Surgical Site Assessment for Soft Tissue Management in Ridge Augmentation Procedures

Yi-Chi Chao, DDS1
Po-Chun Chang, DDS, MSc, PhD2
Jia-Hui Fu, BDS, MS3
Hom-Lay Wang, DDS, PhD4/Hsun-Liang Chan, DDS, MS5

The success of bone augmentation is usually dependent on primary wound closure. This review provides a literature-based system to assess the predictability of achieving primary wound closure. Seven pertinent factors that determine the risk for wound exposure were identified: (1) the width of keratinized mucosa, (2) flap thickness, (3) flap tension, (4) vestibular depth, (5) type and size of the bony defect, and (7) materials used. Clinical cases are used to demonstrate evaluation of these factors. This evaluation system may aid clinicians in differentiating cases with various risks of wound exposure and making decisions on flap modifications and the most appropriate surgical designs. (Int J Periodontics Restorative Dent 2015;35:e75–e83. doi: 10.11607/prd.2097)

In past decades, because of their high long-term success rates, dental implants have emerged as the key treatment modality for restoring edentulous spaces. However, the loss of a tooth inevitably creates a hard tissue and/or soft tissue defect at the residual ridge, thus complicating the rehabilitation process.1 Multiple techniques, such as guided bone regeneration (GBR), block graft, sinus augmentation, ridge split/expansion, and distraction osteogenesis have been developed, attempting to reconstruct the residual ridge to adequate dimensions so that the implant can be placed in the ideal prosthetically driven three-dimensional position.2,3 Although these techniques have been proven to be effective, their success primarily depends on the ability to maintain wound closure throughout the healing period.4–6

Primary wound closure is thought to aid in containing graft materials, providing blood supply to the surgical site, and preventing bacterial contamination and mechanical irritation of the surgical site.5,7 As shown by a meta-analysis,8 sites with membrane exposure had five- to six times less new bone formation compared to sites without membrane exposure after GBR procedures. Thus, primary wound closure is desirable for successful bone augmentation procedures. It has been speculated that...
(1) flap damage during the surgery, (2) tension within the flap, (3) thin soft tissue biotype, and (4) surgical skills of inexperienced clinicians are the main factors associated with incision line opening. Characteristics of the flap, as mentioned before, and its management are indispensable to optimal wound healing. Therefore, the aim of this article is to review key features of the hard and soft tissues and relevant materials for flap design and management that may have a major influence on the predictability of achieving primary wound closure. Strategies for managing soft tissues are discussed and clinical cases illustrating the importance of these factors presented.

Case Reports

Case 1

This patient presented with a missing mandibular right first molar. It was planned to replace the missing tooth with an implant-supported crown. The site to be augmented had a moderate horizontal defect (>3 mm) with insufficient keratinized mucosa (KM) width (<3 mm) on the buccal ridge. The flap thickness, flap flexibility, and vestibular depth were considered adequate (Fig 1a). A titanium-reinforced polytetrafluoroethylene (PTFE) membrane (Cytoplast Ti-PTFE membrane, Osteogenics Biomedical), particulate bone allografts (Puros cortical allograft, Zimmer Dental) along with a tenting screw (Pro-fix Precision Fixation System, Osteogenics Biomedical) were selected for the ridge augmentation procedure. This case is therefore considered one with moderate risk of wound exposure.

One vertical cutback and periosteal releasing incision was made on the buccal flap. Passive flap closure was also achieved with a blunt dissection of the lingual flap (Fig 1b). The membrane was molded to fit the shape of the defect and provide adequate coverage of the graft material. A fixation screw was subsequently used to stabilize the membrane (Fig 1c). The healing was uneventful at 3 weeks (Fig 1d). Ridge/bone augmentation was satisfactory at the time of implant placement 4 months later (Fig 1e).
Case 2

