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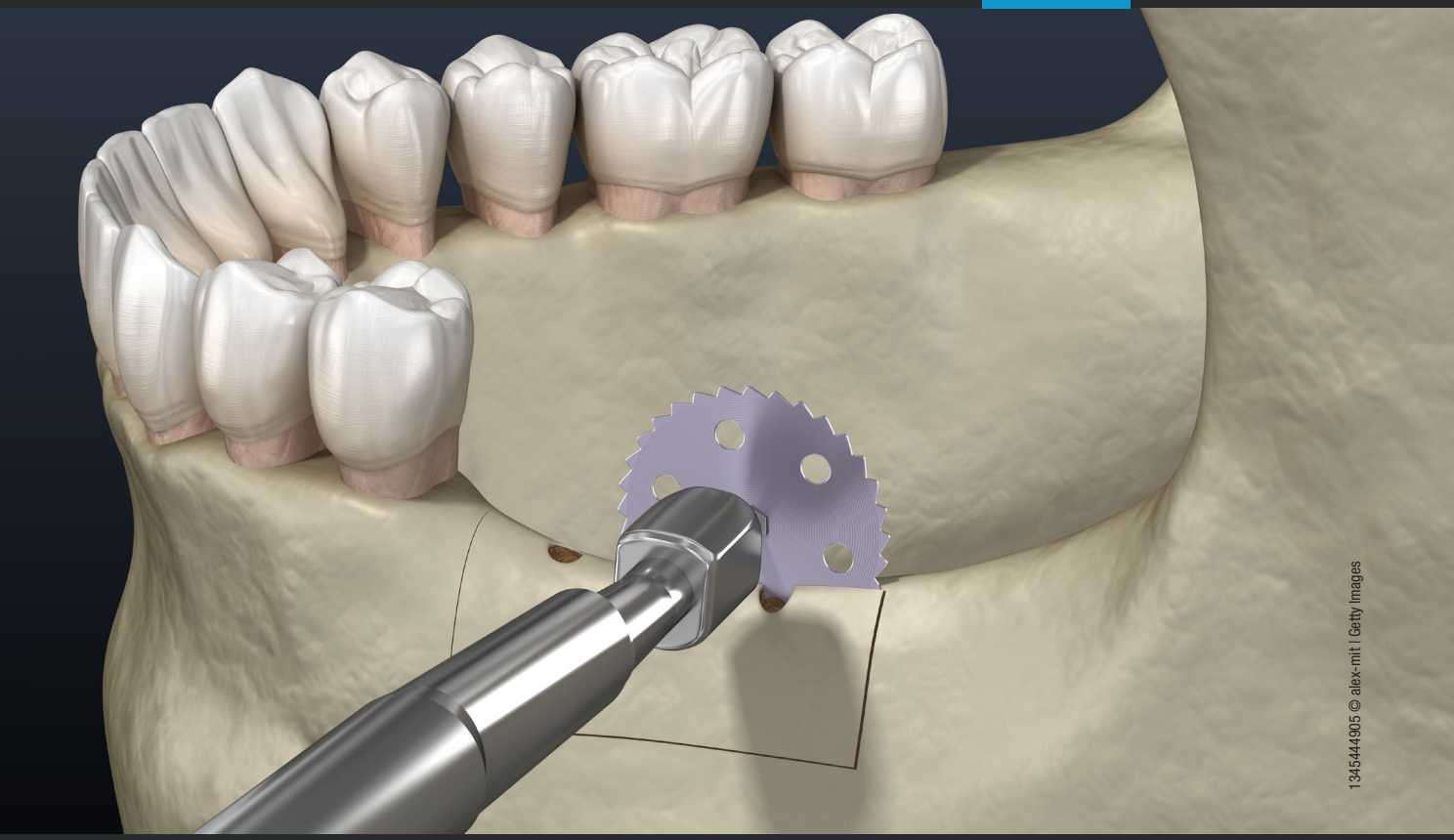

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Guided bone regeneration: A practical guide for choosing the most suitable substitute materials

A peer-reviewed article written by Muhammad H. A. Saleh, BDS, MS, MSD, and Hussein S. Basma, DDS, DESS, MS

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Guided bone regeneration: A practical guide for choosing the most suitable substitute materials

Abstract

This course will discuss the benefits of guided bone regeneration (GBR) as a preferred technique for alveolar ridge augmentation. We will walk the reader through different options of bone augmentation and why we think GBR is the treatment of choice. We will elucidate the key principles of what makes a successful GBR procedure, discuss different bone grafts and barrier membrane materials available in the market, and discuss the pros and cons of using each of them.

Educational objectives

1. Determine when ridge augmentation procedures should be performed
2. Explain why guided bone regeneration (GBR) is the preferred technique of bone augmentation for most clinicians
3. Distinguish the different types of bone grafting materials commonly used in ridge augmentation
4. Describe the different types of barrier membrane materials commonly used in ridge augmentation
5. Justify the rationale for using biologics during GBR procedures

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Dissatisfaction among denture wearers ranges from 10% to 30%.[1,2] As dentures lose their retention and stability, patients tend to have similar complaints: pain on function, difficulty in speech, and deteriorating esthetics. Loss of stability and retention occur mainly due to resorption of the denture-bearing area. Over the long term, mandibular alveolar bone height will decrease around 0.2 mm per year.[3] Many patients prefer a fixed option for tooth replacement, regardless of how convenient or efficient the alternative treatment is.[4]

Dental implants were introduced decades ago, and despite the contemporary technological spur in implant dentistry, ideal three-dimensional implant placement is still an imperative requirement for long-term implant stability, achieving esthetic outcomes, and minimizing the incidence of peri-implant disease.[5-7] Only if a clinician can place an adequate number of dental implants in a biologically and prosthetically favorable position can an ideal fixed implant-retained prosthesis be delivered.

