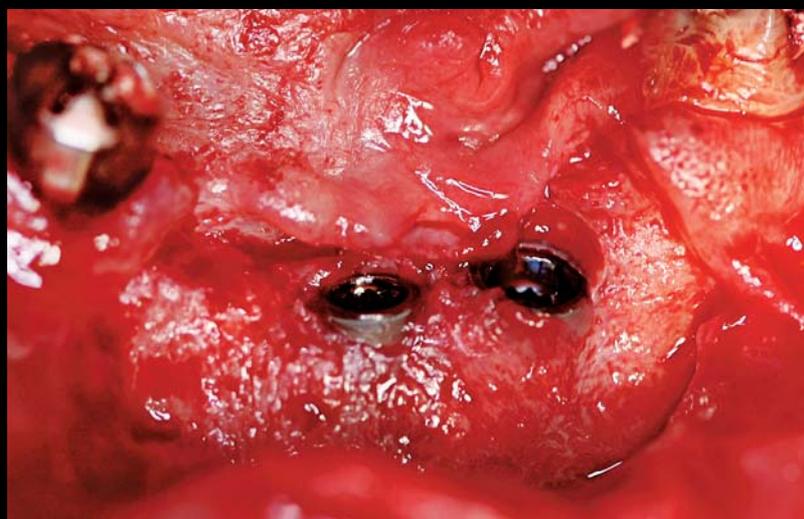# Histologic and Clinical Results of DFDBA With Lecithin Carrier Used in Dental Implant Applications: Three Case Reports

John A. Lupovici, DDS

*Although autogenous bone grafting material has long been considered the gold standard for regeneration of deficient alveolar sites, it has a number of disadvantages. Allograft material avoids many of these but its osteoinductivity has been questionable. An allograft material long used in orthopedics but only recently adapted for oral and maxillofacial grafting sites displays osteoinductivity that has been verified in vitro and offers other clinical benefits. Three treatment reports are presented to illustrate the use of this material, along with histological results.*

**Learning Objectives:**
This article demonstrates the history and use of allograft bone grafting materials in dental implant applications. Upon completing this exercise, the reader should:

- Be aware of the historical performance of graft materials in dental implant procedures.
- Understand the importance of osseous regeneration for successful implant dentistry.

*Key Words: bone grafting, allograft, osteoinductivity, implant regeneration*

*Assistant Professor, New York University College of Dentistry, Department of Periodontics and Implant Dentistry, New York, NY; Private practice, New York, NY.*

*John A. Lupovici, DDS, 425 Madison Avenue, Suite 900, New York NY 10017*
*Tel: 212-251-0030 • E-mail: drlupo@mac.com*

Alveolar bone resorption is a common phenomenon, particularly within the first year after tooth loss.[1-3] Trauma, developmental anomalies, and pathological processes (acute and chronic) also may deprive patients of their native oral bone. In the wake of such phenomena, the residual hard tissue may be inadequate to support dental implants. If implants are placed in the compromised bone, the definitive implant restoration may also be compromised. Negative consequences commonly associated with improperly positioned implants range from biomechanical concerns (eg, screw loosening; fractures of the screw, implant, implant collar, prosthesis, or porcelain)[4-6] to compromised final aesthetics (eg, unnatural emergence profiles, poor screw-access opening positioning).

To avoid such problems and enable clinicians to accurately recreate natural dental function and aesthetics, a variety of bone augmentation strategies have been developed. Onlay, inlay, and veneer grafts;[7-9] sinus augmentation;[10-12] ridge splitting and expansion;[13,14] guided bone regeneration;[15-19] nerve lateralization;[20] and distraction osteogenesis[21] all have a documented record of success when used to treat horizontally and vertically atrophic ridges, extraction sockets, implant-associated defects, and other anatomical deficiencies. Most of these techniques require the use of bone grafting materials, autografts, allografts, xenografts, and alloplasts all have been documented to be successful, used either alone or in combination.

Among them, autogenous bone has long been considered the gold standard. Depending upon the donor site and the manner in which it is harvested, autogenous bone has proven to be osteoconductive, osteoinductive, and nonantigenic—all properties of an ideal grafting material. The use of autogenous bone, however, has also been associated with a number of disadvantages, including patient morbidity; parasthesia, anesthesia, and neurosensory changes to the proximal teeth and tissue; edema; ptosis; incision dehiscence; and infection.[8,22-25] Implants placed in autogenous block grafts have been associated with lower survival rates[26,27] and significant resorption has been reported.[7,28-31]

Allograft bone, commercially available in a variety of sizes, shapes, and processing techniques, is an alternative to autogenous material. Successful results from the use of allografts have been reported in the periodontal and implant-regenerative literature for more than three decades,[32] and using this material frees the patient from the need for a second surgical site.

