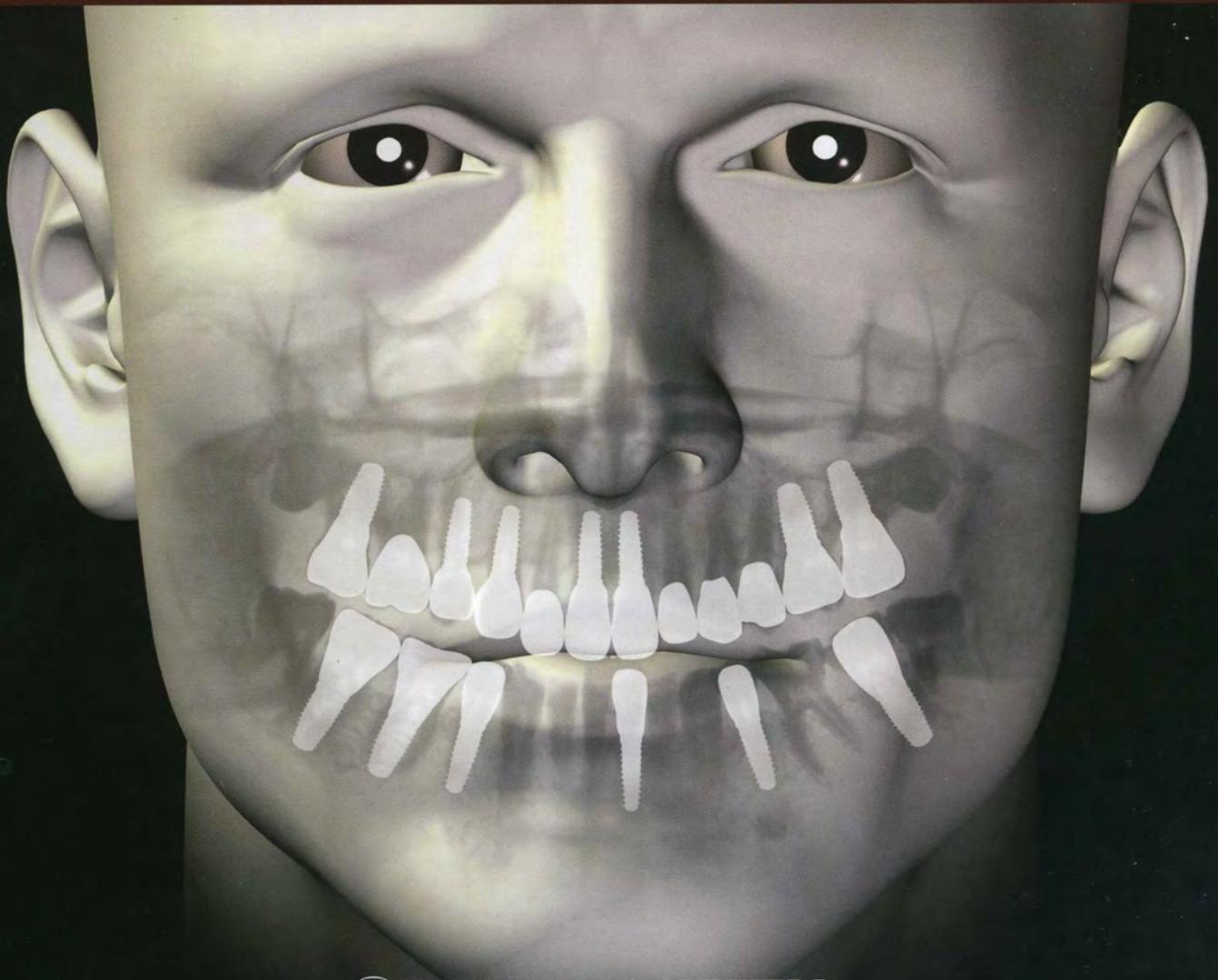


IMPLANT SITE DEVELOPMENT

Editors: **Michael Sonick and Debby Hwang**

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 **WILEY-BLACKWELL**

Implant site preparation: Horizontal ridge augmentation using particulate allograft and the principles of guided bone regeneration

Robert A. Levine DDS

History of predictable regenerative therapy

Regenerative periodontal therapy changed a predominately subtractive periodontal surgical art into one that offers predictable additive/reconstructive procedures to rebuild lost periodontium. The early studies of Nyman, Karring, and others (Nyman, 1991; Nyman et al., 1980) using membranes proved the principle of regeneration; by blocking epithelial, connective, and bone tissues, which negatively affect periodontal regeneration, this technique encourages the tissue, which can predictably regenerate the periodontium (periodontal ligament). This biological concept became known as guided tissue regeneration (GTR) as the periodontal ligament is "guided" into the bony defect by blocking the other tissues from competing. After its introduction, GTR quickly became a revolutionary technique in periodontal therapy, and GTR's obvious need in implant surgery became apparent in the treatment of residual osseous defects, immediate implant placement into fresh extraction sockets, and treatment of fenestration and dehiscence defects. Since bone is the isolated tissue needed to regenerate the defect, guided bone regeneration (GBR) differentiated the procedure from that of treating teeth (GTR) (Buser et al., 1993, 1995; Linde et al., 1993; Sandberg et al., 1993). The principle of GBR also employs a physical barrier or biological membrane to create an adequate environment protected from the invasion of competing, less differentiated, highly proliferative cells from neighboring connective and epithelial tissues, thus promoting a favorable cellular and molecular microenvironment for the regeneration of lost bone tissue (Nyman et al., 1980).

The team approach for a prosthetically driven implant restoration

Surgical extraction of teeth can result in loss of the buccal plate of bone. This can occur when failing to provide a meticulous, minimally traumatic surgery when care is not taken in preserving this thin socket wall (Johnson, 1993, 1969; Lam, 1960; Nevins et al., 2006; Schoop et al., 2003). Socket preservation techniques using numerous methods to preserve the ridge for future implant or esthetic restorative procedures have been developed. It is most ideal at the time of tooth removal when all four socket walls are present. Membrane-protected GBR (bone grafting with an appropriate membrane) is done as the clinician cannot anticipate which site will lose this fragile plate of bone following extraction (Fioellini et al., 2005; Iasella et al., 2003) (Figs. 10.1–10.11). However, we still encounter many long- and short-term extraction sites; these sites may lack bone in a horizontal, and in many cases in both horizontal and vertical, dimension. When this situation occurs, implant placement can be impossible or prosthetically unfavorable when using available bone that is too far apically or lingually. This is most challenging in the esthetic zone in the maxillae in a high-lip line patient. This can result in esthetic, functional, or phonetic difficulties for the patient along with prosthetic challenges for the restorative dentist to correct.

The principles of prosthetically driven implant placement cannot be understated. The "team approach" involving well-informed members of the team (i.e., surgeon, restorative dentist, laboratory technician, patient, and dental hygienist) is critical for the long-term

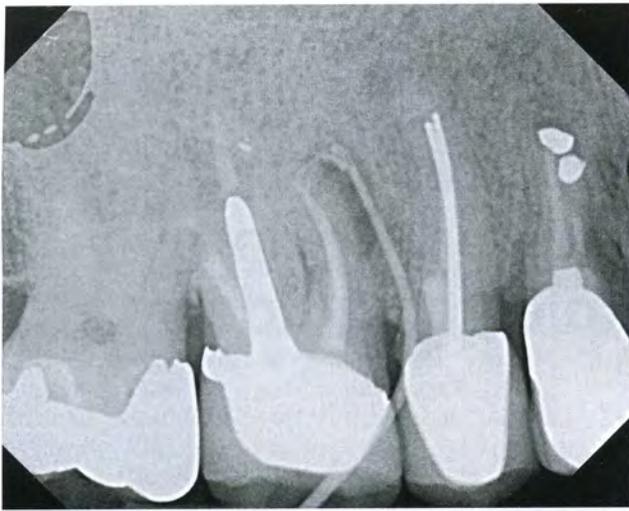


Fig. 10.1 Preoperative periapical X-ray of the #3 area. The patient is a 58-year-old healthy, nonsmoking male. A buccal fistula is followed by a gutta percha point extending to the apex of the mesiobuccal (MB) #3. A vertical root fracture was suspected.



Fig. 10.2 Flap entry reveals a vertical root fracture of mesiobuccal (MB) #3 to the apex. Parafunctional habits, most likely, were contributory.

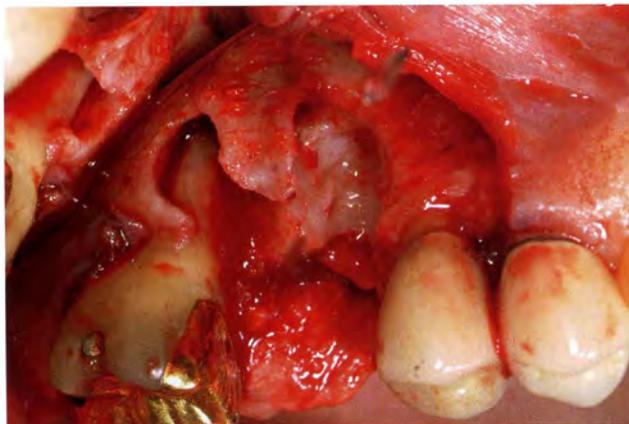


Fig. 10.3 Thorough debridement of granulation tissue and root preparation of #2 reveals significant attachment loss along the mesiobuccal (MB) root of #2. This tooth was treated with GTR (root modification with neutral ethylenediaminetetraacetic acid [EDTA] followed by GEM-21® [Osteohealth, Shirley, NY] and Regenaform®). The socket #3 was treated with Regenaform and a Teflon membrane for GBR, which also covered the MB defect of #2.



Fig. 10.4 Frozen Regenaform® being removed from the heated steady-state water bath in preparation to being molded into place in situ.

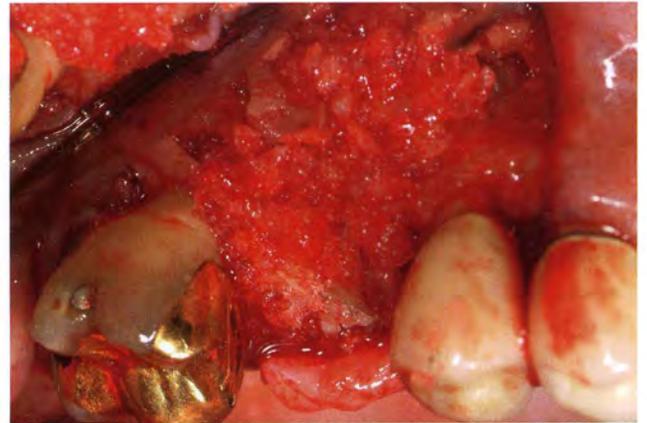


Fig. 10.5 Regenaform® molded and formed into site #2 (periodontal) and #3 (socket) defects.



