Flap Designs for Flap Advancement During Implant Therapy: A Systematic Review

Alexandra B. Plonka, DDS,* Rachel A. Sheridan, DDS, MS,* and Hom-Lay Wang, DDS, MS, PhD†

Implant osseointegration is defined as direct contact between bone and the implant surface evaluated on the light microscope level.[1–3] Implant survival may be maximized when the entire surface is encompassed by sufficient bone volume.[2] To ensure adequate osseous support, bone grafting may be required. This may occur at multiple time points: postextraction for socket augmentation, or in a staged or simultaneous approach with implant placement for ridge augmentation. Bone grafting procedures require flap reflection for access to ascertain bone morphology, quantity, quality, and relevant anatomical structures. A variety of incision designs and reflection techniques may influence flap properties and optimize the outcomes of regenerative procedures. This manuscript provides a comprehensive literature review of various flap designs proposed for bone grafting during implant treatment based on amount of grafting needed. In addition, key surgical principles for enhancing regeneration and the management of flap complications are discussed. The authors have categorized the flap designs by the amount of desired flap reflection to provide primary closure of an augmented ridge volume based on categories described by Greenstein et al[4] (2009) and provide additional clinical recommendations.

Purpose: *Guided bone regeneration (GBR) procedures allow ridge augmentation before or at time of implant placement. GBR outcomes rely on primary passive tension-free wound closure, which may be achieved by a variety of flap designs and surgical procedures. A comprehensive literature review of flap design and management is provided, including material types, incision design, reflection, releasing, and suturing techniques.*

Materials and Methods: *Two reviewers completed a literature search using the PubMed database and a manual search of relevant journals. Relevant articles from January 1990 to September 2015 published in the English language were considered.*

Results: *A variety of flap designs aim to achieve primary passive closure during GBR were introduced. To facilitate case selection and treatment planning, flap designs have been categorized based on their ability to achieve minor (<3 mm), moderate (3–6 mm), and major (≥7 mm) degrees of flap advancement.*

Conclusions: *Techniques such as vertical releasing incisions, periosteal releasing incisions, and split-thickness flaps may be used alone or combined to achieve passivity during GBR. GBR complications may be prevented by imaging and preoperative planning and careful surgical technique especially flap advancement. (Implant Dent 2017;26:145–152)*

Key Words: dental implant, guided bone regeneration, alveolar ridge augmentation, flap design, passive tension flap

Guided Bone Regeneration

Guided bone regeneration (GBR) is a strategy to augment hard tissue around implants before or at the time of their placement. GBR is a modification of guided tissue regeneration (GTR) for implant applications such as ridge augmentation, coverage of fenestration, and/or dehiscences defects at implant placement, grafting of the gap surrounding immediate implants, and treatment of peri-implantitis.[5,6] Like GTR, membranes or barriers may be used to exclude rapidly proliferating epithelial cells to allow more beneficial slowly-growing osteoblasts to infiltrate and promote new bone formation.[7]

GBR may be performed for both horizontal and vertical ridge augmentation. It is recommended for both staged

*Resident, Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI.
†Professor and Director of Graduate Periodontics, Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI.

Reprint requests and correspondence to: Hom-Lay Wang, DDS, MS, PhD, Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, 1011 North University Avenue, Ann Arbor, MI 48109-1078, Phone: (734-763-3325), Fax: (734) 936-0374, E-mail: homlay@umich.edu

ISSN 1056-6163/17/02601-145
Implant Dentistry
Volume 26 • Number 1

DOI: 10.1097/ID.0000000000000510

and simultaneous approaches in cases with at least 3 mm residual buccolingual bone width.[8] Nevins and Mellonig[9] described early cases of horizontal GBR using ePTFE membranes, tenting screws, and autogenous grafts and/or FDBA in a staged approach. Buser et al[10] found lateral bone gain of 3.6 mm in 40 patients treated with ePTFE membranes and autografts with a complication rate of 5%. However, membrane exposure is the most common complication with nonresorbable membranes. Possible mechanisms behind flap sloughing include lack of blood supply due to the impermeable nature of the membrane,[11] in addition to the clinician's inability to advance the flap without tension. Exposure of nonresorbable membranes may lead to failure of the graft.[12]

Collagen membranes are often the absorbable membrane of choice because of their favorable biological properties, including lower risk of exposure.[6] Park et al[13] found more bone gain in absorbable membrane groups versus no membrane (1.66 vs 1.08 mm), using a sandwich simultaneous grafting technique. Nonetheless, flap advancement with primary tension flap closure remains to be one of the key factors to ensure a successful outcome.[14]