The usual caveat is whether this is achievable without grafting. While large-scale grafting can sometimes be avoided by employing streamlined approaches such as the All-on-X concept,[8] even these approaches might not be applicable in severe ridge defects, where the available bony housing cannot accommodate dental implants with regular diameter and/or length. Further, the number and position of implants placed without grafting can be limited in patients with severe resorption.

Sizable bone defects can occur in the alveolar process as a result of periodontal disease, trauma, prolonged edentulism, or other bony lesions. Reconstruction of such defects predictably remains a surgical challenge, yet myriad surgical procedures can be utilized to perform this task.[9]

If appropriate grafting procedures are not performed at the time of tooth extraction, dramatic changes are anticipated to occur in both soft and hard tissue after extraction.[10] Such changes are expected to be even more pronounced in the maxillary esthetic zone, which makes early intervention crucial for achieving favorable esthetics, phonetics, and function.[11]

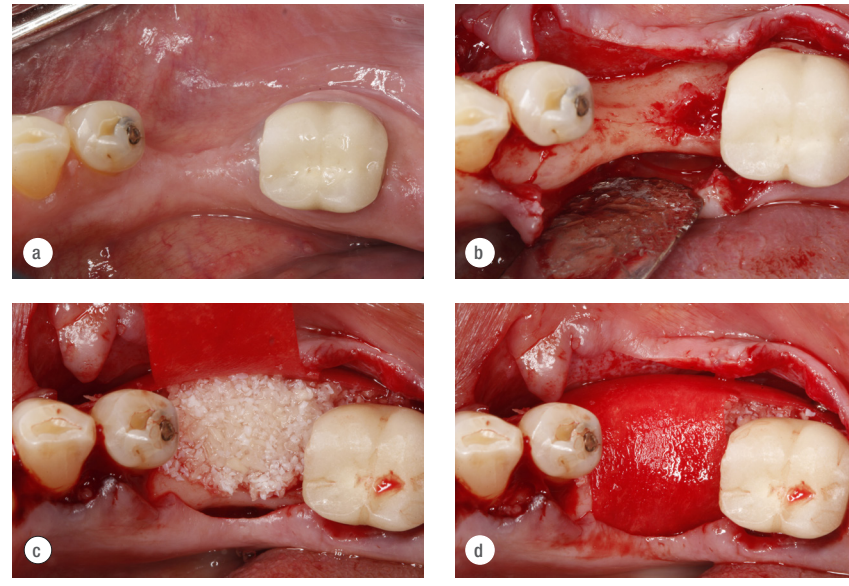

FIGURE 1: Guided bone regeneration procedure using a resorbable membrane and bone graft

Grafting for implant site preparation involves enhancing both hard and soft tissues, thus increasing the alveolar ridge volume beyond the existing skeletal envelope. Bone (hard tissue) grafting procedures are possible utilizing block grafting, guided bone regeneration (GBR), inlay grafting, as well as various distraction methods.

A recent well-designed systematic review and meta-analysis on vertical bone augmentation has established that guided bone regeneration using barrier membranes resulted in comparable bone gain and fewer postoperative complications compared with block grafting and distraction osteogenesis.[12]

Guided bone regeneration

GBR **(figure 1)** is considered the best-documented technique to successfully promote new bone formation, while having a comparatively lower number of, and less severe, complications.[13,14]

GBR was originally derived from the guided tissue regeneration principles around natural teeth.[15] The most central foundations of a successful GBR are laid out in the PASS principle. These include primary wound closure, angiogenesis, space maintenance, and stability of the clot.[16] The surgical intervention itself may be a factor that improves bone turnover through the regional acceleratory phenomenon (RAP) as described by Frost.[17]

Making a decision regarding an optimal GBR procedure is principally based on defect morphology, which might be

TABLE 1: HVAC ridge deficiency classification

Horizontal defects	
H-S	Ridge expansion
	Inlay/onlay grafts
	GBR
H-M	Inlay/onlay grafts
	GBR
H-L	Inlay/onlay grafts
	GBR
Vertical defects	
V-S	Orthodontic extrusion
	GBR
V-M	Orthodontic extrusion
	GBR
	Onlay grafts
V-L	GBR or onlay grafts
	Consider using biologics
Combined defects	
C-S	GBR
	Inlay/onlay grafts
C-M	Combination of GBR and inlay/onlay grafts
C-L	Combination of GBR and inlay/onlay grafts
	Consider using biologics

vertical, horizontal, or both. A knife-edge ridge, where the ridge height is adequate on the lingual/palatal side, is one of the most common indications for horizontal ridge augmentation.[18]

On this basis, Wang and Al-Shammari developed the HVAC ridge deficiency classification, aiming to simplify the choice of augmentation procedure **(table 1)**.[19] A closer look at this classification reveals that GBR is recommended as an individual or part of treatment for all nine types of bony defects, whether horizontal, vertical, or combined.

The general agreement that GBR could be used to manage a variety of bony defects led to its widespread use in clinical practice; however, combined horizontal and vertical defects still represent a challenge to GBR, especially when involving the esthetic zone.[20]

That said, the extent of vertical bone deficiency is what will most likely dictate the treatment choice. Recently, Misch et al. introduced a decision tree for extraosseous vertical bone augmentation (VBA) of the maxilla and mandible.[21] **Figure 2** illustrates the authors' rationale for VBA using GBR and titanium mesh.

