

# USE OF TITANIUM MESH FOR STAGED LOCALIZED ALVEOLAR RIDGE AUGMENTATION: CLINICAL AND HISTOLOGIC-HISTOMORPHOMETRIC EVALUATION

Periklis Proussaefs, DDS, MS  
Jaime Lozada, DDS

## KEY WORDS

Titanium mesh  
Bone grafting  
Xenograft

*Periklis Proussaefs DDS, MS, is in private practice emphasized in Prosthodontics and Implant Dentistry, Encino, Calif. Address correspondence to Dr Proussaefs, 16133 Ventura Boulevard #1100, Encino, CA 91463 (e-mail: Dentalimplants@sbcglobal.net).*

*Jaime Lozada, DDS, is a professor and director, Graduate Program in Implant Dentistry, School of Dentistry, Loma Linda University, Loma Linda, Calif.*

The use of titanium mesh for localized alveolar ridge augmentation was evaluated by clinical, radiographic, laboratory, and histologic-histomorphometric evaluation. Seventeen patients participated in this study. All patients required localized alveolar ridge augmentation before placement of dental implants. An equal mixture of autogenous bone graft and inorganic bovine mineral (Bio-Oss) was used as a bone graft material. Autogenous bone graft was harvested intraorally. Titanium mesh was submerged for 8.47 months (SD 2.83). Impressions were taken intraorally before bone grafting, 6 months after bone grafting, and 6 months after implant placement. Impressions were used to measure the volume of alveolar ridge augmentation and provide linear laboratory measurements regarding the results of bone augmentation. Bone quality (type II–IV) was recorded during implant surgery. Standardized linear tomographs were taken before bone grafting and before implant placement. A biopsy was harvested with a trephine bur from the grafted area during implant surgery for histologic-histomorphometric evaluation. In all cases the grafted area had adequate bone volume and consistency for placement of dental implants. Early mesh exposure (2 weeks) was observed in 2 patients, and late exposure (>3 months) was observed in 4 patients. Volumetric laboratory measurements indicated 0.86 cc (SD 0.69) alveolar augmentation 1 month after bone grafting, 0.73 cc (SD 0.60) 6 months after bone grafting, and 0.71 cc (SD 0.57) 6 months after implant placement. This indicated 15.11% resorption 6 months after bone grafting, and no further resorption occurred after implant placement. Linear laboratory measurements indicated vertical augmentation of 2.94 mm (SD 0.86) 1 month after bone grafting, 2.59 mm (SD 0.91) 6 months after bone grafting, and 2.65 mm (SD 1.14) 6 months after implant placement. The corresponding measurements for labial-buccal augmentation were 4.47 mm (SD 1.55), 3.88 mm (SD 1.43), and 3.82 mm (SD 1.47). Radiographic evaluation indicated 2.56 mm (SD 1.32) vertical augmentation and 3.75 mm (SD 1.33) labial-buccal augmentation. Histomorphometric evaluation indicated 36.47% (SD 10.05) new bone formation, 49.18% (SD 6.92) connective tissue, and 14.35% (SD 5.85) residual Bio-Oss particles; 44.65% (SD 22.58) of the Bio-Oss surface was in tight contact with newly formed bone. The use of titanium mesh for localized alveolar ridge augmentation with a mixture of autogenous intraorally harvested bone graft and Bio-Oss offered adequate bone volume for placement of dental implants. Intraorally harvested autogenous bone graft mixed with Bio-Oss under a titanium mesh offered 36.47% new bone formation, and 15.11% resorption occurred 6 months after bone grafting.

## INTRODUCTION

After the acceptance of dental implants as a valid treatment modality for the totally<sup>1,2</sup> or partially<sup>3,4</sup> edentulous patient, bone grafting has been proposed before<sup>5-9</sup> or simultaneously<sup>9-11</sup> with the placement of dental implants in order to place implants in patients lacking adequate bone volume.

Several methods, materials, and techniques have been used for bone grafting. Extraoral<sup>10,11</sup> and intraoral<sup>5-9,12</sup> donor sites have been used when autogenous bone graft is selected, and xenografts,<sup>13,14</sup> alloplastic bone grafts,<sup>15,16</sup> and allografts<sup>17-19</sup> have also been proposed. Various techniques have been applied to secure the graft material at the recipient site. Nonresorbable membranes,<sup>5,18,19</sup> fixation screws,<sup>6-8,12</sup> dental implants,<sup>10,11</sup> or titanium mesh<sup>20-29</sup> are the most common securing devices.