Fig. 10.6 PTFE membrane (TefGen-FD [Lifecore Biomedical, Chaska, MN]: 100% pure PTFE) in place after customizing with a scissor covering buccal-lingual socket defect of #3. Site #2 bone graft was also protected with the same PTFE membrane. The high-density PTFE membrane is very flexible and adaptable to the bony profiles of the remaining socket. A palatal pedicle graft is in position to cover the membrane upon closure.



Fig. 10.7 Primary soft tissue closure was partially attained with the help of periosteal releasing incisions of the buccal flap and the aid of the palatal pedicle flap; 4-0 PTFE and 6-0 synthetic resorbable sutures (Vicryl®) were used for closure. The membrane was easily removed in one piece at 4 weeks without anesthesia.

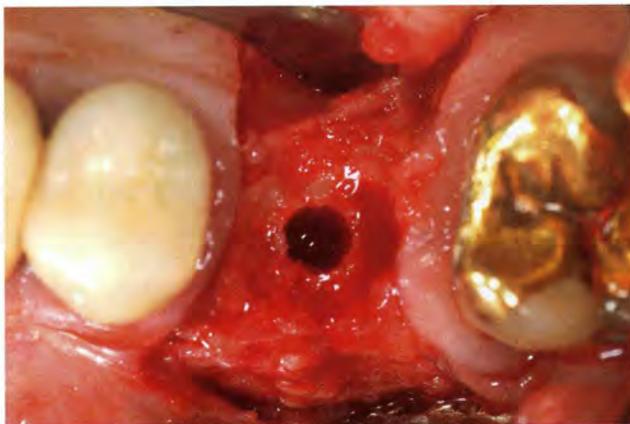


Fig. 10.8 Nine months post-GBR (day of implant surgery). Papillary sparing incisions were made mesially and distally to prevent any additional interproximal attachment loss. Complete healing was noted periodontally associated with #2 buccal and mesial bony defect. Probing depths were within 3 mm along the facial and mesial aspects of #2, with no bleeding upon probing. Excellent socket healing was noted in #3. A trephined bone core was taken of the osteotomy site and sent for histological analysis. Type 2-3 bone quality was noted.

success of the restoration (Levine and Horowitz, 2007; Spear, 2005). Preoperative analysis (Buser et al., 2004; Jaffin, 2007; Levine, 2007) includes a complete medical, dental, compliance, and social smoking history, a detailed clinical periodontal, occlusal, and radiographic examination (complete-mouth X-ray exam or panorex) (Fig. 10.12) along with a thorough analysis of the implant-recipient site including mesiodistal width and buccolingual bone availability. Estimation of the interarch distance and the opposing corresponding arch is necessary to evaluate possible supraeruption of teeth and additional prosthetic, periodontal surgical, and endodontic care that

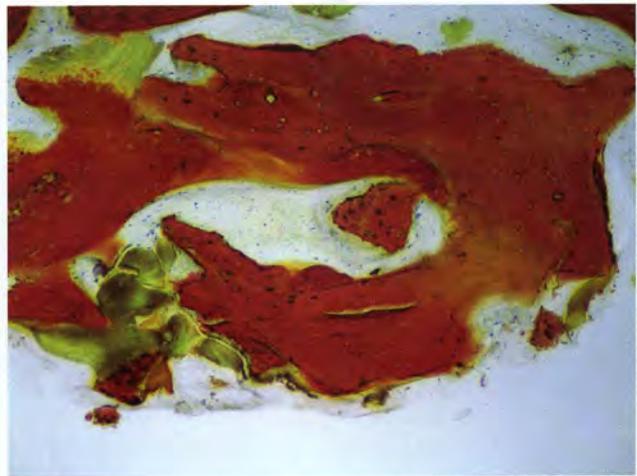


Fig. 10.9 Histology report. Section shows good connectivity and new vital bone attached to allograft. Specimen core showed 52% bone with 80% vital and 20% nonvital (residue of mineralized freeze-dried bone allograft [FDDBA] and DFDBA). (The authors extend their thanks to Dr. Michael Rohrer and Senior Research Scientist Mr. Hari S. Prasad of the Hard Tissue Research Laboratory at the University of Minnesota School of Dentistry for the nondecalcified histological processing and analysis of the retrieved core samples.)

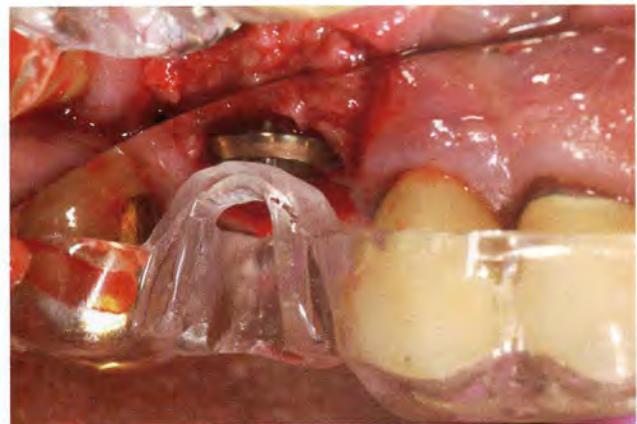


Fig. 10.10 Prosthetically guided implant placement #3. A wide-diameter implant (Straumann® Wide Neck 4.8 × 12 mm SLActive® [Straumann, Andover, MA]) was placed after bone scalloping to remove adequate crest height to position the implant in the proper vertical position for a natural emergence profile. The anatomically correct surgical guide template aids in three-dimensional placement.

may be necessary to correct the problem while ensuring a proper mandibular plane of occlusion after restoration. Digital photographs intra- and extraorally, in addition to mounted diagnostic casts, are necessary to assess the patient's lip line (for esthetic zone cases), interarch space, and occlusion properly. Even after completing all of the above diagnostics, the surgeon may still recommend reformatted cone beam computed tomography (CBCT) scans using a radiographic guide template to visualize the prospective implant site(s) in three dimensions

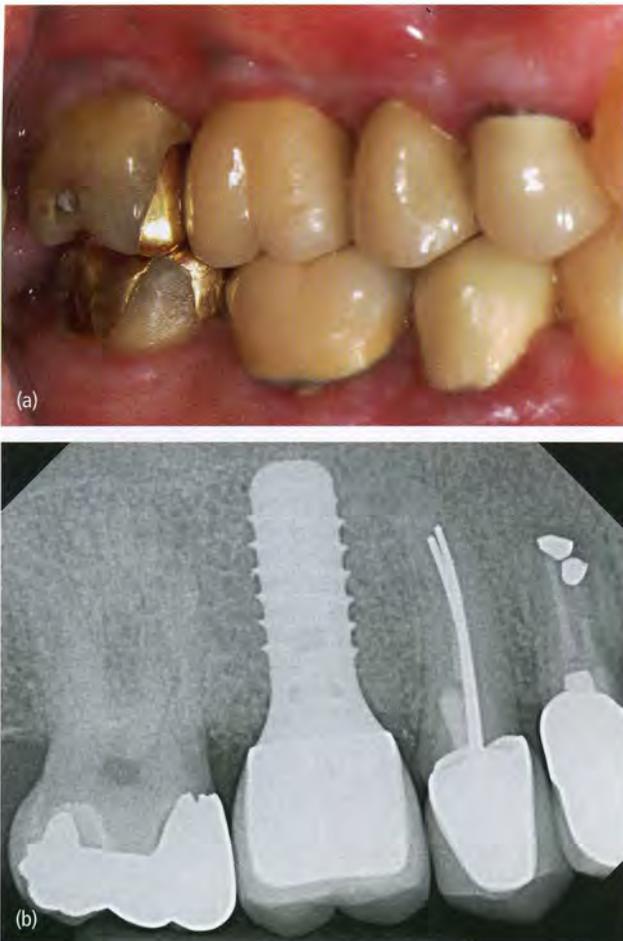


Fig. 10.11 10.11 (a). Final crown #3 with clinically healthy soft tissues noted around both #2 and #3. (b) Final periapical x-ray showing excellent osseous healing around both #2 and #3 and prosthetic fit #3.



Fig. 10.12 Presurgical panorex of edentulous lower right area. The patient is a healthy nonsmoking 40-year-old female. Maxillary posterior reconstruction was recently completed. (Prosthetics: Dr. Zola Makrauer, Huntingdon Valley, PA.)

(Figs. 10.13 and 10.14). If adequate alveolar bone is lacking in a horizontal dimension for the proper three-dimensional (3D) placement of an implant, then the following prosthetic options should be discussed with the patient:

1. Do not follow through with implant therapy; alternative plan would be to do nothing, a conventional fixed crown and bridge prosthesis, or fabrication of a removable partial denture.
2. Place the implant in a nonfavorable prosthetic position. However, this may lead to a compromised outcome as a result, with possible need to surgically remove the implant due to a nonrestorable prosthetic position. This compromised prosthetic position could result in a nondesirable esthetic/phonetic outcome or discomfort posttreatment.
3. Attempt to reconstruct/augment the area to enable the proper 3D placement. Guidelines for mesial-distal, buccal-lingual, and apical-coronal placement will aid the surgeon in the correct position with the use of an anatomically correct surgical guide template (Buser et al., 2004; Jaffin, 2007; Levine, 2007).

Guidelines for horizontal ridge augmentation: diagnosis of the site

When treatment planning a horizontal ridge augmentation procedure, the clinician must consider the residual bone volume needed to allow correct implant positioning, the bone density needed to achieve primary implant stability, and the defect morphology of the peri-implant bone defect (von Arx and Buser, 2006). Gingival biotype and lip line level are additional factors to evaluate in the esthetic zone (Buser et al., 2004; Levine, 2007; von Arx and Buser, 2006).

Common sites for horizontal ridge augmentation

The maxillary anterior sextant commonly requires horizontal ridge augmentation. This area is frequently involved in traumatic injuries with a predisposing thin buccal plate of bone. As a result, there is a loss of all or part of this thin bony profile, creating a facial deformity or concavity upon healing. Other causes include endodontic failure or advanced periodontal disease, traumatic tooth removal resulting from a nonrestorable tooth fracture, or ankylosis (Buser et al., 1993). The other area commonly seen is the posterior mandible due to longstanding narrow ridges resulting from long-term tooth loss or to similar factors noted above (Buser et al., 1995; von Arx and Buser, 2006).