Compared to horizontal augmentation, vertical GBR can be more challenging.[15] The overall complication rate for vertical GBR is reported at 0% to 45.5%, compared with 0% to 24% for horizontal GBR.[16,17] The most commonly reported complication for both procedures is membrane exposure, ranging from 6.95% to 13.1%.[10,16–20] This is largely due to the difficulty in advancing the flap to achieve primary wound closure as well as maintaining flap closure during the healing period.[21,22]

Surgical Principles

Regardless of membrane type or graft material, successful GBR hinges on 4 key properties outlined by the "PASS" principle: primary wound closure, angiogenesis, stability, and space maintenance.[6] Flap design and releasing techniques may facilitate primary closure, critical to success of regenerative procedures. In addition to promoting soft tissue healing and easing postoperative concerns, primary wound closure protects the healing graft and progenitor cells for maximum regeneration.

As previously mentioned, membrane exposure is the most common complication of GBR and often has a negative effect on regenerative potential. Exposure has been reported in 60% of cases of one-stage GBR, leading to 80% less regeneration due to early membrane removal, absorbable membrane dissolution, graft contamination, failure of graft adaptation, and total graft failure.[13] Exposure of ePTFE membranes during a 3 to 6 months healing period reduced the regeneration rate from 96.6% to 46.5%.[23] Nonresorbable ePTFE membranes have been reported to have a higher incidence of wound opening and membrane exposure versus collagen membranes.[20,24] Immediate implant placement may be associated with higher wound opening (80%) than delayed approaches (17%–32%).[20]

In a meta-analysis, Machtei[25] found 6 times more bone gain in nonexposed compared with exposed sites, although only 2 studies were included. In their decision tree, Mellonig and Nevins[26] recommend treating exposed membranes with increased postoperative monitoring, premature removal, attempting coverage, and a staged approach. Depending on the grafting approach, implant components such as cover screws may also be exposed.[27]

Early barrier removal often limits the amount of regeneration achieved but may still lead to successful GBR.[10,27] Potential mechanisms leading to graft failure after exposure include bacterial contamination, presence of foreign bodies, and increased speed of graft resorption.[6,28]

Flap Reflection

Wound closure should be achieved passively, as flap tension increases risk of dehiscence.[29] In addition to prevention of exposure, passive primary closure improves wound healing by eliminating wound tension, preventing loss of blood supply, and subsequent tissue necrosis.[6] Incision design and flap reflection and extension techniques may increase flap mobility, allowing the flap to rest passively over the membrane and increased volume of graft material. Most strategies combine flap extension, vertical incisions, and periosteal releasing incisions to increase mobility and passivity of full-thickness (mucoperiosteal) flaps. Park et al[30] found that the addition of one vertical incision extends the length of the flap by 1.1 mm, the second vertical incision extends the flap 1.9 mm from baseline, and a periosteal releasing incision extends the flap by 5.5 mm from baseline.

Greenstein et al proposed strategies to achieve different strata of flap advancement: minor (<3 mm), moderate (3–6 mm), and major (≥7 mm). Minor flap advancement may be achieved by extending full-thickness flap reflection beyond the mucogingival junction (MGJ). For moderate flap advancement, 2 vertical releasing incisions are recommended, with the addition of periosteal scoring of 1-mm depth as needed. Major flap advancement may require deeper periosteal scoring: 3 to 5 mm into submucosa. In addition, split-thickness flaps may be employed to further extend soft tissue coverage.[4]

These categories of flap advancement are used in this review to group flap reflection techniques for varying degrees of augmentation procedures with the goal of promoting passive primary wound closure to maximize GBR success.

MATERIALS AND METHODS

A literature search was completed using the PubMed database to generate a comprehensive review of flap design strategies proposed for use during ridge and socket augmentation procedures. The flap designs were grouped by their ability to achieve flap extension, based on categories proposed by Greenstein et al (2009). Two reviewers (A.P. and R.S.) searched the PubMed database manually using several search terms and pairs of search terms, including, but not limited to, the words "flap designs," "guided bone regeneration," "ridge augmentation," and "socket augmentation." In addition, a manual search of the following journals was conducted: *The International Journal of Oral & Maxillofacial Implants,* *Clinical Oral Implants Research, Implant Dentistry, Journal of Periodontology*, and the *International Journal of Periodontics and Restorative Dentistry*. Relevant articles in English from January 1990 to September 2015 were included.

RESULTS

FLAP DESIGNS Based on the Need for Flap Advancement

Mild flap advancement (1–3 mm). Mild flap advancement techniques may be employed for GBR limited to a horizontal dimension requiring 1 to 3 mm of advancement (Table 1 and Fig. 1).

