Guided Bone Regeneration in Alveolar Bone Reconstruction

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KEYWORDS

• Guided bone regeneration • Reconstructive therapy • Alveolar bone • Bone reconstruction

KEY POINTS

- Guided bone regeneration for alveolar bone reconstruction is effective and less invasive than other techniques, such as block grafting.
- Reconstructive therapy for atrophic ridges can be achieved following the biological principle of compartmentalization.
- Graft and membrane stability dictates success for regenerative purposes.
- The success of guided bone regeneration relies on flap management to ensure tension-free primary closure.

INTRODUCTION

Although the integrity of the jawbone is preserved through the stimulus of chewing, tooth loss caused by disease or trauma leads to alveolar bone resorption (**Figs. 1** and **2**). In order to compensate for ideal three-dimensional implant placement, numerous techniques and modifications have been proposed, conditioned to the clinical scenario involved. Traditionally, autologous block grafting was advocated as the gold standard for the horizontal and/or vertical reconstruction of edentulous ridges. However, advances in biomaterials and clinical techniques have led to the incorporation of guided bone regeneration (GBR) as a potential alternative in challenging cases.

GBR reflects the concept of compartmentalization, proposed in the late 1970s.[1] Briefly, it consists of preventing the migration of undesired cells through the adaptation of a barrier membrane to the area that is intended to be reconstructed. The barrier membrane provides stability to the bone graft, prevents soft tissue from collapsing into the defect, prevents competing nonosteogenic cell migration into the site, and accumulates growth factors.[2]

In terms of the composition of the membranes, synthetic materials have been used, such as nonresorbable polytetrafluoroethylene (PTFE), as well as resorbable synthetic materials such as a combination of polyglycolic acid and trimethylene carbonate.[3] At present, resorbable materials of xenogeneic origin, such as collagen, are the most commonly used option in GBR. One of the first membranes developed specifically for GBR was the nonresorbable, titanium-reinforced, expanded PTFE membrane. Reinforcement with a titanium frame stabilizes the form of the membrane. The use of these membranes has been well documented, and they are currently considered the gold standard for GBR. More recently, resorbable membranes have been developed that are not form stable. Accordingly, membranes can also be

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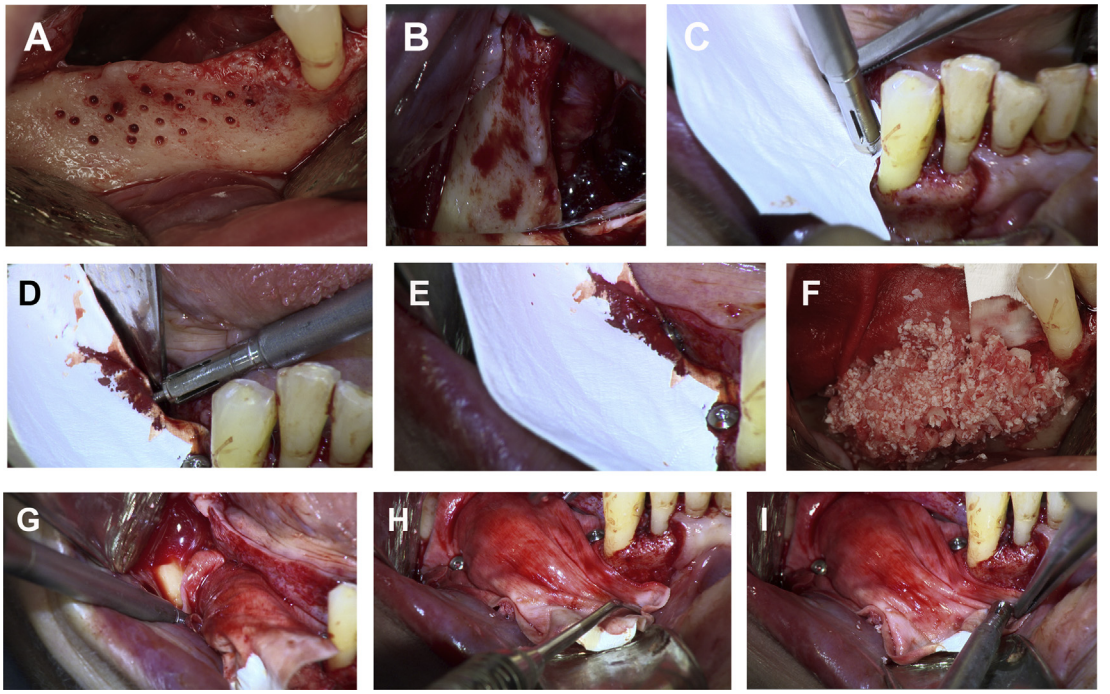

