Cylindrical endosseous implants are commonly used to treat both partially and totally edentulous patients.1-6 However, implant placement may be contraindicated in many clinical situations due to insufficient quantity or quality of bone. A variety of surgical techniques have been used to augment the severely atrophic maxilla prior to, or concomitantly with, implant placement. The LeFort I osteotomy with interpositional iliac bone grafting followed by immediate placement of root form implants has been shown successful.7-8 Alternatively, onlay grafting with autogenous bone from the iliac crest fixed to the maxilla with root form implants has also been described.9-11 Utilizing this onlay technique, Adell et al. reported that 26% of the implanted fixtures were lost during the first five years of function.9

The problem of inadequate bone quality and quantity for implant placement is commonly encountered in the posterior maxilla, especially when the maxillary sinus approximates the alveolar crest. The sinus lift procedure was introduced to address difficulties associated with implant placement in the posterior maxilla.12-14 Problems related to the placement and ultimate success of root form implants in this area include: 1) lack of vertical and/or bucco-lingual dimension due to alveolar ridge resorption; 2) antral pneumatization; 3) poor bone quality; 4) difficult surgical and prosthetic access; and 5) high bite force requirements. Different materials such as autogenous bone,15-20 mineralized or demineralized bone allograft,21-23 hydroxyapatite,24-27 and a variety of combination grafts12,14,20,27,28 have been used for sinus grafting. Although the results of these reports suggest that bone augmentation is possible in the maxillary sinus with a variety of graft materials, it is not yet clear which of these materials provides the most favorable results. This is due in part to the difficulty of obtaining suitable human specimens. Autogenous bone has been promoted as the most effective osteogenic graft material currently available.15-20 However, there are several major limitations to the use of autogenous grafts (ileum, calvar-
ium, rib, chin) including 1) donor site morbidity; 2) need for general anesthesia for bone harvesting;\textsuperscript{20,31} 3) and limited amounts of graft material.\textsuperscript{20} To circumvent these problems, clinicians have turned to alternative graft materials. Since demineralized freeze-dried bone (DFDB) was first introduced by Urist,\textsuperscript{32} it has been utilized extensively as a bone allograft because of its osteoconductive and osteoinductive properties. More recently, DFDB has been used for sinus augmentation.\textsuperscript{12,20,21,28,30}

The following clinical case reports demonstrate the use of demineralized freeze-dried bone and autogenous bone for maxillary sinus augmentation prior to implant placement. The purpose of this paper is to utilize radiographic and histologic data to compare and contrast the short-term healing of these two different graft materials.

**CASE REPORTS**

**Case 1**

A 57-year-old woman presented for the fabrication of an implant-supported fixed maxillary prosthesis. She had been wearing full maxillary and mandibular denture prostheses for more than 30 years. Computerized tomography (CT) revealed an insufficient amount of maxillary bone, in both height and width, for the placement of cylindrical endosseous implants (Fig. 1). The patient agreed to undergo bi-

![Figure 1](image-url)
were composed of mature cancellous bone on a JB-4 microtome and stained with toluidine blue for light microscopic analysis. They were then enlarged with a 4.0 mm cannon drill and implants were placed within the sinuses and on the anterior maxilla (Fig. 3). At this time all specimens were then demineralized with EDTA for 3 weeks. Specimens were sectioned at 10 µm and 1000 to 3000 µm particle sizes was utilized as the graft material (Fig. 7). In order to augment the anterior maxilla, the soft tissue was first expanded with a subperiosteal soft tissue expander, followed by the placement of DFDB. Since previous clinical data suggested that 6 months healing time for a sinus grafted with DFDB was insufficient, we opted to wait for 16 months before fixture placement. A CT scan was taken 14 months following the sinus augmentation procedure. Comparison of this scan to the pre-surgical scan revealed an increase in bone quality and density in the grafted areas (Fig. 8). However, the density of the bone graft was far less than that seen with the autogenous bone graft. At this time, implant sites were prepared and bone cores were obtained from the most distal implant sites in the fashion previously described. Eight implants were subsequently placed. The specimens were prepared as previously described.

Histologic analysis of the bone cores demonstrated bone of poor quality (i.e., only a sparse network of bony trabeculae). Overall, the bone quality deteriorated progressing from the alveolar crest toward the sinus end of the core. Fibrofatty connective tissue was present throughout the graft material (Fig. 7). In order to augment the anterior maxilla, the soft tissue was first expanded with a subperiosteal soft tissue expander, followed by the placement of DFDB. Since previous clinical data suggested that 6 months healing time for a sinus grafted with DFDB was insufficient, we opted to wait for 16 months before fixture placement. A CT scan was taken 14 months following the sinus augmentation procedure. Comparison of this scan to the pre-surgical scan revealed an increase in bone quality and density in the grafted areas (Fig. 8). However, the density of the bone graft was far less than that seen with the autogenous bone graft. At this time, implant sites were prepared and bone cores were obtained from the most distal implant sites in the fashion previously described. Eight implants were subsequently placed. The specimens were prepared as previously described.

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Histologic analysis of the bone cores demonstrated bone of poor quality (i.e., only a sparse network of bony trabeculae). Overall, the bone quality deteriorated progressing from the alveolar crest toward the sinus end of the core. Fibrofatty connective tissue was present throughout the bone core. The midportion of the core exhibited some signs of graft remodeling (Fig. 9). However, unresorbed DFDB particles were observed in the end of the core approximating the elevated sinus membrane (Fig. 10).