Esthetic buccal flap

This technique was proposed for immediate implants in the esthetic zone when a buccal plate defect likely to result in implant fenestration is present.[31,32] This flap is particularly recommended when existing alveolar bone loss, thin tissue biotype, or a combination of both, may result in recession, loss of papilla height, and unfavorable esthetics after flap reflection. It is essentially a replaced flap requiring minimal additional reflection because of limited extent of augmentation. It entails reflecting a full-thickness flap with a horizontal incision in keratinized tissue 3 mm apical to the free gingival margin, followed by 2 vertical releasing incisions extending past the MGJ.

The flap may be performed before or after atraumatic extraction of the hopeless tooth. After implant placement, the buccal plate fenestration may be grafted, such as with the sandwich bone augmentation (SBA) technique,[37] and an absorbable collagen membrane placed. The flap is replaced, and suturing of the vertical followed by the horizontal incisions is performed to minimize tension. Ideally, the implant will be immediately temporized to maximize support of the soft tissue profile.

Mucogingival pouch flap

This technique is also performed for grafting a buccal dehiscence or fenestration defect at implant placement when esthetic concerns are minimal.[33] This flap design uses of papilla preservation incisions and MGJ incisions for "soft tissue camouflage." Another advantage of this technique is it may be performed in cases of limited soft tissue thickness because it does not require splitting the flap, as is seen in other techniques, to achieve primary closure. After flap reflection and grafting with the SBA technique[37] and a collagen membrane, additional flap extension is achieved by periosteal scoring incisions (for additional 2–3 mm advancement).

Periosteal pocket flap

Proposed for horizontal augmentation of knife-edge ridges, this flap is indicated for staged GBR before implant placement.[34] It entails splitting the buccal flap into mucosal and periosteal components to increase flap elasticity and motility for improved primary closure. Mesial and distal vertical releasing incisions in the mucosal flap provide additional flap extension. The periosteal pocket provides both stability and graft containment. A collagen membrane is used to cover the coronal portion of the graft. Horizontal mattress suturing through the lingual flap is performed in 2 stages to engage the buccal periosteal and mucosal layers separately. In a case series, this flap resulted in an average of 4.3 mm horizontal augmentation and 100% implant success rate.[34]

Lateral incision technique

This procedure supports localized horizontal ridge augmentation using a staged approach to GBR.[35,36] The lateral incision is performed from the palatal/lingual aspect to create a split- and full-thickness combined flap. The combined flap design is purported to reduce soft tissue complications as compared with crestal incisions.

Table 1. Flap Designs for Mild (1–3 mm) Flap Advancement

Required Flap Advancement: Mild (1–3 mm)			
		Flap Design	
Name	Indication	Incisions	Reflection
Esthetic buccal flap[31,32]	Immediate implant apical buccal fenestration defect	Horizontal 3 mm apical to free gingival margin Two divergent vertical incisions past MGJ	To expose implant defect
Mucogingival pouch flap[33]	Immediate implant buccal dehiscence or fenestration defect	Semilunar crestal incision with horizontal extension Papilla preservation technique; one vertical	Pouch flap reflection 5 mm beyond defect
Periosteal pocket flap[34]	Horizontal ridge deficiency	Crestal Internal vertical	Create a pocket by reflecting periosteum
Lateral incision technique[35,36]	Horizontal ridge deficiency	Horizontal 3 mm lateroapical to crest Diverging releasing incisions Create periosteal release at base of buccal flap	Reflect combined split-thickness then full-thickness flap

This table lists flap designs that may be used to achieve mild flap advancement. The table lists the indication for which the procedure was proposed. The main incision designs and reflection strategies are outlined in brief.

