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REVIEW ARTICLE

MANAGEMENT OF HORIZONTAL RIDGE DEFECTS

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ABSTRACT

Following tooth removal/extraction, horizontal bone loss occurs at a faster rate and to a greater extent compared to vertical bone loss. Horizontal ridge defects are of increased concern for the placement of dental implants and implant-supported dental prosthesis. Various techniques have been proposed to treat horizontal ridge defects and create sites favorable for dental implant placement. These techniques vary depending upon factors such as the tissue thickness, arch position, and availability of autogenous bone. Each technique has its own advantages and disadvantages & predictive success level. This review focuses on various techniques available to augment horizontal ridge defects for dental implant placement.

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INTRODUCTION

Following tooth removal/extraction, there is an inevitable three-dimensional (3D) loss of alveolar bone. More often than not, horizontal bone loss occurs at a faster rate and to a greater extent compared to vertical bone loss. This has led to the development of several horizontal bone augmentation techniques and numerous materials currently available. It is often difficult to choose the most suitable treatment modality. To validate this decision-making process, Fu and Wang (2011) proposed 'The decision tree' which stems from the 3D buccolingual bone width available at the site of implant placement (Figure 1). In each dimension, techniques are advised after considering factors such as the tissue thickness, arch position and availability of autogenous bone.

Sandwich bone augmentation (SBA) technique (Wang *et al*., 2004; Park *et al*., 2008; Fu and Wang, 2011; Fu and Wang, 2012)

The concept of Guided Bone Regeneration (GBR) was developed for implant dentistry, based on the promising results achieved using GTR for periodontal defects. The American Academy of Periodontology (2001), defined GBR as "procedures attempting to regenerate or augment bone for proper dental implant placement". It has demonstrated predictable bone gain through 'PASS' principle (Primary wound closure, promoting Angiogenesis, maintaining Space for regeneration & obtaining primary implant, and blood clot Stability) (Wang and Boyapati, 2006). The sandwich bone augmentation (SBA) technique is a unique form of GBR that can be used simultaneously with implant placement (Figure 2) (Buser *et al*., 1995).

Indications

1. Horizontal alveolar ridge defect of ≥ 3.5 mm with predictable primary stability.
2. Immediate implant placement.

Contraindications

1. Medically compromised patients.
2. Presence of active infection.

Advantages

1. Reduces treatment time.
2. Eliminates a second surgical procedure.
3. Cost-effective.
4. Delivers positive treatment outcomes for the patient.

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Limitations

1. Technical difficulty associated with achieving primary stability.
2. Membrane exposure.
3. Inability of the resorbable membrane to maintain space.

Rationale

The main component of SBA technique is autogenous bone chips or a fast-resorbing particulate cancellous allograft, which constitutes the first layer and is applied immediately against the implant surface. Creeping substitution of the inner cancellous layer will thus, boost the bone-to-implant contact during the initial healing phase. If the autograft is not sufficient to cover the defect up to the level of adjacent bone, additional bone grafts are needed. Demineralized freeze-dried bone allograft (DFDBA) is the first choice, since it mainly constitutes collagen and releases bone morphogenetic proteins (BMP – 2, -4, -7), which are known to induce bone formation at the defect site. A second layer of slow-resorbing particulate cortical allograft is placed before an absorbable membrane is used to cover the site. It undergoes reverse creeping substitution, thus prolonging space maintenance for bone regeneration. The close proximity among the implant surface, autograft, DFDBA, and surrounding host bone creates an ideal environment for migration and proliferation of osteogenic cells and subsequent replacement of the graft materials by newly formed bone. To ensure that the space needed for augmentation is created/maintained, bovine HA is layered (outer layer) over the grafted area. It is covered up to 2-3 mm (buccolingual direction) beyond the adjacent bone level. In addition, to avoid the invasion of soft tissue cells into the layered graft materials, the use of a barrier membrane is recommended. Absorbable collagen membranes are preferred due to –

1. High biocompatibility with oral tissues,
2. Hemostatic properties,
3. Chemotactic effects on fibroblasts ensuring adequate wound closure, and
4. Lack of need for retrieval.

Factors affecting the success of SBA Technique[2]

1. Primary implant stability – It must be achieved prior to bone augmentation because mobile implants (micromovements of >100μm) often heal with fibrous encapsulation, thereby, compromising osseointegration.
2. Primary wound coverage with passive tension – A sealed environment would eliminate the negative influence of oral microbial flora and promote uneventful healing.

Surgical technique (Wang *et al*., 2004)

The SBA technique employs 3 layers of bone graft materials and an absorbable collagen membrane to exclude the migration of undesirable soft tissue cells from the wound.

Patient selection: Clinically, patients with moderate gingival biotype, adequate width of keratinized tissue and a lateral ridge defect of ≥ 3.5 mm with predictable primary implant stability are selected for this technique.

Flap design: The incisions are designed in accordance with the following 5 goals –

A. Access to the bone defect.
B. Maintenance of blood supply of the elevated flap and the neighboring tissues.
C. Preserving the interdental/inter-implant papillae.
D. Providing sufficient advancement of the flap.
E. Allowing tension-free primary closure.

Proposed flap designs (Park and Wang, 2005):

a. Mucogingival Pouch Flap (MPF).
b. Vestibular approach.
c. Split flap approach
d. Coronally positioned palatally sliding flap.
e. Rotational buccal pedicle flap.

