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Current state of conventional vertical bone regeneration vs with titanium occlusive barriers-literature review

Abstract

Introduction: The alveolar bone is part of a specialized structure of the bones of the face, specifically the maxilla and mandible, this being the main support for the teeth, which is composed of cortical bones that form the vestibular and palatine walls and lingual. It is also made up of spongy bone, within it there are numerous medullary perforations, being smaller in the cortex. The alveolus is subject to continuous changes that are produced by dental eruption, chewing and a variety of periodontal diseases that can influence its constant remodeling.

Materials and methods: An electronic search was carried out to provide support and justification for this literature review. This bibliographic search was carried out in the Pubmed / Medline, Science Direct and Scielo databases of scientific articles published in English, which had the objective of describing the bone remodeling processes that occur in the alveolar bone after dental loss and the possible treatments for vertical bone regeneration that can be provided to the patient for the subsequent placement of the dental implant.

Results: Of the different conventional vertical bone augmentation techniques described in the literature over the years, CAD/CAM titanium meshes are the ones that present the highest percentage of gain. Likewise, greater bone gain was observed combined with collagen membranes than without them. Distraction osteogenesis presented a lower percentage of gain, followed by guided bone regeneration with non-resorbable membrane and, finally, the onlay or bone block graft technique. However, with the recent appearance of titanium occlusive barriers, the literature reports the highest percentage of gain.

Conclusions: Regarding complications, we can conclude that distraction osteogenesis and block bone grafts are those that obtained the highest complication rate, followed by CAD/CAM titanium meshes and non-resorbable membranes.

Keywords: bone, bone defects, vertical bone regeneration, biomaterials for bone regenerations, absorbable membranes

Volume 7 Issue 1 - 2024

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Received: February 13, 2024 | **Published:** February 28, 2024

Introduction

Phases of bone remodeling

a. **Quiescent phase:** the bone is at rest, since the remodeling factors are not yet detected.[1]

b. **Activation phase:** the first step that takes place is the activation of the bone surface prior to resorption, due to the contraction of the limiting cells (mature osteoblasts) and the assimilation of the endosteal membrane, since there is action of collagenases. When the mineralized surface is exposed, the attraction of osteoclasts is created.[2]

c. **Resorption phase:** osteoblasts begin to dilute the mineral matrix and decompose the osteoid matrix. This phase is completed by macrophages and allows the release of the growth factors contained in the matrix/ Radionuclide and Hybrid Bone Imaging, 2012.[3]

d. **Formation phase:** parallel to this, in the reabsorbed areas, the phenomenon of grouping of preosteoblasts takes place, which are attracted by the growth factors that are released from the matrix, which intervene as chemotactics and also stimulate their proliferation.[4] After a few days, the already differentiated osteoblasts will synthesize the osteoid substance that will occupy the drilled areas.[5]

e. **Mineralization phase:** after 30 days of osteoid storage, mineralization begins, and this ends after 130 days in the cortical bone and 90 in the medullary bone.[6]

Bone density

In 1985, Lekholm and Zarb[7] in their study described four types of bone qualities that we can find in both the maxilla and the mandible, these being:

-Type 1 quality: it is mostly composed of homogeneous cortical bone with a small core of trabecular bone.

-Type 2 quality: composed of a large layer of dense cortical bone that surrounds a core of dense trabecular bone.

-Type 3 quality: it is made up of a thin layer of cortical bone that surrounds a trabecular bone of favorable resistance.

-Type 4 quality: it is mostly composed of spongy bone that is surrounded by a thin layer of cortical bone (Figure 1).

Types of bone defects

In 1985, Misch and Judy.8 developed four basic categories to determine the availability of bone in the use of dental implantology in both the maxilla and the mandible, following the natural resorption phenomena in each region. They also included both bone angulation

and crown height for each bone volume, as they affect prosthetic treatment. Years later, they added two subcategories in order to provide a focus for the different implant treatment options, such as bone grafts and future prostheses (Figure 2).