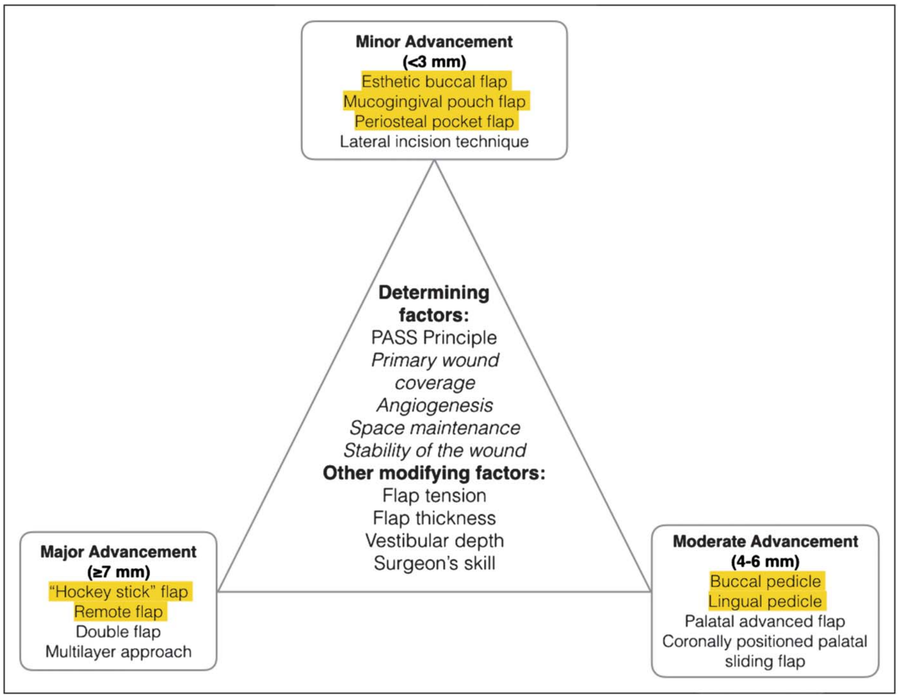

Fig. 1. Principles for achieving passive flap extension. This figure categorizes the surgical flap designs based on the amount of flap advancement that may be achieved by each technique, shown in the boxes on each axis. The author's recommendations for each category, based on experience, are highlighted in yellow. The center of the triangle lists "Determining Factors," which are key principles that determine the degree of flap advancement and success of the GBR procedure. "Other modifying factors" also may have an effect on flap advancement.

Tenting screws may be added with a bone graft and nonresorbable, fixed ePTFE membrane for space maintenance. Horizontal mattress and simple interrupted sutures are used for tension-free primary closure.

Moderate flap advancement (4–6 mm). Moderate flap advancement strategies include pedicle flaps for increased graft coverage, for primary coverage of extraction sockets or implants, and in areas of limited keratinized tissue. Four to 6 mm of advancement can be anticipated (Table 2).

Buccal pedicle flap/graft

This technique was proposed using ePTFE membranes and later converts to absorbable cellulose membranes.[38,39] This flap design is used at socket preservation or immediate implant placement to allow for soft tissue coverage while preventing a discrepancy in the MGJ, loss of vestibule, and limited keratinized tissue, which can result from overextension of the flap. Instead, buccal keratinized gingiva from an adjacent tooth is used as the donor for soft tissue coverage over the membrane through a pedicle[38] or free gingival graft approach.[39] Any excess graft may be used to repair the donor site.[39]

The following techniques involve manipulation of the palatal or lingual flaps:

Vascularized periosteal membrane

This procedure is performed for primary closure over grafted sockets after flapless, atraumatic extraction.[40] An absorbable membrane may or may not be used. Full-thickness buccal and palatal flaps are raised, and the additional flap extension is achieved by internally splitting the palatal flap in half from an apical aspect to form a pedicle and unfolding it over the graft site. The buccal flap is replaced over this extended tissue and sutured with single interrupted sutures.

Lingual pedicle

Like the vascularized periosteal membrane, this procedure also involves a rotated split-thickness connective tissue pedicle from the palate to augment flap length for primary soft tissue closure over grafted extraction sites or deficient ridges.[41,42] The specific buccal flap design includes horizontal incisions of 3 to 4 mm[42] up to 6 to 10 mm[41] in length at the most apical extent of the vertical releasing incisions. In a case series, this flap resulted in 98.8% of 173 sites maintaining soft tissue coverage for 6 months.

Palatal advanced flap

Similar to a lateral pedicle soft tissue graft, this technique involves rotating an L-shaped split-thickness pedicle from the palate for primary coverage of immediate implants.[43]

Coronally positioned palatal sliding flap

This strategy involves creating split-thickness planes of palatal tissue from a full-thickness flap to allow for sliding and rotation similar to a garage door to increase the zone of keratinized tissue and provide primary coverage of barrier membranes during implant placement and simultaneous grafting.[44] First, a full-thickness flap with vertical incisions is raised for implant placement, the flap is split at its edge like the page of a book into a second plane, then at the apical extent of the flap, an additional split-thickness plane is dissected connecting the vertical incisions which allows sliding of the flap to cover the implants with the keratinized tissue. The underlying de-epithelialized palatal tissue will re-epithelialize like a free gingival graft donor site.

Major flap advancement (7 mm or greater). Major flap advancement is required for vertical bone augmentation requiring 7 mm or greater of advancement (Table 3).