Some controversy exists over whether freeze-dried bone allograft (FDBA) or demineralized freeze-dried bone allograft (DFDBA) is superior for regeneration. Successes with both have been documented in case reports, and
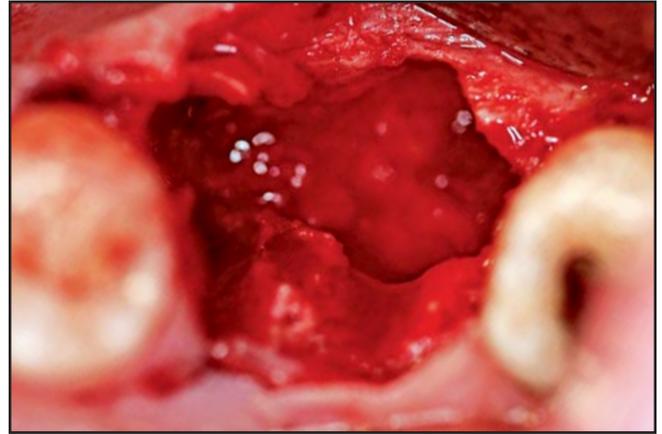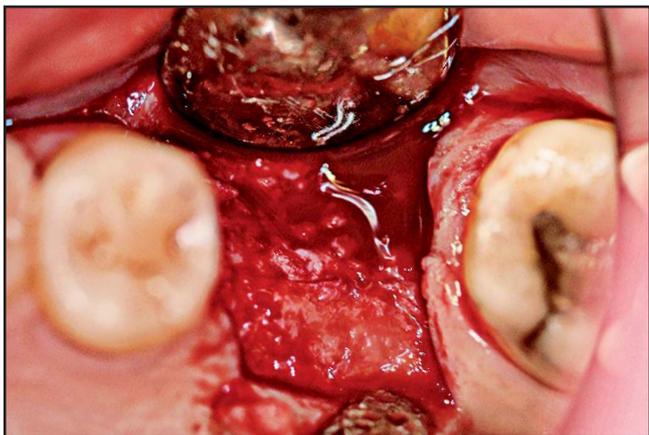


**Figure 1. Initial occlusal view of the extraction socket of the mandibular first molar.**



**Figure 2. Postextraction alveolus filled with allograft (with lecithin carrier) material.**

when used primarily in intraosseous defects, significant clinical differences between the two materials have not been found.[19,33-37] However, DFDBA has historically has been considered to be a better choice in challenging regenerative sites because of the demineralization process. In this process, as described by Urist,[38] the allograft is bathed in an acidic solution, thereby exposing the bone morphogenetic proteins that theoretically render it osteoinductive.

Nonetheless, when used in dental applications in combination with a barrier membrane, clinical results of DFDBA grafts in both humans and animals have varied significantly,[39-42] and the osteoinductivity of the DFDBA has come into question. The variation in clinical results has been linked to a number of potential factors including sterilization techniques,[43-45] particle size,[46] and donor age.[47] The processing techniques of individual bone banks also may affect the inductive capacity of the bone.[48,49]

Figure 3. Occlusal view of the regenerated site three months after extraction and grafting.



Figure 4. The implant was placed in the newly regenerated bone adjacent to the biopsy core harvest site.

An allograft material long used in orthopedics (ie, RegenerOss Allograft Putty, Biomet/3i, Palm Beach Gardens, FL) has recently been adapted for oral and maxillofacial grafting applications. The allograft presents in putty form, consisting of DFDBA (40% by weight), which is suspended in lecithin, an organic phosphatidylcholine. The DFDBA in this allograft receives routine screening for HIV, hepatitis, and other infectious agents and furthermore undergoes a process to verify the osteoinductivity of every sample. This is achieved by means of the Saos cell-proliferation test. Results of this assay have demonstrated a correlation coefficient of 0.850 (p<0.0005) with implantation of demineralized bone into athymic rat muscle.[50]

Although one aspect of the processing technique for removing lipids from demineralized bone has been found to significantly inhibit osteoinduction, adding purified lecithin to the DFDBA appears to restore the osteoinductive activity and enhance biological activity above that of a standard demineralized bone preparation.[51] Naturally present in cell membranes, tissues, and organs, lecithin is believed to play an active role in the biologic calcification that occurs during osteogenesis.[52]

Clinical benefits of the lecithin carrier include the fact that, as a lipid, it is hydrophobic, offering high resistance to irrigation, blood, and saliva. It provides remarkable ease of handling and excellent graft containment after being exuded into the defect site. When incubated at 37 degrees C, the putty maintains a solid state and remains intact at the graft site for 7 to 14 days, after which it is absorbed by the body with no foreign-body reaction. Autogenous or other additional bone grafting material can be easily combined with it, should that option be desired. Other commercially available allograft putties use glycerol as a binding agent and hence may pose concerns over toxicity.[53]

The following clinical cases illustrate the use of this allograft material to regenerate three distinct osseous defects.

