Principles for Vertical Ridge Augmentation in the Atrophic Posterior Mandible:
A Technical Review

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Guided bone regeneration has become more predictable due to advances in material sciences. Nevertheless, vertical ridge augmentation (VRA) remains a potential challenge due to the complexity of soft tissue management. This becomes more complicated in the posterior atrophic mandible due to limited access and poorer blood supply. As such, a number of critical elements must be taken into consideration in treatment planning. Anatomical structures potentially jeopardize intraoperative adverse events such as bleeding or neurosensory disturbances. The attachment of the mylohyoid often compromises lingual flap advancement. This technical review summarizes the critical factors to be assessed prior to VRA for the posterior mandible and provides a sequenced approach to bone grafting and to attaining a tension-free flap for successful bone regeneration and long-term peri-implant tissue stability. Int J Periodontics Restorative Dent 2017;37:639–645. doi: 10.11607/prd.3200
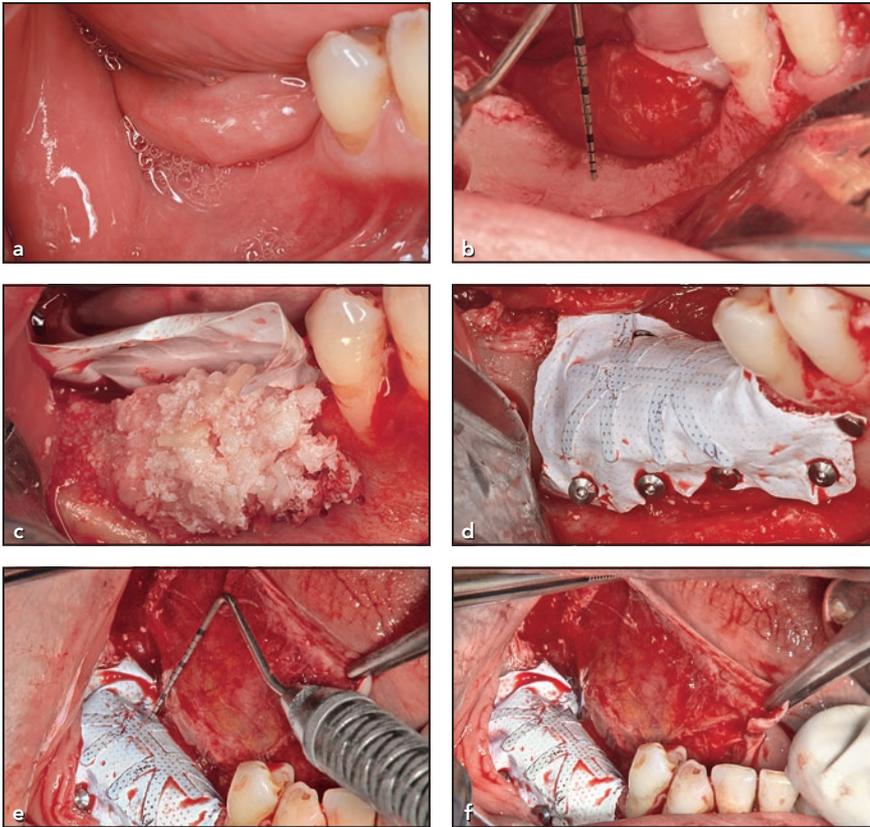
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Guided bone regeneration (GBR) has become more predictable due to advances in material sciences. Nevertheless, vertical ridge augmentation (VRA) remains a potential challenge due to the complexity of soft tissue management.[1,2] Space creation and maintenance can be achieved through the use of a moldable but rigid barrier membrane (ie, titanium-reinforced polytetrafluoroethylene [PTFE]) in combination with a bone substitute capable of serving as scaffolding for the long term.[3–5] Moreover, the use of autogenous bone chips in this protocol maximizes the bone turnover process, leading to greater amounts of newly formed bone over nonmineralized tissue and biomaterial remnants in a shorter time.[6]

The four major elements necessary for successful GBR have been described as primary wound closure, space maintenance, stability of the clot, and angiogenesis to provide access for the cells, nutrients, and oxygen needed for tissue regeneration.[7–9] While wound closure and space maintenance are associated with adequate soft tissue management (ie, flap-free closure) and membrane properties, angiogenesis and clot formation rely primarily on native alveolar bone architecture.[10] As such, the posterior mandible has been classically illustrated as type D1–D2 bone, meaning a thick,