The MPF design have overcome some of the limitations faced by the earlier designs, emphasizing particularly on early wound healing, improved graft retention, minimized membrane exposure, and improved esthetics.

a. A full-thickness midcrestal (or slightly facial to the midcrest) incision is made between the teeth bordering the defect. If the defect extends to 2 or more teeth, the incision is made extending one tooth mesial and distal to the defect (or in fully edentulous arches a 1-to-2-tooth distance beyond the borders of the defect).
b. 2 full-thickness vertical incisions (preserving the bordering papillae) are then made down to the bone, starting in the area of the base of the vestibule and continuing coronally in one continuous cut to meet the crestal incision. The vertical incisions are made parallel or trapezoidal with the base, widening apically to ensure an adequate blood supply and easy coronal repositioning of the flap after augmentation with the graft material.
c. In an edentulous area, the incision design is a rectangular shape, whereas in a dentulous area, the vertical incisions extend apically up to the root apices. These incisions extend past the mucogingival junction into the mucosa and are designed to preserve the mesial and distal papillae while maintaining the blood supply of the neighboring tissue.
d. The papillae and keratinized tissue on the adjacent teeth can be preserved utilizing a Z-shaped incision slightly coronal to the mucogingival junction on the adjacent teeth and continuing apically in a vertical direction to the mucosa.

Recipient Site Preparation

1. The bony defect is debrided of granulation tissue and tissue tags, using curettes and back-action chisels.
2. Cortical perforations (decortications) are then made with a #1 or #2 round bur using high speed with copious irrigation to induce bleeding at the surgical site.
3. Following wound hemostasis, these decortications will help promote graft contact and stability.

Releasing Incisions

1. Periosteal releasing incisions are made with a sharp 15C blade on the inner apical portion of the flap, between

Incision design [Figure 3]	Dimension	Rationale
1.Semilunar crestal incision	Same as keratinized gingival width of the adjacent teeth. In case of gingival recession, it is added to the keratinized gingival width in determining the incision position.	Maximize the flap survival.
2.Papilla preservation incision	1-1.5 mm from the adjacent teeth.	- Avoids tooth-to-membrane contacts. - Serves as an additional guide to prevent the violation of biologic distance from adjacent teeth during osteotomy preparation.
3.Partial vertical incision	Full keratinized gingival length	Visualization.
4.Mucogingival junction (MGJ) incision	A beveled vertical incision is continued along the MGJ until adequate visualization of the defect site is achieved.	- "Soft Tissue Camouflage" – minimizes scar tissue formation because the scar formed is likely to be hidden by the natural MGJ.
5.Pouch flap reflection	5 mm beyond the defect.	Graft retention.
6.Semilunar periosteal scoring	In alveolar mucosa.	Each periosteal scoring allows for 2-3 mm of segmental flap advancement without excessively pulling the flap base.

Advantages	Indications	Cautions
1.Safe in mental nerve area. 2.Easy flap treatment and facilitate wound healing in a thin/narrow keratinized gingiva. 3.Esthetic zone.	All guided bone regeneration procedures (horizontal, vertical and combination classification).	1. Interdental distance <6mm. 2. Thick/occluding membrane. 3. Depth of the implant placement.

the vertical incisions, creating a 2-3mm split-thickness dissection. These releasing incisions allow for better flap release and subsequent advancement for the flap closure.

2. Moreover, a thick biotype of the tissue in the apical area of vertical incision reduces the risk of flap perforation, provides an abundant blood supply and limits the trauma to the augmented site.
3. Making these periosteal incisions early in the surgery is recommended, while good visibility is present, to allow easy access to the apical periosteum for the stabilizing sutures. This exposed apical periosteum will be used as anchorage for the membrane-stabilizing sutures.

Graft material and Membrane placement

1. The inner bone graft layer is composed of autogenous bone. Autograft collected during osteotomy preparation (osseous coagulum) is applied directly against the surface of the implant, providing viable osteogenic cells and enhancing migration of cells from the host bone into the surface of the implant.
2. The middle bone graft layer is composed of DFDBA or human demineralized allograft.
3. The outer bone graft layer is composed of dense particles of HA, which acts as a scaffold/space occupier because of its osteoconductive properties and facilitates new bone formation.
4. After application of these layers of bone graft, a collagen membrane is applied to cover the recipient site.
5. Collagen membranes are preferable because of their physiologic absorption process and high biocompatibility with oral tissues. In addition, collagen is a hemostatic agent and possesses the ability to stimulate platelet aggregation and enhance fibrin linkage, which may lead to initial clot formation, stability, and maturation. Furthermore, collagen is chemotactic for fibroblasts in vitro (Frost *et al*., 2014). This property could enhance cell migration and promote the primary wound coverage that is key for bone augmentation.

Stabilization of the Graft material and Barrier Membrane

Stabilization of the membrane and the underlying graft material is achieved by using horizontal mattress sutures extending from the apical portion of the facial periosteum to the palatal aspect of the flap. To minimize the risk of irritation and infection on the palatal aspect, the suture knot is positioned and stabilized inside the flap and only 2-3 mm of suture is exposed palatally. Proper containment and stabilization of the graft material and membrane with these sutures, combined with pressure on the surgical site with nonwoven moist gauze, is critical in preventing secondary ("rebound") bleeding that may occur when the vasoconstrictors in the anesthetic have dissipated.

Suturing to advance the flap coronally

The mucoperiosteal flap is then coronally repositioned for complete wound coverage without tension. Techniques for flap release include apical partial-thickness elevation and/or dissection of the periosteum which are normally associated with vertical releasing incisions.