This patient presented with an edentulous mandibular posterior region. The site had a large combination defect, shallow vestibule, and insufficient KM (Figs 2a and 2b). Based on the assessment, this case was considered to have a high risk of wound exposure; therefore, a free gingival graft (FGG) was planned first (Fig 2c). Two vertical releasing, cutback, and periosteal releasing incisions were made to facilitate flap advancement (Fig 2d). During the bone augmentation procedure, two tenting screws were placed as tent poles and particulate allograft (enCore combination allografts, Osteogenics Biomedical) was used as a scaffold for bone formation (Fig 2e). The titanium mesh (Osteo-Mesh TM-300, Osteogenics Biomedical) was placed on top of the tenting screws and secured with fixation screws. Five months after the ridge augmentation procedure, the edentulous ridge had satisfactory bone width and height gain (Figs 2f and 2g). The implants were restored with two single crowns in 4 months. The free mucosal margins of the implant crowns were at the level of the adjacent tooth’s margins (Fig 2h).
This patient presented with a failing mandibular posterior fixed partial denture. The mandibular left first premolar was deemed nonsalvageable because of a combined periodontal-endodontic lesion, which resulted in severe bony destruction, as shown in the periapical radiograph (Fig 3a). After elevating a buccal flap, the socket was shown to be devoid of the buccal plate (Figs 3b and 3c). A nonresorbable membrane (Cytoplast PTFE membrane, Osteogenics Biomedical) was secured with two fixation screws after particulate bone grafts were placed (Fig 3d). Membrane was left exposed to perform the open wound technique. An implant was not planned for the distal extraction socket; therefore, a collagen plug was placed in that socket (Fig 3e). Two implants were placed while reconstruction of the buccal bone was observed at the 4-month follow-up (Fig 3f).
(Puros cortical allograft, small particle, Zimmer Dental) was placed in the socket (Fig 3d). The membrane was left exposed (Fig 3e). At the time of implant placement, the buccal bone was observed to be fully reconstructed (Fig 3f).

Discussion

Soft tissue features

Four key features are important in achieving primary wound closure: (1) width of KM, (2) flap thickness, (3) flap flexibility (tension), and (4) vestibular depth (Fig 4). Adequate KM width on the edentulous ridge is generally desirable because it may determine the tear resistance of the flaps under suture tension. A study comparing vertical ridge height gained between block and particulate bone allografts showed that when the KM width was less than 3 mm, the incidence of incision line opening was almost twofold greater than sites with KM width of 3 mm or more. It is thus proposed that sites with KM width of less than 3 mm have an increased risk of wound opening. An FGG, the gold standard for increasing KM, may be indicated for these sites. Furthermore, it was found that implants with an adequate band of KM were more resistant to plaque accumulation, mucosal inflammation, attachment loss, and mucosal recession, especially in the rough-surfaced coated implants. Therefore, if KM width is found to be inadequate, it may be indicated to increase KM width before performing any bone augmentation procedures.

Studies have demonstrated that a thicker flap provides greater mechanical strength, enhances revascularization, and increases bone regeneration and thus improves resistance to incision line opening and incorporation of graft materials into the recipient site. A clinical trial concluded that a thicker flap (≥ 1 mm) had significantly lower incidence of incision line opening compared with a thin flap when subjected to flap tension of 15 g or more. In addition, the literature on root coverage procedures states that when the flap thickness is 1 mm or more, the incidence of complete root coverage is higher. Therefore, it is proposed that having a thick flap (≥ 1 mm thickness) is beneficial to achieving and maintaining primary wound closure.

The degree to which a flap can be advanced is related to the flexibility (tension) of the flap. The number of elastic fibers, thickness of the periosteum, and components of the extracellular matrix in the flap may account for the differences in flap tension among individuals. Generally, a highly flexible (lower tension) flap is more desirable than a taut flap such that there is zero tension on the flap is more important than flap thickness. This is because under zero tension, both thick and thin flaps perform equally well in maintaining primary wound closure, but if there is slight flap tension, a thick flap is preferred.

A shallow vestibule poses anatomic limitations in advancing a flap. The flexibility of a shorter flap is decreased because of the shallow vestibule; therefore, greater force is needed to approximate the flap edges. Because the flap is short, its base is closer to the insertion of peri-oral muscles such as the orbicularis oris and buccinator muscles. Muscle pulls have an adverse effect on wound stability and closure.