Fig. 1. Treatment of a representative case of the sausage technique in the posterior mandible using a natural collagen membrane. (*A*, *B*) Labial and occlusal views of a healthy 75-year-old woman with a thin posterior mandibular ridge. Note the triangle of bone distal to the last tooth. This was designed by us to place a pin. (*C*) Labial view of the pin placed within the bony triangle. (*D*) Labial view of the second pin placed distolingual. (*E*) Labial view of the 2 pins in place, stabilizing the native collagen membrane. (*F*) Labial view of the composite graft (1:1 proportion of autograft and ABBM) in place. (*G*) Labial view of the next distobuccal pin placement. (*H*) Labial view showing elasticity of the membrane. (*I*, *J*) Labial view of mesiobuccal pin placement. Note that the membrane is stretched out. (*K*) Labial view of the next step, which is the push-up step. The graft is positioned to the crest. Once the membrane is pushed up, the graft is secured with 2 additional titanium pins. (*L*, *M*) Labial view of the stretched out and stabilized membrane. Note that the graft is completely immobilized, which is checked using either finger pressure or pressure from an instrument. (*N*) Labial view of flap closure. (*O*) Occlusal view of the regenerated bone. Note the nice wide ridge after uneventful healing at 8 months. (*P*) Occlusal view of 3 implants in place. (*Q*) Periapical radiograph after 5-year follow-up, showing stable bone. ABBM, anorganic bovine bone mineral. (*From* Urban I. Vertical and horizontal ridge augmentation: new perspectives. Batavia (IL): Quintessence; 2017. p. 123; with permission.)

classified as form stable or non–form stable. Form-stable, nonresorbable, titanium-reinforced membranes are considered the gold standard for both vertical and horizontal augmentation.

Although this concept was initially proposed for the regeneration of tissues associated with the periodontium, the proof of principle was soon applied to regenerate edentulous alveolar ridges. This process was first evaluated by Dahlin and colleagues.[4] On histology, it was observed that half of the samples in which GBR was applied with Teflon membranes showed complete bone healing after 3 weeks, whereas the control sites showed no signs of healing after 22 weeks. Posteriorly, the technique was extended to humans and exhaustively evaluated to improve the biomaterials and the technique. Note that, at the time, particulate autogenous bone was the primary source for scaffolding protected by nonresorbable barrier membranes. Now, developments in material sciences allow clinicians to use bone fillers from other sources (ie, other species or cadavers) and, as aforementioned, resorbable membranes can be used to facilitate and simplify the technique tailored to the clinical needs.

BIOLOGIC PRINCIPLES

Four main principles have been described to achieve successful GBR (**Table 1**).[5]

INDICATIONS/CONTRAINDICATIONS

Indications:

- Fenestration bone defects
- Dehiscence bone defects

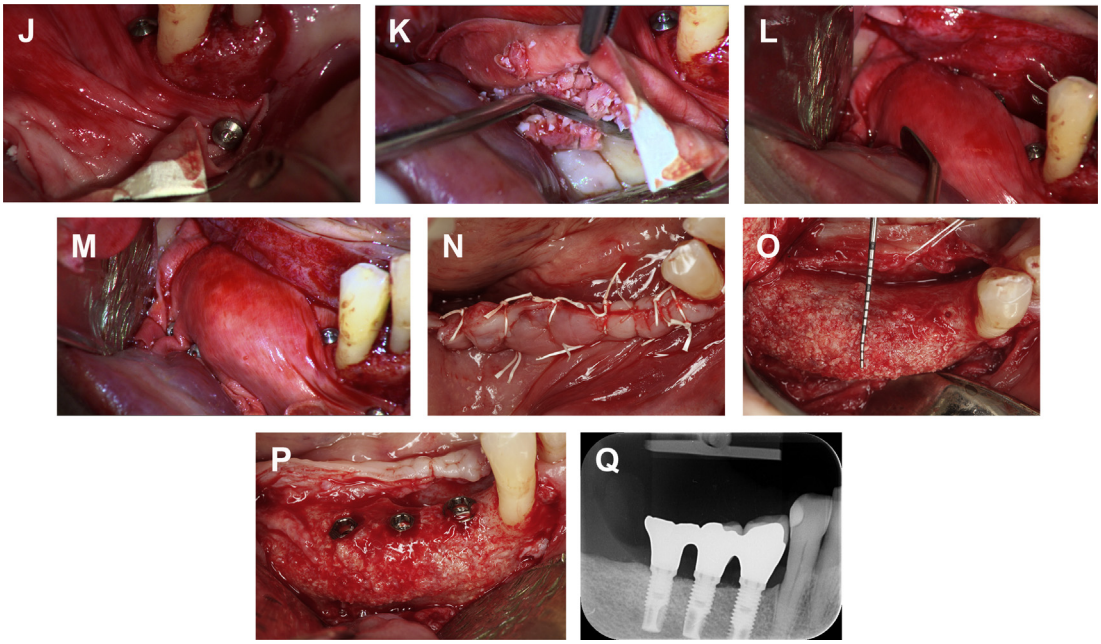

Fig. 1. (*continued*)

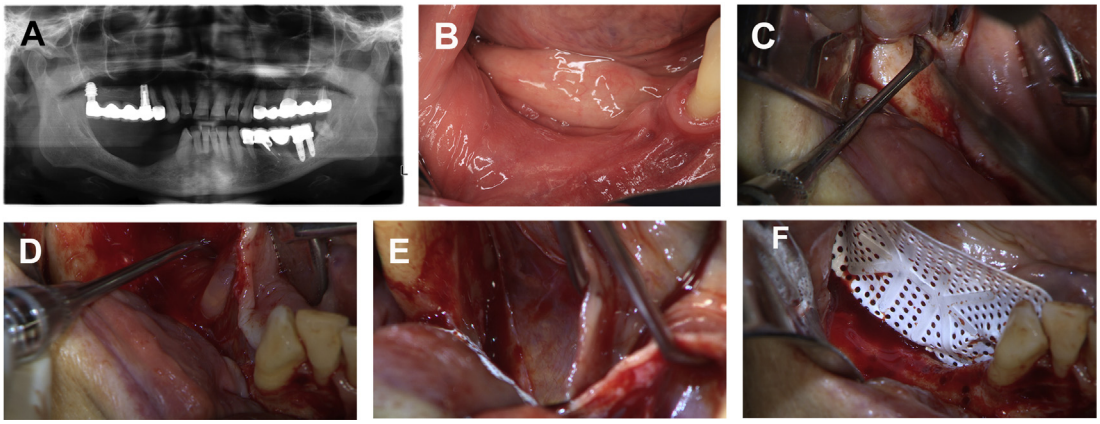

Fig. 2. Step-by-step treatment of a significant vertical defect with placement of implants into regenerated bone. (*A*) Panoramic radiograph showing a vertical defect on the right posterior mandibular defect after implant failure. Note that, on the left side, failing implants were planned to be removed before the regenerative procedure on the right side. (*B*) Labial view of the vertical deficiency of the posterior mandible. (*C–E*) Labial and occlusal views of the modified lingual flap release. Elevation of the retromolar pad (zone I). Careful elevation of the soft tissue located above the superior fibers of the mylohyoid muscle using a blunt instrument (zone II). Semiblunt periosteal release using the back end of a number 15C scalpel blade and blunt stretching of the tissues on the anterior area of the flap (zone III). (*F*) Labial view of the vertical defect. A dense polytetrafluoroethylene (PTFE) membrane was fixed on the lingual side. (*G*) Particulate autogenous bone graft mixed with ABBM is placed on the ridge. (*H*) Buccal view of the dense PTFE-titanium reinforced membrane secured over the graft with titanium tacks. Note that the membrane should not be in contact with the neighboring tooth. (*I*) Vertical flap release (~20 mm). (*J*) The buccal periosteal incision is superficial and the clinician should make certain that only the periosteum is cut and that no incision is made deeper into the tissue. (*K*) Since most patients have "periosteal cross bundles," the flap cannot be advanced as necessary once the periosteal incision has been completed. The dense fibers are gently cut with "sweeping" incisions, using the blade first in a 90-degree angle, like "playing the guitar" as the authors call this motion. (*L*) Then a blunt periosteal instrument should be used in a coronal pushing motion to separate the elastic fibers. This will ensure that the flap will be significantly advanced with less chance of causing injuries to vital anatomical structures. (*M*) Labial view of tension-free double-layer closure of the flap. (*N–P*) Labial and occlusal views of the regenerated bone.

