How to Select Replacement Grafts for Various Periodontal and Implant Indications

Yung-Ting Hsu* and Hom-Lay Wang†

Focused Clinical Question: How are bone replacement grafts for various periodontal and implant indications properly selected?

Summary: The purpose of this paper is to review the properties of available bone replacement materials and provide guidelines of how to choose certain graft materials for different clinical indications (e.g., periodontal defects, peri-implant defects, socket augmentation, ridge augmentation, and sinus augmentation).


Key Words: Alveolar ridge augmentation; bone substitutes; guided tissue regeneration; peri-implantitis; sinus augmentation therapy; socket graft.

Background

Alveolar bone, as a part of periodontium, plays a primary role in the maintenance of both the natural dentition and dental implants. Resulting from periodontal disease or trauma, bony destruction leads not only to functional concerns but also esthetic impairment. To regain lost bone tissue, the use of bone replacement grafts has been introduced and widely applied in periodontal and implant therapy.

Early researchers, Dr. Gerald Bowers and Dr. Robert Schallhorn, established the fecundated principles of osseous grafting by conducting a series of research projects over the past decades. In a landmark article published in 1977, the advantages of osseous grafting procedures was suggested, including reconstruction of lost periodontium, cessation of disease progression, and improvements in both function and esthetics.1 Indeed, the efficacy of osseous grafting has been demonstrated in histologic assessments,2-6 which become the rationale for the use of bone substitutes in modern dentistry.

Properties of Bone Replacement Grafts

Bone replacement materials have been used in several situations, such as infrabony defects,7 furcation defects,8 ridge augmentation,9 socket preservation,10 peri-implant defects,11 and sinus augmentation.12 To achieve desirable outcomes and maximal effectiveness, the selection of osseous grafting materials should be based on their unique features, therapeutic objectives, and indications.1 This paper aims to provide guidelines for clinicians to select osseous grafts for periodontal or implant indications. In addition, the characteristics of bone substitutes used are reviewed.

Autografts

Autogenous bone replacement grafts, transplanted within the same individual, are obtained from either extraoral or intraoral sites. In general, autografts are considered as the gold standard in most clinical situations because of the capacity of osteogenesis and no risk of disease transmission. With various harvesting techniques, characteristics of autografts may represent minor differences with regard to donor sites. For example, cancellous bone and marrow grafts possess the greatest induction potential of osteogenesis.17,18 Compared to the osseous coagulum techniques, the bone blend technique yields the mixture of cortical and cancellous graft of a larger particle size with clinically manageable and predictable properties. However, osseous coagulum and bone blend techniques can only procure a limited amount of bone, whereas cancellous bone and marrow grafts lead to additional surgical insult and
**TABLE 1** Properties, Advantages, and Disadvantages of Bone Replacement Grafts

<table>
<thead>
<tr>
<th>Bone Replacement Graft</th>
<th>Properties</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Indications</th>
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<tbody>
<tr>
<td>Autografts (obtained from the same individuals)</td>
<td>Osteogenesis/ osteoinduction/ osteoconduction</td>
<td>Capacity of osteogenesis</td>
<td>Limited availability</td>
<td>Class II furcation defect</td>
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<td></td>
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<td>Elimination of the potential complications of histocompatibility</td>
<td>Additional surgical intervention</td>
<td>2-wall periodontal defects</td>
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<td></td>
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<td>No risk of disease transmission</td>
<td>Possible complications: root resorption, ankylosis</td>
<td>2-wall or circumferential peri-implant defects</td>
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<td>Intact, thick-walled extraction sockets</td>
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<td></td>
<td>Horizontal ridge augmentation: OBG, ridge split/expansion, GBR</td>
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<td>Sinus augmentation</td>
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<tr>
<td>Allografts (obtained from different individuals of the same species)</td>
<td>Osteoinduction/ osteoconduction</td>
<td>Possible osteogenesis</td>
<td>Possible disease transmission</td>
<td>Class II furcation defect</td>
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<td></td>
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<td>No need for additional surgical intervention</td>
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<td>2-wall periodontal defects</td>
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<td>Sinus augmentation</td>
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<tr>
<td>Xenografts (obtained from different species)</td>
<td>Osteoinduction (?)/ osteoconduction</td>
<td>No need for additional surgical intervention</td>
<td>Possible disease transmission</td>
<td>2-wall or circumferential peri-implant defects</td>
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<td>Slow resorption rate</td>
<td>2-wall or 3-wall extraction sockets</td>
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<td>Horizontal ridge augmentation: ridge split/expansion, GBR</td>
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<td>Sinus augmentation</td>
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<tr>
<td>Alloplasts (synthetic grafts)</td>
<td>Osteoconduction</td>
<td>No risk of disease transmission</td>
<td>Slow resorption rate</td>
<td>2-wall or circumferential peri-implant defects</td>
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<td>No need for additional surgical intervention</td>
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<td>Sinus augmentation</td>
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? = not enough evidence.
expense. Additionally, root resorption is a common concern when fresh iliac grafts are used. 