## Case Presentations
### Case #1
A 47-year-old, systemically healthy female patient presented with a periodontally hopeless mandibular right first molar. Following administration of local anesthesia (lidocaine with epinephrine 1:100,000), the molar was sectioned, and the mesial and distal roots were atraumatically elevated from the alveolus (Figure 1). Care was taken to avoid traumatizing the alveolus. All granulation tissue was carefully curetted from the socket, which then was filled with the inductive allograft putty (Figure 2). A 2-mm–thick slice of a collagen wound dressing material was placed over the graft to better contain the putty. The tissues were sutured, and no attempt to achieve primary closure was made.

The patient received antibiotic therapy consisting of amoxicillin 250 mg three times a day for one week. The regenerated area remained unloaded throughout the healing process. The patient returned for evaluation at one, three, six, and 12 weeks postoperatively. Soft tissue healing was uneventful.

Three months after the extraction and augmentation, the patient presented for implant placement. Intraoral examination revealed successful maintenance of the alveolar ridge width. Following administration of anesthesia, a full-thickness flap was reflected, and the preservation of the hard tissue was confirmed (Figure 3). A 3-mm trephine histology core was harvested on the mesial aspect of the graft site. This specimen was immediately fixed in 10% neutral buffered formalin for later histological preparation and examination.

The osteotomy created by harvesting the trephine core was enlarged, and the bone quality was noted to be Type 2 to 3, according to the Lekholm and Zarb scale. A parallel-walled implant was placed (Figure 4), and primary stability was verified. The tissues were then sutured, and primary closure was achieved.

Three months after implant placement, osseointegration was verified radiographically. A full-thickness flap was reflected to enable placement of a healing abutment. To accommodate this, removal of a 1 mm × 2mm wedge of augmented bone from the distal aspect of the previously regenerated socket was found to be necessary. The harvested bone was immediately stored in 10% neutral buffered formalin for later histological examination.

*Histological Processing & Examination*
Both samples were dehydrated in increasing grades of ethanol and subsequently infiltrated with resin. Following embedding in methylmethacrylic resin, the samples were polymerized and sectioned vertically using a cutting-grinding unit. The 250-μm–thick units obtained were further reduced by microgrinding and polishing to a final thickness of approximately 20 μm to 30 μm. The sections were stained with hematoxylin and eosin and then examined under a light microscope equipped with an image system.

Microscopic examination of the histologic section obtained at three months revealed newly formed bone and minimal residual graft material. The residual graft particles that were present were in close contact with bone or connective tissue. The new lamellar bone present appeared vital with osteocytes in the lacunae (Figure 5).

The histology sample obtained at six months displayed further new bone and vasculature with a reduced presence of residual graft material as well as medulary space. No histological signs of inflammation were present in any of the sample slices (Figures 6 and 7).

### Case #2
The patient was a 54-year-old male who presented for full-mouth rehabilitation with fixed, implant-retained restorations. His medical history was unremarkable. The same antibiotic regimen as described above was administered. A crestal incision of one edentulous mandibular segment was made, and reflection of a full-thickness gingival flap revealed the horizontal dimension of the residual alveolar ridge to be approximately 4 mm to 5mm. Two implants were placed according to the manufacturer's protocol, and primary stability was achieved
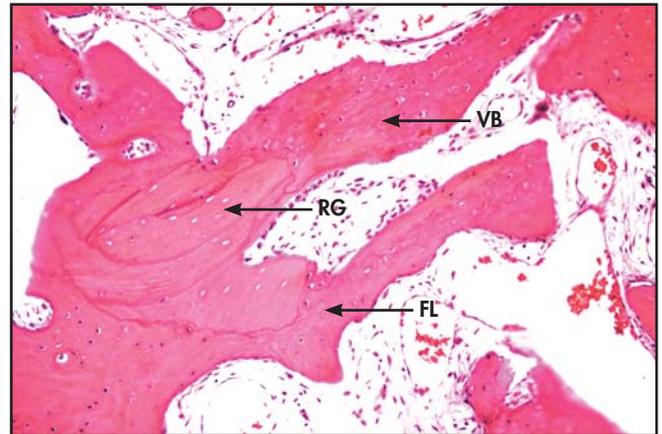


**Figure 5. Three-month histology of newly formed bone, in association with residual graft material. A large degree of trabeculation is evident. Original magnification ×10.**
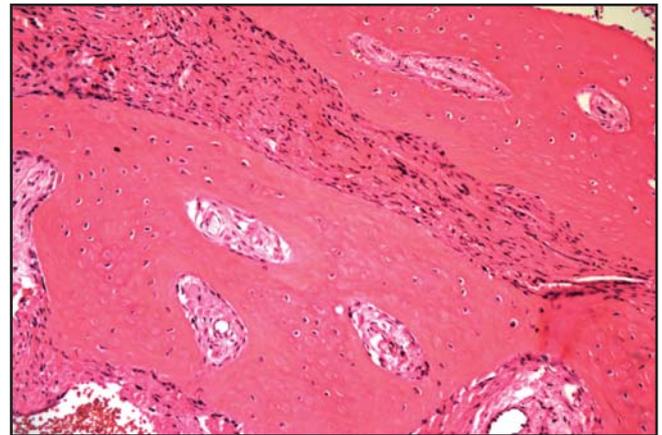