"Hockey stick" flap

Tinti and Parma-Benfenati[45] proposed this technique to accommodate significant vertical ridge augmentation around implants. The full-thickness buccal flap has "hockey stick"–shaped apical extensions of the vertical incisions. Another term for these extensions is "cutback" incisions.[49] In the mandible, the full-thickness lingual flap is extended to the mesial at least 3 teeth beyond the defect, where it

Table 2. Flap Designs for Moderate (4–6 mm) Flap Advancement

Required Flap Advancement: Moderate (4–6 mm)		Flap Design	
Name	Indication	Incisions	Reflection
Buccal pedicle[38,39]	Implant dehiscence defect, immediate implant,[6] extraction socket[7]	Horizontal incision on buccal to delineate pedicle graft Palatal intrasulcular incisions extending mesial and distal by one tooth Vertical releasing incisions at buccal and lingual Rotate buccal pedicle for primary closure over implant (trim excess pedicle as needed)	Full-thickness reflection with partial thickness at buccal pedicle
Vascularized periosteal membrane[40]	Socket augmentation	Circumferential intrasulcular incisions around tooth to be extracted Close socket with palatal split pedicle overlaid by buccal flap	Full-thickness buccal and palatal flap, then split-thickness lingual pedicle
Lingual pedicle[41,42]	GBR ± extraction or implant placement	Palatal Split tissue near crest with angled incision Vertical incisions Buccal Crestal incision Vertical incisions on mesial and distal to vestibule Horizontal incisions at apical end of vertical incisions	Partial thickness palatal flap and full-thickness buccal flap
Palatal advanced flap[43]	Immediate implant	L-shaped incision with vertical incisions extending palatally Parallel incisions extending distally forming other leg of "L" De-epithelialize inner triangle	Split-thickness dissection of "L" flap and rotation to cover implant
Coronally positioned palatal sliding flap[44]	GBR around implants	Horizontal incision Parallel vertical incisions, 2–3 mm longer than planned coronal position 2 mm thick horizontal incision extending 2 mm coronal to extent of verticals Connect vertical incisions apically External bevel apico-coronal incision to split tissue	Full-thickness elevation to place membrane

This table details flap designs that may be applied for moderate flap advancement. The original surgical procedure for which the flap was used is listed ("Indication"). The key incisions and reflection techniques are summarized.

terminates with a vertical incision no more than 1 mm beyond the MGJ. The lingual flap reflection involves raising the mylohyoid muscle while containing and protecting vital structures in the floor of the mouth. In the maxilla, a coronally positioned palatal flap[44] is used. The periosteum (along with muscle fibers in the mandible) is split from the outer, mucosal portion of the flaps. The goal is the extension of the flap beyond the incisal edges of the adjacent teeth. Grafting is performed with autogenous particles over the implant threads covered with a membrane secured with fixation screws. The "first line of closure" is achieved with horizontal mattress "U-stitches" 3 mm apart followed by interposing simple interrupted sutures.

Remote flap

This flap is a modification of Tinti and Parma-Benfenati's[45] "Hockey stick" flap design for horizontal or vertical ridge augmentation.[46] Modifications include extending the flap in edentulous areas 5 mm beyond the graft site (compared with 3 mm). Full-thickness flaps are reflected 5 mm beyond the defect, which includes reflection beyond the mylohyoid muscle in the lingual posterior mandible. Periosteal releasing incisions are used to increase flap mobility. Suturing is performed with horizontal mattress followed by simple interrupted sutures.

Double flap

This flap was derived for vertical and horizontal GBR in the posterior mandible.[47] A review of anatomical

Table 3. Flap Designs for Major (≥7 mm) Flap Advancement

Required Flap Advancement: Major (≥7 mm)			
		Flap Design	
Name	Indication	Incisions	Reflection
"Hockey Stick" flap[45]	Vertical ridge augmentation around implants	Intrasulcular incisions on buccal and lingual extending to mesial line angle of adjacent teeth	Buccal: full-thickness flap
		Buccal "Hockey stick" vertical incisions on mesial line angles of adjacent teeth 7–8 mm distal to membrane if edentulous Lingual Intrasulcular extension incision mesially 3+ teeth Two vertical releasing incisions 1 mm beyond MGJ on the mandible Periosteal releasing incisions	Lingual Mandible: full-thickness flap to raise entire floor of mouth Maxilla: palatal sliding flap, if necessary[11]
Remote flap[46]	Horizontal and/or vertical GBR	Midcrestal incision Divergent verticals 1 tooth (or 5 mm away from site if edentulous) Verticals connected with periosteal releasing incisions	Full-thickness reflection past MGJ and 5 mm beyond defect (past mylohyoid line in the mandible)
Double flap[47]	GBR	Crestal incision Vertical releasing incision 2 mm from terminal tooth	Partial thickness flap on the buccal and periosteal flap reflection
Multilayer approach[48]	GBR, mucogingival surgery, or periodontal plastic surgery	C-shaped vertical on buccal	Combined full-partial thickness: Full-thickness, then partial thickness 2–3 mm beyond MGJ
		Paracrestal incision	Reflection of periosteum for 1.5–2 mm thick inner flap

This table describes flap incision and reflection techniques suggested for major flap advancement. The application for the procedure is given ("Indication"), followed by a brief description of the major incisions and reflection technique.

considerations led to the design of a midcrestal horizontal incision with a single vertical incision at the mesial aspect of the flap to preserve blood supply to the avascular crestal portion of the edentulous ridge while avoiding vital structures. Similar to the periosteal pocket flap,[34] the mucosal and periosteal flaps are elevated and sutured separately.

