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Ridge Augumentation Techniques In Preprosthetic Surgery-A Review

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Abstract: Rehabilitation of missing teeth with dental implant-supported restorations has become a predictable treatment option in dentistry. The stability of hard and soft tissues around the implant is fundamental for long-term success. However, due to factors such as trauma, oncologic diseases, and missing teeth, vertical and horizontal bone loss is expected, and the available bone may not be suitable for optimum implant placement. Ridge augmentation procedures are applied to increase in the volume of the deficient sites for implant treatment. Autogenous block bone augmentation and guided bone regeneration (GBR) are two surgical approaches for implant placement. Autogenous bone is widely used for augmentations because of its osteogenic potential. A myriad of biomaterials, including xenografts, allografts, alloplasts, and composite grafts, are available for GBR. The aim of this chapter is to provide a brief summary of these methods and to discuss the advantages and pitfalls of ridge augmentation techniques.

Keywords: Alveolar ridge deficiency, guided bone regeneration, iliac block bone augmentation, biomaterials, autogenous bone.

INTRODUCTION

Rehabilitation of edentulous sites with implant-supported restorations is a reliable technique with a predictable outcome. Alveolar ridge resorption after tooth loss is very common and may compromise the placement of implants. Trauma, oncologic diseases, oral infections, and congenitally missing teeth may also cause severe bone deficiency. A wide range of surgical procedures, such as guided bone regeneration (GBR) through the use of resorbable and non-resorbable membranes, intra- and extra-oral block grafting, and distraction osteogenesis, can be applied for reconstruction of alveolar ridge deficiencies [1–3]. Defect morphology plays an important role in the success of alveolar ridge augmentation techniques. Defects can basically be classified as intrabony or extrabony defects [4]. .It is easier to maintain space, stabilize the augmented site, achieve primary soft tissue closure, and protect the grafting site in intrabony defects than in extrabony defects. Therefore, intrabony defects are much easier to augment through techniques such as socket augmentation and sinus floor elevation. Extrabony defects can be more challenging in cases such as lateral and vertical augmentations (Figure 1) [5].The amount of augmentation may also influence the risk assessment of the operation. Particularly for vertical augmentation, complications are more likely if a large amount of height is needed outside the natural bone after bone regeneration.This article is focused on GBR and extra-oral bone block techniques that are widely used for ridge augmentation.

Guided Bone Regeneration (GBR)

GBR is a surgical technique that increases the amount of alveolar ridge for implant placement using barrier membranes with or without bone substitutes [4]. Regeneration at the deficient site depends on the exclusion of soft tissue (epithelial cells and fibroblasts) from osteogenic tissue (osteoblasts) during organization of the bone [6]. Osteoblasts are mainly responsible for increasing the amount of regenerated alveolar ridge. However, osteoblasts do not regenerate the alveolar ridge as quickly as epithelial and connective tissue cells grow. The success of the GBR approach mainly depends on the exclusion of soft tissue cells during bone remodeling by slowly working osteoblasts [6]. Aghaloo et al. evaluated the success of ridge augmentation techniques (GBR, onlay block grafting, distraction osteogenesis, ridge splitting, and mandibular interpositional grafting) based on implant survival in a systematic review [7]. They found that GBR may be the best way to augment the ridge according to implant survival.The GBR technique can be applied in two stages (delayed approach) or in one stage (simultaneous approach with implant placement). If the bone deficiency is low and implant stability can be achieved, the one-stage approach can be applied (Figure 2).

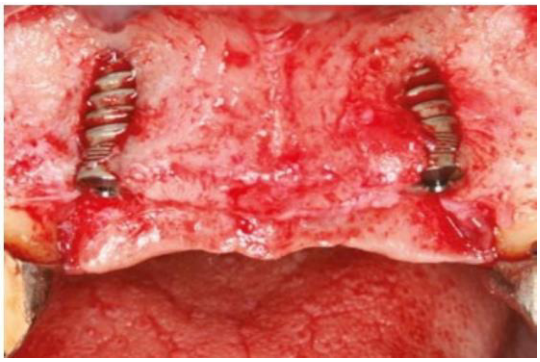


Figure. 2
However ,if a greater amount of bone must be regenerated ,then the two stages approach is preferable and the complication risk will be reduced.The predictability of GBR is based on several principles ,such as space maintenance ,stability ,nutrition and primary closure.