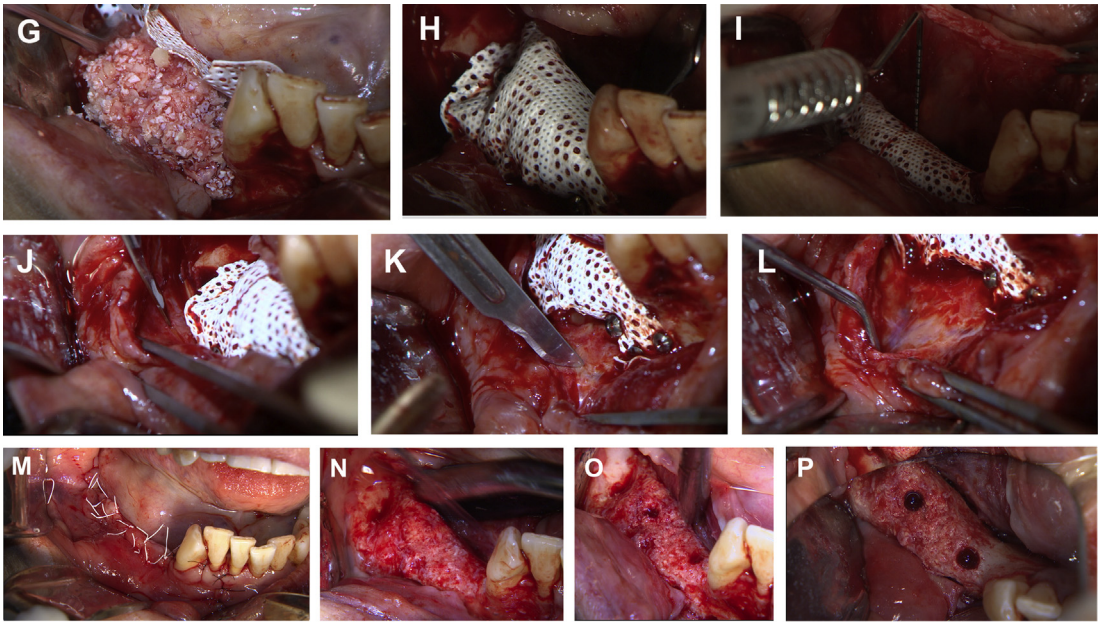

Fig. 2. (*continued*)

- Horizontal bone defect
- Vertical bone defect
- Combined vertical and horizontal bone defects
- Contained 2-wall to 3-wall and circumferential peri-implantitis defect
- Extraction sites with/without immediate implant placement

Contraindications:

- Smoking
- Uncontrolled systemic disorders
- Poor plaque control (>15% full-mouth plaque and bleeding indexes)
- Patient rejection
- Inability to achieve primary wound closure
- Inability to stabilize the bone filler and/or barrier membrane
- Poor clinical skills
- Uncontained peri-implantitis defects

Technique/procedure: vertical and horizontal ridge augmentation.

Preoperative considerations

- Understanding the anatomy
- Understanding the biological principles in order to apply them
- Comprehensive assessment of the area using cone-beam computed tomography
- Evaluation of the feasibility of other less invasive methods (ie, short or narrow dental implants)
- Examine personal oral hygiene measures

Table 1
Principles to achieve successful guided bone regeneration

Principle	Purpose	Outcome
Primary wound closure	Enhance undisturbed healing via tension-free closure	Incision design and subperiosteal scoring incision
Angiogenesis	Provide nutrients and oxygen	Corticotomies
Space creation and maintenance	Provide space and prevent collapse	Intrinsic to membrane/bone filler
Stability of the wound clot	Blood clot formation	Primary wound closure

Data from Wang HL, Boyapati L. "PASS" principles for predictable bone regeneration. Implant Dent 2006;15:8–17.