Multilayer approach

This technique uses principles of plastic and microsurgery to obtain a double partial thickness buccal flap along with the coronally positioned palatal sliding flap.[44,48]

DISCUSSION

Complication Management

Complications have been reported in up to 25% of horizontal and 45.5% of vertical bone augmentation procedures; in response, several authors have proposed systems for complication classification and management.[10,16,50] The primary issue associated with barrier membranes is early exposure, reported as a percent of complications in one review as 0% to 24% of horizontal GBR at implant placement, 11.9% for staged horizontal GBR, 13.1% for vertical GBR at implant placement, and 6.95% for staged vertical GBR.[17] The use of absorbable membranes has reduced the incidence of membrane exposure; however, severe ridge deficiencies may require the use of nonresorbable membranes so identification, diagnosis, and management of membrane exposure and other complications remain essential. Complications may be grouped into 2 major categories: those caused by direct surgical trauma or those that occur during healing.

Flap sloughing may result from an interruption of blood supply leading to tissue necrosis; thus, proper flap management is essential by avoiding excessive flap thinning or perforation during periosteal release.[50]

Other surgical complications include damage to vascular and neurologic structures.[10] Prevention is key by way of appropriate presurgical imaging and planning, as well as intraoperative identification and avoidance of vital structures. In the mandible, the lingual and sublingual artery, in addition to other contents of the sublingual space, must be avoided during incisions and flap reflection. In the maxilla, the greater palatine neurovascular bundle is most susceptible to trauma. Neurosensory disturbances can be avoided by respecting the mental nerve, lingual nerve, and rarely, the infraorbital nerve.[50] In addition to attention to clinical detail, the use of imaging is imperative, including preoperative radiographs and cone beam computed tomography imaging when indicated.

Healing Complications

Membrane exposure with or without bacterial contamination and infection is not uncommon, especially with nonresorbable membranes.[16,17,50] Small (<3 mm) asymptomatic exposures may be left in place for a maximum of 1 month under twice-daily chlorhexidine disinfection and regular patient follow-up. Larger, but "clean," exposures require immediate membrane removal and possible suturing to prevent infection of the graft. Presence of exudate or abscess necessitates membrane removal and curettage of any residual graft material to avoid destruction of the original ridge.[50]

Bone graft particle exposure is generally incidental. Patients should be informed as to this possibility so it does not cause alarm. Exfoliating particles in otherwise healthy healing sites may be simply removed with cotton pliers and, in most cases, is a relatively painless procedure. When block grafting is used, exposure may be more detrimental and may require trimming or complete removal of the graft.

Fixation screw exposure can be prevented by restricting their use to thicker biotypes. If it occurs, it may be treated with chlorhexidine disinfection.

Conclusions

This review provides strategies that have been proposed since the advent of GBR to increase flap mobility, extension, and length for passive primary closure of grafted sites. Generally, vertical releasing, cutback, and periosteal scoring incisions of varying number and length provide flap extension to cover a variety of bone graft volumes. Dissection of split-thickness flaps and harvesting of pedicle grafts may augment the soft tissue quantity as needed. The demands of the bone volume must be weighed against practical considerations with increasing technique sensitivity and operating times of these more advanced techniques. Furthermore, as graft and barrier materials evolve with technology, surgical procedures, especially designs for tension-free flap advancement, must be re-examined.