Healing

Sutures are generally removed 10-14 days after surgery. The patient should be seen every 4-6 weeks for evaluation of the wound healing progress. If initial membrane exposure is avoided, healing normally proceeds uneventfully.

Maintenance

Recall visits at once in a month include examination of the surgical site, debridement of the surgical site and provisional restoration.

Guided bone regeneration (GBR)/staged approach

The concept of GBR was described first in 1959 when cell-occlusive membranes were employed for spinal fusions.

Indications

1.As an alternative to simultaneous approach in treating dehiscence- or fenestration defects.

Rationale

GBR and GTR are based on the same principles that use barrier membranes for space maintenance over a defect, promoting the ingrowth of osteogenic cells and preventing migration of undesired cells from the overlying soft tissues into the wound. The sequence of bone healing is not only affected by invasion of non-osteogenic tissue, but also by the defect size and morphology. To accomplish the regeneration of a bone defect, the rate of osteogenesis extending inward from the adjacent bony margins must exceed the rate of fibrogenesis growing in from the surrounding soft tissue. A staged approach is preferred where autogenous bone grafts either in blocks or particulate form are firmly secured onto the ridge and a barrier membrane is placed (Figure 3). Primary closure of the wound site is attained, and the site is left to heal for 4 - 6 months before implant placement (McAllister and Haghighat, 2007; Mellonig, and Nevins, 1995). The placement of a cell-occlusive barrier membrane between the gingival connective tissue of the flap and the bone creates a space for the formation of blood clot. Space making is critical, because it allows cells in the isolated space to undergo an amplified cell division in a stabilized environment. Also, this physical barrier protects the blood clot by diverting mechanical stress that acts on the tissue flap during the early stages of wound healing. Micromovement of the flap over the blood clot during initial wound healing directly influences cellular differentiation. Movement of 10-20 μm during the early stages of healing is enough to divert the differentiation of mesenchymal cells from osteoblasts to fibroblasts (Haney *et al*., 1993).

Advantages

1. Space provision over a horizontal defect.
2. Promotes the in-growth of osteogenic cells while preventing migration of undesired cells from the overlying soft tissue.

Surgical technique (Buser et al., 1995; Buser et al., 1999)

1. Administration of local anesthesia.
2. A buccal split-thickness incision is placed at approximately 4mm from the mucogingival junction (Figure 4a and 4b). The intact soft-tissue cover is reflected.
3. At the mesial aspect of the flap, the incision is extended into the sulcus of the adjacent tooth. Distally, the flap is extended into the retromolar area to harvest a corticocancellous bone graft.
4. Following supraperiosteal preparation, the periosteum is cut at the level of mucogingival junction.
5. Subsequently, the combined split-thickness and full-thickness flap are carefully elevated with a fine periosteal elevator and held away with retraction sutures (Figure 4c).
6. Numerous perforations are drilled into the cortical bone with a small round bur (decortication) (Figure 4d).
7. The site in the retromolar area is selected to harvest 2 corticocancellous bone grafts (Figure 4e). The harvesting procedure is initiated with a small round bur to mark the outline of grafts by drilling holes.
8. The grafts are perforated in the center portion with a small, 2.2mm pilot drill – this allows stable fixation to the recipient site with miniscrews (Figure 4f and 4g).
9. A space of approximately 3 mm is left between the 2 grafts - this allows for a larger extension for the augmentation procedure.
10. Placement of the graft – i. cortical surface faces buccally. ii. Cancellous surface is in close contact to the host bone with its perforated cortical layer.
11. The barrier membrane is approx. shaped to extend 3-4 mm beyond the defect margin – this allows for close adaptation of the membrane to the surrounding bone.
12. Small holes are drilled in the membrane using a membrane punch.
13. The membrane is applied to the surgical site and affixed to the bone with 3 fixation screws on the buccal aspect (Figure 4h and 4i).

a.The tent screw has 3 primary functions (Misch, 2008)

i. It gives a visual indication of how much autograft should be harvested.
ii. It helps to maintain space under the barrier membrane during bone formation.
iii. It decreases the movement of particulate graft under the transitional prosthesis.

14. The remaining spaces around the bone grafts are filled with bone chips – this creates the desired shape of the new alveolar crest. Subsequently, the membrane is closely adapted to the newly created alveolar crest & tucked underneath the mucoperiosteal flap on the lingual aspect.
15. Furthermore, the membrane is precisely trimmed with a scalpel close to the adjacent tooth mesially to create a small zone of uncovered bone – this allows complete flap adaptation and minimize the potential for membrane contamination from the sulcus.
16. Wound closure → Initially, 4 vertical mattress sutures are given, followed by numerous interrupted sutures for close adaptation of the wound margins. A distance of 3-5 mm of the keratinized mucosa between 2 sutures is important to prevent the rupture of soft tissue (Figure 4j and 4k).
17. 7 days following surgery, the interrupted sutures are removed and wound is gently cleansed.
18. 14 days following surgery, the vertical mattress sutures are removed and patient is subsequently scheduled for weekly follow-up until primary soft-tissue healing is achieved (4 weeks). After this, the recall visits are only once in 6 weeks to check for the soft tissue status.
19. 9 months following the membrane surgery, the site is re-opened with a crestal incision.
20. The miniscrews and membrane are removed and a gain in the crest width is revealed (Figure 4l).