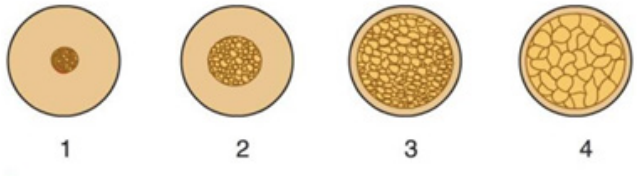

Figure 1 Scheme of bone qualities according to Lekhonlm and Zarb, 1985.[7]

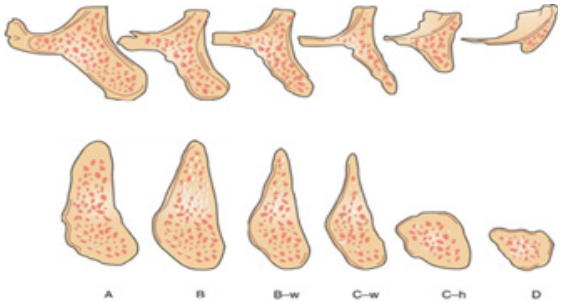

Figure 2 Classification of alveolar bone defects according to Misch and Judy, 1985.[8]

The categories to determine the available bone are the following:

a. Division A: it is the ideal time to offer the patient prosthetic rehabilitation on implants, since we find an abundant bone that retains all its dimensions both in width and height, which will benefit the patient by reducing treatment costs and the complexity of it.

b. Division B: it is composed of almost insufficient bone, in the mandible the resorption in the anterior area is usually more stable than in the posterior, on the other hand, in the posterior area of the maxilla the resorption is usually maximum.

There are three possible treatments for this type of division:

i. Osteoplasty, to allow the placement of implants of 4 mm or larger diameter. When a result of 12 mm height is produced with this technique, it is called class A division, and below 12 mm it becomes C-h division.

ii. Place narrow diameter implants.

iii. Autogenous bone grafts or a combination of allografts and alloplastic material with or without guided bone regeneration (GRO) techniques, and wait 4 to 6 months for implant placement. In B-W division bones, autologous bone augmentation is recommended.

c. Division C: we find a compromised bone, with a greater defect in the posterior areas, both in the maxilla and the mandible, placing the inferior alveolar nerve canal and the maxillary sinus as a limiting factor.

In this division the following treatment options are proposed:

i. Osteoplasty (C-w).

ii. Autologous bone grafts.

iii. Rafts in blocks.

iv. Maxillary sinus lifting techniques.

v. Placement of short implants (C-h).

vi. Placement of subperiosteal implants (C-h, C-a partial or totally edentulous).

d. Division D: long-term bone resorption will cause a complete loss of the residual ridge and result in atrophy of the basal bone.

In this division the following treatments are suggested:

i. Autologous iliac crest grafts.

ii. Maxillary sinus elevation techniques.

iii. Endosseous implants on certain occasions.

In 1985, Lekholm and Zarb[7] published a classification based on the degree of ridge atrophy related to the insertion of Branemark devices. This classification consists of 5 morphologies, according to "Practical Techniques in Periodontics and Implant Dentistry", Wiley, 2022.

a. Morphology A: the alveolar ridge is practically intact.

b. Morphology B: when there is minor resorption of the alveolar ridge.

c. Morphology C: there is advanced resorption of the alveolar crest to the base of the dental arch.

d. Morphology D: resorption begins at the base of the dental arch.

e. Morphology E: presents extreme resorption at the base of the dental arch (Figure 3).

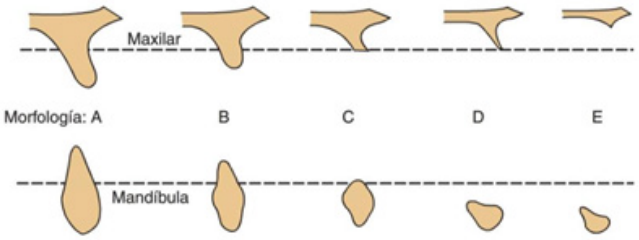

Figure 3 Classification of alveolar bone defects according to Lekholm and Zarb, 1985.[7]