GBR can be performed either simultaneously (combined) or prior to implant placement (staged). Whenever possible, simultaneous approach is favored, as it offers the patient a reduced number of surgical interventions, treatment time, and costs.

However, primary implant stability as well as recipient site blood supply and the ability to achieve primary closure must be considered as simultaneous placement of dental implants may limit both of these critical factors.

If postgrafting complications do occur, treatment is more predictable if the original surgery did not involve simultaneous implant placement.[12] Still, in cases with advanced bone resorption resulting in a need to graft outside the bony envelope (i.e., add bone in a horizontal plane without adjacent bony walls that can support the graft and/or serve as a source of osteogenic potential), a staged approach is always preferred **(figure 3)**.[22,23] Numerous successful, applicable staged GBR approaches have been prescribed in the literature.[24,25]

Overcorrection at augmentation is typically recommended, considering the tendency of bone to remodel with some degree of resorption over time.[26,27] Because of that, minimizing volume changes at the future implant site remains the most important criterion for long-term success of implant rehabilitation.

Bone graft materials

Autogenous bone **(figure 4a)** is the gold standard due to its osteogenic and osteoinductive characteristics, through which cells and bioactive molecules such as bone morphogenetic proteins (BMP) are provided to induce *de novo* bone formation, which eventually leads to graft incorporation into the host bone.[27-29] However, compared to other graft material types, autogenous grafts may result in additional morbidity from a second surgical site and an increase in the rate of graft resorption, which might range from 18% to 60% of the augmented volume.[30-32]

This leaves the clinician with one of two choices: utilizing other grafts without osteogenic potential or considering a hybrid graft material selection to harness the beneficial autogenous graft properties while preserving volumetric stability.

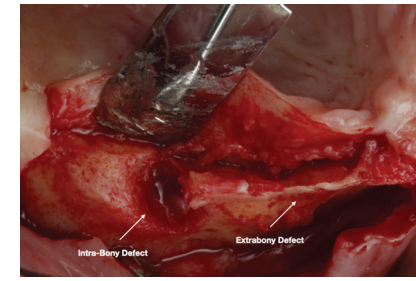

FIGURE 3: Intrabony and extrabony defects

The increased rate of resorption of autogenous grafts can be controlled by several methods. One convenient and commonly used method is the addition of deproteinized bovine bone mineral particles (DBBM) to autogenous graft. DBBM **(figure 4b)** offer an exceptionally low substitution rate; this results in a significantly lower rate of graft resorption after six months of healing.[33,34] In addition to the direct physical protection from resorption, amalgamating the graft with DBBM will indirectly decrease the volume of autogenous bone needed, which in turn will decrease the percentage of anticipated resorption. This also means that the size of harvested bone will decrease, potentially resulting in decreased morbidity.

Meta-analyses comparing bone graft materials demonstrated that a combination of autogenous bone with a bone substitute (i.e., allograft and/or xenograft) led to the greatest final amount of bone formation within the sinus cavity.[35,36]

Note that bone substitutes may not only eliminate donor site morbidity associated with autogenous bone, but may also have similar outcomes for implant success when compared to autogenous bone when used in severe defects.[37] But these histologic differences do not necessarily translate into clinical recompenses.[38]

In addition to being biocompatible, bone substitute material should prevent collapse of the created space for bone formation (space-making capability) and be replaced with newly formed bone through bone remodeling by osteoclasts

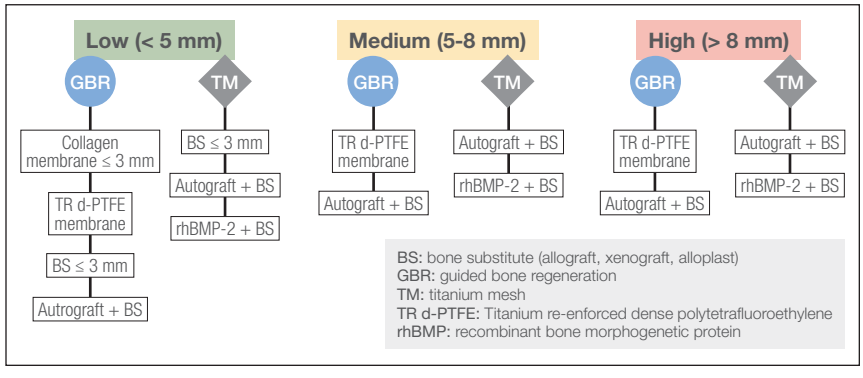

FIGURE 2: A simplified version of the Misch et al. decision tree for vertical bone augmentation of maxillary and mandibular defects.[20]

FIGURE 4: Bone grafting materials used in GBR procedures: (a) autogenous graft; (b) xenograft; (c) allograft

(bioabsorbability).[39] The space-making capability of bone substitutes should be considered separately from the bone formation since maintenance of the augmented volume during healing is crucial to control the three-dimensional alveolar bone morphology.[40]

There might be a few advantages of autogenous bone over other bone substitutes, but when choosing the most appropriate type of graft, one should assess not only the osteogenic capability of the bone, but also the bioabsorbability and the space-making capability.