Table 2
Critical preoperative factors

Critical Factor	Management
Soft tissue phenotype and presence of keratinized mucosa	Consider soft tissue augmentation via incision design. However, the authors do not perform soft tissue grafting before bone grafting, because it might lead to the development of scar tissue
Simultaneous vs staged approach	In cases of vertical ridge augmentation, when <4 mm is needed, a simultaneous approach is suitable. For horizontal ridge augmentation, if primary stability can be achieved, a simultaneous approach can be performed; however, in case of complications, treatment is easier and more successful if surgery does not involve simultaneous implant placement (ie, staged approach)
Implant position	In general, a slightly subcrestal implant position is advocated in regenerated bone
Defect morphology	In general, more favorable outcomes are expected in the presence of a concave topography instead of a convex ridge morphology
Systemic factors and deleterious habits	Smoking should be restricted at least 3 mo before the grafting procedure. Other systemic factors and deleterious habits that can impair wound healing must be further controlled
Active periodontal disease	The periodontal condition must be stable before planning any reconstructive surgery
Nature of the periosteum	If the patient has undergone previous attempts of GBR, the periosteum might be scarred, and this impedes adequate coronal advancement to secure tension-free flap closure

- Evaluate eligibility according to the patient risk profile and deleterious habits (ie, smoking)

CRITICAL PREOPERATIVE FACTORS

Critical preoperative factors are listed in Table 2.

Guided Bone Regeneration for Horizontal Ridge Defects

The so called knife-edge ridge, or Cawood and Howell class IV edentulous jaw, represents a unique problem for horizontal augmentation. The necessary height of the ridge is adequate on the lingual/palatal side but the width is insufficient, often making implant placement impossible without prior treatment.[6] The difficulty of using GBR has been that stabilization of the particulate graft is a challenge in such defects when the clinician is not using a form-stable titanium-reinforced membrane. More recently, clinicians have used non–form-stable collagen membranes to reconstruct severely thin ridges. In most cases, the necessary bone gain was not achieved, and most of the bone growth was obtained apically from the crest.

Sausage-technique surgery has been developed to overcome these challenges.[7] This technique uses a collagen membrane fixated with titanium pins. The aim is to secure bone graft stabilization on the crest so that no migration or collapse of particles occurs. A more rapidly reabsorbing natural collagen membrane and 1:1 mixture of autogenous particulate bone/anorganic bovine bone mineral (ABBM) as grafting material should be selected for horizontal augmentation (Fig. 1).[7,8]

Surgical Procedure

1. Safety flap (Fig. 2). The safety flap is a full-thickness flap that, depending on the

Table 3
Lingual zones of interest

Zone	Site	Management
First	Retromolar pad	Tunneling and lifting
Second	Molar region	Blunt dissection
Third	Premolar region	Horizontal hockey-stick periosteal incision and blunt tissue advancement

Data from Urban IA, Monje A, Lozada J, et al. Principles for vertical ridge augmentation in the atrophic posterior mandible: a technical review. Int J Periodontics Restorative Dent 2017;37:639–45.

extension, comprises vertical incisions located 2 to 3 teeth beyond the edentulous area. In the posterior mandible, a full-thickness, midcrestal incision is made in the keratinized gingiva with a surgical scalpel (number 15). The distal extension of the crestal incision ends within 2 mm of the retromolar pad. For surgical access, a distal oblique vertical incision is made toward the coronoid process of the mandible. A vertical incision is placed mesiobuccally at least 1 tooth away (preferably 2) from the surgical site. Mesiolingually, a 3-mm to 4-mm incision is made at the mesiolingual line angle of the most distal tooth in front of the defect. Then, periosteal elevators are used to reflect a full-thickness flap beyond the mucogingival junction and at least 5 mm beyond the bone defect.

2. Preparation of the lingual flap. The lingual flap is raised to the mylohyoid line, where attachment of the fibers of the mylohyoid muscle can be identified. Because the mylohyoid attachment is deeper mesially to the region of the second bicuspid, the depth of flap elevation does not follow the location of the muscle.
3. Preparation of the recipient site. Corticotomies are made using a medium-sized round bur to promote bleeding.
4. Trimming of the collagen membrane according to the size and morphology of the defect.
5. Tacking of the membrane using pins. In the case of the posterior mandible, the first pin that should be placed is the crestal pin distal to the last tooth in order to stabilize the membrane and then place the lingual pins.
6. Mixing of the composite autogenous bone previously harvested from the recipient site or other source (ie, mandibular ramus) and the ABBM in 1:1 proportion.
7. Molding of the membrane over the graft material, securing the membrane by tacking it with pins in the mesial and distal areas to achieve total immobilization of the graft beneath the membrane. This molding must be checked using either finger pressure or pressure from an instrument.
8. Tension-free closure, achieved via periosteal scoring incisions at the buccal site of the mandible and modified lingual flap advancement. The rationale for this flap design is based on the location of the attachment of the mylohyoid muscle and also on the protection of vital anatomic landmarks such as the lingual nerve and sublingual artery. There are 3 zones of interest at the lingual site[9] (**Table 3**).
9. Suturing. Horizontal mattress sutures are used, combined with single interrupted sutures using nonresorbable suture material.