Space Maintenance

Maintenance of space at the augmented site is one of the fundamental principles of the GBR technique. A protected space is needed for hard-tissue cells to regenerate bone that excludes soft-tissue cells during healing and maturation.Bone substitutes, membranes, tenting screws, titanium, and bone plates are suggested for the maintenance of space. Jovanovic et al. evaluated the treatment groups in a pre-clinical study on GBR. They found that significant bone gain could be achieved when membrane and graft material were used than when no membrane was used [8] . Space maintenance can be challenging depending on the properties of the defect site. When significant bone augmentation is required in a severely resorbed alveolar ridge, creating space is more critical for the success of GBR.

Grafting Biomaterial

Currently, the use of a bone substitute material in GBR applications is the standard of care. The primary types of bone substitutes are autogenous bone, xenografts, allografts, and alloplasts [4] . An ideal biomaterial for bone regeneration should have the ability to form new bone, and bone formation must be balanced with the speed of resorption [4, 6] . Autogenous bone is the gold standard for augmentation because of its osteogenic potential. It has the ability to regenerate bone through the mechanisms of osteogenesis, osteoinduction, and osteoconduction [4, 6] . Osteogenesis is the production and evolution of bone at every site, even in the absence of local undifferentiated mesenchymal stem cells. Osteoinduction is the transformation of undifferentiated mesenchymal cells into pre-osteoblasts and osteoblasts. Therefore, the graft material should be in contact with living bone. Osteoconduction provides a non-living scaffold for the regeneration of bone [9.] By using local bone harvesting techniques, morbidity can be lowered during autogenous bone collection. Scraping autogenous bone from a location near the recipient site may simplify bone harvesting, decrease morbidity, and reduce the treatment time (Figure 3).

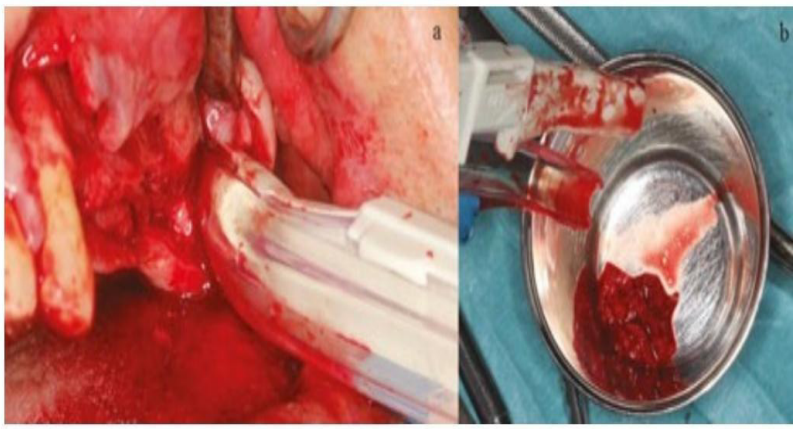


Figure 3
Bone harvesting from tuber site.

Peleg et al. found that the use of a bone scraper to harvest autogenous bone at the ramus resulted in no neurosensory injuries to the anatomical tissues and minimal morbidity in the patients [10] .There are also novel rotary tools to harvest bone easily from local sites (Figure 4).

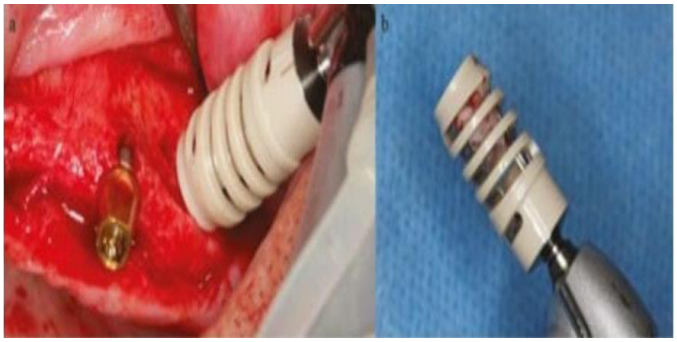


Figure 4
Bone harvesting rotary instrument.