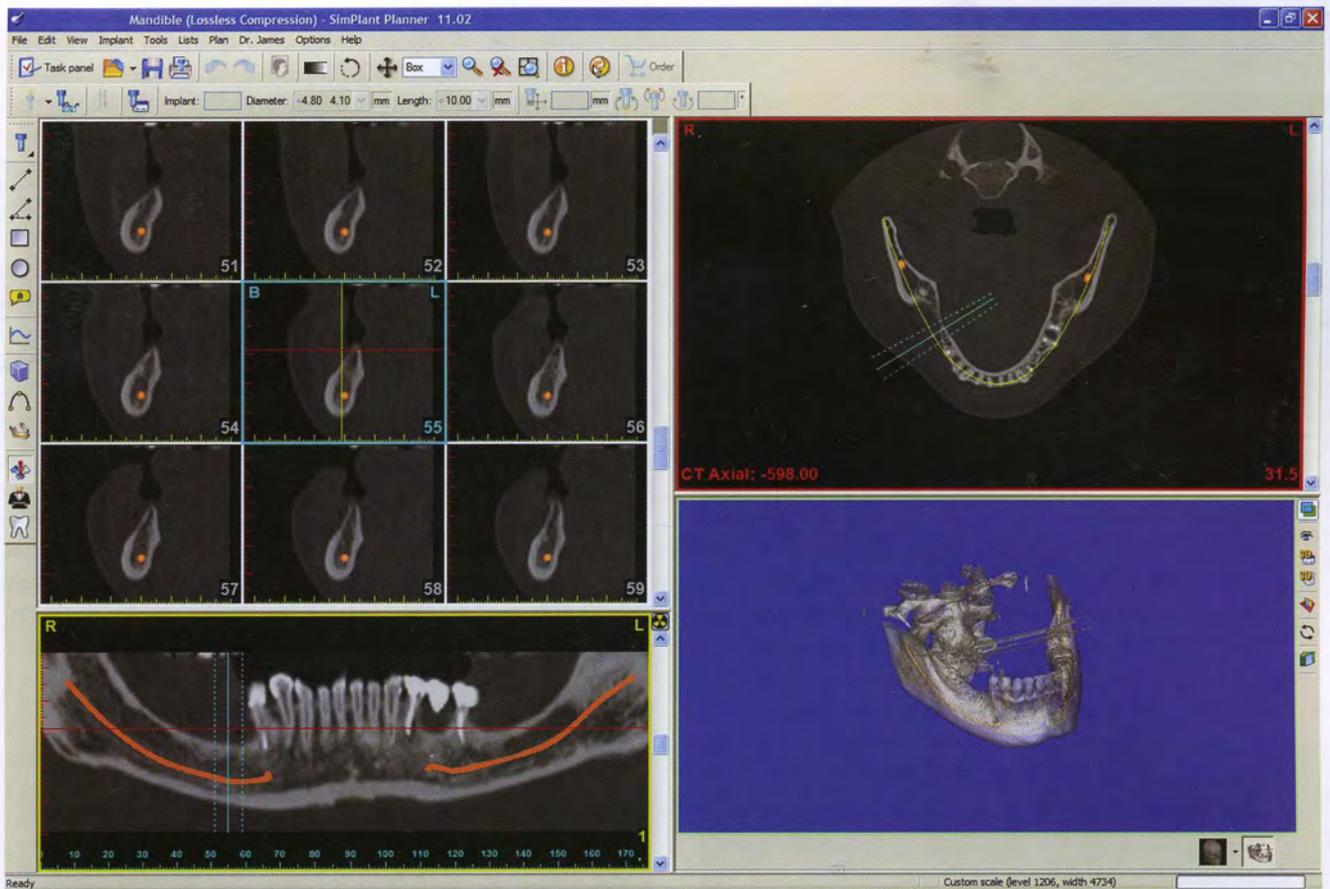


Fig. 10.13 Preplanning software (SimPlant®, Materialise, Glen Burnie, MD) of lower right proposed implant sites #30 and #31 in a vertical direction.

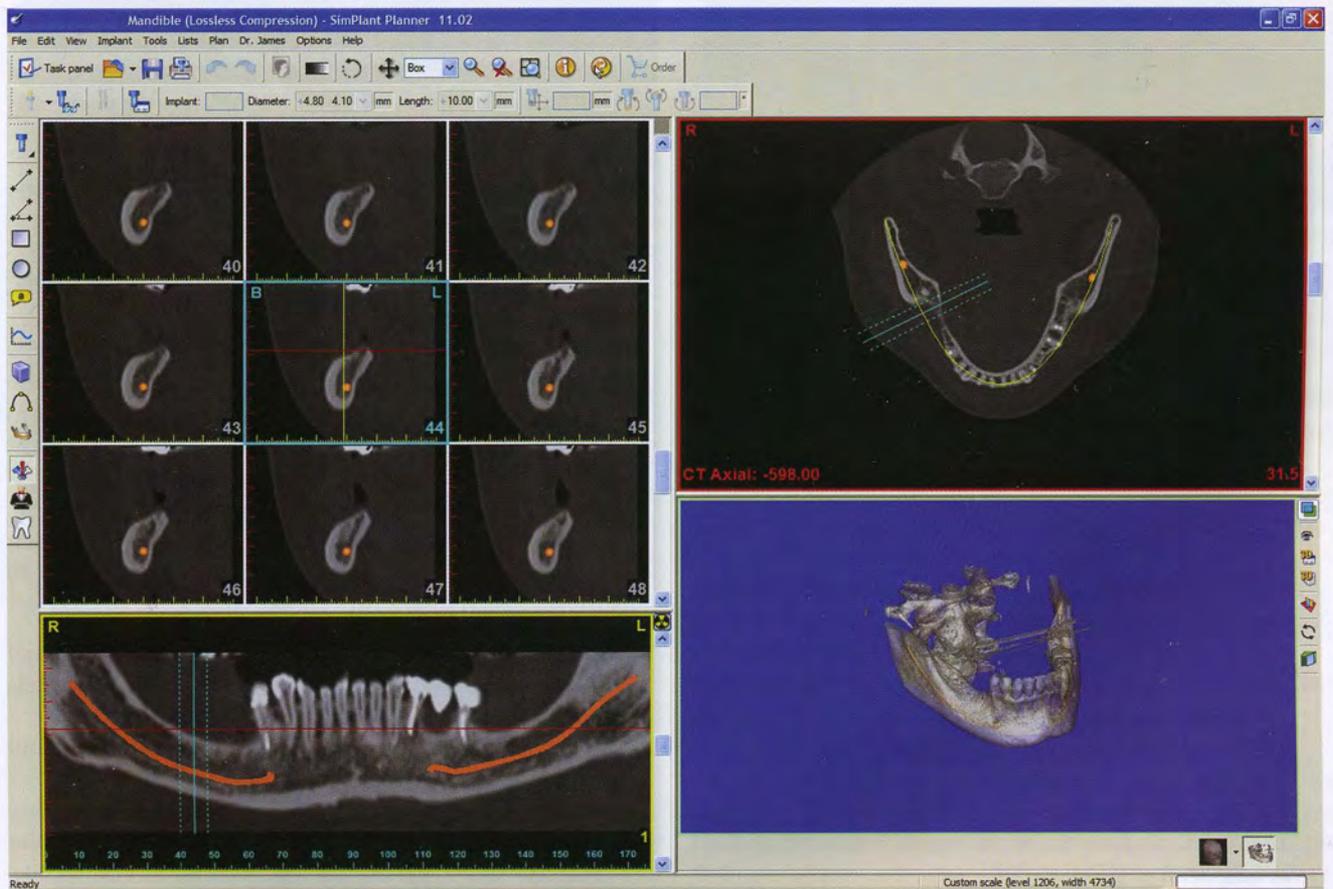


Fig. 10.14 Preplanning cross-sectional view of site #30 revealed a significant buccal horizontal defect that would require a prosthetically unacceptable location too far to the lingual at the expense of significant crestal bone height to place.

When the implant surgeon interviews a potential implant patient, the edentulous area is extensively examined clinically for the following factors to insure a successful "prosthetically guided" team approach:

1. *Orofacial bone width through thorough palpation of the buccal and lingual aspects of the ridge.* The use of reformatted dental implant computed tomography (CT) software will enable the clinician to measure the available width of bone prior to surgery. It is recommended to use a radiographic guide template worn by the patient during scanning to give the critical 3D information to the surgeon, restorative dentist, and patient so there will not be any surgical or prosthetic surprises for any "team members." Otherwise there will be some guesswork as to the actual position of the implant, which will frequently affect the prosthetic plan and fees. Too often, we see in private practice the "team approach" not used resulting in a very disappointed and unhappy patient due to esthetic, phonetic, or discomfort issues. We do not just place implants in any tooth gap areas without proper presurgical and prosthetic planning.
2. *Vertical height of bone.* The correct apicocoronal placement of an implant may require a combination of both horizontal and vertical augmentation prior to placement. The radiographic guide template worn during scanning will help measure the amount of vertical discrepancy, which is most critical in esthetic zone areas. Correcting bony deficiencies in three dimensions is important prior to implant placement to assure a final functional and esthetic result (Artzi et al., 2003; Canullo et al., 2006; Rocuzzo et al., 2007; Simion et al., 2006, 2007b, 2008). In addition, situations where the remaining bone height is too small for proper anchorage of oral implants or when unfavorable crown-to-implant ratios may result if vertical augmentation is not achieved prior to implant placement need to be properly assessed presurgically.
3. *The amount and thickness of remaining keratinized tissue.* A key to horizontal and vertical bone augmentation procedures is continued primary closure of the soft tissues postsurgically to allow unimpeded healing of the underlying bone graft without early dissolution (resorbable membrane) or infection (nonresorbable membrane) of the overlying membrane because of early opening of the incision line (Buser et al., 1993, 1995). The bound-down nature along with the uncomplicated procedure of suturing to keratinized tissue makes this tissue the most ideal to surgically work with. Frequently, implant surgeons ignore this very important aspect. Having margins of nonkeratinized alveolar mucosa to suture to and trying to maintain closure is much more challenging and results in less predictability with the procedure. Soft

tissue augmentation procedures *prior* to augmentation may be necessary to reconstruct the soft tissue defect or to add keratinized tissue dimension in preparation to reconstruct the hard tissue defect. This is frequently seen in the posterior mandible, for a lack in horizontal bone width frequently accompanies a lack in adequate dimension of keratinized gingiva.

4. *Bony undercuts, which can be viewed easily with a CBCT scan or through palpation clinically of buccal and lingual areas.* Buccal undercuts are most noticeable in the maxillae in anterior and bicuspid areas; lingual undercuts are often seen in the posterior mandible and less frequently in the anterior mandible. A reformatted CBCT scan is an important adjunct to initial treatment planning as sinus floor position, sinus health and morphology, mandibular nerve position, alveolar ridge width and height, along with bony undercuts, are easily viewed and measured.

In summary, taking the guesswork out of implant surgery with a "prosthetically guided" team approach will insure a more predictable, functional, and esthetic result and a thoroughly happy patient.