Hom-lay Wang in 2002,[9] proposed a new classification of bone defects based on the Seiberts classification with some modifications, both soft and hard tissue defects were included in this scheme with their respective treatment option. Seibert's three categories are still present, but with the use of simpler terminology, which classifies them into class I (horizontal), class II (vertical) and combined defects, subdividing in turn into small ones (s, ≤ 3 mm), medium (m, 4 to 6 mm) and large (l, ≥ 7 mm).

a) Horizontal defects: those small and medium soft tissue defects that can be treated with the "roll" technique, connective tissue grafts or inlay. In the case of larger defects they can be treated with a combination of connective tissue grafting and/or interpositional grafts. Treatment of small hard tissue defects for future implant placement can be accomplished by osteotome-based vertebral expansion procedures, ridge splitting, ROG, or piezoelectric surgery. Medium and large defects may require procedures such as monocortical inlays, onlay grafts from intraoral or extraoral sources, or ROG. "Nuno Cruz, Maria Inês Martins" Surface Comparison of Three Different Commercial Custom-Made Titanium Meshes Produced by SLM for Dental Applications", Materials, 2020.

b) Vertical defects: This type of deficiency presents a challenge in terms of treatment planning. Small and medium defects can be treated with onlay connective tissue grafts, while large defects can be planned with multiple onlay grafting procedures. You can also resort to a joint treatment with the orthodontic area, to extrude the tooth before extracting it and thus achieve a small correction of the ridge in a vertical direction. As for medium and large defects, they can be treated using onlay grafts or ROG procedures.

c) Combined defects: This type of defect presents even greater challenges for the clinician. A combination of soft and hard tissue augmentations is generally required for correction of these defects. Small and medium-sized defects can be performed using a combination of multiple soft tissue procedures, with ROG with block inlay/onlay grafts with or without distraction. Larger defects are difficult to treat, in most cases block grafts (tibia, ribs, calvaria) are needed for ridge augmentation (Figure 4).

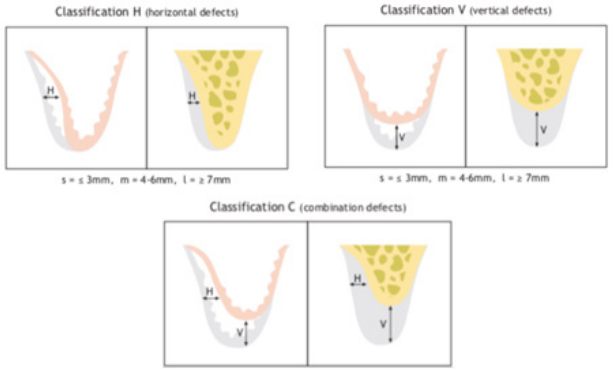

Figure 4 Classification of alveolar defects according to Hom-lay Wang, 2002.[9]

Chiapasco in 2018,[10] is based on the concept of "implant placement driven by prosthetic restoration" optimizing both the function and aesthetics of the patient, for which it publishes an article based on evidence and oriented to future restoration, in turn describes in detail a diagnostic protocol, classification of bone defects and the main augmentation techniques.

One of the general rules when performing a restoration on implants is that viability must first be verified from a prosthetic point of view. As a diagnostic method we can use plaster molds and a wax-up, since it will allow us to recognize discrepancies or asymmetries of the edentulous ridges. If we are only going to restore one hemiarch, the contralateral side should be taken as a reference, both to evaluate the alveolar crest and dental morphology. On the other hand, a Cone Beam Computed Tomography (CBCT) should be performed in conjunction with facial and intraoral clinical photographs, since they are a very important tool when defining the appropriate treatment plan for the patient.

Once the bone defect has been identified, it must be analyzed whether the bone volume is adequate for the placement of the prosthetically guided implant, or whether it is necessary to perform a graft procedure.