Figs 1a to 1f *Representative case of the step-by-step treatment of a significant vertical defect and placement of implants into regenerated bone. (a) Buccal view of a vertical deficiency of the posterior mandible. Note that the floor of the mouth is higher than the ridge. (b) In addition to the severe vertical bone defect, the ridge was also knife edge. (c) Particulated autogenous bone graft mixed with anorganic bovine bone mineral is placed on the ridge. (d) Buccal view of the titanium-reinforced high-density polytetrafluoroethylene membrane secured over the graft with titanium tacks. Note that the membrane is not in contact with the neighboring tooth. (e, f) Buccal view of the released lingual flap. Note the excellent flexibility of the well-released lingual flap.*

compact bone overlies a thin porous layer. This has a negative effect on blood supply and, consequently, on bone regenerative outcomes.[11] It has recently been reported that an atrophic bony structure reduces the mineral density and thus may be more suitable for regenerative therapy.[10] The posterior mandible is one of the most challenging due to the compromised access, neighboring anatomical structures, and frequent lack of adequate soft and hard tissue.

The goal of this technical review is to present the most critical factors/considerations for successful VRA in the atrophic posterior mandible.

Materials and Methods

The present technical review provides an overview of the principles and critical factors that should be taken into consideration when performing VRA in the posterior mandible.

### Presurgical Evaluation of Biotype and Available Keratinized Mucosa

In thin tissue biotype scenarios and when keratinized mucosa (KM) is minimal or completely lacking, a careful flap elevation should be performed to avoid perforation in the flap. A double-layer closure results in thick tissue over the graft with the first layer of sutures placed in the mucosa. Preliminary soft tissue grafting prior to VRA is contraindicated as the presence of scarring compromises flap management and blood supply for the VRA procedure as described elsewhere.[12]

Surgical Management

Once the key elements are under control and the patient has been informed of and accepted the rigorous treatment plan sequence, hard and soft tissue management (including flap design to achieve tension-free flap closure and preparation of the recipient site) will ultimately determine success. The treatment protocol is illustrated in Fig 1.