Evidenced-based horizontal ridge reconstruction using GBR principles and the staged approach

The ability to rebuild lost hard tissue in a horizontal and, in selected cases, in a vertical dimension using GBR therapy is well documented (Araujo et al., 2002; Artzi et al., 2003; von Arx et al., 2001; Block and Degen, 2004; Buser et al., 1993, 1995; Canullo et al., 2006; Hammerle et al., 2008; Jovanovic et al., 2007; Levine and Horowitz, 2007; Longoni et al., 2007; Rocuzzo et al., 2007; Schwarz et al., 2007, 2008; Simion et al., 2006, 2007a,b, 2008). The GBR procedure is the more predictable procedure of the two for localized horizontal ridge reconstruction prior to implant placement. The surgical procedure, however, is technically demanding and requires a precise and systematic surgical technique (Buser et al., 1993, 1995). Maximizing the treatment outcomes using this approach is dependent on the following important *key* factors to insure success (Fugazzotto, 2004):

1. Adequate flap incision design for access and final passive primary soft tissue closure to avoid membrane exposure (Fig. 10.15).
2. Complete debridement of the osseous defect of all soft tissue remnants (Fig. 10.16).
3. Intramarrow penetrations of the host cortical bone surface to activate bone formation and to open the marrow space allows fast ingrowth of blood vessels,



Fig. 10.15 Pretreatment clinical view of surgical site. Adequate keratinized gingiva is noted, which will aid in final suturing after the GBR procedure. The ridge crest is noted to be significantly to the lingual aspect.

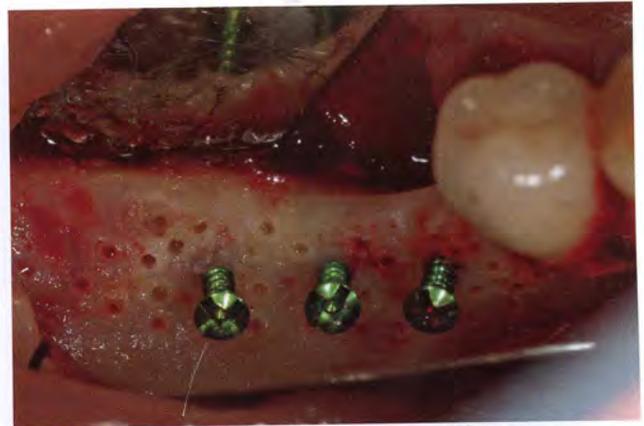


Fig. 10.17 Numerous intramarrow penetrations were created by Piezosurgery[®] tip OP4 (Mectron, Carasco, Italy) with copious amount of water irrigation. It is recommended to complete the periosteal releasing incisions of the buccal flap at this time prior to graft placement.



Fig. 10.16 After thorough degranulation of osseous surface, three 7-mm Lorenz tenting screws (Biomet, Jacksonville, FL) are placed approximately 3–4 mm from the osseous crest. Note that the ridge crest of 2-mm width is located far to the lingual aspect in relation to the lingual cusp of #29.

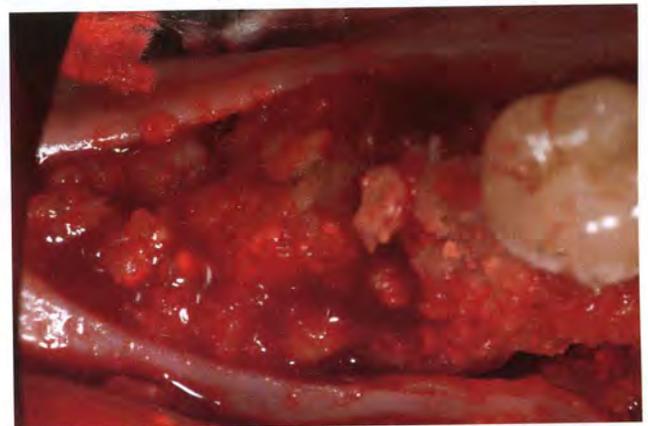


Fig. 10.18 Frozen Regenaform[®] in place after removal from heated water bath.

- which insures rapid revascularization and graft remodeling (Fig. 10.17).
4. Stabilization of blood clot formation and space maintenance through use of particulate or block grafts (autogenous, allograft or xenograft material). This aids to prevent membrane collapse and the loss of potential regenerative space (Fig. 10.18).
 5. Use of supporting tenting screws as additional space-maintaining devices (see Figs. 10.16 and 10.17).
 6. Protection of the developing blood clot and graft material by using a well-fitting stabilized fixated membrane (resorbable or nonresorbable). A closely adapted membrane to the surrounding bone prevents the ingrowth of competing nonosteogenic cells into the defect area. This frequently requires using surgical tacks, which also help to prevent micromotion of the membrane insuring bone and not soft tissue healing under the membrane (Fig. 10.19).
 7. Attainment of tension-free primary soft tissue closure through appropriate releasing incisions and horizontal and interrupted sutures (Fig. 10.20).
 8. Sufficiently long healing period of at least 4 (autogenous) to 8 (xenograft) months depending on grafting material used (Figs. 10.21–10.30).
 9. Control of overlying forces during the postoperative phase of treatment.
- A very important factor that the author notes is the importance of salivary control during these procedures to help in preventing postoperative complications. This is especially important in the mandibular posterior areas.



Fig. 10.19 Ossix® Plus membrane in place. Prior to placement, the membrane is moistened thoroughly with sterile saline for moldability and laid upon calcium sulfate powder. No surgical tacks were used in this case as the membrane, once moistened, had no memory and is easily placed. Horizontal mattress sutures will act as surgical tacks in an apical direction to also stabilize the membrane.



Fig. 10.22 Clinical view at 8 months postoperative. Compare with Fig. 10.15. The incision line remained closed for the duration of healing.



Fig. 10.20 Tension-free closure with 4-0 PTFE (horizontal mattress and single interrupted), 4-0 gut (single interrupted), and 6-0 Vicryl® (single interrupted). The initial crestal incisions prior to flap reflection were carefully made to allow keratinized tissue to be sutured both buccally and the lingually.



Fig. 10.23 Horizontal bone healing confirmed. Incision design was slightly lingual to the crest to maximize keratinized tissue to the buccal. Papillary-sparing incisions were made distal to #29. Regeneration was complete, with bone covering over completely the most posterior tenting screw. Numerous remnants of the Ossix® Plus membrane were noted and removed. A demarcation line is seen between the host bone and the reconstructed bone, which was due to membrane collapse along the demarcation line between host and grafted bone. Ridge reconstruction was measured at 7 mm; thus, horizontal bone healing of 5 mm was noted.



Fig. 10.21 Radiograph of the lower right quadrant (LRQ) at 6 months. Increase in vertical height was also noted. Compare with Figs. 10.12 and 10.13.

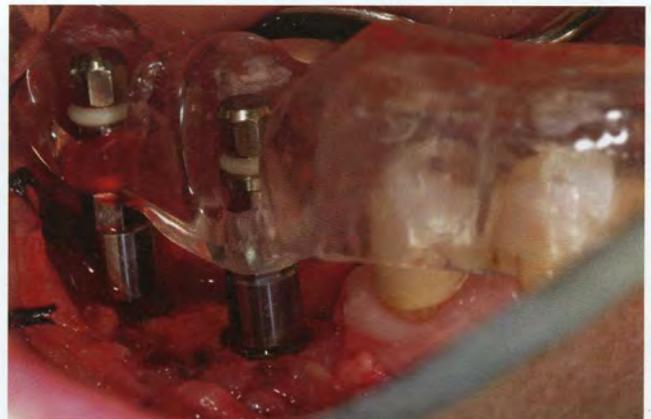


Fig. 10.24 Prosthetically guided implant placement with an anatomically correct surgical guide template in place.

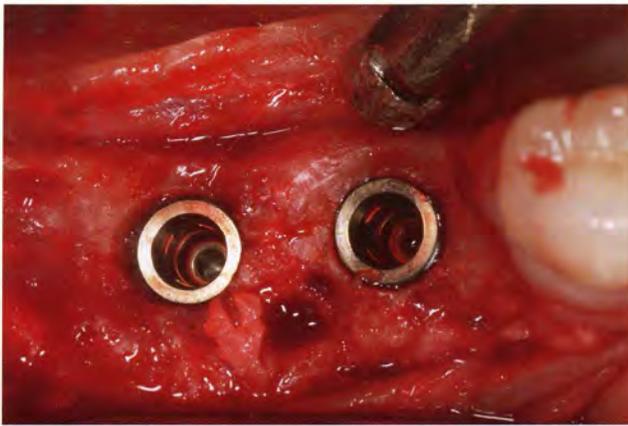


Fig. 10.25 Two bone-level regular connection (RC) Straumann® SLActive® implants (Straumann, Andover, MA) in place (#30: 12 × 4.8mm; #31: 10 × 4.8mm). The ridge was reduced approximately 1 mm lingually prior to placement. A trephined bone core was taken interproximally to the facial aspect of the implants. Bone quality was noted as type 2. Compare with Figs. 10.16 and 10.17.

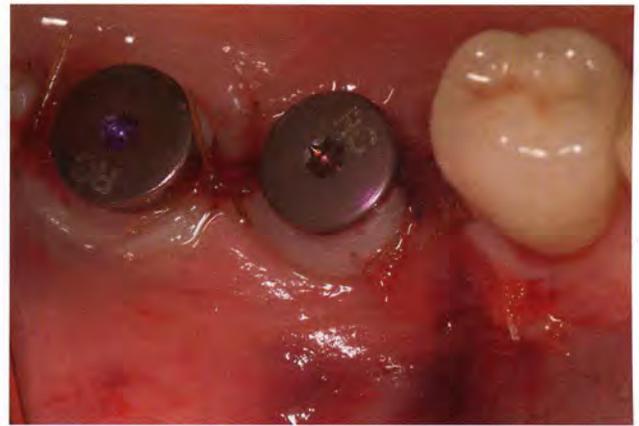


Fig. 10.26 Closure with 4-0 chromic gut sutures after tapered healing abutments in place. Note that adequate keratinized tissue will form to the facial. This was preplanned by the initial incision design.