Classification of bone defects according to a prosthetic diagnostic protocol and its various surgical treatment options:

a. Class 1: The implants can be placed in the ideal position since there is no discrepancy and it does not interfere with the future restoration. In this class, no type of bone augmentation is necessary since the implant is completely surrounded by residual bone and these can be placed with surgical guides. In some cases we can find small defects that can affect the anterior area, this being an area of high aesthetic demand, which is why a connective tissue graft is recommended.

b. Class 2: we find a moderate horizontal deficit, however, the implants can be placed in a prosthetically correct position, in some cases during the placement of the implant a fenestration or dehiscence may occur in the vestibular cortex and this will not guarantee us a favorable long-term diagnosis, which is why it is advisable to perform a simultaneous bone augmentation procedure with the placement of the implants. Among the recommended treatments for this type of defects would be ROG with autologous bone and/or alloplastic materials, covered by resorbable or non-resorbable membranes, and sagittal osteotomy techniques, with the use of expanders and the use of implants with a narrow diameter. In cases where aesthetics is affected, a connective tissue graft is recommended.

c. Class 3: we find a significant horizontal deficit which will prevent us from placing the implant in an adequate prosthetic position and therefore achieving good primary stability.

The main surgical techniques for the correction of deficits in this class are:

i. ROG techniques with autogenous particulate bone and/or alloplastic materials in sets with resorbable or non-resorbable membranes.

ii. Autogenous bone graft blocks from donor sites that could be both intraoral and extraoral and also non-autogenous bone blocks.

iii. In most cases, after performing an ROG, we perform soft tissue augmentation before prosthetic rehabilitation on implants to optimize the shape of the edentulous ridge and provide the patient with greater aesthetics.

After having performed the ROG, you should wait approximately 4 to 9 months (depending on the type of treatment selected) for the subsequent placement of the implant.

d. Class 4: in this class we find a combined bone deficit (horizontal and vertical). When we find vertical defects, the complexity of the treatment increases and the surgical techniques are more demanding, since they are associated with a higher rate of complications. The patient should be informed that there are postoperative risks such as membrane exposure, infection, resorption, and increased morbidity.

The main surgical techniques for combined defects are according to "Paolo Casentini" Horizontal bone-augmentation procedures in implant dentistry: prosthetically guided regeneration", Periodontology 2000, 201"

i. Autologous bone blocks.

ii. ROG techniques with autogenous particulate bone or alloplastic materials with the use of resorbable or non-resorbable membranes.

iii. Lefort I Osteotomy, advancing and descending the jaw. This type of treatment is indicated for severe atrophies of the jaw (Figure 5).

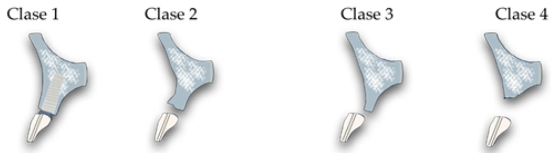

Figure 5 Classification of bone defects according to Chiapasco, 2018.[10]

Guided bone regeneration

ROG can be described as a surgical procedure that allows us to increase the alveolar bone when it is deformed due to tooth loss, periodontal diseases or consequences of trauma, reasons for which it can cause a reduction in both vertical and horizontal dimensions which prevents us from correctly placing dental implants. As we know, alveolar regeneration is a unique event since the site previously occupied by dental roots does not have bone, and for bone to form a series of events must arise that begin with the deposition of a provisional matrix of connective tissue that Finally, it is replaced by bone tissue and then by lamellar bone. One of the most used substitutes when a dental organ is lost is usually osseointegrated implants, which provide us with both the lost facial aesthetics and the chewing function, therefore, ROG techniques are indicated as long as the patient needs them and there is no possibility of placing short implants.[11]

ROG techniques can be performed in one surgical phase, which would involve the simultaneous placement of the implants and bone augmentation, or in two surgical phases, first performing the bone augmentation, and then, after a few months, the placement of the implants.[12] In this second phase, it must be taken into account that the thickness of the vestibular cortex must be at least 2 mm, to guarantee stability of the peri-implant soft tissues. For the success of these procedures, a membrane must be used to act as a barrier to prevent soft tissue migration before osteogenic cells begin to form and at the same time seal the gap to develop new bone matrices. "Alberto Monje "Guided Bone Regeneration in Alveolar Bone Reconstruction", Oral and Maxillofacial Surgery Clinics of North America, 2019"

On the other hand, the literature supports that in certain cases in which there is not the adequate amount of bone for the correct placement of the implants, surgical techniques can be used, such as grafts in intraoral blocks obtained from the residual ridge, the symphysis mandibular and the mandibular body or branch, or extraoral, coming from the iliac crest and tibia, for the reconstruction of said defects.[13]

a) Indications for bone regeneration:

i. Fenestration bone defects.