Onlay graft (block graft)

Onlay bone grafts are used for external augmentation of horizontal (veneer graft), or vertical alveolar deficiencies as well as combined defects (saddle graft) (Prasad *et al*., 2014)

Indications (Waasdorp and Reynolds, 2010; Prasad et al., 2014)

1. In situations where primary stability cannot be achieved in residual ridge width <3.5mm.
2. When harvested from the symphysis – can be used for predictable bone augmentation up to 6 mm in horizontal and vertical dimensions. Up to 3-teeth edentulous site can be grafted. Bone density of the graft – D1 or D2.
3. When harvested from ramus – used for horizontal or vertical augmentation of 3 to 4 mm. Bone density of the graft – D1.

Advantages (Waasdorp and Reynolds, 2010; Toscano et al., 2011)

1. Large volume of bone that can be harvested and carved into various shapes.
2. Self- contained and provide an inherent ability to support the soft tissue.
3. Preferable, corticocancellous block grafts enhance revascularization of the cancellous portion, and mechanical support and rigidity of the cortical portion.

***Drawbacks* (*Waasdorp and Reynolds, 2010*)**

1. Temporary paresthesia when harvested from chin.
2. Unpredictable graft resorption.
3. Higher risk of wound dehiscence and osseointegration failure.
4. Total graft loss.
5. Lower values of bone-to-implant contact and compromised implant position, thereby making the one-step procedure undesirable from a prosthetic viewpoint.

***Rationale* (*Waasdorp and Reynolds, 2010*)**

Autogenous bone grafts may be derived from intraoral or extraoral donor sites. Intra-oral sources for block grafts are symphysis, body and ramus of the mandible with ramus being the preferred site as local consequences of graft harvest are less. Intraoral graft site is preferred when augmenting smaller defects. Allogenic bone may also be used as an onlay graft. If autogenous bone grafts are used, it is highly recommended to use corticocancellous bone blocks. Compression screws are placed to fix bone blocks to the residual alveolar crest that should be extensively perforated to increase blood supply to the host-graft interface. Cancellous bone alone and particulate bone, if not associated with membranes of titanium meshes, do not provide sufficient rigidity to withstand tension from the overlying soft tissues or from the compression by provisional removable dentures, and may undergo almost complete resorption. Implant placement may be immediate or delayed.

***The Art of Block Grafting* (*Toscano et al., 2011*)**

Sources for harvesting bone blocks: Intra-oral – Autogenous; Extra-oral – Autogenous, Allogenous.
Sites: Intra-oral - Mandibular symphysis and the ramus buccal shelf.

Symphysis Block Graft Harvesting

Bone block graft size available from this location has been found to be an average of 10 mm (height) x 15 mm (width) x 6 mm (thickness), with a bone volume of approximately 860 mm. The symphysis offers over 50% larger graft volume than that obtained from the mandibular ramus. The average symphysis graft has been found to be composed of 65% cortical bone and 35% cancellous bone. This corticocancellous nature of bone facilitates faster vascular in-growth once the block has been placed, resulting in more rapid integration and less potential resorption during healing. Moreover, bone blocks harvested from sites formed by intramembranous mechanisms (intraoral) have been shown to revascularize faster than those from an endochondrally (extraorally) derived formation pathway. Rule of 5's – The "Rule of 5's" must be implemented in assessing and performing block harvest. This rule requires that at least 5mm of uninvolved bone is present beyond the proposed osteotomy margins of the block and the surrounding structures, providing a margin of safety to prevent potential morbidity. Symphyseal thickness must be sufficient for obtaining the desired block size without violating the lingual cortex of the mandible (Figure 6). The sulcular and attached gingiva incisions involve full thickness mucoperiosteal flap reflection, lifting the mentalis muscle off with the periosteum as reflection proceeds to the inferior border of the anterior mandible. When performing the vestibular incision, a more technically demanding approach is needed. This incision is made through the mucosa 1-2 mm below the mucogingival junction followed by partial thickness dissection apically for 3 mm to preserve 3mm of periosteum and mentalis muscle fibers on the bone, which will later be used to reattach the mentalis muscle. A full thickness incision is made and the flap reflection is continued until the mental foramina are located and the inferior border of the mandible is reached. Once these structures are identified, the "rule of 5's" can be applied to identify the target area for safe block harvest. The block outline must be 2 mm larger than the target size to permit contouring of the block after removal. Osteotomy can be performed with a rotary bur, sagittal saw, or piezotome instrument. The latter two instruments are preferred over a rotary bur due to the narrow width of the resulting cut, reducing bone lost during osteotomy. While most rotary burs are at least 1 mm in diameter, use of a sagittal saw or piezotome instrument results in a precise cut of only 0.5- 0.7 mm in width which preserves bone and also results in comparatively less surgical trauma to the bone. When closing the vestibular approach, a resorbable suture is first used to secure the mentalis muscle to the 3 mm periosteal/muscle layer left on the bone during the initial incision. This is achieved by interrupted sutures at regular intervals across the mentalis release. The overlying mucosa is then closed with a continuous interlocking suture. For sulcular and attached gingiva incisions, the mentalis muscle remains attached to the periosteum and does not need to be sutured. Closure of these latter 2 incision types involves interrupted sutures at papilla areas (sulcular) or along the attached gingival incision line.

Drawbacks/Complications–

i. Post-operative morbidity.
ii. Incision dehiscence at the donor site – 10.7%
iii. Temporary paresthesia (for up to 6 months)– 9.6%
iv. Altered lower incisor sensation – 29%
v. Chin ptosis (esthetically unpleasing chin droop)

Ramus Block Harvesting

The mandibular ramus is nearly 100% cortical in nature. The mandibular ramus buccal shelf block graft provides adequate bone for augmentations involving a span of 2-3 teeth.