**Figure 6. Six-month histology sample displaying new bone and vasculature, with a reduction in medullary space. Original magnification ×10.**
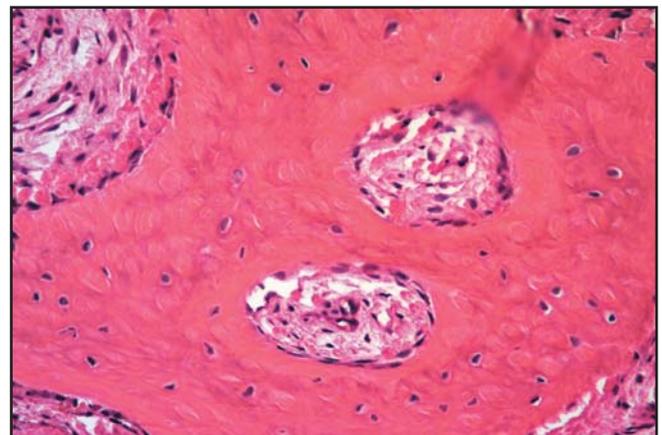


**Figure 7. High-power magnification of six-month sample displaying blood vessel. Original magnification ×40.**

**Figure 8. A buccal dehiscence defect exposed four threads on the facial aspect of the mesial implant.**



**Figure 9. RegenerOss Allograft Putty (Biomet/3i, Palm Beach Gardens, FL) was applied to cover the residual threads.**



**Figure 10. A biologic membrane was adapted over the graft material.**

for both. A buccal dehiscence defect, however, exposed four threads on the facial aspect of the mesial implant (Figure 8).

RegenerOss Allograft Putty (Biomet/3i, Palm Beach Gardens, FL) was applied to the dehiscence to completely cover the exposed threads (Figure 9), and a biologic membrane was trimmed to fit the contours of the graft site and placed in position (Figure 10). Passive primary closure was obtained by means of periosteal releasing incisions.

Primary closure was maintained throughout the healing period. Five months after implant placement, a radiograph indicated successful osseointegration. One month later, re-entry for healing abutment connection revealed that the previously exposed threads were completely encased in newly regenerated bone (Figure 11).

### Case #3

A 44-year-old male patient presented with a failing three-unit anterior maxillary fixed partial denture that had been fabricated 15 years earlier. Examination revealed that the right central incisor structure was inadequate to support a replacement restoration. The left central incisor site, a longstanding pontic, was an atrophic knife-edge ridge. The left lateral incisor presented with severe periodontal involvement, vertical loss of attachment, and mesiobuccal loss of all facial plate to the apex.

After the patient began antibiotic treatment, a papillary-preserving releasing incision was made on the mesial of the right lateral incisor, extending to the left canine. A full-thickness flap was reflected, and the right central incisor and left lateral incisor were extracted, revealing a loss of horizontal and vertical bone (Figures 12 and 13).

The allograft putty material was adapted to the ridge (Figure 14), and a resorbable cross-linked collagen membrane was placed on top of the putty. Periosteal releasing incisions were made to attain passive primary closure.

After six months of healing, papillary-preserving incisions were made, and a full-thickness flap was reflected, revealing notable regeneration of the alveolar crest (Figure 15). Two implant osteotomies were created in the two lateral incisor sites, and a 2 mm × 8 mm trephine core was harvested from a point midway between them for histological examination, and immediately stored in 10% neutral buffered formalin for histological examination. The regenerated bone was judged to be Type 2 to 3. Two implants were then placed in the lateral incisor positions, and primary stability was achieved. The implants healed unremarkably.
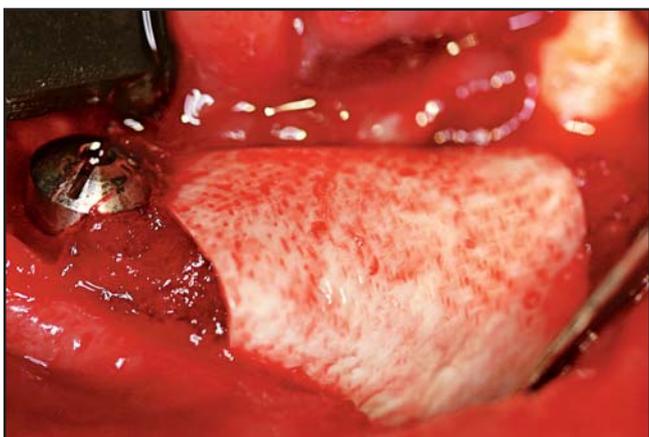
Histological preparation was executed in the same manner as described above. Microscopic examination of the histologic section revealed vital bone cells in conjunction with notable woven bone (Figure 16). The amount of residual graft particles noted in this sample was minimal and concentrated in the middle sections.