Defect features and materials used

Compared with a vertical or combination defect, a horizontal defect is relatively easier to manage. This is possibly because of greater surface area of bony walls available to contain the graft material and provide revascularization. Studies have shown a higher incidence of wound opening for vertical ridge augmentation compared with horizontal ridge augmentation. According to the horizontal, vertical, and combination (HVC) classification, a large defect is one that is 3 mm or greater, and requires greater flap advancement, making it much more challenging. Graft materials that are used for augmentation procedures may influence wound closure. Compliant membranes, such as absorbable...
and PTFE membranes, are gentler to the flap compared with titanium-reinforced membranes and titanium meshes, which can potentially open the wound because they have a tendency to revert to their original shape after being molded to cover the defect.29–31 Another consideration is the influence of materials on flap vascularity. Nonresorbable membranes may impede early vasculature anastomosis of the flap and regenerated tissues,32 resulting in inadequate blood supply and thus predisposing to wound exposure. In addition, they are more prone to infection if unfortunately exposed.33 Therefore, rigid and nonresorbable materials require more meticulous flap management.

Management strategies for flap advancement

With the aforementioned discussion in mind, it is proposed that these seven factors be considered carefully before ridge augmentation (Table 1). Cases that are at a higher risk for wound exposure are sites with KM width of more than 3 mm, thin flap thickness (< 1 mm), low flap flexibility (high tension flap), low vestibular depth, a combination (vertical and horizontal) or vertical defect of more than 3 mm ridge deficiency, or use of rigid/nonresorbable materials. The more parameters that meet the high-risk criteria, the higher the probability of wound exposure with bone augmentation procedures. Therefore, for high-risk cases, the flap has to be modified accordingly to maximize the opportunity of primary wound closure. However, flap modifications are technique sensitive and may lead to longer surgical time, higher cost, and increased patient morbidity. For example, vertical incisions might sever the lateral blood supply of the flaps.34 When vertical incisions were incorporated in coronally advanced flaps for root coverage, the incidence of complete coverage and postoperative course of healing were inferior.35 Thus, the “as simple as possible” rule should always be followed for designing flaps.19

For correcting a small bony defect, an envelope flap may be sufficient. If more flap advancement is required, several methods are available with various effects to facilitate flap advancement for wound closure (Table 2). A periosteal releas-

---

**Table 1 Factors to be considered before bone/ridge augmentation**

<table>
<thead>
<tr>
<th>Factors</th>
<th>Risk of wound opening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of KM</td>
<td>≥ 3 mm</td>
</tr>
<tr>
<td>Mucosa thickness</td>
<td>&gt; 1 mm</td>
</tr>
<tr>
<td>Vestibular depth</td>
<td>Adequate</td>
</tr>
<tr>
<td>Flap flexibility</td>
<td>High</td>
</tr>
<tr>
<td>Bony defect type</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Bony defect size</td>
<td>&lt; 3 mm</td>
</tr>
<tr>
<td>Membrane used</td>
<td>Absorbable membrane</td>
</tr>
</tbody>
</table>

KM = keratinized mucosa; PTFE = polytetrafluoroethylene.

**Table 2 Various flap designs and modifications to facilitate wound healing**

<table>
<thead>
<tr>
<th>Flap modification</th>
<th>Biologics</th>
<th>Open wound technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGG</td>
<td>PRP</td>
<td>PTFE membrane</td>
</tr>
<tr>
<td>Vertical releasing</td>
<td>PDGF</td>
<td>Other absorbable membrane</td>
</tr>
<tr>
<td>Periosteal scoring</td>
<td></td>
<td>(eg, amniotic and extracellular membranes)</td>
</tr>
<tr>
<td>Cutback incision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascularized connective tissue flap (maxilla)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double flap design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periosteal pouch technique</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lingual extension (mandible)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FGG = free gingival graft; PRP = platelet rich plasma; PTFE = polytetrafluoroethylene; PDGF = platelet-derived growth factor.
ing incision is able to extend a flap significantly more than two vertical releasing incisions, whereas a single vertical releasing incision only exerts a modest effect.36 A cutback incision, a horizontal incision at 45 to 60 degrees toward the center of the flap, is another technique to increase flap advancement.37