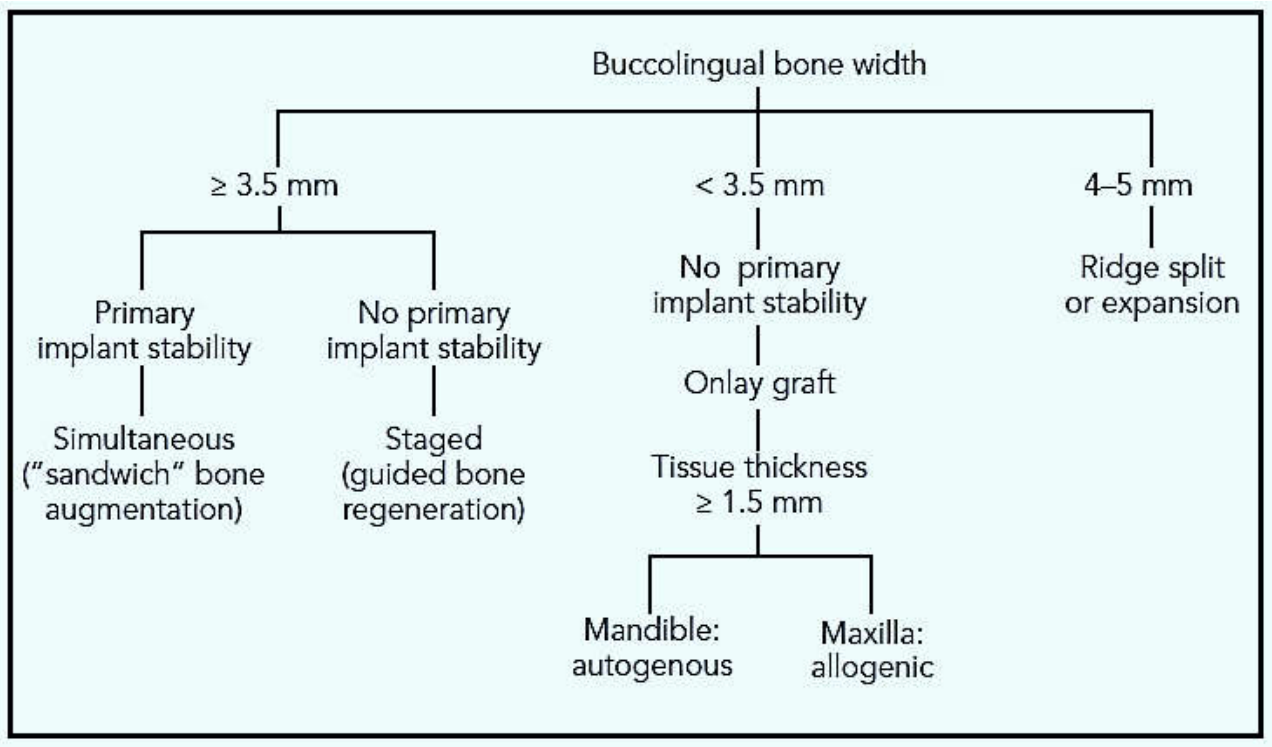

Figure 1. Horizontal bone augmentation – The Decision Tree

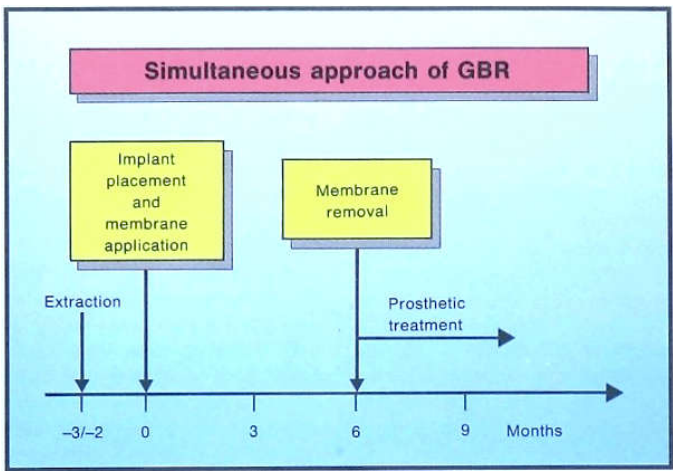

Figure 2. Simultaneous approach

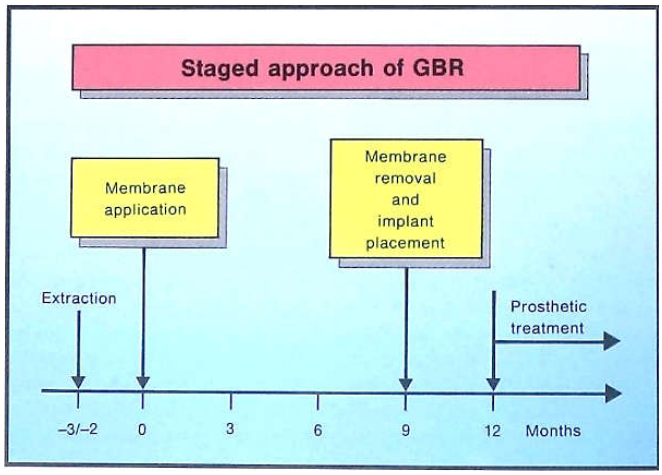

Figure 3. Staged approach

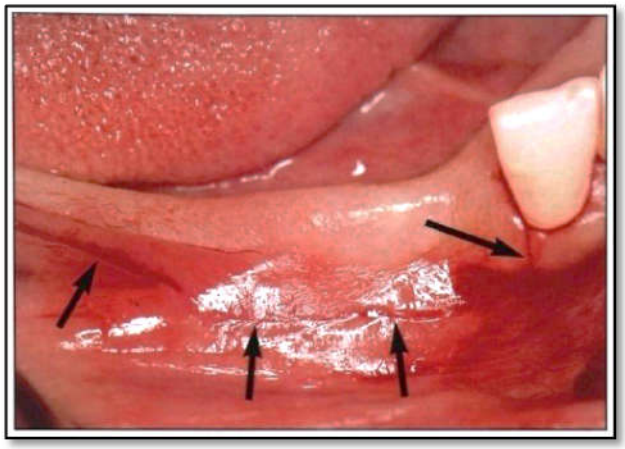

Figure 4a. Incision

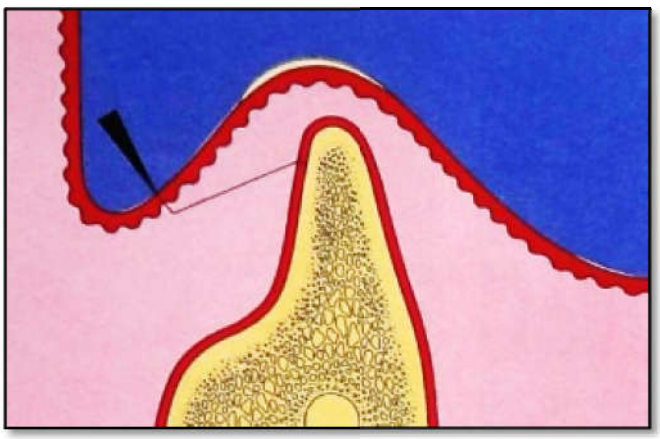

Figure 4b. Schematic representation of the incision

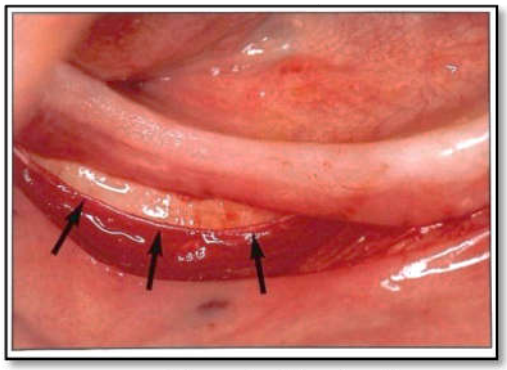

Figure 4c. Flap elevation

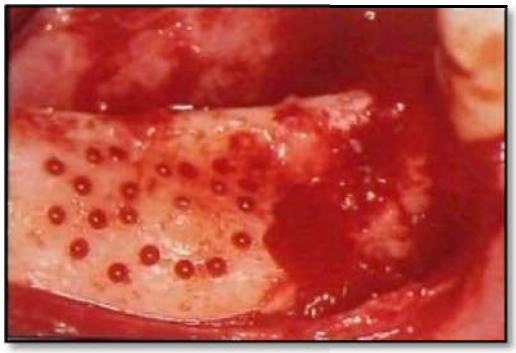

Figure 4d. Decortication

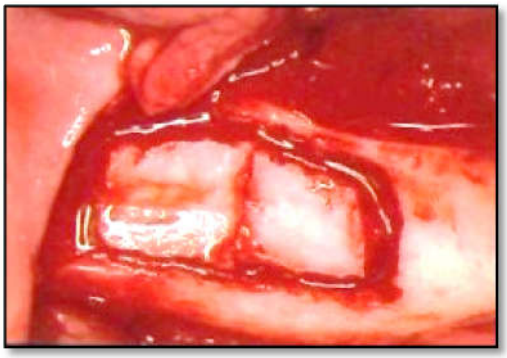

Figure 4e. Harvesting corticocancellous bone grafts

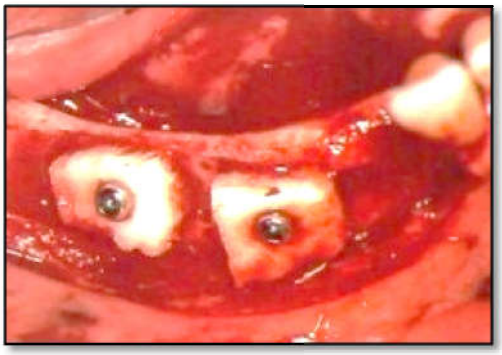

Figure 4f. Fixation of the graft with miniscrews

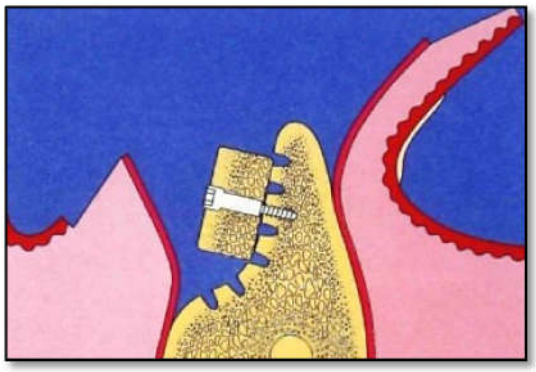

Figure 4g. Schematic representation of the graft fixation

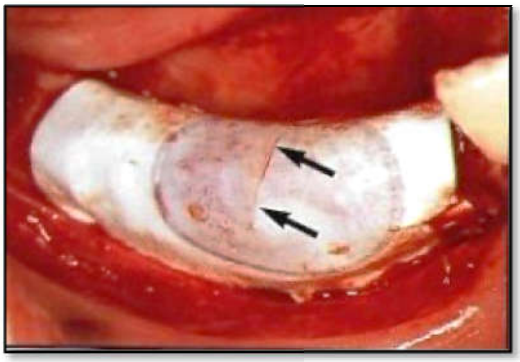

Figure 4h. Placement of a barrier membrane

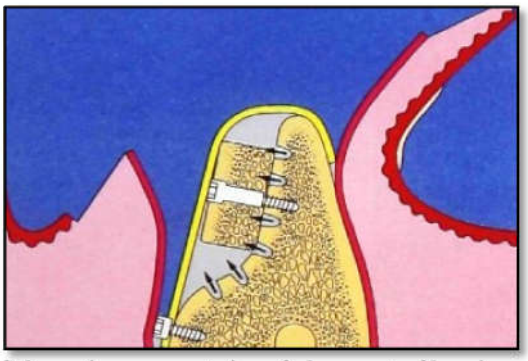

Figure 4i. Schematic representation of placement of barrier membrane

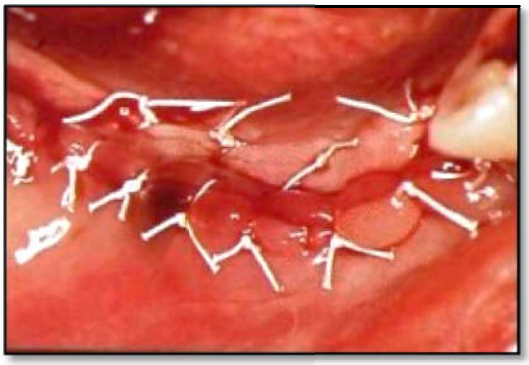

Figure 4j. Wound closure

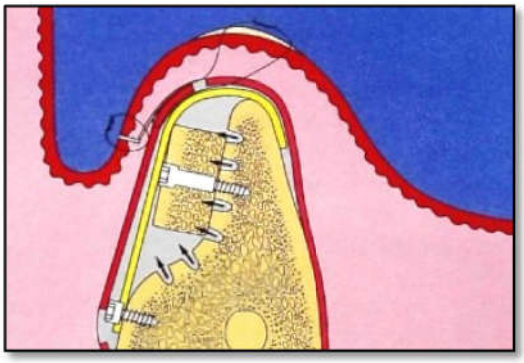

Figure 4k. Schematic representation of wound closure

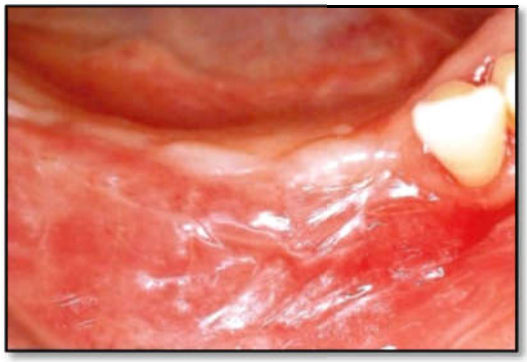

Figure 4l. Postoperative gain in crestal width