## Discussion

The success of attempts at osseous regeneration has been shown to depend substantially on the defect morphology and the graft material used. In this case series, the same material (ie, allograft putty) was utilized in three different types of defects.

When lesions are intraosseous, such as an extraction socket, proper containment of the graft material within the alveolar housing is limited only by the area of ingress to the bone, such as the socket entrance. In such situations, graft containment may be achieved in one of several ways. One technique utilizes a biocompatible collagen wound-dressing material over the graft material.54 This protects the graft from displacement while at the same time inducing blood-clot formation via platelet aggregation and stabilizing the wound. The collagen material also functions chemotactically to attract fibroblasts and promote wound coverage.[55,56] If a membrane or collagen sponge is not used to contain the allograft within the defect, the surgeon should attempt to achieve primary closure to prevent displacement of the graft material. In the opinion of the author, this is particularly important when using RegenerOss Allograft Putty (Biomet/3i, Palm Beach Gardens, FL) as a grafting material, as the tactile feeling and taste of the lecithin carrier tends to prompt increased patient tongue habits that could potentially displace the material.

When the graft material must be applied outside the skeletal envelope, space maintenance becomes a concern. The lecithin carrier of the aforementioned allograft putty has some space-maintaining properties, as the successful results seen in Case 2 and 3 attest. In the opinion of the author, however, combining the putty with an osteoconductive graft material is apt to yield even more predictable superior clinical results.

It should be noted that in the two cases reported here in which the regenerated bone was later entered surgically, the bone was judged to be of Type 2 or 3, despite displaying excellent histological results. The explanation for this may lie in the nature of the demineralized allograft material. Even though no statistical difference in percentages of new bone formed has been found between sites grafted with DFDBA versus FDBA,[57] significantly less residual bone was documented at the DFDBA-grafted sites. If the mineralized material takes
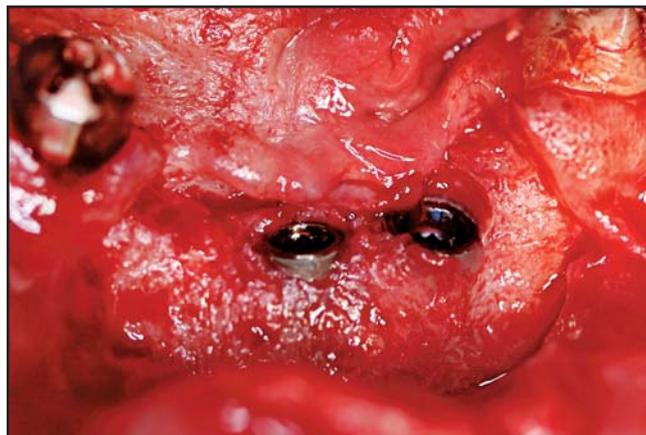


**Figure 11. Intraoperative view of the newly regenerated bone five months after grafting.**
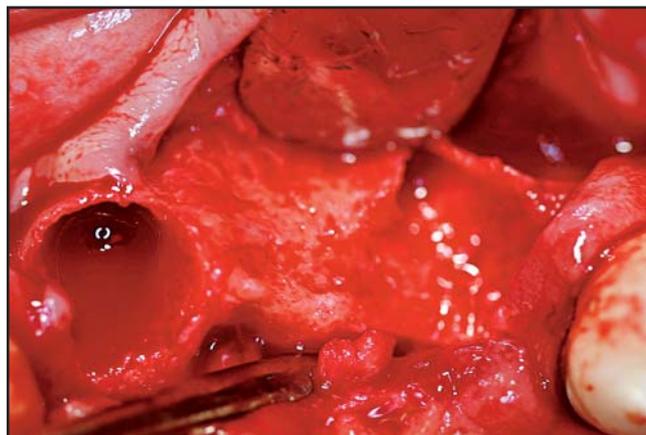