The Safety Flap

The rationale behind the safety flap design is that it will provide enough soft tissue to accommodate the increased dimension of the grafted ridge. A full-thickness, midcrestal incision is made in the keratinized gingiva with a no. 15 surgical scalpel. The distal extension of the crestal incision ends within 2 mm of the retromolar pad. For surgical access, a distal oblique vertical incision is
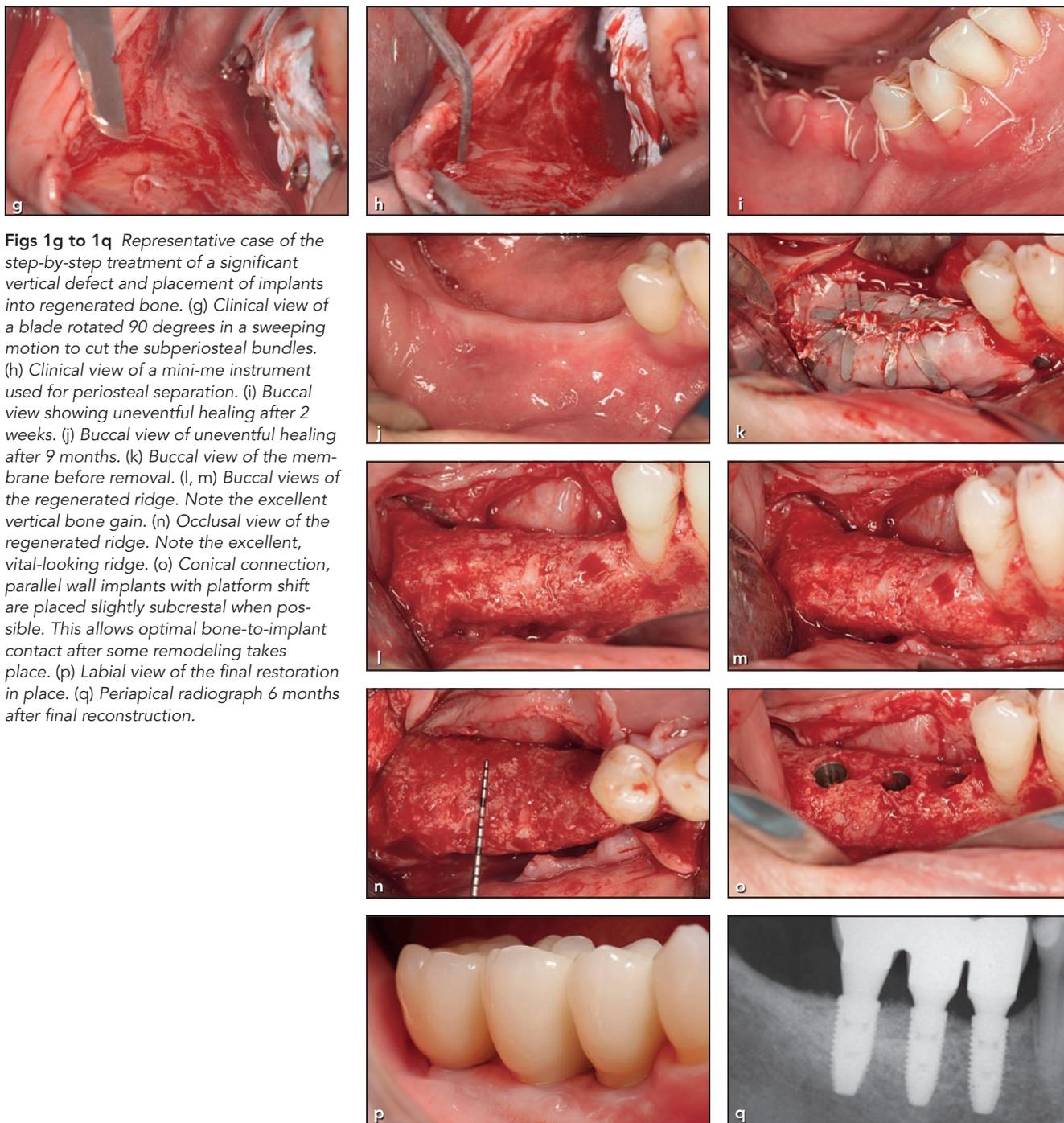
Figs 1g to 1q *Representative case of the step-by-step treatment of a significant vertical defect and placement of implants into regenerated bone. (g) Clinical view of a blade rotated 90 degrees in a sweeping motion to cut the subperiosteal bundles. (h) Clinical view of a mini-me instrument used for periosteal separation. (i) Buccal view showing uneventful healing after 2 weeks. (j) Buccal view of uneventful healing after 9 months. (k) Buccal view of the membrane before removal. (l, m) Buccal views of the regenerated ridge. Note the excellent vertical bone gain. (n) Occlusal view of the regenerated ridge. Note the excellent, vital-looking ridge. (o) Conical connection, parallel wall implants with platform shift are placed slightly subcrestal when possible. This allows optimal bone-to-implant contact after some remodeling takes place. (p) Labial view of the final restoration in place. (q) Periapical radiograph 6 months after final reconstruction.*

made toward the coronoid process of the mandible. A vertical incision is made mesiobuccally at least one tooth (preferably two) away from the surgical site. Mesiolingually, a 3- to 4-mm incision is made at the mesiolingual line angle of the most distal tooth in front of the defect. Periosteal elevators are then used to reflect a full-thickness flap beyond the mucogingival junction and at least 5 mm beyond the bone defect. The lingual flap is elevated to the mylohyoid line, where the attachment of the fibers of the mylohyoid muscle can

be identified. Since the mylohyoid attachment is deeper mesially than the region of the second premolar, the depth of flap elevation does not follow the location of the muscle. Instead, it is carefully prepared slightly deeper than the elevation of the molar region, corresponding with the muscle attachment.

Recipient Site Preparation

The recipient bone bed is prepared with multiple decortication screw holes using a small round bur. The authors do not automatically advocate the use of tenting screws; the membrane will be molded owing to the titanium reinforcement, and the densely filled graft will provide enough support. The number and location of tenting screws will be based on the extent of the defect to be grafted, but generally speaking, two to three should be enough to contain a large defect.

Membrane Adaptation

An appropriately sized membrane is selected and trimmed so that it totally covers the volume of the graft and the edges will not be in contact with the natural teeth. The membrane should rest on at least 2 mm of the adjacent bone. Membrane fixation is a critical aspect of this procedure since the graft must be immobilized for graft incorporation to occur. The membrane is stabilized first on the lingual/palatal sides using titanium pins or 3-mm titanium screws on at least two points. If the placement of the first lingual pin is difficult, a temporary pin is placed on the crest just behind the last tooth. This fixation makes the positioning of the lingual

pins much easier starting from the mesiolingual side. After membrane stability is ensured, the temporary pin placed on the crest can be retrieved (Fig 2).