ii. Dehiscence.

iii. Horizontal bone defects.

iv. Vertical bone defect.

v. Combined defects (horizontal and vertical).

vi. Defects contained in 2 to 3 circumferential walls due to peri-implantitis defects.

vii. Postextraction sockets with and without immediate implant.

b) Contraindications for bone regeneration according to Radionuclide and Hybrid Bone Imaging, 2012.

i. Smoking patients.

ii. Uncontrolled systemic diseases.

iii. Inability to achieve primary closure.

iv. Inability to stabilize bone filling and or barrier membrane.

v. Little experience of the clinician.

vi. Uncontained peri-implantitis defects.

Discussion

After the extraction of a tooth, whether due to trauma, cysts, tumors or advanced periodontal disease, the alveolar bone undergoes dimensional changes that can be detrimental to the placement of dental implants in the correct position, compromising their future rehabilitation. These changes can occur horizontally, vertically or in combination, with the posterior area of the mandible and maxilla being the most affected areas, since the bone is resorbed more quickly than in the anterior area. Different authors have developed various classifications regarding jaw atrophy, based on the quantity and quality of bone available.[14]

One of the biggest clinical challenges today is vertical bone regeneration, for which there are various procedures prior to therapy with dental implants.[15] Chiapasco and Casentini in 2018,[10] conducted a study based on the concept of "implant placement driven by prosthetic restoratio, in which they described in detail a diagnostic protocol for the classification of bone atrophies and the main vertical bone augmentation techniques. Bone regeneration with non-resorbable membranes, distraction osteogenesis, onlay graft or block graft or Le Fort osteotomy. In turn, Scavia et al., in their 2021 study, proposed a new ROG technique with d-PTFE, in pocket, obtaining encouraging results, with a bone increase of 8.78 mm, being similar to the average reported in the literature.

Likewise, Wang et al. determined that for these procedures to achieve their objective, 4 biological principles must be met: primary closure, angiogenesis, creation and maintenance of space, and clot stability. Alveolar ridges with severe bone deficits and inadequate soft tissue volume present difficulties for stability of the grafted material and primary closure.[16]

Numerous comparative studies have been carried out that assess the effectiveness of the different biomaterials used for bone augmentation, with autogenous bone being the material of choice, despite the morbidity and possible complications of the donor site.

The growth of soft tissue is faster than the formation of bone tissue, so the membranes act as a barrier preventing the migration of soft tissue to the area we want to regenerate.[17]

Likewise, it is known that membrane exposure compromises the effectiveness of the ROG. Chiapasco and Zaniboni,[18] described in their 2006 comparative study that 20% of the e-PTFE membranes presented exposures and infections, with a coverage of 63 to 100% despite their exposure, while the collagen membranes presented a 95% coverage.

Recently, the possibility of performing vertical bone regeneration procedures with a subperiosteal barrier membrane without the need to use any type of biomaterial has been studied, since it provides a stable blood clot that transforms into bone tissue.[19]

They observed that the same amount of bone formed under fully airtight occlusive membranes compared to semipermeable membranes. It has also been shown that these barriers have osteoconductive properties. However, Lundgren in 1998 conducted a comparative study in rats, in which he used totally occlusive versus perforated barriers to evaluate the composition and quality of the tissue formed over time. They reported that the quality of bone obtained was better in the case of totally impermeable barriers than in semipermeable ones. Other authors, such as Perret carried out a series of cases in which they evaluated the bone changes obtained after the placement of a titanium barrier to achieve bone regeneration, obtaining a vertical bone gain of 7mm in the vestibular and 4mm in

the lingual, stating that the use of occlusive barriers without primary closure are successful in alveolar reconstruction.[20]

Table of the different vertical bone regeneration techniques

Comparative table of the different vertical bone regeneration techniques in terms of bone gain and the percentage of complications of the different existing procedures (Table 1).

Regarding the vertical regeneration procedure with completely hermetic titanium occlusive membranes, Van Steenberghe conducted a clinical trial describing a bone gain of 16 mm without the need for bone grafting.