These autogenous particulate grafts can be used alone or with biomaterials as a composite. Composite grafts greatly reduce the amount of autogenous bone required and therefore reduce morbidity.Bone graft substitutes have osteoconductive properties. However, the use of bone grafting material is very popular among clinicians because of benefits such as the unlimited availability, lack of a need to harvest bone (hence, reduced donor-site morbidity), reduced operation time, and reduced risk of postoperative complications [4, 6].Xenografts are bone grafts obtained from animals such as cows, horses, or species other than human [4, 6]. Deproteinized bovine bone (DBB) is a xenograft material that is frequently used in GBR applications. DBB is osteoconductive and has an interconnecting pore system that serves as a scaffold for the migration of osteogenic cells; the inorganic bone substance has a microscopic structure similar to that of natural cancellous bone [11, 12]. DBB particles are incorporated over time within the living bone, and DBB resorbs very slowly and has lowsubstitution rates. Therefore, it can provide space maintenance over a very long term [4, 6.] .It was shown that DBB graft particles remain present even after 10 years postoperatively [13]. Chackartchi et al. reported that the mean percentage of new bone was 28 ± 6% using DBB alone 6–9 months after sinus augmentation [14]. Materials with low-substitution rates are good scaffolds for host bone growth during healing, and they inhibit resorption of the augmented site [4, 6]. However, increased amounts of residual graft particles may negatively impact the healing of the augmented site and decrease the rate at which the implant surface area is integrated with the newly formed bone [15]. In challenging cases that require a greater amount of bone augmentation, such as vertical, horizontal, or both, DBB can be mixed with autogenous particulate bone and applied as a composite [2]. The authors recommend allowing 6–9 months for healing of lateral/vertical augmentations before implant placement. During long-term healing, DBB particles prevent the shrinkage of the augmented site, and autogenous particles facilitate the incorporation of this scaffold with the living natural bone. The authors do not recommend implant placement during the early stages of bone healing (less than 4–5 months) for two-stage augmentations because implant stability may be compromised or severe marginal bone loss may occur before loading [4, 6].Allografts are bone grafts obtained from the same species but are genetically dissimilar from the recipient [4, 6] .Allograft donors are meticulously screened, and specimens are carefully processed to reduce the possibility of disease transmission. Freeze drying is a commonly used process. Mineralized allografts (MAs) provide stability and space by maintaining their physical properties during the bone remodeling phase [4, 6]. Osteoconductive scaffolds provide volume enhancement and effective site management for successful dental implant placement after augmentation [16.] MAs can be composed of cortical and cancellous particles. Mineralized cortical particles with slow resorption rates offer a scaffold, whereas cancellous particles that have faster resorption rates and are prone to resorption may provide a space for the ingrowth of bone cells and angiogenesis. Therefore, if the amount of cortical graft particles is increased in the composite, less resorption can be expected [17]. Demineralized allograft (DA) contains bone morphogenic proteins and stimulates osteoinduction. However, DA is highly biodegradable and has less compressive strength than DBB and MA. Therefore, it is often mixed with other slowly resorbed graft materials to maintain space . The authors recommend using MAs in challenging cases, and demineralized grafts are recommended in well-protected defects such as socket augmentation. Implants can be placed safely after 4 months of healing in well-protected defects . The authors do not recommend using DA in challenging cases, such as vertical and lateral augmentation, because a great amount of bone loss can be expected after long-term healing [12].The possibility of disease transmission from xenografts and allografts to humans has drawn attention to synthetic bone graft substitutes . Alloplasts are synthetic and also have osteoconductive properties that provide a scaffold for bone regeneration . Various synthetic graft materials have been developed for crestal ridge augmentations, such as synthetic hydroxyapatite (HA), beta-tricalcium phosphate (β-TCP), and calcium sulfate (CS) [4]. HA has a low or very limited resorption rate [4]. β-TCP and CS are highly biodegradable and have less compressive strength than synthetic HA and DBB [21, 22]. CS can be completely resorbed within 1 month . Therefore, according to the defect properties, these materials can be mixed with slow resorbable materials in different ratios to maintain space during healing [21, 22]. By increasing the amount of resorbable material in the composite, the rate of new bone formation can also be increased. However, the space maintenance capacity will be reduced, even in sinus augmentation applications [24].The particle size in the graft may also affect the resorption time and the success of the procedure. There are conflicting articles in the literature regarding graft particle usage [14, 25]. Particles that are too small may be resorbed too rapidly, and advanced shrinkage of the augmented site can be observed. Particles that are too large may prevent angiogenesis and delay and/or reduce new bone formation [25]. Chackartchi et al. compared the use of small and large particles in grafts during two-stage sinus floor augmentation with regard to new bone formation and vertical bone height stability. The authors could not detect any statistically significant differences between the small and large graft particles [14].Several factors, such as the graft properties, membrane choice, surgical technique, use of compression during packing of the

graft material, availability of natural bone, composition of the graft, and activity of the host bone, may influence the resorption rate at the augmented site and may therefore affect space maintenance [26].