Allografts

Because of limited availability of autogenous bone grafts, allografts have been introduced as alternative bone replacement grafts in extensive bony defects. Allografts are harvested from different individuals of the same species, and they possess osteoconductive and osteoinductive properties and eliminate the need for a second surgical site. The main alternative is autografts, but the main concern with allografts is the possible antigenicity and potential for disease transmission, although the frequency is rare. To prevent disease transmission, fresh-frozen grafts are no longer used. Instead, freeze-dried bone allografts (FDBAs) and decalcified FDBAs (DFDBAs) are widely available from tissue banks. Despite harvesting from similar sources, minor differences of properties are presented. Compared to DFDBA, FDBA tends to be more slowly resorbed and thus is better for space maintenance. DFDBA has the potential for osteoinduction with more expression of bone morphogenetic protein. Therefore, DFDBA is indicated for periodontal regeneration, whereas FDBA is more suitable for augmentation procedures. In addition, allografts can be classified as cortical, cancellous, and mixed based on the location of the donor site. It is believed that cancellous bone shows better bone incorporation and more rapid revascularization compared to cortical bone. However,
FIGURE 1 Disease-related indications: periodontitis. SRP = scaling and root planing.

FIGURE 2 Disease-related indications: peri-implantitis.

FIGURE 3 Implant-related indications: socket augmentation.
limited evidence is available to clarify the differences and the primary indications for these allografts.

**Xenografts and Alloplasts**

Osteoconductive bone replacement grafts include xenografts and alloplasts. Serving as the scaffold of bone regeneration, xenografts are obtained from species other than human, such as bovine, porcine, and coral. Similar to alloplasts, xenografts avoid additional surgical insult in regenerative procedures, leading to less patient discomfort. Despite osteoconductivity, osteoinductibility of xenografts has also been demonstrated in an animal study. Nevertheless, iatrogenic transmission of prion-related diseases is the main concern with the use of bovine products, although the risk has declined as a result of appropriate preventive measures. Synthetic bone substitutes are alternatives as an osteoconductive scaffold in regenerative procedures and have no risk of disease transmission and no need of second surgical sites. The types of alloplasts used in periodontal and implant indications include absorbable/non-resorbable hydroxyapatite (HA) products, β-tricalcium phosphate (β-TCP), polymethylmethacrylate and hydroxylethylmethacrylate calcium-layered polymer, polyactic acid polymer, and bioglass materials. Instead of formation of new attachment, it appears that alloplasts act as non-irritating fillers that support periodontal repair.

**Additional Options**

Recently, a revolution in properties of materials has been generated with the use of tissue engineering, the combination of different bone materials, and the changes in processing techniques. To improve the regenerative outcomes, the use of synthetic collagen or growth factors in conjunction with osteoconductive materials has been proposed to promote both bone formation and to speed wound healing. Moreover, the combination of mineralized and demineralized allografts has been introduced in addition to a mixture...
of cortical and cancellous allografts. At present, there is limited evidence supporting the superiority of any of these combinations compared to a conventional formula.

To date, there is no ideal bone replacement graft that is suitable for all regenerative procedures. Selection of bone grafts should be based on properties of materials, indications/clinical scenarios, and the purpose of the grafting procedures.

Decision Process and Clinical Scenarios: Bone Grafts for Periodontal and Implant Indications

The main indications of bone grafting procedures can be divided into both periodontal and peri-implant disease-related sites and implant site development applications. They include regenerative procedures for destruction caused by periodontal or peri-implant diseases and bone augmentation procedures for implant site preparation. In addition to defect morphology, selection of bone replacement grafts should be based on their properties corresponding to indications. Decision trees regarding disease-related and implant-related indications are proposed in Figures 1 through 4.

Disease-Related Indications

Periodontal defects (clinical scenario 1). Bone replacement grafts have been widely used in conjunction with membrane barrier technique in guided tissue regeneration (GTR) procedures. Intrabony defects and Class II furcation defects are the main indications for bone grafting. In addition to formation of new attachment, favorable results in terms of probing depth reduction and clinical attachment gain have been reported with the use of all types of bone grafts. The additional benefits of GTR in combination with bone grafts and growth factor–releasing devices, such as peptide coating, platelet-rich plasma, and enamel matrix derivative protein, have been evaluated and remain controversial. Compared to allografts, limited evidence is available to support the superiority of the use of xenografts or alloplasts in the treatment of periodontal defects. In addition to the concerns of disease transmission with xenografts, there are few human trials with large sample sizes demonstrating the efficacy of alloplasts on periodontal regeneration. Therefore, autologous bone grafts and allografts are recommended because of the capacity of osteoconduction, osteoinduction, and osteogenesis (Fig. 1).

