because there usually is room in the zygoma for two implants if properly spaced), the patient being be able to palpate tip of implant by pressing on the facial skin (if the implant is inserted too far in a thin soft tissue-faced individual, it may be palpable, and although not reported to date, it may be able to be approached surgically through the skin and drilled down flush under cooling irrigation), damage to the eye or orbital contents (not seen in the routine protocol when careful attention is given to retractor placement and confirming it to be outside the orbit by two people palpating its location), and too-palatally positioned zygoma abutments (these enter the arch more palatal than other abutments, but it is rare that a patient complains much about this; keeping the zygoma implant as close to the residual alveolus as possible helps prevent this).

Summary

The placement of the zygoma implant can offer patients the benefit of osseointegrated dental rehabilitation, which is less invasive, less time consuming, lower in surgical morbidity, and less expensive while being more predictable than previous treatments for the severely atrophic fully edentulous maxilla.

Here is a typical panoramic x-ray of a restored patient treatment (Fig. 28), and here is a typical clinical view of a restored patient with two zygoma implants and two shorter anterior implants (Fig. 29).

Further readings

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