The second method for limiting bone resorption is using barrier membranes.[41] A combination of these techniques has been utilized since the early 2000s, when several groups started using autogenous grafts together with DBBM and collagen membranes to offer graft protection against resorption.[42,43]

An acceptable alternative for using autograft might be allografts **(figure 4c)**. Generally, allografts exist in two forms: demineralized freeze-dried bone allograft (DFDBA) or mineralized freeze-dried bone allograft (FDBA). Since FDBA is mineralized, it has a slower resorption rate compared to DFDBA while still providing an osteoconductive scaffold. The demineralization process of the DFDBA removes the mineral portion of the graft, which exposes the underlying bone growth factors such as bone morphogenetic proteins (BMPs).[44] Due to this fact, DFDBA may have a higher osteoinductivity than FDBA.[45,46] However, this is contingent on the quality and quantity of the bone matrix in the graft material. This basically means it depends on whether the bone bank would verify the activity/availability of BMPs in DFDBA or not.[47]

Available bone grafts include: (table 2)

- Autograft: Bone that is transferred from one site to another within the same individual for the purpose of grafting
- Allograft: A graft from a donor of the same species as the recipient but not genetically identical
- Xenograft: A graft that is transferred from an individual of a different species
- Alloplast: A synthetic material that is employed as a space filler within an osseous defect for the purpose of defect repair

Barrier membranes

Cell-occlusive barrier membranes serve to prevent the population of a space with unwanted cell types (e.g., epithelial and/or connective tissue cells) and can be used alone or in combination with graft materials and/or growth factors to achieve bone regeneration.[48] This is accomplished by avoiding the proliferation of nonosteogenic cells (i.e., epithelium and connective tissue) or cell exclusion[49] into the defect. In fact, initially, the key objective of using any sort of bone graft beneath barrier membranes was to prevent the collapse of the membrane into the defect.[50,51] The current perception, though, is that both have synergistic effects, which was confirmed by significantly reduced graft resorption in studies with longer follow-up.[52] Hence, combining bone grafts with barrier membranes is now considered the standard of care.[53]

Barrier membranes are generally divided into two main categories: nonresorbable and resorbable.

Nonresorbable membranes

Expanded polytetrafluoroethylene (e-PTFE), a nonresorbable barrier membrane, was the first generation of barrier membranes to be used for GBR procedures around dental implant defects.[54,55] The chief advantages of e-PTFE are the lack of immunologic reaction and resistance to enzymatic degradation. Additionally, incorporation of titanium bands within the e-PTFE membranes increases their mechanical stability to maintain the space grafted throughout the healing period, thus maintaining the grafted shape and volume until graft consolidation is completed. These titanium-reinforced e-PTFE membranes allow the clinician to individually shape the membrane to fit most clinical situations.

TABLE 2: Types of bone grafts

Bone type	Autogenous	Allograft	Xenograft	Alloplast
Origin	Bone from same individual	Bone from same species (different individual; cadaver)	Bone from different species	Bone from synthetic origin
Properties	Osteogenic*	Osteoconductive	Osteoconductive	Osteoconductive
	Osteoinductive**	Osteoinductive (only DFDBA)		
	Osteoconductive***			

*Bone contains vital bone cells that make new bone.
**Bone contains undifferentiated cells that can be stimulated to develop into bone-forming cells. ***Bone serves as surface that promotes bone growth (scaffold)

A disadvantage of e-PTFE is the high incidence of premature membrane exposure, which is seen more frequently in individuals who smoke and/or at sites with compromised healing.[56] When this takes place, the membrane surface will be rapidly colonized by oral microbes.[57] Subsequently, adjacent tissues may become infected, necessitating early membrane removal and impediment of the regeneration process.[58,59]

More recently, dense polytetrafluoroethylene (d-PTFE) **(figure 5)** became an increasingly used nonresorbable barrier material. Compared to e-PTFE, d-PTFE seems much more biocompatible, demonstrating approximately 50% fewer complications.[12] But compared to resorbable membranes, d-PTFE exhibits suboptimal tissue adhesive properties that could risk the flap integrity.[60]

A preliminary study has demonstrated recently developed titanium-reinforced PTFE mesh perforated by macropores to possibly improve vascularization by permitting direct contact between periosteum and bone grafts.[61] More rigorous basic and clinical trials will be indispensable to prove such claims.

Titanium mesh **(figure 6)** can be effectively used as a nonresorbable barrier for GBR.[62] The physical characteristics of titanium mesh have proven advantageous for successful treatment of challenging defects such as combined vertical and horizontal defects.[63] Though these defects might be very challenging, titanium mesh proved to help rebuild them efficiently if used properly.[64] Unfortunately, the greater stiffness of this kind of barrier is usually associated with a higher rate of complications, such as mesh exposure and partial—or in some cases total—failure of the augmentation procedure.[65]

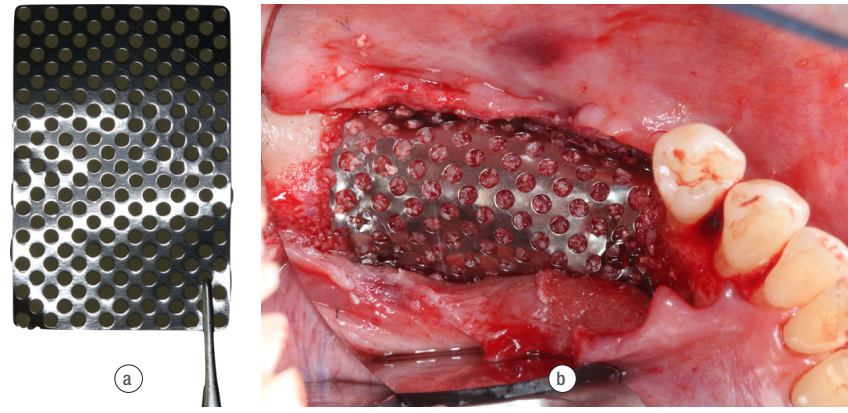

FIGURE 6: Titanium mesh (a) used to augment severe bony defects (b)