Horizontal as well as vertical augmentation of 3 to 4 mm can be achieved with this donor site, the former being more predictable. Ramus cortical bone blocks have a maximum thickness of 4 mm, providing a rectangular graft with a length approaching about 35 mm and a height of up to 10 mm, depending on patient specific anatomy. For the ramus graft, a minimum distance of 10 mm is needed to safely remove a ramus block graft without injury to the inferior alveolar nerve.
The incision design for access to the ramus is by 2 different approaches: 1) Vestibular or 2) Sulcular. The vestibular incision begins in the buccal vestibule, medial to the external oblique ridge, and extends anteriorly and laterally to the retromolar pad. This technique has the advantage of not disturbing the periodontium of the adjacent teeth. Alternatively, the sulcular incision starts intrasucularly around the mandibular molars and then extends from the distofacial line angle of the second molar along the external oblique ridge. The sulcular technique is beneficial when the recipient site is nearby, such as the mandibular first molar region. Regardless of the incision design selected, the incision up to the ascending ramus should be no higher than the level of occlusal plane. This minimizes the possibility of severing the buccal branch of facial nerve, the buccal artery, or, exposing the buccal fat pad where these structures are located. After the incision, a subperiosteal full thickness flap reflection proceeds by blunt dissection, exposing the anterolateral aspect of the ramus. The flap may be elevated superiorly along the external oblique ridge and anterior ramus to the base of the coronoid process. The ramus osteotomy procedure is accomplished in similar fashion to the symphysis graft with regard to penetrating the cortical layer and controlling effective x-pattern cut-through at the block corners to ensure a free release. As with the symphysis graft, the osteotomy can be accomplished with a rotary bur, piezoelectric saw, or sagittal saw, the latter two having the advantage of more conservative cutting. Following removal of the bone block, any sharp edges around the ramus area are smoothened with a round bur or bone file. A hemostatic dressing may be placed into the donor area. Alternatively, a particulate bone allograft (such as FDBA) may be placed in the defect as well, especially in the case of a large block harvest. Closure of the donor area is best completed with an interrupted or running horizontal mattress resorbable suture to evert the wound edges for maintenance of primary closure during healing.