Bone Grafting

The autogenous particulated bone graft harvested from the mandibular ramus (with a bone scraper device or back action chisel) mixed with the long-lasting grafting material is placed into the defect and the membrane is folded over and stabilized with additional titanium pins or screws. To better condense and compact the grafting material, a medium-to-large long-lasting graft material particle size is recommended.[13]

Modified Lingual Flap Advancement

The flap design is based on the location of the attachment of the mylohyoid muscle and on the protection of vital anatomical landmarks such as the lingual nerve and the sublingual artery. In the authors' experience, this technique has demonstrated significantly more flap advancement than other published techniques.[14–16,29] There are three zones of interest on the lingual aspect.[17] The first zone has to be handled so that the nerve is protected and the flexibility is achieved with blunt management. This is achieved through tunneling and lifting on the retromolar pad. In the second zone, it is important that the muscle is not reflected from the mandible. Flap advancement is achieved with blunt dissection protecting the key anatomical

landmarks, leading to detachment of the soft tissues from the intact mylohyoid muscle. The third zone is the region in which membrane exposure most typically occurs, as this is where the clinician may easily miss advancing the flap. A horizontal hockey stick periosteal semiblunt incision is used in this zone.

Buccal Flap Advancement

Due to the potential for nerve injury, extensive bleeding, and tissue damage that may impair the vascularization of the flap, the periosteo-elastic technique is recommended. This is performed by first making a gentle periosteal incision without invading the connective tissue below it. The mental nerve is protected, particularly in severe atrophies where the vertical incision must be made more apically. Subperiosteal bundles are then released from elastic fibers, and elastic fibers are separated using the Prichard periosteal or minime instrument.

Flap Closure

The flap must be sutured in two layers. The first layer is closed with horizontal mattress sutures placed 5 mm from the incision line, and then single interrupted sutures are used to close the edges of the flap. With this technique, the flap margins are averted. This intimate connective tissue–to–connective tissue contact provides a barrier preventing exposure of the membrane (Fig 3). The vertical incisions are then closed with single interrupted sutures, moving from the apical area to the crestal area, preferably using PTFE material.
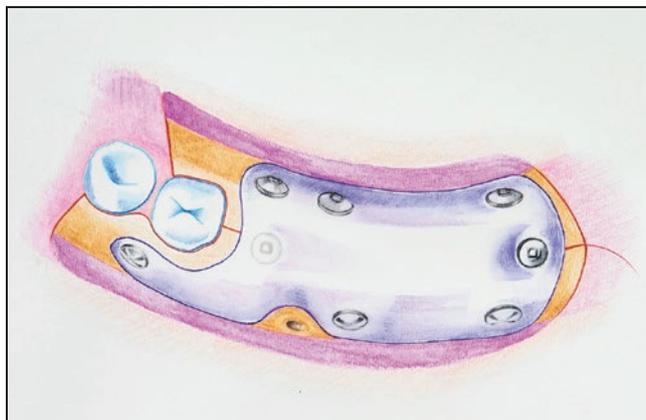
Fig 2 *Schematic drawing representing the occlusal view of the final fixation of the membrane.*
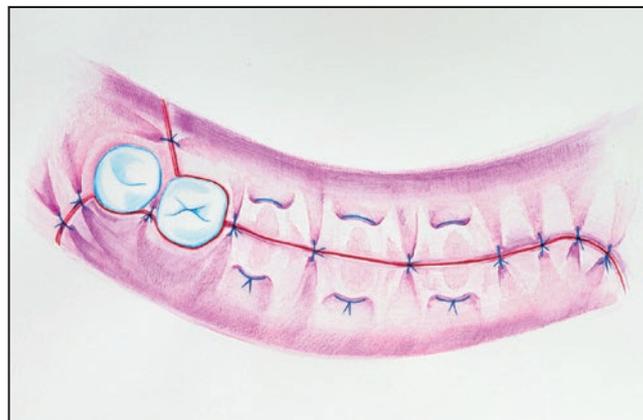

Fig 3 *Schematic drawing representing the occlusal view of the double layer closure of the flap.*

Discussion

Simultaneous Versus Staged Approach

Simultaneous VRA and implant placement can be selected for cases requiring < 4 mm of VRA. The staged approach for implant placement should be used in all cases requiring ≥ 4 mm of newly built bony structure. It is technically possible to treat even more severe defects with simultaneous VRA. However, staged augmentation procedures are indicated for the following reasons.

Safety

In the event of complications such as membrane exposure or a low-grade infection, the clinician is able to salvage the major portion of the bone graft. If an implant has been placed simultaneously, bacteria may adhere to the implants and lead to complete loss of the graft and the implant, creating a worse scenario than at baseline.