POSTPROCEDURE PATIENT CARE

- Chemical plaque control is performed using 0.12% chlorhexidine solution from 24 hours after surgery and until suture removal.
- Antiinflammatory medication such as ibuprofen 200/600 mg 3 times a day for 7 days is provided.
- Antibiotic therapy such as amoxicillin 500 mg 3 times a day for 7 days or clindamycin 600 mg 3 times a day is used in patients allergic to β-lactamases.
- Corticosteroids are not routinely used, because they may decelerate healing and increase the risk of postoperative infection.

POSSIBLE COMPLICATIONS

1. During implant/graft surgery
   - Lack of primary stability caused by insufficient graft maturation or an inadequate drilling sequence.
   - Nerve injury.
2. Early postoperative complications ($\leq$3 weeks)
   - Membrane exposure as a result of inadequate surgical management (insufficient flap release to achieve tension-free closure).
   - Low-grade, medium-grade, or high-grade infection resulting from membrane exposure and/or graft contamination during surgery.
3. Late postoperative complications (>4 weeks)
   - Membrane exposure caused by trauma. This unfortunate event may lead to early

Table 4
Clinical results in the literature

Author	Number of Participants	Follow-up	Type of Augmentation	Type of Membrane	Bone Filler	Bone Gain (mm)	Implant Survival (%)	Peri-implant Marginal Bone Loss
Urban et al,[8] 2014	19	6 mo	VRA	Dense PTFE	AB + ABBM	5.45 ± 1.93	100	NR
Urban et al,[7] 2011	22	8 mo	HRA	Synthetic resorbable membrane	AB ± ABBM	5.56 ± 1.45	100	NR
Urban et al,[3] 2009	35	12–72 mo	VRA	Expanded PTFE	AB + ABBM	5.5 ± 2.29	100	1.4 ± 0.57 mm at 12 mo 1.42 ± 0.1 mm at 72 mo
Urban et al,[10] 2017	16	1–15 y	VRA ± HRA	Dense PTFE and collagen membrane	AB + ABBM	VRA: 5.1 ± 1.8 HRA: 7.0 ± 1.5	100	1.4 ± 1 mm

Abbreviations: HRA, horizontal ridge augmentation; NR, not recorded; VRA, vertical ridge augmentation.

Table 5
Current controversies and future considerations

Clinical Controversies	Future Considerations
Effectiveness of different bone substitutes to achieve ridge augmentation	To examine the different bone substitutes combined or not with autogenous bone
Plausibility of incorporating customized scaffolds according to site morphology	To gain insight to the accuracy of custom-made scaffolds and nonresorbable barrier membranes
Advantages and disadvantages of GBR vs other procedures for tissue reconstruction	To evaluate the clinical, radiographic, and patient-reported outcomes of GBR vs other procedures for tissue reconstruction
Efficacy of biologic agents and platelet-derived aggregates on regenerative outcomes	To evaluate the clinical, radiographic, and patient-reported outcomes of GBR using biologic agents
Radiographic peri-implant marginal bone level and clinical parameters of augmented bone vs implant placed in pristine bone	To compare the clinical and radiographic outcomes of implants placed in augmented vs pristine bone over the long term (>10 y)

membrane removal and less-than-expected bone gain.

4. Late technical and biological complications
   - Peri-implant diseases as a consequence of poor plaque control.

CLINICAL RESULTS IN THE LITERATURE

The results from clinical trials reported in the literature are presented in **Table 4**.

CURRENT CONTROVERSIES/FUTURE CONSIDERATIONS

Current controversies and future considerations are presented in **Table 5**.

SUMMARY

GBR represents a plausible, viable, and effective alternative for the reconstruction of atrophic ridges. Crucial technical aspects, such as the achievement of tension-free flap closure, and stability of the graft and barrier membrane are of paramount importance to secure successful outcomes. The procedure requires great technical expertise and is indicated for low-level patient risk profiles (ie, adequate personal oral hygiene measures and nonsmokers).

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