Disclosure

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

References

1. American Academy of Periodontology. *Glossary of Periodontal Terms*. 4th ed. Chicago, Il: American Academy of Periodontology; 2001:28.
2. Spray JR, Black CG, Morris HF, et al. The influence of bone thickness on facial marginal bone response: Stage 1 placement through stage 2 uncovering. *Ann Periodontol.* 2000;5:119–128.
3. Branemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg Suppl.* 1977;16:1–132.
4. Greenstein G, Greenstein B, Cavallaro J, et al. Flap advancement: Practical techniques to attain tension-free primary closure. *J Periodontol.* 2009;80:4–15.
5. Simion M, Dahlin C, Trisi P, et al. Qualitative and quantitative comparative study on different filling materials used in bone tissue regeneration: A controlled clinical study. *Int J Periodontics Restorative Dent.* 1994;14:198–215.
6. Wang HL, Boyapati L. "PASS" principles for predictable bone regeneration. *Implant Dent.* 2006;15:8–17.
7. Melcher AH. On the repair potential of periodontal tissues. *J Periodontol.* 1976;47:256–260.
8. Fu JH, Wang HL. Horizontal bone augmentation: The decision tree. *Int J Periodontics Restorative Dent.* 2011;31: 429–436.
9. Nevins M, Mellonig JT. The advantages of localized ridge augmentation prior to implant placement: A staged event. *Int J Periodontics Restorative Dent.* 1994;14:96–111.
10. Buser D, Dula K, Hirt HP, et al. Lateral ridge augmentation using autografts and barrier membranes: A clinical study with 40 partially edentulous patients. *J Oral Maxillofac Surg.* 1996;54: 420–432; discussion 432–423.
11. Vergara JA, Quinones CR, Nasjleti CE, et al. Vascular response to guided tissue regeneration procedures using nonresorbable and bioabsorbable membranes in dogs. *J Periodontol.* 1997;68:217–224.
12. von Arx T, Kurt B. Implant placement and simultaneous ridge augmentation using autogenous bone and a micro titanium mesh: A prospective clinical study with 20 implants. *Clin Oral Implants Res.* 1999;10:24–33.
13. Park SH, Lee KW, Oh TJ, et al. Effect of absorbable membranes on sandwich bone augmentation. *Clin Oral Implants Res.* 2008;19:32–41.
14. Fu JH, Oh TJ, Benavides E, et al. A randomized clinical trial evaluating the efficacy of the sandwich bone augmentation technique in increasing buccal bone thickness during implant placement surgery: I. Clinical and radiographic parameters. *Clin Oral Implants Res.* 2014;25:458–467.
15. McAllister BS, Haghighat K. Bone augmentation techniques. *J Periodontol.* 2007;78:377–396.
16. Rocchietta I, Fontana F, Simion M. Clinical outcomes of vertical bone augmentation to enable dental implant placement: A systematic review. *J Clin Periodontol.* 2008;35(8 suppl):203–215.
17. Milinkovic I, Cordaro L. Are there specific indications for the different alveolar bone augmentation procedures for implant placement? A systematic review. *Int J Oral Maxillofac Surg.* 2014; 43:606–625.
18. Dahlin C, Lekholm U, Becker W, et al. Treatment of fenestration and dehiscence bone defects around oral implants using the guided tissue regeneration technique: A prospective multicenter study. *Int J Oral Maxillofac Implants.* 1995;10:312–318.
19. Hammerle CH, Jung RE, Yaman D, et al. ridge augmentation by applying bioresorbable membranes and deproteinized bovine bone mineral: A report of twelve consecutive cases. *Clin Oral Implants Res.* 2008;19:19–25.
20. Zitzmann NU, Naef R, Scharer P. Resorbable versus nonresorbable membranes in combination with Bio-Oss for guided bone regeneration. *Int J Oral Maxillofac Implants.* 1997;12:844–852.
21. Leong DJ, Oh TJ, Benavides E, et al. Comparison between sandwich bone augmentation and allogenic block graft for vertical ridge augmentation in the posterior mandible. *Implant Dent.* 2015; 24:4–12.
22. Chan HL, Benavides E, Tsai CY, et al. For vertical ridge augmentation in the posterior mandible: A pilot study. *Int J Periodontics Restorative Dent.* 2015;35: 515–522.
23. Simion M, Baldoni M, Rossi P, et al. A comparative study of the effectiveness of e-PTFE membranes with

and without early exposure during the healing period. *Int J Periodontics Restorative Dent.* 1994;14:166–180.

24. Jensen SS, Terheyden H. Bone augmentation procedures in localized defects in the alveolar ridge: Clinical results with different bone grafts and bone-substitute materials. *Int J Oral Maxillofac Implants.* 2009(24 Suppl):218–236.

25. Machtei EE. The effect of membrane exposure on the outcome of regenerative procedures in humans: A meta-analysis. *J Periodontol.* 2001;72:512–516.

26. Mellonig JT, Nevins M. Guided bone regeneration of bone defects associated with implants: An evidence-based outcome assessment. *Int J Periodontics Restorative Dent.* 1995;15:168–185.

27. Li J, Wang HL. Common implant-related advanced bone grafting complications: Classification, etiology, and management. *Implant Dent.* 2008;17:389–401.