At stage 2 surgery 8 months following implant placement, 2 fixtures were lost due to fibrous encapsulation, and 6 fixtures were clinically osseointegrated.

**DISCUSSION**

The cases reported above demonstrate that sinus augmentation in severely resorbed regions of the posterior maxilla

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IMZ, Interpore Corporation, Irvine, CA.

*CUI Corporation, Santa Barbara, CA.

*Branemark System, Nobelpharma USA, Chicago, IL.
is possible using different graft materials. Following the histologic analysis of bone cores obtained at the time of implant placement, it was determined that samples taken from sites grafted with autogenous bone contained more mineralized bone than samples from DFDB grafted sites. Furthermore, specimens from the latter sites still contained remnants of DFDB indicating that the graft was still not completely replaced, even 16 months post-implantation. New bone formation was limited and fibrous encapsulation of the allogeneic graft material was common in the portion of the graft approximating the elevated sinus membrane. Bone cores subsequently obtained from an additional 10 cases, 5 grafted with autogenous bone and 5 where allogeneic bone was implanted, have shown similar results (unpublished data). It appears from the progression of resorption and remodeling from the alveolar crest to the sinus membrane seen in the DFDB cores that the osteoprogenitor cells repopulating the sinus grafts are derived mainly from cells residing in the residual maxillary alveolar ridge and not from the elevated sinus membrane. Also, it is doubtful
that resorption and replacement of the allogeneic graft material will occur once it has become encapsulated in fibrous connective tissue.

The radiological observations were grossly consistent with the histologic findings. Based upon subjective comparison of the CT scans, sinuses grafted with autogenous cancellous bone exhibited greater bone density than sites grafted with DFDB. In addition, the clinical implant success was higher in the patient grafted with autogenous bone (100%) than in the patient grafted with allogeneic bone (75%).

Our observations are generally consistent with those of other investigators. Burchardt reviewed the healing process following the use of different forms of graft materials and concluded that both vascular penetration and bone formation were faster and more extensive when autogenous bone was the graft material.33 His findings are supported by a number of clinical studies which report a high percentage of implant fixture success when autogenous bone is used as the graft material during sinus augmentation.15-20

Deminerlized freeze-dried cancellous bone has been used for sinus augmentation with variable results.12,20,21,28-30

Chanavaz reported 20 cases in which DFDB was used without major complication.13 However, others have observed that the quality and quantity of the "regenerated" bone seen in trephined bone cores was insufficient for predictable implant retention.14,21

Other types of graft material used alone or in combination have been implanted during maxillary sinus augmentation. Irradiated mineralized cancellous allograft has been used successfully in combination with an expanded polytetrafluoroethylene membrane.** Histologic analysis of trephined bone cores obtained 6 months post-implantation demonstrated the presence of significant amounts of mineralized bone.21 However, cancellous bone contains virtually no bone morphogenetic protein (BMP) and the amount of radiation required to sterilize mineralized allograft may destroy the remaining bone matrix, thereby altering the osteoinductive properties of the graft.23 Bovine bone has also been used successfully.4 Other investigators have utilized non-resorbable hydroxyapatite with or without DFDB.20,24 Non-resorbable hydroxyapatite is purely an osteoconductive material. It has no osteoinductive capacity and does not osseointegrate to fixtures.26,35 Therefore, theoretically its use will decrease the area of direct bone contact with implant fixtures, predisposing them to clinical failure. In contrast, resorbable hydroxyapatite acts as a mineral reservoir and a scaffold upon which the body creates new bone. This bone is available for implant fixture osseointegration. Successful use of resorbable hydroxyapatite alone or in combination with DFDB has been documented.26,27-29

Based on review of the literature, and the radiographic, histologic, and clinical observations from the cases presented, sinuses augmented with autogenous bone exhibit characteristics that are considered more desirable for im-

**Gore-Tex periodontal material, W.L. Gore and Associates, Flagstaff, AZ.
plant placement. When compared to allogeneic DFDB used alone, autogenous bone results in an increased bulk and density of bone with more rapid bone formation and remodeling. In addition, implant placement into autogenous graft sites has been highly successful. The specific type of DFDB used in this case did not seem to produce bone of sufficient quantity or quality to allow predictable implant placement. Consequently, autogenous bone currently appears to be the graft material of choice for maxillary sinus augmentation. However, because of the limitations of autogenous bone as a grafting material, additional investigation into different forms of DFDB (different particle sizes, etc.) and other alternative grafting materials is necessary.

Acknowledgments
The authors would like to thank Dr. Susan Cutler for her great clinical contribution. We also would like to thank Dr. Johnathan Korostof for reviewing the manuscript and for his valuable comments.
Figure 7. Clinical operative view showing sinus access window packed with demineralized freeze-dried allogeneic bone. The graft is a combination of particle sizes 300 to 500 μm and 1000 to 3000 μm.

Figure 8. Representative sections of the right (top) and left (bottom) maxilla from the CT scan 16 months following bilateral sinus augmentation and anterior onlay bone grafting with demineralized freeze-dried allogeneic bone. The sinuses show increased height and width of bone. However, note the decreased density of the augmented bone.
DFDB graft material. The bottom (alveolar) portion is normal cancellous bone. The whole specimen is infiltrated by fibro-fatty marrow (original magnification × 11.2).

REFERENCES
19. Hirsch JM, Ericsson I. Maxillary sinus augmentation using mandib-


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Accepted for publication March 8, 1994.