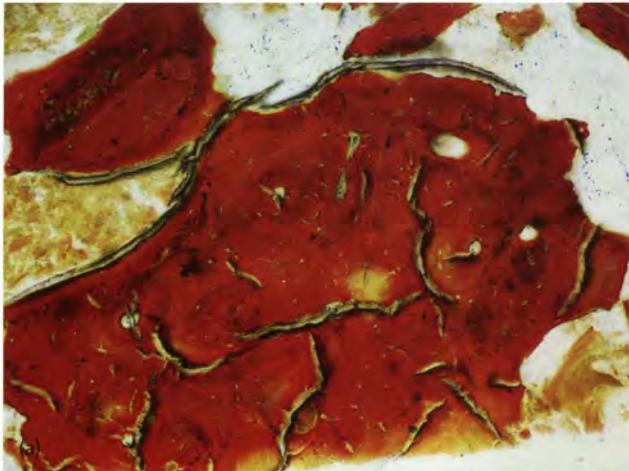


Fig. 10.27 (a and b) Histology of trephined bone core taken at time of reentry and implant placement from interproximal and facial to both implants. This core shows 42% bone, 30% of which is vital. The bone volume of allograft is 70%. A very large amount of the core consists of allograft, the majority of which is mineralized allograft with some demineralized allograft. In this high-power image (×2.6H), the large piece of bone is almost all mineralized allograft. In the upper left is a small piece of mineralized allograft that stains a lighter red surrounded by new bone formation. (b) Image 2.8H shows new bone formation surrounding a piece of mineralized allograft in the center. (The authors extend their thanks to Dr. Michael Rohrer and Senior Research Scientist Mr. Hari S. Prasad of the Hard Tissue Research Laboratory at the University of Minnesota School of Dentistry for the nondecalcified histological processing and analysis of the retrieved core samples.)

Frequently, the use of three chairside assistants are necessary for the procedure: One is in the standard position suctioning and retracting; a second is standing in front of the patient retracting the tongue and making sure the lingual aspect is kept saliva-free and dry; a third's duty is taking care of all regenerative materials for the surgeon that he or she may require during the procedure. Being able to properly document these cases also requires more than one dental assistant to aid in retraction as well as to air-spray directly on the photographic mirrors to eliminate mirror fogging.

Choice of bone graft material

Autogenous bone graft material is considered the "gold standard" for intraoral and orthopedic surgical procedures requiring bone grafting; its capability for osteoconduction and osteoinduction, combined with the presence of osteogenic cells, makes it highly effective (Gazdag et al., 1995; Newman et al., 2008; Vaccaro, 2002). Unfortunately, autogenous grafting is associated with donor site morbidity, additional procedures leading to increased operative time, and patient-related variables

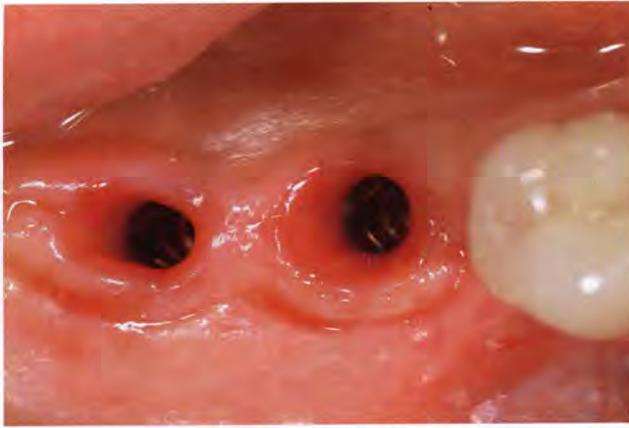


Fig. 10.28 Excellent soft tissue healing noted for both bone-level implants at 6 weeks. Reverse torque of both implants at 35Ncm was completed successfully at this visit using the implant carrier device and the Straumann torque wrench (Straumann, Andover, MA) to confirm bone healing and commence the prosthetic phase, which followed immediately after this visit with the restorative dentist.



Fig. 10.29 Completed prosthetics: single crowns #30 and #31. (Prosthetics: Dr. Zola Makrauer Huntingdon Valley, PA; Dental laboratory: Benchmark Dental Studio, Southampton, PA [Robert Burns, MDT].)



Fig. 10.30 Final radiographs of #30 and #31 showing excellent osseous healing and prosthetic fit.

such as inconsistent volume and quality of graft (Fugazzotto, 2004; Gazdag et al., 1995; Longoni et al., 2007; Newman et al., 2008; Ruskin et al., 2001; Vaccaro, 2002). Thus, the question is raised as to the cost-benefits of autogenous versus nonautogenous graft material. It is true that in nonmembrane therapy, autogenous bone is a better choice; however, assuming the meticulous surgical protocol of GBR therapy, there are no advantages of autogenous bone grafting other than speed in regeneration and graft incorporation. Nonautogenous graft material healing is comparable with autogenous grafts placed beneath membranes. Thus, the clinician must ask, "Is the cost-benefit of acceleration of autogenous graft healing justified?" If the donor site is in the same quadrant as the horizontal ridge augmentation procedure, then the answer may be yes; if a second surgical site is necessary, then justification of this approach may be difficult (Fugazzotto, 2004).

The ideal bone graft substitute is biocompatible, bioresorbable, osteoconductive, structurally similar to bone, easy to use, and cost-effective. Allograft and xenograft (Artzi et al., 2003; von Arx et al., 2001; Canullo et al., 2006; Hammerle et al., 2008; Longoni et al., 2007; Simion et al., 2006, 2007a,b) materials have several potential benefits over autograft. A relatively unlimited volume of uniform quality graft is available without donor site morbidity as seen in chin and ramus autogenous donor sites. Allografts are available either frozen or freeze-dried and as processed allogenic cortical, corticocancellous, and cancellous grafts.

Regenaform[®] (Exactech, Gainesville, FL) is an assayed, demineralized bone matrix (demineralized freeze-dried bone allograft [DFDBA]), inert biological carrier matrix (gelatin), and nondemineralized cortical and cancellous chips (ratio is 80% cancellous and 20% cortical). Regenaform has been evaluated in human clinical studies and has shown to induce bone formation (Levine and Horowitz, 2007; Longoni et al., 2007; Newman et al., 2008; Ruskin et al., 2001; Vaccaro, 2002). Each lot is tested to verify osteoinductive potential set forth with the Urist model. This is achieved by implanting a sample from each lot into an intramuscular site in a rat model, and after 4 weeks ex novo bone formation is measured through radiological, histological, and analytical analyses. Only the lots that meet preset criteria are released for distribution.

Indications for its use include alveolar ridge augmentation, extraction sockets for ridge preservation/site preparation, maxillary sinus augmentation, periodontal defects, craniofacial augmentation, root resection, apicoectomy, cystectomy, and tumor resection. Given its moldable nature, the material can be shaped more easily and quickly than autogenous blocks, and is still able to fill the entire defect. A stabilized membrane or titanium mesh (via tacks or bone screws) helps in eliminating

micromovement for improved osseous healing (Caton, 2004; Clagett, 2007; Levine and Horowitz, 2007; Longoni and Sartori, 2005; Longoni et al., 2007; Ruskin et al., 2001). A recent study by Fontana et al. (2008) showed similar results to autogenous bone chips in vertical ridge augmentation when stabilized expanded polytetrafluoroethylene (ePTFE) membranes were used in a split-mouth study of five patients. The histomorphometric analysis revealed a mean percentage of mineralized bone of 32.98% (SD: 8.27%) for the Regenaform (test) group and 34.13% (SD: 11.13%) for the autogenous bone chip (control) group. This data is in accordance with the percentage of 36.6% (SD: 11.86%) showed by Simion et al (Fontana et al., 2008) on vertical ridge augmentation by means of autogenous bone and titanium-reinforced ePTFE membrane. The authors concluded that allogenic bone matrix (Regenaform) associated with a titanium-reinforced ePTFE membrane could be as effective as autogenous bone chips for GBR procedures in vertical ridge augmentation of severely atrophic ridges. The advantage of using this bone substitute was to perform vertical ridge augmentation without harvesting autogenous bone and thus reducing the invasiveness of the surgery and donor site morbidity (Fontana et al., 2008).

Choice of membrane

Nonresorbable membranes

Membranes used for GBR in conjunction with endosseous implants should be safe and effective with certain critical criteria for usage: biocompatibility, cell occlusiveness, integration by host tissues, clinical manageability, and a space making function (Hardwick et al., 1994). The first clinically available membrane consisted of ePTFE, which has been tested extensively experimentally and was used widely clinically (Becker and Becker, 1993; Buser et al., 1993, 1995; Cortellini and Tonetti, 2000; Fontana et al., 2008; Hammerle and Jung, 2003; Hardwick et al., 1994; Jovanovic and Nevins, 1995; Karring and Cortellini, 1999; Simion et al., 1998). This first-generation membrane is hydrophobic, nonresorbable, and requires a second procedure to remove. In addition, the use of ePTFE membranes is more difficult to handle and requires fixation to prevent micromovement, which results in soft tissue healing, not the desired bone healing (Hammerle and Jung, 2003). Moreover, a titanium-reinforced membrane version is available and is made of a double layer of ePTFE with a titanium framework interposed (Fontana et al., 2008; Hammerle and Jung, 2003; Jovanovic and Nevins, 1995). The titanium-reinforced ePTFE version is limited to specific indications such as large bony defects, extraction socket defects when the buccal plate is partially or completely missing, or supracrestal areas as in vertical ridge aug-

mentation procedures when space maintenance requires a rigid membrane and when primary soft tissue closure is attainable. (Canullo et al., 2006; Hammerle and Jung, 2003; Jovanovic and Nevins, 1995; Simion et al., 1998, 2006, 2007b, 2008; Tinti et al., 1996) (Figs. 10.31–10.53). For the ePTFE nonresorbable membranes, incision design and flap management are demanding and the technique harbors a certain risk of wound dehiscence, membrane



Fig. 10.31 Presentation of a healthy, nonsmoking 55-year-old male with buccal swelling to #9. Recently, the patient experienced trauma to the area while eating. #9 had a full-coverage porcelain crown and the other five anterior teeth had recently been restored with porcelain veneers. Deep (>10 mm) probing depths were noted facially to #9; a vertical root fracture to the apical third was suspected.



Fig. 10.32 Pretreatment periapical X-ray revealing midapical third root fracture and severe bone loss associated with #9.

Esthetic risk factors	Low	Medium	High
Medical status	Healthy patient and intact immune system		Reduced immune system
Smoking habit	Non-smoker	Light smoker < 10 Cig/D	Heavy smoker > 10 Cig/D
Patients esthetic expectations	Low	Medium	High
Lip line	Low	Medium	High
Gingival biotype	Low scalloped Thick	Medium scalloped Medium thick	High scalloped Thin
Shape of tooth crowns	Rectangular	Slightly triangular	Triangular
Infection at implant site	None	Chronic	Acute
Bone level at adjacent teeth	≤ 5mm to contact point	5.5 to 6.5mm to contact point	7mm to contact point
Restoration status of neighboring teeth	Virgin		Restored
Width of edentulous span	1 tooth ≥ 7mm	1 tooth ≤ 7mm	2 teeth or more
Soft tissue anatomy	Intact soft tissue		Soft tissue defects
Bone anatomy of alveolar crest	No bone deficiency	Horizontal bone deficiency	Vertical bone deficiency

Fig. 10.33 Implant Esthetic Risk Profile.