Resorbable membranes

Resorbable membranes have several advantages over nonresorbable variants, such as elimination of the second surgery needed for membrane removal; better cost-effectiveness; and significantly decreased incidence of membrane exposure.[66,67] Application of these membranes also tends to be much easier than nonresorbable ones.[53]

The most used resorbable barrier membranes are collagen based **(figure 7)**. Collagen-based membranes have multiple features that render them attractive for GBR. Collagen membranes have comparable clinical outcomes with nonresorbable membranes; it has even been suggested that they may promote more favorable wound healing and improved overall bone regeneration.[68]

Collagen membranes do not come free of limitations, however. Their main disadvantage is their lack of rigidity, leading to poor space-maintaining properties.[69] Their rate of degradation is dependent upon the amount of collagen cross-linking and can be faster than that required for optimal bone regeneration.[70] Early loss of collagen membrane barrier function also makes it less useful for bigger augmentation procedures.[49] Hence, these membranes are more qualified for the types of defects that do not require extra fixation and stability.[71]

Different approaches have been attempted to enhance the mechanical properties of the collagen membrane and slow its degradation. A common method used is simply applying two layers of the same collagen membrane. It has been suggested that a second layer may reduce micromovement and improve its stabilization.[42] This was found to enhance the efficacy of the grafting procedure in terms of less bone resorption and higher bone density compared with a single-layer collagen membrane.[72] The same also was found for GBR procedures.[73] Moreover, it was recently reported that a double layer of collagen membrane resulted in increased soft tissue thickness, compared with a single membrane layer.[74]

Another commonly used method was chemical cross-linking of collagen membranes, which resulted in significant improvements of collagen stability and extended membrane resorption.[75,76] The amount of time that cross-linked membranes took to resorb was found to be directly proportional to the degree of cross-linking.[77] However, residues of chemicals (amides or aldehydes) have been reported to induce inflammation at the implant site.[78]

It has also been reported that the level of cross-linking is directly related to decreased tissue integration and increased foreign body reaction.[77] Thus, one should assume that the predictability of cross-linked

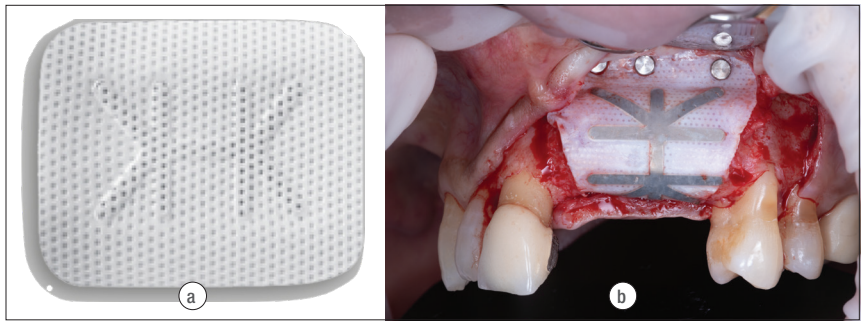

FIGURE 5: dPTFE membrane (a) used in GBR procedures (b)

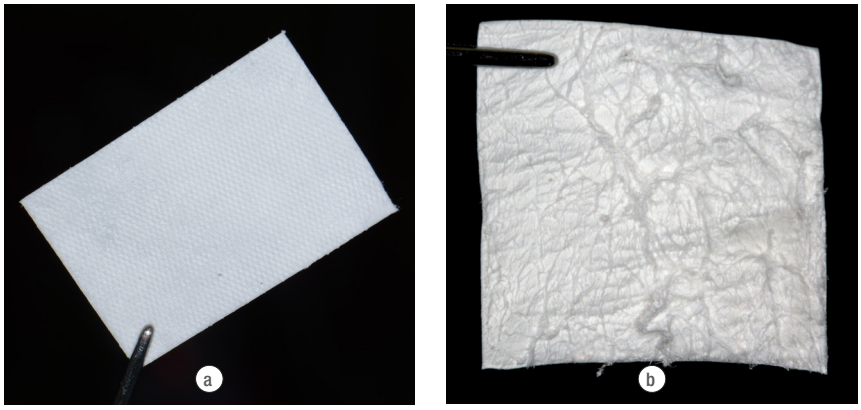

FIGURE 7: Resorbable collagen membranes. (a) Cross-linked membrane (b) Non-cross-linked membrane

collagen membrane depends heavily on the preparation and processing procedures.[79]

Acellular dermal matrix (ADM) **(figure 8)**, a tissue graft substitute derived from human skin after removal of the epidermis and all dermal cells, has also been clinically applied for ridge preservation and treatment of peri-implant defects.[80,81] ADM has also been shown to have better strength and stiffness than cellular dermal membrane.[82] When ADM was compared to e-PTFE for socket bone augmentation, no statistical difference between the two with respect to bone composition and horizontal and vertical bone loss was found.[83]

Other types of collagen membranes derived from human dura mater or pericardium have been suggested.[84] In 2013, a prospective multicenter trial indicated that lateral ridge augmentation using bovine pericardium membrane and allograft predictably achieved an increased horizontal ridge width prior to implant placement.[85] Though, when porcine pericardium membranes were compared to collagen membranes, no significant differences were found in both grafts, but less radiographic bone loss was observed in the pericardium group.[86,87] Human amnion membranes were also developed using decellularization and sterilization techniques.[88,89]