Taking into account the studies analyzed, the average bone gain between the different types of conventional vertical regenerations is 6.85 mm. In the case of occlusive barriers, the bone gain described is 16 mm. However, more long-term studies are needed to confirm the success rate of implants placed in regenerated bone with occlusive barriers.[21]

Table 1 Representative analysis of the different vertical bone regeneration techniques, indicating their bone gain and their percentages of complications

Author	Magazine	Year	Study	Technique	Gain in mm	Complication in %
Chiapasco	Clin. Oral. Imp. Res.	2021	Retrospective clinical study.	CAD/CAM titanium mesh.	8.9mm	/
Cucchi	Clin. Oral. Imp. Res.	2021	Clinical trial.	CAD/CAM titanium mesh.	/	Membrane 13% Without membrane 33%
Urban	Clin. Oral. Imp. Res.	2021	Multivariate analysis.	ROG with d-PTFE.	5.2mm	3%
Scavia	J. Contemp. Dent. Pract.	2021	Preliminary results.	ROG with d-PTFE.	8.78mm	/
Urban	J. Clinical Periodontology.	2019	Systematic review and meta-analysis.	ROG with e-PTFE.	4.31mm	12.1%
Urban	J. Clinical Periodontology.	2019	Systematic review and meta-analysis.	ROG with d-PTFE.	4.99mm	12.1%
Urban	J. Clinical Periodontology.	2019	Systematic review and meta-analysis.	Distraction osteogenesis.	8.4mm	47.3%
Urban	J. Clinical Periodontology.	2019	Systematic review and meta-analysis.	Block graft.	3.46mm	23.9%
Brigulio	Inter. J. of Dentistry.	2019	Systematic review.	ROG with titanium meshes	12.4±3.1mm	34.8%
Elnayef	The Int. J. of Oral Maxillofacial Impl.	2017	Systematic review and meta-analysis.	ROG	3.83mm	Infection 5.8-31.8% Dehiscence 8-27%
Elnayef	The Int. J. of Oral Maxillofacial Impl.	2017	Systematic review and meta-analysis.	Distraction osteogenesis.	6.8mm	Infection 8-57% Elimination of the distractor 6.8-18%
Elnayef	The Int. J. of Oral Maxillofacial Impl.	2017	Systematic review and meta-analysis.	Block inlay graft.	4.92mm	Infection 10-20% Dehiscence 8-30%
Elnayef	The Int. J. of Oral Maxillofacial Impl.	2017	Systematic review and meta-analysis.	Onlay block graft.	3.47mm	Infection 10-16% Dehiscence 3.8-45.8%
Yun	The Int. J of Oral and Maxillofacial Impl.	2016	Systematic review and meta-analysis.	Distraction osteogenesis.	7.65mm	/
Yun	The Int. J of Oral and Maxillofacial Impl.	2016	Systematic review and meta-analysis.	Onlay bone graft.	5.83mm	/
Van Steenberghe	Clin. Oral. Impl. Beef.	2003	Clinical trial.	Occlusive barriers.	16mm	20%

Conclusion

There are various techniques for vertical bone augmentation such as: guided bone regeneration with non-resorbable membranes, distraction osteogenesis, block bone grafts, le fort I, personalized CAD/CAM titanium meshes and bone regeneration with titanium occlusive barriers.

Conventional techniques obtained an average bone gain of 6.85 mm and occlusive membranes of 16 mm. Despite the limitations of this bibliographic review, vertical bone regeneration with titanium occlusive membranes is a promising technique, and although, using other techniques, the percentage of complications is high, with this technique it can be reduced. However, long-term studies of regeneration with the occlusive barrier technique are needed and long-term studies are needed to assess the success rate of implants placed in this regenerated bone.

Acknowledgments

None.

Conflicts of interest

The author declares that there are no conflicts of interest.

Citation: Jessika MM, Alberto MBC, González ZP. Current state of conventional vertical bone regeneration vs with titanium occlusive barriers- literature review. *MOJ Sports Med.* 2024;7(1):15–20. DOI: 10.15406/mojsm.2024.07.00156

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