**Figure 12. A full-thickness mucoperiosteal flap was reflected, and the maxillary right central incisor and left lateral incisor were extracted, revealing the narrow dimensions of the ridge.**
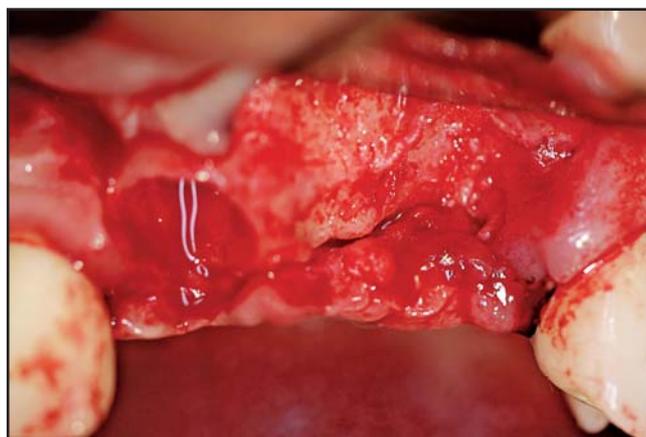


**Figure 13. The facial view of the defect revealed vertical alveolar loss in conjunction with the horizontal defect seen in figure 12.**

**Figure 14. RegenerOss Allograft Putty (Biomet/3i, Palm Beach Gardens, FL) was adapted to the ridge before being covered with a resorbable collagen membrane.**
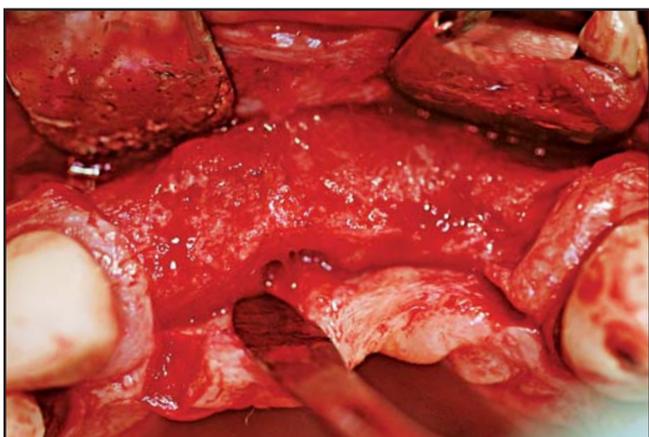


**Figure 15. Re-entry after six months demonstrated excellent bone regeneration and an increase in both the vertical and horizontal ridge dimensions.**
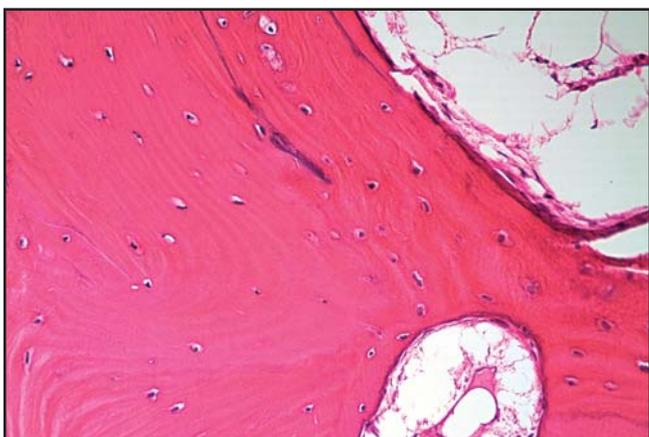


**Figure 16. Histology revealed vital bone cells in conjunction with notable woven bone.**

longer to resorb, sites regenerated with it might appear to be harder while in fact being no more successful than sites grafted with demineralized material.

## Conclusion

The results obtained in the cases presented in this short-term preliminary report indicate that DFDBA combined with a lecithin carrier can be used to successfully augment a variety of deficient alveolar sites. Although the regenerated bone in two of the three cases was Type 2 to 3, histological findings confirmed the development of well-vascularized bone marrow and newly formed bone. While the osteoinductivity of the allograft bone within the putty has been verified via in vitro bioassay, the results of this clinical care report cannot conclusively support the clinical relevance. Future controlled clinical trials are recommended.

## Acknowledgment

## References

1. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extractions: A clinical & radiographic 12-month prospective study. Int J Periodont Rest Dent 2003;23:313-323.
2. Simon BI, Von Hagen S, Deasy MJ, et al. Changes in alveolar bone height and width following ridge augmentation using bone graft and membranes. J Periodontol 2000 ;71:1774-1791.
3. Nevins M, Camelo M, De Paoli S, et al. A study of the fate of buccal wall of extraction sockets of teeth with prominent roots. Int. J Periodont Rest Dent 2006;26:19-29.
4. Rangert B, Jemt T, Jorneus L. Forces and moments on Branemark implants. Int J Oral Maxillofac Impl 1989;3:241-247.
5. Patterson EA, Burguete RL, Thoi MH, Johns RB. Distribution of load in an oral prosthesis system: an in vitro study. Int J Oral Maxillofac Impl 1995;5:552-560.
6. Khraisat A, Abu-Hammad O, Dar-Odeh N, Al-Kayed AM. Abutment screw loosening and bending resistance of external hexagon implant system after lateral cyclic loading. Clin Implant Dent Relat Res 2004;3:157-164.
7. Proussaefs P, Lozada J. The use of intraorally harvested autogenous block grafts for vertical alveolar ridge augmentation: A human study. Int J Periodont Rest Dent 2005;25:351-363.
8. Misch C. Comparison of intraoral donor sites for onlay grafting prior to implant placement. Int J Oral Maxillofac Impl 1997;12:767-776.
9. Pikos MA. Block autografts for localized ridge augmentation: Part I. The posterior maxilla. Implant Dent 1999;8:279-285.
10. Boyne P, James R. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg 1980;38:613-616.
11. Tatum H Jr. Maxillary and sinus implant reconstructions. Dent Clin North Am 1986;30:207-229.
12. Lazzara RJ. The sinus elevation procedure in endosseous implant therapy. Curr Opin Periodontol 1996;3:178-183.