Several studies indicated the superior effect amnion chorion membranes have on wound healing.[90] Amnion membranes have overall favorable mechanical properties and good flexibility. One specific membrane was reported to promote bone growth while having a superior barrier

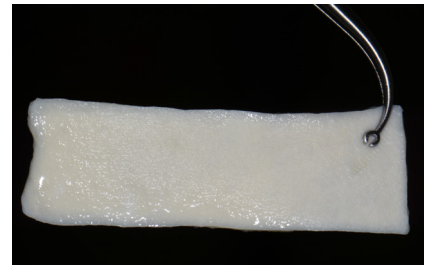

FIGURE 8: Acellular dermal matrix (ADM)

function in terms of fibrous tissue exclusion invasion.[89]

A general rule that should be kept in mind is that larger defects will need more time to heal, and thus necessitate a membrane with superior space maintaining qualities and resorptive qualities that reflect the anticipated healing time. Both time and space maintenance are not best offered by resorbable membranes; for that reason, nonresorbable membranes are usually the material of choice for larger ridge augmentation procedures.[91]

While several types of resorbable and nonresorbable membranes exist, the process of membrane selection is usually made on a case-by-case basis. While your choice should always be aiming for the least invasive approach, it should not be compromising much on predictability.

Utilization of growth factors (biologic materials) to gain enhanced regeneration

Tissue regeneration is based on a triad of cells, scaffolds, and signaling molecules such as growth factors. Utilizing growth factors has symbolized a new age in periodontal and bone regeneration in medicine and dentistry.[92] The foundation that the use of these biological mediators is based upon is to regulate cellular events involved in tissue repair, including chemotaxis, differentiation, and tissue vascularization.[93]

As mentioned above, a successful GBR depends on several factors, but the obtainability of these factors varies from one case to another, which might be related to local or systemic factors.[16] Therefore, research has been directed toward enhancing growth factors, aiming at overcoming more complex situations, where the regeneration process is less predictable.[44,94] In such situations, application of biologic agents might be a sensible decision to promote sufficient quantity and quality of bone regenerated.[95]

These materials are expected to improve early wound healing and overall tissue regeneration. This occurs as a result of improved cellular differentiation, proliferation, and migration. The most used and investigated biologics for GBR are platelet-rich fibrin (PRF), recombinant human platelet-derived growth factor (rhPDGF), and synthetic peptide binding protein P–15. As such, utilization of these biologics would ideally result in faster healing and/or enhanced regenerative outcomes.[96]

Platelet-rich fibrin **(figure 9)** has been used increasingly in the past 10-20 years to promote tissue regeneration due to its abundance of growth factors, lack of chemical additives, the formation of a fibrin clot with entrapped regenerative cells, and leucocytes, which promote steady release of growth factors.[97]

PRF has therefore been used for bone grafting procedures, although full-sized fibrin clots have typically been cut into smaller PRF fragments and mixed with various biomaterials, forming what is now commonly called "sticky bone." These clots can be flattened to use as a lone barrier in GBR procedures or as an additional barrier over collagen membrane to promote soft-tissue healing.[98,99] However, an actual benefit from using PRF alone is yet to be proved. A recent systematic review that aimed to assess the benefit of PRF on bone formation for GBR procedures by looking into human controlled clinical

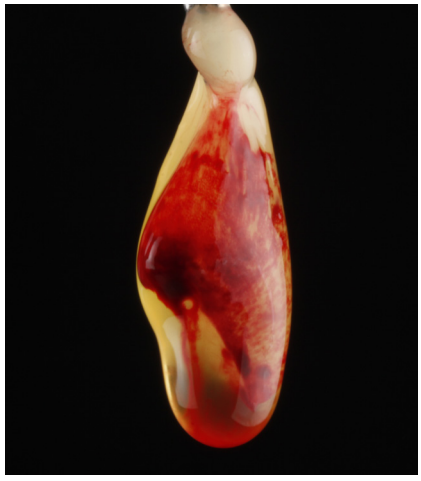

FIGURE 9: Platelet-rich fibrin (PRF)

trials concluded that PRF offered little or no advantage in terms of new bone formation for GBR, sinus augmentation, or treatment of peri-implantitis.[100]

Bone morphogenetic proteins (BMP), platelet-derived growth factor, vascular endothelial growth factor (VEGF), and insulin-like growth factor (IGF-1) among several other growth factors, have been assessed for such procedures.

In a systematic review assessing the outcomes of using different growth factors for alveolar ridge augmentation, BMP-2, BMP-7, platelet-derived growth factors, and parathyroid hormone (PTH) were found to have the ability to stimulate bone augmentation to various extents.[101] In that study and others, BMP-2 was positively correlated with promotion of local bone regeneration; this typically occurred in a dose-related pattern (increased effect was demonstrated for higher doses).[101-103]

In one study of dehiscences in critically sized defects, BMP-2 led to excessive bone formation beyond the volume originally augmented.[104] It is also noteworthy that rhBMP-2-loaded collagen membrane performed lateral onlay grafts as effectively as rhBMP-2-loaded bone substitute while showing less bone-residual bone substitute.[105]

The recombinant human platelet-derived growth factor–BB (rhPDGF-BB) **(figure 10)** is one of the most investigated growth factors for the promotion of wound repair.[106] One study compared rhPDGF + TCP with autogenous graft and found that the two treatment groups had similar outcomes in all the investigated parameters.[107]

Another randomized controlled trial demonstrated that the use of rhPDGF + β-TCP with GBR for immediate implants placed at molar sites was as successful as conventional implant therapy in fully healed extraction sites.[108]

Conclusion

Rehabilitation of severely atrophied jaws of edentulous patients is a complex process and successful treatment requires a detailed understanding of the biologic mechanisms of healing as well as the optimal techniques to enhance such healing.