Barrier membranes

Barrier membranes are routinely used to maintain space. There are two kinds of barrier membranes: resorbable and non-resorbable [4, 6].

Resorbable membranes

The most important advantages of resorbable membranes are the elimination of membrane removal after healing, resulting in decreased morbidity, easy manipulation, and lower rate of complications. However, resorbable membranes are not very successful in comparison with non-resorbable membranes with regard to space maintenance. These membranes must be used with bone graft substitutes and additional tools, such as tenting screws or plates for space maintenance.Resorbable membranes that are made of native collagen (non-cross-linking) show high biocompatibility resulting in good tissue integration and rapid vascularization (Figure 5) .

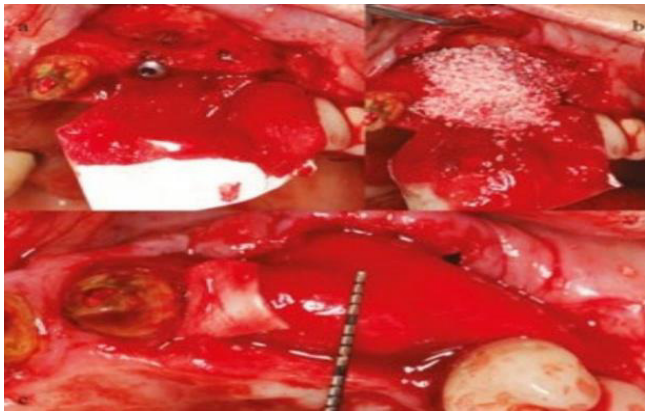
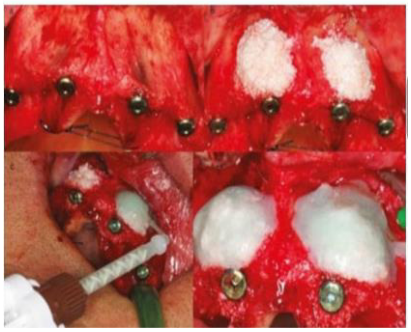


Figure 5
Native collagen resorbable membrane.

However, these membranes may lose their barrier function early due to rapid biodegradation . The resorption time depends on the membrane's properties, the cellular activity of the native bone, and exposure [29]. One of the most important benefits of non-crosslinked collagen membranes is the spontaneous closure of membrane exposure during the healing period . Epithelization of the exposed membrane occurs within weeks after mucosal dehiscence. Although spontaneous healing of the exposure occurs, the grafting volume may be negatively affected during healing, and some bone loss may be expected [4, 6.] Simion et al. compared the effects of exposed and non-exposed membranes on bone regeneration at the site of implant insertion . Bone regeneration was 99.6% with nonexposed membranes and 48.6% with exposed membranes . There are also studies showing predictable results with late membrane exposures up to 6 months [5]. Therefore, every effort should be made to ensure primary closure of the grafted site during healing. Some clinicians recommend using double non-cross-linked membrane over the grafted site to extend the resorption time for better barrier function [6].Cross-linking resorbable collagen membranes were produced to extend the degradation time in GBR applications. In a preclinical study, different collagen membranes were compared to evaluate the resorption time . It was found that if the amount of cross-linking collagen fibrils was increased, the resorption time was also extended. However, tissue biocompatibility was decreased. There are also studies showing good results regarding tissue integration and bone regeneration using these membranes . Various types of cross-linked membranes may affect biocompatibility and tissue integration differently [6]. Membranes made of polylactic acid/polyglycolic acid copolymer (PGLA) are also available. These synthetic membranes simplify the clinical manipulation and reduce the application time [6]. Although studies have shown that this material is highly biocompatible and degrades without acidic products, concerns about the healing mechanism remain (Figure 6)