In the vascularized connective tissue flap design, the overlying soft tissue is split via split thickness incisions so that there is more soft tissue over the augmented site for primary wound closure in the maxilla.38 A double flap incision design was introduced to reduce tension caused by the periosteum on the flap.39 The buccal flap was split into the mucosal and periosteal layer. The periosteal layer is used to stabilize the membrane and the tension-free mucosal layer is used to maintain wound closure. The periosteal pocket flap, similar to the double flap design, involves creating a periosteal pouch at the site of augmentation.40 Bone substitutes and the membranes are placed within the partially enclosed pouch, thus increasing stability of the graft materials and the blood clot. It was reported that the augmented sites did not have any postoperative complications, and a mean 4.3 mm of horizontal ridge augmentation was achieved. In the mandible, the lingual flap can be further released by blunt dissections apicocoronally beyond the mucogingival junction to the insertion of the mylohyoid muscle and mesiodistally across several adjacent teeth.41

The future of soft tissue management

Biologic agents, eg, platelet rich plasma (PRP) and platelet-derived growth factor (PDGF), activate migration, proliferation, and differentiation of various cells that are essential for wound healing. High concentration of angiogenic and mitogenic growth factors in PRP, such as transforming growth factor beta,42 PDGF, and epidermal growth factor43 may decrease inflammation, increase early wound strength, and result in early deposition of collagen, glycosaminoglycan, and fibronectin. A comparative study44 suggested that the application of PRP had no titanium mesh exposure, compared with almost 30% when it was not used. A case series45 using PDGF for vertical ridge augmentation resulted in satisfactory soft tissue healing. The evidence suggested that biologic agents might be used for accelerating the early phase of wound healing in cases with a higher risk of wound exposure, thereby aiding in maintaining primary wound closure over the healing period.

Although primary wound closure is essential in GBR, it may not be mandatory for socket augmentation. Having the extraction site heal by secondary intention preserves the vestibular depth and the KM width. The PTFE membranes, an inert barrier to stabilize the blood clot and prevent migration of bacteria and epithelial cells, have been used for this indication.46 Absorbable membranes that may contain signaling proteins or growth factors for tissue repair may also be used in this manner, such as the amniotic membrane (BioXclude, Snoasis Medical)47–49 and the extracellular membrane (DynaMatrix, Keystone Dental).50 However, their ability to withstand early degradation when exposed in the oral cavity remains to be demonstrated.

Conclusions

A thorough evaluation of soft tissue conditions helps to determine the corresponding management for desired wound healing. It is also important to consider the types of bone defects and materials used for selecting proper flap designs and modifications. Further research is required to validate this assessment system. Biologic agents might be used to accelerate wound healing for challenging cases. The open wound technique for socket augmentation with the use of PTFE or other absorbable membranes deserves further investigation.

Acknowledgments

The authors reported no conflicts of interest related to this study.

References

3. Chiapasco M, Zaniboni M, Boisco M. Augmentation procedures for the rehabilita-

4. Fugazzotto PA. Maintenance of soft tissue closure following guided bone re-
    generation: technical considerations and report of 723 cases. J Periodontol 1999;
    70:1085–1097.

5. Lang NP, Hammarle CH, Bragger U, Lehmann B, Nyman SR. Guided tissue regenera-

6. Wang WL, Boyapati L. “PASS” principles for predictable bone regeneration. Im-

7. Burkhardt R, Lang NP. Role of flap tension in primary wound closure of mucoperi-

8. Machtet EE. The effect of membrane exposure on the outcome of regenerative

9. Fontana F, Mascher A, Rocchieta I, Simion M. Clinical classification of com-
    plications in guided bone regeneration procedures by means of a non-resorb-

10. Burkhardt R, Preiss A, Joss A, Lang NP. Influence of suture tension to the ear-

11. Daylene JM, Leong T-JO, Benavides E, Misch CE, Wang H-L. Comparison Be-
    tween Sandwich Bone Augmentation and Allogenic Block Grafting for Vertical Ridge Augmentation in the Posterior
    Mandible, thesis.

12. Thoma DS, Benic Gl, Zwahlen M, Ham-
    merle CH, Jung RE. A systematic review assessing soft tissue augmentation

    Appl Biomater 2013.

14. Lin GH, Chan HL, Wang HL. The significan-

15. Wilderman MN, Penel BM, King K, Bar-
    ron JM. Histogenesis of repair following osseous surgery. J Periodontol 1970;41:
    551–565.