Ridge split or expansion technique (Scipioni *et al*., 1994; Koo *et al*., 2008; Demetriades *et al*., 2011; Tolstunov and Hicke, 2013; Yaman *et al*., 2014; Tair, 2014; Bassetti *et al*., 2015; Martinez *et al*., 2014; Santagata *et al*., 2015**)**

Synonym – 1. Ridge Split technique/procedure (RSP).
2. Greenstick-fracture technique (Scipioni *et al*., 1994)
3. Crystal ridge bone augmentation (Martinez *et al*., 2014)

Indication

1.A collapsed alveolar ridge demonstrating a narrow width (<5 mm in many cases) and grossly adequate alveolar height is the most common situation for the RSP.

Rationale

A 3-mm alveolar ridge generally consists of 3 thin bone layers (in a horizontal sandwich fashion): 2 cortical plates (about 1 mm each) separated by 1 cancellous layer (about 1 mm). The wider the cancellous bone layer (the layer where the split is done), the easier it will be to accomplish the RSP.

Surgical Considerations

1. Bone density. The maxillary alveolar ridge is generally less dense than the mandibular alveolar ridge and more amenable to a single-stage RSP.
2. Blood supply to the alveolar process and the role of periosteal vascularization. Periosteum plays a critical role in vascularization of the buccal cortex and in graft osteogenesis. At least 1/3rd of early graft osteogenesis can be attributed to the periosteum alone. Meticulous tissue manipulation preserving the periosteum and its role in peripheral vascularization is extremely important in RSP.
3. Treatment of the wound as a result of the RSP and appreciation of the wound healing by secondary intention analogous to the grafted extraction socket.

Surgical Technique

1. Preoperatively, the alveolar ridge is evaluated visually and by palpation. Palpating the ridge with 2 fingers sliding along the alveolar crest helps to develop a tactile sense of the ridge thinness and presence of bone undercuts.
2. Commonly, the vertical extension of the split approximates the future implant length and falls into the 8- 12 mm range.
3. Although there are many surgical modifications, traditionally the ridge-split technique consists of a single surgical stage in the maxilla and a two-stage approach in the mandible.
4. Maxillary Single-stage alveolar RSP

A full- thickness incision of the appropriate length is performed in the edentulous area at the crest of the ridge. The flap is a limited crestal full-thickness flap just large enough to see the top of the alveolar crest. Instruments -- range from scalpel blades to spatula osteotomes, piezoelectric surgical systems, and ultra-fine fissure burs. In the single-stage procedure, a crestal bone cut is initiated and carried to depth with a spatula osteotome. A greenstick separation of the deficient buccal cortical plate from the palatal portion of the alveolar bone leads to an opening of the bony gap with formation of a buccal vascular osteoperiosteal flap. The 7-8-9-10 rule can be a guide for the ideal implant-oriented alveolar ridge augmentation after the RSP, where at least 7-8 mm of bone width and 9-10 mm of bone height are necessary. The second aspect of RSP is grafting/GBR. The grafting in the ridge-split technique is done internally (inside the split). The graft is loosely packed into the created bone gap from the bottom up. The remaining portion of the procedure is concluded with the goal of preserving the created alveolar width and promoting healing by secondary intention. A split and grafted ridge is covered with an appropriately sized membrane (resorbable or non - resorbable) followed by continuous locking or multiple interrupted suturing without tension. The described surgical approach of ridge split/expansion can be successfully used for anterior or posterior maxilla or for a full maxillary arch.

5. Mandibular two-stage alveolar RSP

a. Stage 1: Corticotomy - The goal of corticotomy is to section through the exposed buccal cortex around the periphery of the buccal bony plate, which is to be laterally repositioned at the stage-2 surgery. A full-thickness incision of the appropriate length is performed in the edentulous area at the crest of the ridge with 2 releasing incisions that should extend beyond the bone cuts. Peripheral corticotomies outlining a "buccal door" are performed:

1. Crestal (similar to the maxillary procedure),
2. Apical (about 10-12 mm), &
3. 2 vertical connecting corticotomies.

The corticotomies are connected as a continuous rectangular line, extending through the buccal cortical plate into the cancellous layer of the bone, paying particular attention to the 2 apical corners of the outlined bone osteotomies. The crestal corticotomy is directed towards weakening of the buccal cortical plate in the areas where successful Stage-2 procedure is guaranteed. The buccal flap is repositioned and sutured. This buccal flap, is allowed to undergo revascularization and healing for 4-5 weeks.

b. Stage 2: Splitting and Grafting – The second stage of the mandibular ridge expansion procedure is done in a manner similar to a single stage of the maxillary ridge split, using a limited-reflection flap. A crestal incision is made, wide enough to see the crestal corticotomy (closed approach). Papilla-sparing curved incisions are created toward the buccal and lingual side at the mesial and distal extensions of the groove. Tissue is reflected to the lingual side as needed, but the tissue on the buccal side is to be elevated at the points where the buccal curved incisions are carried onto the adjacent bone. The spatula osteotome is then tapped to depth with the osteotome of the next thickness and a controlled lateral force is to be used for mobilization of the buccal plate. Thus, a buccal mucoosteoperiosteal flap with its own buccal soft-tissue blood supply is created and manipulated (widened). An overall ridge expansion up to 8-10 mm is usually adequate, and grafting, similar to that described previously is performed. A 4-6 months waiting period is recommended before an implant placement.

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