Non-resorbable membranes

When a higher amount of bone augmentation is required, reinforced non-resorbable membranes are used. Reinforced membranes withstand the pressure from the surrounding tissues, resulting in the prevention of membrane collapse and allowing the bone to be regenerated during healing. Titanium mesh, titanium-reinforced expanded polytetrafluoroethylene (e-PTFE), and dense polytetrafluoroethylene (d-PTFE) membranes are most commonly used, and their benefits have been demonstrated in published studies [2, 4, 6]. Urban et al. augmented alveolar ridges vertically using e-PTFE membranes . The mean vertical augmentation was 5.5 mm after 6–9 months of healing. They concluded that vertical augmentation with e-PTFE membranes and particulate autografts are a reliable method for the reconstruction of deficient alveolar ridges.Currently, e-PTFE membranes are not used in oral surgery due to high rates of complications related to membrane exposure. d-PTFE membranes are novel titanium-reinforced nonresorbable membranes that have replaced e-PTFE membranes and are used for the reconstruction of critical-sized defects, such as sites requiring vertical augmentation. The highly porous structure of e-PTFE membranes allows ingrowth of the oral microflora when the membrane is exposed. Exposure results in high rates of infection, regardless of whether it occurs early or late during healing. Due to the high porosity of the membrane, it is almost impossible to mechanically or chemically clean the exposed site of the membrane; therefore, early removal of the membrane is required. After removal, it is generally discovered that GBR has failed due to infection, and re-augmentation is needed. e-PTFE membranes must be completely healed in primary closure, and they have no tolerance for exposure [4, 6].Novel d-PTFE membranes are manufactured in a dense micro-porous form that prevents oral bacteria from entering the grafted site when exposed. These membranes are also easy to mechanically and chemically clean. The removal of a d-PTFE membrane after healing is also easy to perform and takes less time than the removal of titanium-mesh membranes (Figure 7).

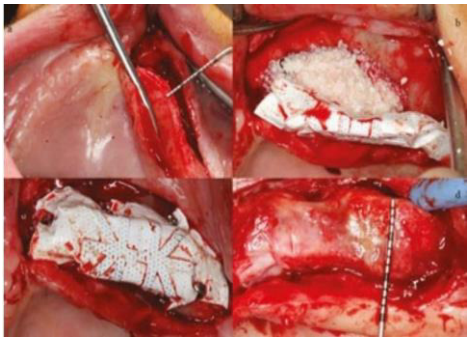


Figure 7
Titanium reinforced non-resorbable membrane.

Ronda et al. reported a mean defect fill of 5.49 mm after 6 months of healing at vertically augmented sites using d-PTFE membranes . Urban et al. observed an average bone gain of 5.45 mm using d-PTFE membrane with a mixture of bovine bone and autogenous particulate bone [2]. They also found a high rate of new bone formation (36.6%) on core biopsies that were taken at the time of implant placement. They concluded that treatment of vertically deficient alveolar ridges with GBR using a mixture of particulate autogenous bone and bovine grafts with d-PTFE membrane is a reliable method.Although a high level of success with non-resorbable titanium-reinforced d-PTFE membranes has been reported in the literature, these membranes must be applied cautiously in selected patients. Non-resorbable membranes have higher complication rates than resorbable membranes . If a d-PTFE membrane begins to be exposed, the amount of exposure can increase incrementally during healing [5]. Therefore, if early exposure of this membrane occurs, the prognosis may not be predictable. However, late exposures may be better tolerated with meticulous mechanical cleaning. If an infection does not occur 3–4 months after grafting, removal of the membrane may preserve the regenerated bone [5]. Complications regarding membrane exposure are less likely with resorbable membranes. The cost of GBR with titanium reinforced membranes may also be higher than with resorbable membranes. Jensen et al. reported comparable amounts of bone gain between resorbable and non-resorbable membranes used for horizontal augmentation [15]. If minor augmentation is planned at a deficient site, resorbable collagen membranes should be considered first due to their low risk of complications. If the natural bone is not too thin, lateral augmentation can be successfully performed using collagen membranes with mixed autogenous particulate grafts and lowsubstitute graft materials such as DBB.Titanium mesh is another alternative to non-resorbable membranes, and this type of mesh has a good space maintenance advantage . It can be easily trimmed and bent according to the defect site. Another advantage, and also a disadvantage, of mesh over a PTFE membrane is that the holes within the membrane allow vascularization and nutrition from the periosteum to the grafting site [4–6]. However, bone can also grow from inside these holes over the mesh. After healing, the mesh can integrate with newly formed bone and complicate removal during surgery at the second stage.

Stability

The stability of the augmented site in GBR applications during healing is an important factor for achieving success. The initial blood clot formation and stabilization of graft particles will result in predictable bone formation [5]. Although barrier membranes will cover the augmented site and exclude epithelial and connective tissue cells from the regenerating bone, additional tools are needed to provide stability and also to increase the resistance of the augmented site from the flap, lip, and mastication force pressure [5].Membrane fixation systems can be used to secure resorbable membranes effectively. By using manual or

automatic handles, tacks stabilize the membrane to the natural bone and prevent migration of the graft and soft tissue invasion (Figure 8).