A working plan including the number of implants, size, and form, even their position in the jaw, and the type of superstructure, should be developed ahead of treatment initiation. Several types of bone substitutes and resorbable and nonresorbable membranes exist.

The selection process should be made based upon patient and site-related factors. The choice of the most suitable material and techniques should be based upon scientific evidence, with preference for less invasive and more predictable approaches. A focus on enhancing the underlying biologic healing potential will allow practitioners to achieve predictable success.

FIGURE 10: Hydrating allograft bone particles with rh-PDGF

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MUHAMMAD H. A. SALEH, BDS, MS, MSD, is a clinical assistant professor University of Michigan School of Dentistry Department of Periodontics and Oral Medicine. He is actively involved in research, serving as a peer reviewer and publishing more than 50 periodontics and implant-related peer-reviewed articles. A winner of multiple national and international awards, Dr. Saleh's research interest is primarily focused on risk factors of periodontitis and peri-implantitis, and guided bone regeneration.

HUSSEIN S. BASMA, DDS, DESS, MS, is an assistant professor in the Department of Periodontology at the University of Alabama at Birmingham. He is a diplomate in the American Board of Periodontology, and lectures nationally and internationally about periodontology and implant dentistry. Dr. Basma has authored numerous peer-reviewed scientific articles and abstracts. His teaching efforts focus on bone augmentation, full-arch rehabilitation, multidisciplinary care, and integration of technology.

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QUESTIONS

1. Which of the following is considered the central foundation of successful guided bone regeneration?
   A. Primary wound closure
   B. Angiogenesis
   C. Space maintenance
   D. All of the above

2. Regarding horizontal ridge augmentation with simultaneous implant placement: If implant primary stability could be achieved, a simultaneous approach is preferable. However, if complications occur, treatment is more predictable if surgery didn't involve simultaneous implant placement.
   A. First statement is true; second statement is false
   B. First statement is false; second statement is true
   C. Both statements are true.
   D. Both statements are false.

3. A bone graft with osteoinductive, osteoconductive, and osteogenic characteristics is:
   A. Allograft
   B. Autogenous graft
   C. Xenograft
   D. Alloplast

4. Which of the following is a disadvantage of harvesting and using autogenous bone grafts?
   A. Significant rate of graft resorption
   B. Added morbidity from a second surgical site
   C. A and B
   D. None of the above

5. The main purpose for using a resorbable barrier in GBR procedures is:
   A. Avoiding proliferation of nonosteogenic cells into the defect
   B. Decreasing morbidity
   C. Faster healing
   D. None of the above

6. All of these are classified as nonresorbable barriers except:
   A. d-PTFE
   B. e-PTFE
   C. Collagen membrane
   D. Titanium mesh

7. A cross-linked collagen membrane usually resorbs ___ a non-cross-linked membrane?
   A. Similar to
   B. Faster than
   C. Slower than
   D. None of the above

8. Xenografts have ___ properties.
   A. Osteogenic
   B. Osteoconductive
   C. Osteoinductive
   D. All of the above

9. Membrane exposure can have a negative impact on bone healing. This exposure will lead to bacterial infiltration.
   A. First statement is true; second statement is false
   B. First statement is false; second statement is true
   C. Both statements are true.
   D. Both statements are false.

10. Which of the following is a growth factor that has the ability to enhance the results of bone augmentation?
   A. BMP-2
   B. BMP-7
   C. Platelet-derived growth factors
   D. All of the above

11. All the following have been successfully documented to perform the function of a barrier membrane except:
   A. Pericardium
   B. Alloderm
   C. Amnion
   D. Platelet-rich plasma

12. Making a decision regarding an optimal GBR procedure is principally based on defect morphology, which might be:
   A. Horizontal defect
   B. Vertical defect
   C. Combined defect
   D. All of the above

13. All of the following are advantages for using resorbable barriers rather than nonresorbable ones except:
   A. Elimination of second surgery needed for membrane removal
   B. Better cost effectiveness
   C. Better for vertical defects
   D. Decreased incidence of membrane exposure

14. Cross-linked membranes usually resorb faster than non-cross-linked membranes. However, the residues of chemicals used to cross link those membranes induce inflammation at the grafting site.
   A. First statement is true; second statement is false
   B. First statement is false; second statement is true
   C. Both statements are true.
   D. Both statements are false.

15. Addition of growth factors to a bone graft is indicated:
   A. In complex situations; ridge is very deficient
   B. When regeneration is less predictable
   C. A and B
   D. None of the above

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QUESTIONS

16. Alloplasts:
    A. Are of synthetic origin
    B. Contain vital bone cells that make new bone
    C. Are osteoconductive
    D. A and C

17. Freeze-dried bone allografts have a ___ resorption rate than demineralized freeze-dried bone allografts.
    A. Slower
    B. Similar
    C. Faster
    D. None of the above

18. Which of the following bone grafts has osteoinductive properties?
    A. Autogenous
    B. DFDBA
    C. FDBA
    D. A and B

19. Amalgamating the graft with DBBM will indirectly decrease the volume of autogenous bone needed. This, in turn, will decrease the percentage of anticipated resorption.
    A. First statement is true; second statement is false
    B. First statement is false; second statement is true
    C. Both statements are true.
    D. Both statements are false.