Healing

The staged approach allows more time for maturation of the regenerated bone prior to placing and subsequenly loading the implants. A preclinical study demonstrated that placing implants even in an extraction socket might interfere with and slow down the new bone formation.[18] This could also be an important factor in VRA since this is a biologically demanding defect.

Soft Tissue

In simultaneous cases, the healing abutments are placed when the membrane is retrieved. However, in many of these cases, the amount of KM is minimal. If KM is completely lacking, increasing it by soft tissue grafting of the buccal and lingual aspects of the implants is challenging. Thus, the long-term prognosis of these implants may be less favorable since they are more subject to inflammation.[19]

Crestal Bone Changes

The regenerated posterior mandible is the region of the jaw where patients are at increased risk of progressive peri-implant marginal bone loss. There are several explanations for this.

The soft tissues are usually thinner than requirement for the biologic width, particularly in the posterior mandibular area.[20] While in natural dentition the biologic width was determined to be ~2 mm,[21] it was found to be 3.5 mm in posterior sites.[22] Hence the biologic width can be formed at the expense of marginal bone loss after prosthesis delivery. This early bone loss has been regarded as physiologic and should be controlled to promptly detect progressive pathologic bone loss (ie, peri-implantitis). Thus, tissue biotype/thickness must be assessed and soft tissue grafting[23] and/or modified implant-abutment connections (ie, platform-switching)[24] should be considered.

The distal implant platform is commonly at a higher level compared to the mesial aspect. This is typical in the posterior mandible, and it often leads to greater peri-implant bone loss on the most distal implant.

Certain implant systems are difficult to place subcrestally, and the top portion of the implant may be positioned supracrestal at implant placement. In such cases, due to implant roughness and assuming that adequate oral hygiene is more challenging in the mandibular posterior sextants, they will be more prone to biofilm attachment to the surface, which could potentially lead to peri-implantitis.

Mucogingival Considerations

The need for a minimum amount of KM around teeth and implants to preserve the health and stability of the gingival and mucosal tissues still remains controversial.[25] Nevertheless, the current understanding seems to indicate that the presence of a band of KM might minimize plaque and gingival indexes around rough surface implants.[26] In fact, a wider band of KM leads to better soft and hard tissue preservation, less inflammation, and easier professional and home-care maintenance.[26]

There are three main clinical scenarios in the mandible for reconstruction of the KM depending on the amount present and the amount required. The solution is to perform a free gingival graft before the second stage, as it is not realistic to graft on the lingual side during or after abutment installation. Gingival grafting is a must in these situations.[27]

If < 4 mm KM is present, the clinician can decide if reconstruction is absolutely necessary. The incision at the uncovery has to be made at least 2 mm buccal from the lingual mucogingival junction to ensure that enough KM is present on the lingual side. Also, a decision can be made whether to perform a gingival graft on the buccal side at this point or if the mucosa on the buccal side is clinically acceptable. A gingival graft can be performed a few months later if the patient struggles to clean the implants.

If ≥ 4 mm KM is present, the clinician should distribute the KM evenly during the implant uncovery procedure.

Presence of Dentition

The presence of dentition in molar sites of the atrophic mandible is not uncommon. This might be a drawback in flap advancement and in adequately placing the barrier membrane, thus increasing the exposure rate. The authors recommend a critical evaluation of the periodontal and restorative prognosis of such teeth to determine the plausibility of restoring the atrophic mandible with alternatives such as a short implant-supported prosthesis or using the molar as the abutment of a fixed prosthesis. In situations in which the overall prognosis is unfavorable, performing extraction(s) at least 2 months before bone grafting is recommended. Regenerative therapy can follow after spontaneous soft tissue healing of the alveoli.

Defect Morphology

The importance of ridge morphology (concave/flat/convex) must not be underestimated since this will dictate containment of the bone graft along with the clot and thereby the numerous growth factors acting as chemoattractants and mediating the recruitment of mesenchymal stem cells. As such, more favorable results could be expected in the presence of concave topography, while less bone would be gained in flat/convex topography.[28]

Conclusions

Vertical ridge augmentation of the atrophic posterior mandible must be executed with an understanding of the local anatomical landmarks.[29] Due to the high rate of complications reported in the literature, adequate sequencing of techniques to attain tension-free flap closure must be followed. Critical factors must be assessed and controlled as part of the initial therapy to determine treatment feasibility for the patient.

Acknowledgments

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