Source: Reprinted from *ITI Treatment Guide. Vol. 1—Implant Therapy in the Esthetic Zone. Single Tooth Replacements*. Buser D, Belser U, Wismeijer D, eds. 2007, p. 20; Quintessence Publishing Co., Ltd.; with permission from the authors.



Fig. 10.34 Lip line esthetics: low lip line noted. Based on the patient's high esthetic demands, desire not to replace any adjacent veneers postsurgery, extensive bone loss locally, thin scalloped periodontium, and a horizontal ridge deficiency with a vertical component of crestal bone loss, a *moderate to high esthetic risk profile* was discussed with the patient presurgically. Patient was fully informed of possible postoperative sequelae and accepted treatment as proposed.



Fig. 10.35 Eight weeks postextraction of #9. Soft tissue concavity was noted. A minimally invasive/minimally traumatic flapless extraction technique was used to remove #9 with PiezoSurgery® tips EX1, EX2 (Mectron, Carasco, Italy), with the placement of a soft tissue palatal epithelialized graft ("socket seal") to maintain the keratinized gingival dimensions.

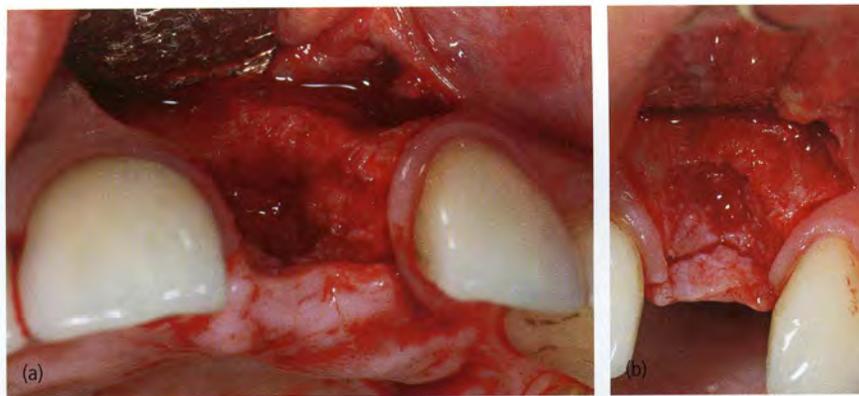


Fig. 10.36 (a and b) Papillary-sparing incision design with divergent vertical releasing incisions up into the alveolar mucosa so as to be away from the membrane margins upon closing. The horizontal osseous defect was to the apex of the extracted tooth. Slight vertical crestal bone loss was also noted in height. It is recommended to complete the periosteal releasing incision of the buccal flap at this time, prior to placing the bone graft. This incision needs to extend under both vertical releasing incisions to enable adequate mobility of the buccal flap to ensure tension-free closure.

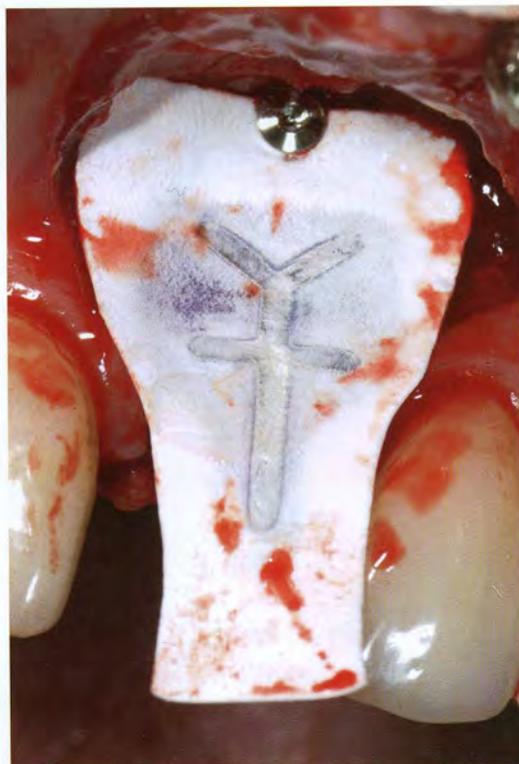


Fig. 10.37 Titanium-reinforced GORE-TEX® ePTFE customized to the defect area, extending 3 mm lateral to the defect facially and just lightly touching, in a slightly undermined position, the retained papillae on either side. The ePTFE membrane was used for the combination treatment of horizontal and vertical crestal bone loss to better support the ability to gain vertical height. A surgical tenting screw was avoided due to the thinness of the coronal palatal bone and concern with perforation out of the palatal wall. One surgical tack is in place apically to stabilize the membrane along with one to be placed lingually, which will be removed with the membrane at implant placement. It is recommended that the membrane is placed and tacked down facially prior to graft placement so as to minimally disturb the graft material with final lingual positioning and tacking of the membrane.



Fig. 10.38 Frozen Regenaform® after removal from a heated water bath as it becomes very moldable and covered with calcium sulfate to help in osseous healing and handling of the material.



Fig. 10.39 The tacked down ePTFE membrane is bent back to allow placement of the bone graft, which is molded into place in both a vertical and horizontal direction. The author suggests using surgical-grade calcium sulfate powder mixed into and on the outer surface of the graft, which helps in graft stabilization and molding to the defect.



Fig. 10.40 The ePTFE membrane has been brought over and the titanium struts have been carefully rounded and contoured over the Regenaform® bone graft material and secured and tucked under the palatal flap's periosteum. A single lingual tack was placed to fully immobilize the membrane.



Fig. 10.43 6.5 months postoperative and day of implant placement. The incision line remained closed for the duration of healing. Favorable contours were noted in three dimensions clinically with no noticeable soft tissue scarring.

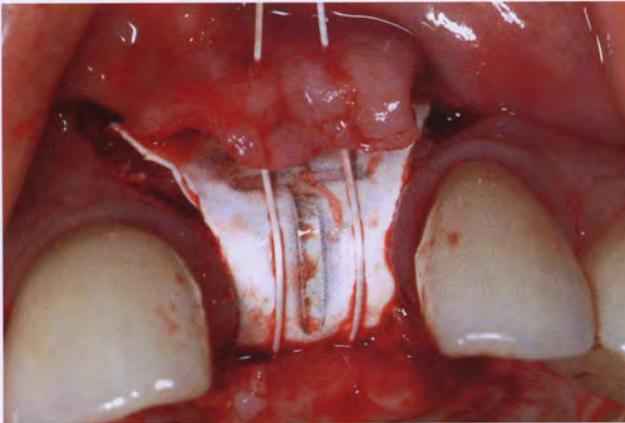


Fig. 10.41 Initial closure suture is a horizontal mattress using a 4-0 PTFE suture. A tension-free closure is anticipated and confirmed by drawing the buccal flap into position upon tying this first suture. A horizontal periosteal releasing incision had been completed prior to graft placement, extending under both vertical releasing incisions for mobility of the buccal flap.

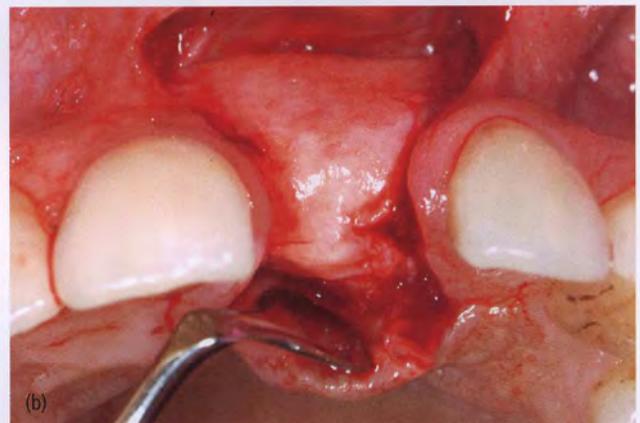
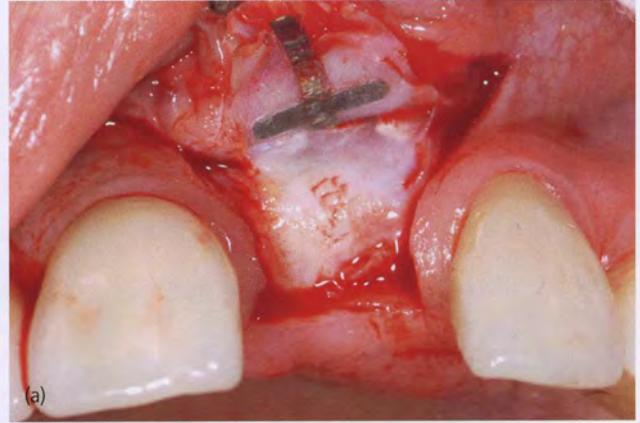


Fig. 10.44 (a and b) Papillary-sparing incisions used to prevent interproximal tissue loss. Upon flap reflection, it was noted that the ePTFE membrane was attached to the buccal flap due to connective tissue ingrowth into the membrane. This is normal healing with ePTFE membranes due to large pore size of the material. Careful sharp dissection of the ePTFE is necessary to separate the membrane from the flap, which is shown here.

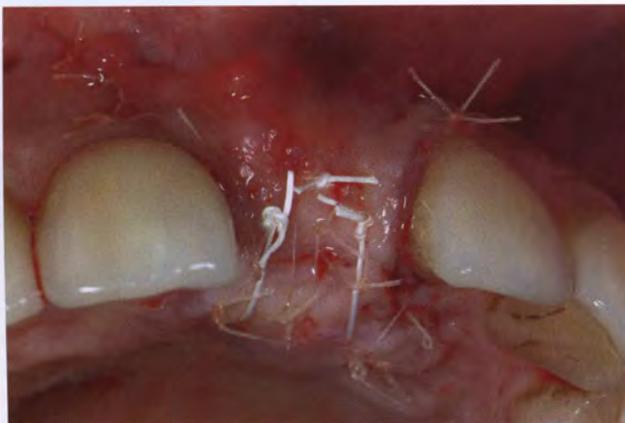


Fig. 10.42 Completed tension-free suturing with two additional 4-0 PTFE sutures and numerous 6-0/7-0 long-term synthetic resorbable (Vicryl®) sutures. The vertical releasing incisions should be closed with 6-0/7-0 sutures to avoid postoperative incision line scarring, which may result from larger diameter sutures and poorly approximated tissues.



Fig. 10.45 Total ridge reconstruction noted clinically. The healed bone was hard and characteristic of type 2 bone quality. A trephined bone core was taken at the time of implant placement for histological evaluation. This core shows 39% bone, 42% of which is vital. The bone volume of allograft is 58%. This $\times 1.5H$ image shows a large piece of mineralized allograft with new bone formation formed on the top. Above that is the demineralized allograft that shows no recalcification. (The authors extend their thanks to Dr. Michael Rohrer and Senior Research Scientist Mr. Hari S. Prasad of the Hard Tissue Research Laboratory at the University of Minnesota School of Dentistry for the nondecalcified histological processing and analysis of the retrieved core samples.)