13. Duncan J, Westwood R. Ridge widening for the thin maxilla: A clinical report. Int J Oral Maxillofac Impl 1997;12:224-227.

14. Scipioni A, Bruschi G, Calesini G. The edentulous ridge expansion technique: a five year study. Int J Periodont Rest Dent 1994;14(5):451-459.

15. Mellonig NT, Nevins M. Guided bone regeneration of bone defects associated with implants: an evidence-based outcome assessment. Int J Periodont Rest Dent 1995;15(2):168-185.

16. Zitzmann N, Naef R, Schärer P. Resorbable versus nonresorbable membranes in combination with Bio-Oss for guided bone regeneration [published erratum appears in: Int J Oral Maxillofac Implants 1998;13(4):576]. Int J Oral Maxillofac Impl 1997;12(6):844-852.

17. Dahlin C, Lekholm U, Becker W, et al. Treatment of fenestration and dehiscence bone defects around oral implants using the guided tissue regeneration technique: A prospective multicenter study. Int J Oral Maxillofac Impl 1995;10:312-318.

18. Tolman D. Reconstructive procedures with endosseous implants in grafted bone: A review of the literature. Int J Oral Maxillofac Impl 1995;10:275-294.

19. Block M, Degen M. Horizontal ridge augmentation using human mineralized particulate bone: preliminary results. J Oral Maxillofac Surg 2004;62:67-72, Suppl 2.

20. Jensen J, Reiche-Fischel O, Sindet-Pederson S. Nerve transposition and implant placement in the atrophic posterior mandibular alveolar ridge. J Oral Maxillofac Surg 1994;52:662-668.

21. Urbani G, Lombardo G, Santi E, Consolo U. Distraction osteogenesis to achieve mandibular vertical bone regeneration: A case report. Int J Periodont Rest Dent 1999;19:321-331.

22. Pikos M. Block autografts for localized ridge augmentation: Part II. The posterior mandible. Implant Dent 2000;9:67-75.

23. Schwartz-Arad D, Levin L, Sigal L. Surgical success of intraoral autogenous block onlay grafting for alveolar ridge augmentation. Implant Dent 2005;14:131-138.

24. Raghoebar GM, Louwerse C, Kalk WW, Vissink A. Morbidity of chin bone harvesting. Clin Oral Implants Res 2001;12(5):503-507.

25. Clavero J, Lundgren S. Ramus or chin grafts for maxillary sinus inlay and local onlay augmentation: comparison of donor site morbidity and complications. Clin Implant Dent Relat Res 2003;5(3):154-160.

26. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Impl 2007;22(Suppl):49-70.

27. Wallace SS, Froum SJ. Effect of maxillary sinus augmentation on the survival of endosseous dental implants. A systematic review. Ann Periodontol 2003;8(1):328-343.

28. Misch CM, Misch CE, Resnik RR, Ismail YH. Reconstruction of maxillary alveolar defects with mandibular symphysis grafts for dental implants: a preliminary procedural report. Int J Oral Maxillofac Impl 1992;7(3):360-366.

29. Raghoebar GM, Batenburg RH, Vissink A, Reintsema H. Augmentation of localized defects of the anterior maxillary ridge with autogenous bone before insertion of implants. J Oral Maxillofac Surg 1996;54(10):1180-1186.

30. Widmark G, Andersson B, Ivanoff CH. Mandibular bone graft in the anterior maxilla for single-tooth implants. Presentation of surgical method. Int J Oral Maxillofac Surg 1997;26(2):106-109.

31. McAllister BS, Haghighat K. Bone augmentation techniques. J Periodontol 2007;78(3):377-396.

32. Libin BM, Ward HL, Fishman L. Decalcified, lyophilized bone allografts for use in human periodontal defects. J Periodontal 1975;46(1):51-56.

33. Piattelli A, Scarano A, Corigliano M, Piattelli M. Comparison of bone regeneration with the use of mineralized and demineralized freeze-dried allografts: a histological and histochemical study in man. Biomaterials 1996;17(11):1127-1131.