28. Hung SL, Lin YW, Wang YH, et al. Permeability of Streptococcus mutans and Actinobacillus actinomycetemcomitans through guided tissue regeneration membranes and their effects on attachment of periodontal ligament cells. *J Periodontol.* 2002;73:843–851.

29. Burkhardt R, Lang NP. Role of flap tension in primary wound closure of mucoperiosteal flaps: A prospective cohort study. *Clin Oral Implants Res.* 2010;21:50–54.

30. Park JC, Kim CS, Choi SH, et al. Flap extension attained by vertical and periosteal-releasing incisions: A prospective cohort study. *Clin Oral Implants Res.* 2012;23:993–998.

31. Steigmann M. Aesthetic flap design for correction of buccal fenestration defects. *Pract Proced Aesthet Dent.* 2008;20:487–493; quiz 494.

32. Steigmann M, Wang HL. Esthetic buccal flap for correction of buccal fenestration defects during flapless immediate implant surgery. *J Periodontol.* 2006;77:517–522.

33. Park SH, Wang HL. Mucogingival pouch flap for sandwich bone augmentation: Technique and rationale. *Implant Dent.* 2005;14:349–354.

34. Steigmann M, Salama M, Wang HL. Periosteal pocket flap for horizontal bone regeneration: A case series. *Int J Periodontics Restorative Dent.* 2012;32:311–320.

35. Buser D, Dula K, Belser U, et al. Localized ridge augmentation using guided bone regeneration. 1. Surgical procedure in the maxilla. *Int J Periodontics Restorative Dent.* 1993;13:29–45.

36. Buser D, Dula K, Belser UC, et al. Localized ridge augmentation using guided bone regeneration. II. Surgical procedure in the mandible. *Int J Periodontics Restorative Dent.* 1995;15:10–29.

37. Wang HL, Misch C, Neiva RF. "Sandwich" bone augmentation technique: Rationale and report of pilot cases. *Int J Periodontics Restorative Dent.* 2004;24:232–245.

38. Becker W, Becker BE. Guided tissue regeneration for implants placed into extraction sockets and for implant dehiscences: Surgical techniques and case report. *Int J Periodontics Restorative Dent.* 1990;10:376–391.

39. Novaes AB Jr, Novaes AB. Soft tissue management for primary closure in guided bone regeneration: Surgical technique and case report. *Int J Oral Maxillofac Implants.* 1997;12:84–87.

40. Santana RB, de Mattos CM. Efficacy of vascularized periosteal membranes in providing soft tissue closure at grafted human maxillary extraction sites. *Int J Oral Maxillofac Implants.* 2009;24:81–87.

41. Fugazzotto PA. Maintaining primary closure after guided bone regeneration procedures: Introduction of a new flap design and preliminary results. *J Periodontol.* 2006;77:1452–1457.

42. Fugazzotto PA. Maintenance of soft tissue closure following guided bone regeneration: Technical considerations and report of 723 cases. *J Periodontol.* 1999;70:1085–1097.

43. Goldstein M, Boyan BD, Schwartz Z. The palatal advanced flap: A pedicle flap for primary coverage of immediately placed implants. *Clin Oral Implants Res.* 2002;13:644–650.

44. Tinti C, Parma-Benfenati S. Coronally positioned palatal sliding flap. *Int J Periodontics Restorative Dent.* 1995;15:298–310.

45. Tinti C, Parma-Benfenati S. vertical ridge augmentation: Surgical protocol and retrospective evaluation of 48 consecutively inserted implants. *Int J Periodontics Restorative Dent.* 1998;18:434–443.

46. Urban IA, Lozada JL, Jovanovic SA, et al. vertical ridge augmentation with titanium-reinforced, dense-PTFE membranes and a combination of particulated autogenous bone and anorganic bovine bone-derived mineral: A prospective case series in 19 patients. *Int J Oral Maxillofac Implants.* 2014;29:185–193.

47. Hur Y, Tsukiyama T, Yoon TH, et al. Double flap incision design for guided bone regeneration: A novel technique and clinical considerations. *J Periodontol.* 2010;81:945–952.

48. Hurzeler MB, Weng D. Functional and esthetic outcome enhancement of periodontal surgery by application of plastic surgery principles. *Int J Periodontics Restorative Dent.* 1999;19:36–43.

49. Chao YC, Chang PC, Fu JH, et al. Surgical site assessment for soft tissue management in ridge augmentation procedures. *Int J Periodontics Restorative Dent.* 2015;35:e75–e83.

50. Fontana F, Maschera E, Rocchietta I, et al. Clinical classification of complications in guided bone regeneration procedures by means of a nonresorbable membrane. *Int J Periodontics Restorative Dent.* 2011;31:265–273.