20. Which of the following techniques can be used for bone augmentation?
    A. Block grafting
    B. Guided bone regeneration
    C. Inlay/onlay grafting
    D. All of the above

21. Which of the following is not a bone substitute used in bone augmentation procedures?
    A. Alloplast
    B. Xenograft
    C. Allograft
    D. Amnion chorion

22. Which recombinant human platelet-derived growth factor has been heavily documented for use in alveolar bone augmentation?
    A. rhPDGF-BB
    B. rhPDGF-AA
    C. rhPDGF-AB
    D. None of the above

23. Which of the following is/are considered benefits for the use of platelet-rich fibrin?
    A. Abundance of growth factors
    B. Lack of chemical additives
    C. Formation of fibrin clot that promotes release of growth factors
    D. All of the above

24. What does "sticky bone" consist of?
    A. PRF + bone graft
    B. PRP + bone graft
    C. rhPDGF + bone graft
    D. BMP-2 + bone graft

25. Which of the following is considered an advantage of amnion membranes?
    A. Early induction of repair
    B. Promotion of hemostasis
    C. Pain relief
    D. All of the above

26. What are the three main components necessary for tissue regeneration?
    A. Cells + scaffolds + signaling molecules
    B. Soft tissue + bone graft + teeth
    C. Cementum + PDL + dentin
    D. None of the above

27. Freeze-dried bone allograft FDBA is considered:
    A. Osteoinductive
    B. Osteoconductive
    C. Osteogenic
    D. A and B

28. Which of the following statements is true?
    A. ePTFE membranes have at least twice the number of complications that dPTFE barriers have.
    B. Compared to dPTFE, ePTFE seems much more biocompatible.
    C. Disadvantages of e-PTFE are mainly an increased rate of premature membrane exposure.
    D. A and C

29. Which of the following is considered a disadvantage of collagen membranes?
    A. Lack of rigidity
    B. Poor space-maintaining properties
    C. In some situations, the rate of membrane degradation is much faster than that required for optimal tissue regeneration.
    D. All the above

30. For severe horizontal defects, it is preferable to use ___ or ___ membranes.
    A. Cross-linked; nonresorbable
    B. Cross-linked; non-cross-linked
    C. PRF; non-cross-linked
    D. Non-cross-linked; nonresorbable

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EXPIRATION DATE:	APRIL 2026

ANSWER SHEET

Guided bone regeneration: A practical guide for choosing the most suitable substitute materials

NAME: TITLE: SPECIALTY:

ADDRESS: EMAIL: AGD MEMBER ID (IF APPLIES):

CITY: STATE: ZIP: COUNTRY:

TELEPHONE (PRIMARY): TELEPHONE (OFFICE):

REQUIREMENTS FOR OBTAINING CE CREDITS BY MAIL/FAX: 1) Read entire course. 2) Complete info above. 3) Complete test by marking one answer per question. 4) Complete course evaluation. 5) Complete credit card info or write check payable to Endeavor Business Media. 6) Mail/fax this page to DACE. If you have any questions, please contact dace@endeavorb2b.com or call (800) 633-1681. A score of 70% or higher is required for CE credit.

COURSE CAN ALSO BE COMPLETED ONLINE AT A LOWER COST. Scan the QR code or go to dentalacademyofce.com to take advantage of the lower rate.

Educational Objectives

1. Determine when ridge augmentation procedures should be performed
2. Explain why guided bone regeneration (GBR) is the preferred technique of bone augmentation for most clinicians
3. Distinguish the different types of bone grafting materials commonly used in ridge augmentation
4. Describe the different types of barrier membrane materials commonly used in ridge augmentation
5. Justify the rationale for using biologics during GBR procedures

Course Evaluation

1. Were the individual course objectives met?

   Objective #1: Yes No Objective #3: Yes No Objective #5: Yes No

   Objective #2: Yes No Objective #4: Yes No

Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 0.

2. To what extent were the course objectives accomplished overall?	5	4	3	2	1	0
3. Please rate your personal mastery of the course objectives.	5	4	3	2	1	0
4. How would you rate the objectives and educational methods?	5	4	3	2	1	0
5. How do you rate the author's grasp of the topic?	5	4	3	2	1	0
6. Please rate the author's effectiveness.	5	4	3	2	1	0
7. Was the overall administration of the course effective?	5	4	3	2	1	0
8. Please rate the usefulness and clinical applicability of this course.	5	4	3	2	1	0
9. Please rate the usefulness of the references.	5	4	3	2	1	0
10. Do you feel that the references were adequate?	Yes		No			
11. Would you take a similar course on a different topic?	Yes		No			

12. If any of the continuing education questions were unclear or ambiguous, please list them.

    _____

13. Was there any subject matter you found confusing? Please describe.

    _____

14. How long did it take you to complete this course?

    _____

15. What additional dental continuing education topics would you like to see?

    _____

    _____

    _____

Mail/fax completed answer sheet to:
Endeavor Business Media
Attn: Dental Division
7666 E. 61st St. Suite 230, Tulsa, OK 74133
Fax: (918) 831-9804

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4.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	19.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
5.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	20.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
6.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	21.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
7.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	22.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
8.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	23.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
9.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	24.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
10.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	25.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
11.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	26.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
12.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	27.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
13.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	28.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
14.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	29.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
15.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	30.	Ⓐ	Ⓑ	Ⓒ	Ⓓ

EXAM INSTRUCTIONS
All questions have only one answer. If mailed or faxed, grading of this examination is done manually. Participants will receive confirmation of passing by receipt of a Verification of Participation form. The form will be mailed within two weeks after receipt of an examination.

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