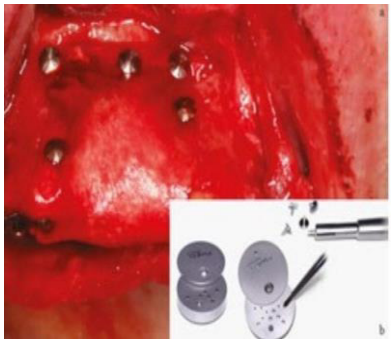


Figure 8
Bone tacks.

Another advantage is that tacking membranes simplify suturing because the membrane does not move during suturing. If lingual or palatal tacking is needed, the angled neck of the handle can be used to simplify the application. Generally, the tacks are made of titanium, and they do not need to be removed at the second-stage surgery. The authors recommend removing tacks that are placed coronally and leaving apically positioned ones to reduce morbidity from excessive flap elevation at the time of implant placement. If tacks are left, they may disturb the patient in the future, and they can be easily removed using a small circular incision around the tack.Tacks may not be strong enough to secure non-resorbable membranes. Generally, membrane fixation screws are used for stabilization. The aggressive tip and thread design engage the membrane and bone and allow for precise placement in soft and dense bone (Figure 9).

Figure 9
Bone screws.

The authors recommend using short screws in the mandible and longer screws in the maxilla due to its low density; it is easier to engage longer screws in soft bone. If lingual or palatal screwing is needed, surgical hand pieces can be used to simplify the application. At the second surgery, the non-resorbable membrane and all screws must be removed. If any screw is left, the membrane may not be removed easily.Tenting screws can also be used under resorbable or non-resorbable membrane to prevent pressure from the environment and also to stabilize the augmented site. The treaded part of these screws engages the natural bone, and the smooth part remains at the augmented site (Figure 10).

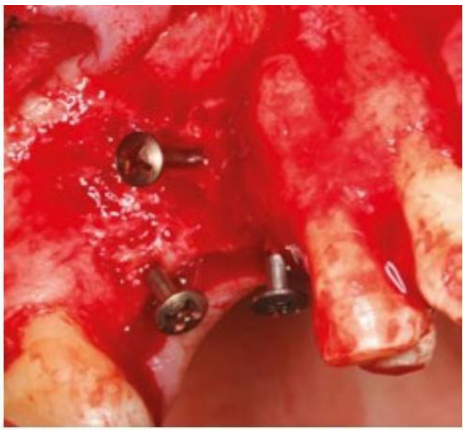


Figure 10
Tenting screws.

Another advantage of using tenting screw is that the clinician may estimate the amount of future bone gain at the time of the operation based on the length of the smooth part. For example, if 5 mm of bone gain is needed, an 8-mm tenting screw can be used and 3 mm of bone will stabilize the screw.Metal plates that are generally used for orthognathic or trauma surgery can be used for space maintenance [4, 6]. The plate is fixed to the natural bone with screws, and the space between the bone and plate is filled with graft material. A resorbable membrane covers the augmented site. The authors recommend avoiding the use of overly thick plates to prevent soft tissue exposure during healing. Thin cortical strut allografts can also be used for space maintenance in a method known as the Shell technique. Space is created between the cortical strut and the host bone as with metal plates, but there is no need to remove the cortical struts during the second-stage surgery. However, these bone struts are very vulnerable during screwing, and they can be easily broken into pieces [4, 6].

CONCLUSION

Many novel techniques, biomaterials, and tools have been described in the literature that clinicians may use to reconstruct bone deficiencies. However, most importantly, the success of alveolar ridge augmentation procedures mainly depends on clinician experience and skill. The surgical risks may be increased for challenging reconstructions. Therefore, the clinician and patient should carefully evaluate the benefits and risks of the operation and decide on the most ideal treatment option. Prosthetic-driven augmentation is recommended for a better outcome. If the clinician focuses only on ridge augmentation techniques to solve bone deficiency problems, he or she may overlook other treatment options that may have lower risks and less morbidity, such as using short, narrow, or tilted implants. After all, ridge augmentation is being performed for the ideal placement of dental implants.

CONFLICT OF INTEREST

Conflict of interest declared none.

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