In Figure 5, a periodontal defect is shown on the distal aspect of the mandibular second molar. After debridement, an intrabony defect was noticed and treated with a GTR procedure using mineralized allograft (Fig. 6). Promising results with complete bone fill were achieved 4 years after treatment (Fig. 7).

Peri-implant defects. Regenerative procedures have been evaluated in the treatment of peri-implantitis. Regardinng defect morphology of peri-implant lesions, guided bone regeneration (GBR) is indicated in 2-wall or 3-wall intrabony defects and circumferential defects (Fig. 2). In human models, various bone replacement grafts have been applied to manage peri-implant bone loss with positive outcomes. They include autologous, allogeneic, xenogenic, and synthetic bone substitutes. In a recent systematic review, the results suggested that complete bone fill was achieved in ≤10.4% of GBR-treated peri-implant lesions, whereas 85.5% of peri-implant defects showed bone gain. Because of the heterogeneity of experimental design, to date, limited evidence is available to make a conclusion to suggest any specific types of bone replacement materials. Additional research is expected to address the regenerative procedures in peri-implant lesions.

Implant-Related Indications

Socket augmentation (clinical scenario 2). To prevent ridge resorption after tooth extraction, socket augmentation is necessary for future implant site development. The use of bone replacement grafts allows better space creation and maintenance by preventing potential collapse of membranes. Compared to non-grafted sites or collagen-grafted sites, desirable results in grafted sites have been shown in previous studies, including less dimensional changes,
greater mineralized component, and better organization of bone structures.\textsuperscript{10,71-73}

In socket augmentation, it has been suggested that the use of bone replacement grafts should be selected based on the remaining walls of extraction sockets.\textsuperscript{74} However, autologous bone failed to prevent ridge resorption despite its osteogenic properties. Indeed, 25\% of reduction was shown on the coronal portion of the ridge.\textsuperscript{75} Histologically, allografts were replaced by newly formed bone, whereas the extraction sockets grafted with xenografts exhibited a delayed healing pattern.\textsuperscript{75-79} Up to 61\% of vital bone fill was reported in an allograft group compared to only 26\% in a xenograft group,\textsuperscript{79} although xenografts may have benefits in minimizing dimensional changes.\textsuperscript{72,75} In addition, fibrous encapsulation surrounding the residual bone particles has been observed when xenografts and alloplasts were used as the grafting materials,\textsuperscript{76,80,81} leading to reduction of bone-to-implant contact after implant placement.

In short, any type of a resorbable osseous graft is recommended for placement in a socket with intact and thick walls. For 2-wall or 3-wall sockets, both allografts and xenografts are effective for socket augmentation. In a socket with one bony wall remaining, a bone block graft or GBR with particulate grafts might be a better option (Fig. 3).

Figures 8 through 10 show a socket augmentation procedure using mineralized bone putty that was applied immediately after extraction of a fractured maxillary premolar. Six months later, a full-thickness flap in the same region was reflected for implant placement. Minimal dimensional changes were visualized, which provided a good foundation for implant placement and restoration.

**Ridge augmentation (clinical scenario 3).** With the advent of implant dentistry, techniques, such as onlay bone grafting (OBG), ridge split/expansion, or GBR with particulate bone grafts,\textsuperscript{82} were proposed for horizontal bone augmentation. Techniques used to gain vertical height included onlay block grafting, distraction osteogenesis, and GBR.

For OBG, allogenic\textsuperscript{9,83} and xenogenic\textsuperscript{84} bone blocks as well as chin or ramus autografts\textsuperscript{85,86} have been used for horizontal ridge augmentation. Although there is no need for donor site, greater graft resorption has been reported in the patients treated with allograft blocks compared to autologous block grafts.\textsuperscript{87} With a 7\% to 8\% failure rate, complications associated with cancellous block allografts were significantly greater in the mandible than in the maxilla.\textsuperscript{88} In addition, the efficacy of xenogenic block grafts was also evaluated in recent years. A feasibility study was conducted by Schwarz et al.\textsuperscript{84} to compare equine- and bovine-derived cancellous bone blocks in lateral ridge augmentation in a dog model. Minimal bone formation and grafting integration was shown in bovine grafts, although no adverse events were reported. Thus, it is suggested that block autografts can be effective in both jaws, whereas block allografts may be more predictable for the maxilla. Block xenografts may be a feasible option, but the efficacy remains unknown.