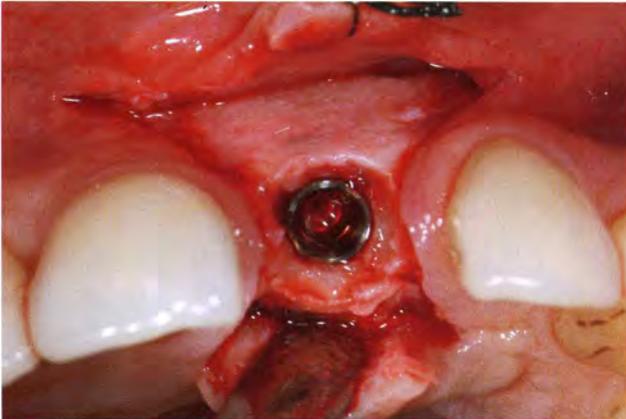


Fig. 10.46 Placement of a Straumann® regular connection (RC) bone-level 4.1×10 -mm SLActive® implant (Straumann, Andover, MA) in a prosthetically favorable position with the aid of an anatomically correct surgical guide template. Note the 2 mm (buccal)–3 mm (palatal) of reconstructed bone. Vertical bone scalloping was needed so as not to place the implant too shallowly. This was determined by measuring from the mid-buccal of the apical portion of the surgical guide template and creating a 3–4 mm distance from the anatomically correct template gingival margin location and the osseous crest. This prosthetic room is necessary to provide adequate emergence profile for a bone-level implant. Seven to eight millimeters of horizontal ridge reconstruction was measured.

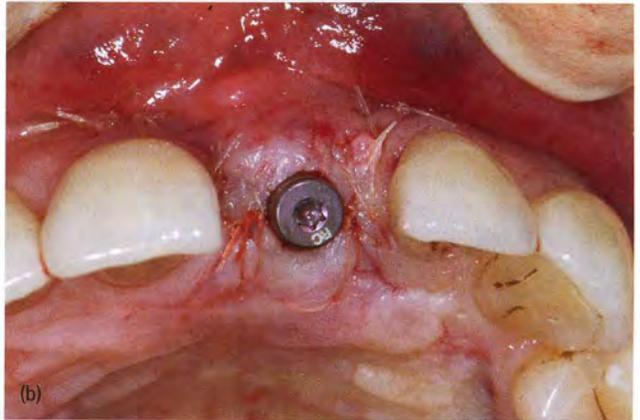


Fig. 10.47 (a and b) A 6-mm bottleneck healing abutment in place. This design undersupports the facial tissues at this time to allow for marginal pressure-free healing. A palatal connective tissue (CT) graft taken from the lingual of #12 and #13 was sutured under the buccal flap to give more facial support to the flap for final esthetics. This abutment will be replaced in 8 weeks with a tapered healing abutment that pushes facially the tissues causing temporary soft tissue blanching. This will help support the tissues and will be followed shortly by a properly contoured screw-retained provisional with correct emergence profiles. Even though a >35 -Ncm insertion torque was delivered, a waiting period of 6–8 weeks is still appropriate before loading as the implant is in 100% grafted/reconstructed bone. Immediate loading should be avoided if possible.



Fig. 10.48 Subepithelial connective tissue graft taken lingual to the upper left premolar area. The tissue thickness is most ideal without concern for nasopalatine nerve innervation damage.



Fig. 10.49 Eight weeks postimplant placement, the undercontoured healing abutment is changed with a conical healing abutment to start stretching and pushing out the facial tissues to accept the screw-retained provisional restoration with ideal subgingival emergence profile. This is accomplished by using topical anesthetic placed subgingival upon removal of the original healing abutment and inserting slowly the tapered healing abutment. Note the soft tissue blanching that will dissipate in a few minutes. Compare this figure with that of Fig. 10.43 as the interproximal soft tissue heights were maintained by the previously described meticulous incision design and flap management.



Fig. 10.51 Final case, #9. (Restorative dentist: Dr. Rob Sattler, Southampton, PA; Dental laboratory: Benchmark Dental Studio, Southampton, PA.) A Straumann Etkon zirconia custom abutment (Straumann, Andover, MA) was used as final abutment.



Fig. 10.50 Three weeks after screw-retained lab-processed provisional placement. The subgingival contours are carefully developed on the lab bench to establish ideal emergence profile for the final restoration. Subgingival contours are flat on the buccal exiting the implant to the gingival margin, and then becomes convex in buccal (to match the supragingival profiles of #8) and interproximal areas to support the papillae. The provisional in esthetic zone cases is used as the "blue-print" for the final crown, which will be duplicated using computer-aided design/computer-aided manufacturing (CAD/CAM) technology, and a zirconia abutment will be fabricated. (Restorative dentist: Dr. Rob Sattler, Southampton, PA; Dental laboratory: Benchmark Dental Studio, Southampton, PA [Robert Burns, CDT].)

exposure, and subsequent site infection, producing increased patient morbidity and decreased local tissue repair if the membrane is removed prematurely. Soft tissue recession may result, causing a significant negative postoperative sequelae in the esthetic zone (Augthun et al., 1995; Chiapasco et al., 1999; Murphy, 1995). These surgical complications encouraged the testing and production in the mid-1990s of bioresorbable barrier membranes that are presently used.

The author, in large extraction site defects, uses an improvement of the nonresorbable Teflon membrane frequently where primary soft tissue closure is not possible. The high-density, 100% pure PTFE is virtually impervious to bacteria (<1.36- μ m pores). This second-

generation nonresorbable membrane is easily removed (at 3–4 weeks) in one piece without anesthesia (see Figs. 10.1–10.11). The highly porous ePTFE membranes are vulnerable to bacterial invasion and can be difficult to remove since they are frequently incorporated into the tissues. The ePTFE membrane is limited in usage where tension-free primary soft tissue closure is attainable at the time of surgery (Table 10.1).

Bioresorbable membranes

Bioresorbable membranes appear to have overcome the above-mentioned problems (Table 10.2). In general, more consistent soft tissue healing has improved with bio-



Fig. 10.52 Final periapical X-ray, #9.



Fig. 10.53 Final full smile (note: low lip line).

resorbable membranes compared with nonresorbable membranes. Collagen possesses chemotactic and platelet-aggregation properties and is naturally resorbed. Yet the barrier function and longevity of the resorbable membranes may vary considerably from one to another, thereby limiting their function and regeneration potential (Hammerle and Jung, 2003; Owens and Yukna, 2001; Stavropoulos et al., 2004; Zellin et al., 1995; Zitzmann et al., 1997; Zhao et al., 2000).

In addition, bioresorbable membranes are not capable of maintaining sufficient space unless the defect morphology is favorable when the bony margins can adequately support the membrane as they have the tendency to lose their mechanical strength once placed. This results in failure in bone regeneration due to failure in space maintenance. Using tenting screws in conjunction with bone graft material can prevent the collapse

Table 10.1 Advantages of second-generation, high-density, 100% pure PTFE nonresorbable membranes (Cytoplast®) and TefGen-FD versus first-generation, ePTFE (GORE-TEX) nonresorbable membranes for socket preservation

Virtually impervious to bacteria (<1.36- μ m pores)
Flap advancement and primary wound closure is not required, which results positively in an increased zone of keratinized attached gingiva upon healing
Predictable bone regeneration seen with ridge maintenance
Usually removed in 3–4 weeks in one piece without local anesthesia
Easy handling; flexible and moldable and does not require surgical tacks (unless titanium-reinforced form is used)
Cost-effective to the clinician and patient

Table 10.2 Benefits of bioresorbable membranes versus ePTFE membranes

Advantages of bioresorbable membranes

Membrane removal is not necessary

Cost-effective

Flexibility with surgical techniques at stage 2 surgery to treat a residual dehiscence or fenestration-type defect remaining after the initial GBR procedure and incomplete healing. The surgeon is frequently still able to place a healing abutment or provisional restoration without concerns of membrane infection or retrieval and resulting recession and esthetic compromise.

Decreased patient morbidity, for early membrane removal is not necessary as when using nonresorbable ePTFE membranes

Disadvantages of resorbable membranes

Unknown duration of membrane function due to high variance in the degradation profiles between the various resorbable membranes (i.e., cross-linked vs. noncross-linked). Is the membrane fully present in a time frame long enough to provide for the desired GBR?

Membrane resorption process: Will it interfere with wound healing and GBR?

Membrane support is needed to maintain the potential regenerative space with either bone graft material with or without tenting screws to prevent membrane collapse and reduction in the regenerative space. This consequence results in a reduction of bone regeneration seen clinically.

Source: Adapted from Hammerle and Jung (2003); with permission from John Wiley & Sons, Inc.

of the membrane, which aids in membrane stability, space maintenance, and bone regeneration (see Figs. 10.12–10.30).

When comparing resorbable membranes, differences have been noted. By comparing a resorbable membrane of polyglycolide-co-trimethylene carbonate (PGA:TMC) to a resorbable noncross-linked bilayer type I and III porcine collagen membrane over DFDBA in a localized bone defect in the canine model, the former membrane allowed a greater amount of bone regeneration than the defect protected by the collagen membrane or control (DFDBA alone) (Zhao et al., 2000). Collagen cross-linking increases its biodurability (Stavropoulos et al., 2004) and enables collagen-based membranes to support long-term osteogenic activity. At the same time, other tissues are excluded from entering the defect by altering its resistance to collagenase degradation (Friedman et al., 2001;

Rothamel et al., 2005). Collagen membranes cross-linked by glycation (GLYM) to produce a bovine type I collagen membrane for GBR have shown completed GLYM ossification when in direct contact with bone in surgically created defects in the canine model, suggesting that GLYM may serve as an ossification substrate (Zubery et al., 2007). GLYM may also have a more predictable degradation profile and may be more resistant to degradation if prematurely exposed as compared with noncross-linked collagen membranes (Zubery et al., 2007). In a clinical human study, in five of seven cases, GLYM maintained its barrier effect for 25 weeks and induced dense, new bone along its interface with underlying tissues. The authors suggest that the glycated collagen in GLYM membranes (Ossix[®] Plus, Colbar, Rehovot, Israel) is capable of inducing mineralization followed by active osteoblastic cell invasion, along with complete ossification of the membrane without additional peptides or any other molecules. This collagen is stable, non-immunogenic, and has been used extensively in humans without any adverse reactions (Zubery et al., 2008) (see Figs. 10.12–10.30). Thus, differences in mechanical properties, degradation time, and lack of integrated biological components could influence the regenerative outcome (Rothamel et al., 2005; Schantz et al., 2002; Zubery et al., 2007, 2008).