34. Rummelhart JM, Mellonig JT, Gray JL, Towle HJ. A comparison of freeze-dried bone allograft and demineralized freeze-dried bone allograft in human periodontal osseous defects. J Periodontol 1989;60(12):655-663.

35. Francis J, Brunsvold M, Prewett A, Mellonig J. Clinical evaluation of an allogeneic bone matrix in the treatment of periodontal osseous defects. J Periodontol 1995;66:1074-1079.

36. Block M, Finger, I Lytle R. Human mineralized bone in extraction sites before implant placement. J Am Dent Assoc 2002;133:1631-1638.

37. Minichetti JC, D'Amore JC, Hong AY, Cleveland DB. Human histologic analysis of mineralized bone allograft (Puros) placement before implant surgery. J Oral Implantol 2004;30:74-82.

38. Urist M, Mikulski A, Boyd S. A chemosterilized antigen-extracted autodigested alloimplant for bone banks. Arch Surg 1975;110:416.

39. Becker W, Schenk R, Higuchi K, et al. Variation in bone regeneration adjacent to implants augmented with barrier membranes alone or with demineralized freeze-dried bone or autologous grafts: A study in dogs. Int J Oral Maxillofac Impl 1995;10:143-154.

40. Smukler H, Landi L, Setayesh R. Histomorphometric evaluation of extraction sockets and deficient alveolar ridges treated with allograft and barrier membrane: A pilot study. Int J Oral Maxillofac Impl 1999;14:407-416.

41. Parashis A, Andronikaki-Faldami A, Tsiklakis K. Comparison of 2 regenerative procedures – guided tissue regeneration and demineralized freeze-dried bone allograft – in the treatment of intrabony defects: A clinical and radiographic study. J Periodontol 1998;69:751-758.

42. Becker W, Lynch SE, Lekholm U, et al. A comparison of ePTFE membranes alone or in combination with platelet-derived growth factors and insulin-like growth factor-1 or demineralized freeze-dried bone in promoting bone formation around immediate extraction socket implants. J Periodontol 1992;63(11):929-40.

43. Lian J, Gundberg C. Osteocalcin. Biochemical consideration and clinical applications. Clin Orthop Res 1998;226:267-291.

44. Aspenberg P, Lindqvist S. Ethene oxide and bone induction. Controversy remains. Acta Orthop Scan 1998;69:173-176.

45. Tshamala M, Cox E, De Cock H, et al. Antigenicity of cortical bone allograft in dogs and effect of ethylene oxide-sterilization. Vet Immunol Immunopath 1999;69:47-59.

46. Shapoff CA, Bowers GM, Levy B, et al. The effect of particle size on the osteogenic activity of composite grafts of allogeneic freeze-dried bone and autogenous marrow. J Periodontol 1980;51:625-630.

47. Schwartz Z, Somers A, Mellonig JT, et al. Ability of commercial demineralized freeze-dried bone allograft to induce new bone formation is dependant on donor age but not gender. J Periodontol 1998;69:470-478.

48. Schwartz Z, Mellonig J, Carnes DL Ability of commercial demineralized freeze-dried bone allograft to induce new bone formation. J Periodontol 1996;67:918-926

49. Zhang M, Powers RM, Wolfinbarger L. Effect of demineralization process on the osteoinductivity of demineralized bone matrix. J Periodontol 1997;68:1085-1092.

50. Adkisson HD, Strauss-Schoenberger J, Gillis M, et al. Rapid quantitative bioassay of osteoinduction. J Orthop Res 1999;18:503-511.

51. Han B, Tang B, Nimni ME. Combined effects of phosphatidylcholine and demineralized bone matrix on bone induction. Connect Tissue Res 2003;44:160-166.

52. Wuthier RE. Effect of phospholipids on the transformation of amorphous calcium phosphate to hydroxapatite in vitro. Calcif Tissue Res 1975;19(3):197-210.

53. Wang JC, Kanim LE, Nagakawa IS, et al. Dose-dependant toxicity of commercially available demineralized bone matrix. Spine 2001;26(13):1429-1435.

54. Wang H-L, Tsao Y-P. Histologic evaluation of socket augmentation with mineralized human allograft. Int J Periodont Rest Dent 2008;28:231-237.

55. Gross J. Ridge preservation using HTR synthetic bone following tooth extraction. Gen Dent 1995;43:364-367.

56. Sableman E. Biology, biotechnology, and biocompatibility of collagen. In: Williams DF (ed). Biocompatibility of Tissue Analogs (ed 1). Boca Raton: CRC Press; 1985:27-66.

57. Cammack GV Jr, Nevins M, Clem DS III, et al. Histologic evaluation of mineralized and demineralized freeze-dried bone allograft for ridge and sinus augmentations. Int J Periodont Rest Dent 2005;25(3):231-237.