Ridge split in combination with different particulate graft has shown promising results in most studies.\textsuperscript{89-91} However, limited evidence is available, especially when compared to other treatment modalities. Regarding GBR, several techniques and different graft materials have been used with satisfactory results.\textsuperscript{92} With non-resorbable barrier membranes plus
tenting screws, promising outcomes have been achieved with the majority of bone replacement grafts.\textsuperscript{93-96} In an animal study, Fiorellini et al.\textsuperscript{95} demonstrated that implant osseointegration can be successfully achieved after GBR using expanded polytetrafluoroethylene membranes regardless of the types of osseous grafts used. Using absorbable barrier membranes, ridge augmentation can be applied along with simultaneous implant placement (Fig. 11), which is known as the sandwich bone augmentation technique. A combination of various bone grafts is preferred. They include layers of cancellous and cortical allografts\textsuperscript{97,98} (Fig. 12) and the mixture of autogenous grafts and deproteinized bovine bone mineral.\textsuperscript{99,100} This combination of bone replacement grafts is advantageous because of the capacity of space maintenance with low-turnover-rate bone grafts and the property of osteogenesis/osteoinduction/osteoconduct of autografts/cancellous allografts. Compared to baseline, marked bone formation was noticed after treatment (Fig. 13).

Vertical ridge augmentation is one of the greatest challenges in implant dentistry. Despite high long-term implant survival rate (92.1\% to 100\%), varying implant success rates (76.3\% to 97.5\%) and vertical bone gain (2 to 8 mm) were discussed in a systemic review.\textsuperscript{101} Complications were also demonstrated in various studies.\textsuperscript{91,102,103} Although desired results have been suggested with the application of various types of bone grafts,\textsuperscript{104-107} the predictability remains unclear. A proposed decision tree is shown in Figure 4.

Sinus augmentation (clinical scenario 4). In the maxillary posterior region, a common ridge deficiency preventing success implant placement is insufficient ridge height. To increase vertical dimension, sinus augmentation procedures have been widely applied in modern implant therapy, resulting in high implant survival rates and a low incidence of complications.\textsuperscript{108} Although the potential of bone formation in sinus without the use of bone substitutes has been proposed,\textsuperscript{109} the results remain controversial, and the stability of the blood clot with sinus lifting is questionable.\textsuperscript{110-113} From previous studies, comparable clinical outcomes and a similar histologic appearance have been suggested regarding the efficacy of different types of bone replacement materials\textsuperscript{12,114-116} as long as the membranes were not exposed. To date, no association has been found between the type of grafts used in sinus augmentation and surgical outcomes in terms of implant survival rates and occurrence of complications.\textsuperscript{117} Despite the ability of osteogenesis of autografts, resorbable bone grafts with slow resorption may also be suitable in sinus augmentation procedures for dimension maintenance.\textsuperscript{118} Therefore, all types of bone replacement grafts are suitable in sinus augmentation procedures. Indeed, sinus elevation

**FIGURE 11** Clinical scenario 3. 11a Preoperative view showing ridge deficiency and fenestration on the buccal aspect of the implant. 11b Radiograph taken at baseline. Ridge deficiency was noted on the buccal aspect of the edentulous ridge. Yellow arrow indicates the ridge deformity noted on the buccal aspect of the edentulous ridge.

**FIGURE 12** Clinical scenario 3. GBR with sandwich technique. Ridge augmentation was performed using cancellous allografts as the inner layer and cortical allografts as the outer layer.

**FIGURE 13** Clinical scenario 3. 13a Reentry at 6 months postoperatively. Predominant bone formation and complete bone coverage were observed at the buccal aspect of the implant. 13b Radiograph taken 6 months postoperatively. Predominant bone formation on the buccal aspect of the implant was seen. Yellow arrow indicates predominant bone formation on the buccal aspect of the ridge after GBR.
using a layered approach with various types of bone grafts may be effective in achieving promising outcomes.

In Figures 14 through 16, a case of implant placement with simultaneous sinus lifting is reported. A layered approach was performed in a 65-year-old patient who had insufficient ridge height on the right maxillary posterior region. With a lateral window technique, autogenous grafts were placed in the apical portion (≈5-mm height). The middle portion consisted of cortical and cancellous allografts, whereas the coronal portion was filled with the combination of xenograft and allografts, which have a slower resorption rate. A collagen membrane was applied to cover the bone grafts on the outside of lateral window. Two years after surgery, both clinical and radiographic examination displayed consistent and favorable results (Fig. 16).

Conclusions
With the advent of technology, autologous bone grafts remain the best choice in most situations but are no longer the only option in modern dentistry. Various bone replacement grafts from other sources are available, and they display different properties. With various available grafts and regenerative techniques, full awareness of their features and indications is the cornerstone of successful regeneration. Using these guidelines, careful case and material selection corresponding to different indications can be beneficial to achieve predictable and consistent treatment outcomes.
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CORRESPONDENCE:
Dr. Hom-Lay Wang, Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, 1011 N. University Ave., Ann Arbor, MI 48109-1078. E-mail: homlay@umich.edu.
References