Long-term results of GBR procedures

Implant survival rates placed into augmented/regenerated bone using GBR membrane barriers have shown excellent results. In two 5-year studies, no significant differences were seen in cumulative implant survival rates between implants placed in augmented versus nonaugmented bone (Buser et al., 1996; Zitzmann et al., 2001). Although the data is from two long-term studies only, it is generally accepted that the survival rates are similar between implants placed in augmented or non-augmented sites.

Postoperative visits

Postoperative therapy after horizontal ridge augmentation/GBR procedures require a careful reevaluation of the soft tissues at each visit with a review of the patient's plaque control. Our patients will be on an antibiotic commencing 1 hour prior to surgery and continuing for 7 days postsurgery in conjunction with a 0.12% chlorhexidine (CHG) oral rinse for the first 2 weeks. We see our patients at 10–14 days postsurgery and every 1–2 weeks thereafter to reevaluate healing until soft tissue closure is confirmed clinically. The nonresorbable PTFE sutures (horizontal mattress and single interrupted) are left in place for 2–3 weeks. In each procedure, additional 4-0 chromic gut, 6-0 synthetic resorbable (Vicryl[®],

Ethicon, Somerville, NJ) sutures (resorption time 5–8 weeks) or 6-0 plain gut sutures may also be used, aiding in the intimate closure of the crestal incision line as single interrupted sutures. Vertical releasing incisions are closed with either 5-0/6-0 plain gut sutures. This is very important in the esthetic zone as a key to avoid scarring. Thus, in any GBR procedure, up to three different types of sutures may be used to aid in predictable primary soft tissue closure.

At each postoperative visit, the clinician checks healing visually and through light palpation of the surgical site to be sure there are no signs of infection or suppuration present. If a nonresorbable membrane is used, very close monitoring of the above is needed until primary closure is confirmed at 4–8 weeks. When primary soft tissue closure is confirmed, we schedule the patient at 4–6 weeks between appointments until the final reevaluation at 6–8 months in preparation for implant surgery.

Complications

Postsurgical complications can occur so it is important that the clinician addresses them properly and in a timely manner.

Increased risks occur if the patient is a smoker, leading to increased postoperative complications due to smoking's affect on healing. Smoking cessation/reduction is an important conversation to have prior to your patient's surgery.

Complications include the following:

- Postoperative swelling with loss of primary closure and membrane exposure. With a healthy individual, we recommend a presurgical steroid dose pack or a herbal anti-inflammatory agent (arnica) to aid in the control of postoperative swelling. We also use, in addition, a nonsteroidal anti-inflammatory drug (NSAID) for inflammation reduction and pain control. If a resorbable membrane is exposed too early, the GBR procedure goals can be in jeopardy. The patient needs to be informed with this possibility, as well as the potential need to add additional bone/membrane in the future prior to or at the implant surgical visit. Seeing the patient frequently and instructing them in keeping the surgical site clean with a CHG rinse and topical application of CHG can reduce a potential problem. Once the membrane has become exposed and contaminated by saliva, resuturing is not an option. If a nonresorbable ePTFE membrane becomes exposed, it needs to be removed at the first sign of infection as noted clinically by suppuration from the margin of the membrane upon light palpation of the surgical area. Complications of a GBR procedure by means of a nonresorbable membrane happen according to the scientific literature, with an incidence

varying from 9% to 18% (Hammerle et al., 2008; Merli et al., 2006, 2007; Simion et al., 2001). Topical application of CHG with a redosing of a systemic antibiotic would be appropriate, with weekly monitoring until the membrane is removed. Since surgical tacks are used routinely in titanium-reinforced ePTFE cases, an increased patient morbidity with an increased chance of graft failure will occur with early membrane retrieval of a nonresorbable ePTFE membrane due to infection (Figs. 10.54–10.60).

- Although 100% reconstruction is our goal with all GBR procedures, this does not occur predictably. Membrane collapse and loss of regenerative space making or bone graft mobility/resorption under the membrane may provide only 50–90% reconstruction

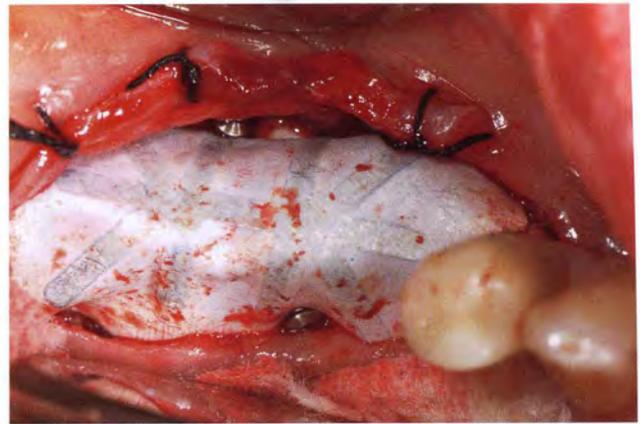


Fig. 10.56 The membrane is now secured in the lingual aspect with a single surgical tack, making it immobile.

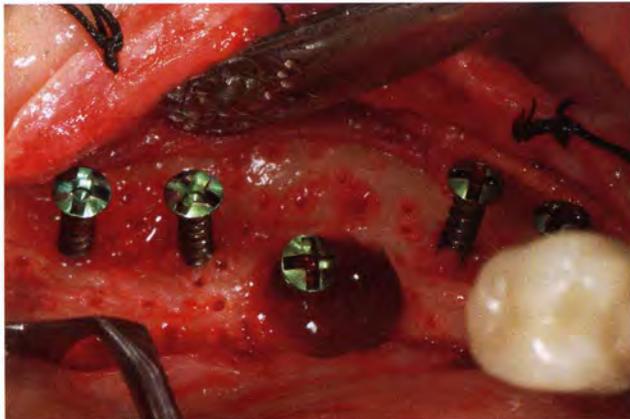


Fig. 10.54 Lower left surgical entry to reconstruct horizontal and vertical bone loss in preparation for the placement of two to three implants. A failed titanium plasma-sprayed (TPS) implant was removed from site #19 (see concavity in bone), which was a distal abutment for a three-unit fixed bridge (#19-#20-#21). Five Lorenz 7-mm tenting screws (Biomet, Jacksonville, FL) are in place.



Fig. 10.57 Primary soft tissue closure is achieved with a buccal flap periosteal releasing incision and 4-0 PTFE horizontal mattress and single interrupted sutures of 4-0 PTFE and 6-0 vicryl material.

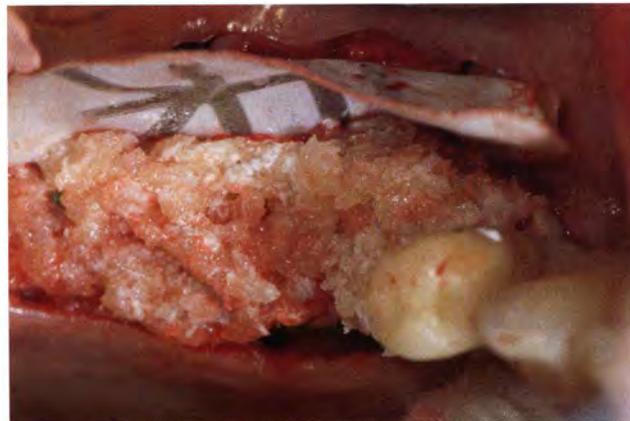


Fig. 10.55 Titanium-reinforced ePTFE GORE-TEX® membrane is secured to the facial bone with two surgical tacks. Regenaform® is packed (mixed with the patient's blood-derived plasma rich in growth factors [PRGF]) to the facial and in a vertical direction for both horizontal and vertical augmentation.



Fig. 10.58 Surgical site at 4 weeks postoperative. The ePTFE GORE-TEX® membrane had been exposed since 2 weeks postoperative. The exposed membrane was cleaned by the patient with CHG daily in rinse and topical application and the site was checked at 1–2-week intervals for signs of infection and need for removal. The exposed area increased with time.



Fig. 10.59 Exposed ePTFE membrane at 3 months with signs of infection (suppuration upon light palpation of the tissues) requiring its removal at this visit.



Fig. 10.60 Removed membrane at 3 months showing bacterial contamination of the exposed area and the anterior aspect of the membrane where the suppuration was clearly noted clinically. Most of the graft was lost and this case was considered a surgical failure. Lack of keratinized gingiva (KG) at the outset may have contributed to the failure as the incision sites opened early. A second GBR procedure was attempted after addition of KG with acellular dermal matrix (ADM).

of the desired site. The use of tenting screws to maintain the regenerative space and the tacking down of the membrane to prevent any micromovement is imperative to the predictable success of this procedure. The possibility of partial reconstruction of the defect needs to be addressed with the patient prior to surgery; in addition, additional GBR may be necessary at the time of implant placement to correct a dehiscence/fenestration defect or more. As noted above, the worst-case scenario is minimal to no reconstruction achieved due to factors discussed previously.

- Compromised esthetic/phonetic result of the final restoration because of poor team planning or implant placement due to the failure to use an anatomically

correct surgical template properly or failure to use one at all. The basis of the success of this procedure is a prosthetically guided bone reconstruction and implant placement using a team approach.

Conclusions

1. GBR is a predictable, safe, and successful procedure to augment bone in a horizontal direction in a staged membrane-assisted approach, where insufficient bone volume is present for prosthetically guided implant placement.
2. Horizontal ridge augmentation/GBR procedures are technically demanding and require a meticulous, precise, and systematic surgical execution for success due to the procedure's difficult nature. The skills and experience of the clinician are a critical factor in the success of the treatment (Hammerle and Jung, 2003).
3. Allograft materials such as Regenaform are available, which have clinical and patient benefits over use of autogenous bone in membrane-assisted horizontal ridge augmentation/GBR procedures.
4. Bioresorbable membranes show similar success rates obtained with nonresorbable membranes with less patient morbidity in the treatment of horizontal ridge deficiencies.
5. Survival rates of implants placed in regenerated bone is similar to implants placed in native, nonaugmented bone.
6. A team approach to patient care is essential to the overall long-term success involving the patient, periodontist/surgeon, restorative dentist, laboratory technician, and dental hygienist.
7. New materials such as recombinant human bone morphogenetic protein-2 (rhBMP-2) and platelet-derived growth factors (PDGF) are being tested in large extraction socket defects in humans, which in conjunction with bone grafting and stabilized titanium mesh (for space maintenance) has shown significant vertical and horizontal bone reconstruction in "off-label" usage for advanced bony defects. More studies and Food and Drug Administration (FDA) approval are necessary before routine usage. These large bony lesions are unpredictably treated today using the present GBR methods described in this chapter requiring both vertical and horizontal bone reconstruction.

Acknowledgments

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This chapter is dedicated to the memory of my professors and mentors Dr. Leonard Abrams and Dr. Herman Corn.

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