Few reports in the literature address histologic evidence in humans of the results obtained by using titanium mesh for localized alveolar ridge augmentation. In addition, limited knowledge is available regarding the resorption rate of the grafted area. The current study provides a clinical, radiographic, laboratory, and histologic-histomorphometric evaluation of the use of titanium mesh for localized alveolar ridge augmentation in conjunction with intraorally harvested intramembraneous autogenous bone graft and inorganic bovine mineral.

## MATERIALS AND METHODS

*Patient selection*

Seventeen consecutively treated patients (10 men and 7 women;

mean age 50.6 years, range 18-83) participated in this study (Table 1). The patients required a bone grafting procedure before the placement of dental implants (Figure 1). For all patients, titanium mesh (Osteo-Tram, Osteomed Inc, Addison, Tex) was used during the bone grafting procedure in conjunction with intraorally harvested intramembraneous bone graft and inorganic bovine mineral (Bio-Oss, Osteohealth Co, Shirley, NY). Bone grafting procedures were performed during the period July 1998 to April 2001. Treatment was performed at the Center for Prosthodontics and Implant Dentistry at Loma Linda University (LLU). All patients were treated by graduate students of the Graduate Program in Implant Dentistry and signed the corresponding informed consent approved by the Institutional Review Board at LLU in order to have a biopsy taken during implant surgery.

*Surgical protocol*

At the time of bone grafting procedure or implant placement, the patients were given a choice of (1) local anesthesia only, (2) local anesthesia with oral sedation (Halcion 0.25 mg), or (3) local anesthesia with intravenous sedation.

Full-thickness buccal-lingual or labial-palatal flaps were reflected at the recipient site (Figure 2). The donor site was the chin area (8 patients), the ascending ramus area (5 patients), an extraction socket (2 patients), the maxillary tuberosity (1 patient), or the mandibular tori (1 patient) (Table 1). Harvesting of the bone graft was performed according to the standard procedure described elsewhere.<sup>6</sup>

For the ascending ramus area, after administering block anesthesia for the inferior alveolar

canal, a crestal incision was made distal to tooth #32 or #17 area. The incision followed the direction of the ramus, and a vertical releasing incision was placed distal to tooth #32 or #17 area and to the ramus area. Full-thickness buccal-lingual flaps were reflected. Under copious irrigation and by using a fissure bur, a block graft was harvested. A bone chisel (ACE Surgical Supply Co, Brockton, Mich) was used to detach the graft, which was then particulated. For the chin area, the donor side received collagen hemostatic agent and was then sutured.

For the extraction socket, the bone from the edges of the socket was removed with a rongeur instrument, and additional bone was removed from the socket with a bone curette (ACE Surgical Supply Co). Bone harvesting from the maxillary tuberosity (patient 11) was performed with a 4-mm internal diameter trephine bur (ACE Surgical Supply Co), whereas bone harvesting from the mandibular tori (patient 8) was performed with a fissure bur and a chisel by a previously described technique (Figure 3).<sup>30</sup>

The autogenous graft particles were mixed in equal portions with Bio-Oss particles. The recipient site was perforated to induce bleeding and promote the incorporation of the graft.<sup>31</sup> The particulate graft was then loaded on the titanium mesh and placed at the recipient site (Figure 4). Periosteal fenestration<sup>32,33</sup> was performed along the labial-buccal flap to enable primary closure. The mesh was secured in place with fixation screws (Figure 4). The flap was then sutured.

The sutures were removed 2 weeks after the bone graft surgery. The bone graft was allowed to heal for 5 to 13 months before implant placement (Figure 5,

Table 1). The titanium mesh was removed 1 to 2 months before the implant placement at a separate procedure. Full-thickness labial-buccal and lingual-palatal flaps were reflected, and the mesh was removed after unscrewing the fixation screws.

Hydroxyapatite (HA)-coated root form implants (SteriOss, Nobel Biocare, Yorba Linda, Calif, for patients 1 to 15; Sustain, Life-core Biomedical Inc, Chaska, Minn, for patients 16 and 17) were placed 1 to 2 months after the removal of the mesh with the aim of a surgical stent (Figures 6 and 7). All patients were treatment planned to receive an implant-supported screw-retained fixed partial denture or single implant-supported cement-retained crown.

### Radiographic evaluation

All patients received pre- and postoperative panoramic radiographs. In addition, periapical radiographs were made before the bone grafting procedure and before implant placement (after the bone grafts had healed). Linear tomographs were made before bone grafting and before implant placement and were standardized by using 1 vertical and 1 horizontal light beam provided by the manufacturer of the radiographic unit (Scanora Type SBR 1C, Orion Co, Helsinki, Finland). Light beams assisted in positioning each patient's head when tomographs were made.

Measurements for the vertical and labial-buccal bone augmentation were made by evaluating the pre- and postoperative linear tomographs. One investigator (P.P.) made all measurements. For the linear tomographs, the distortion rate (1.7) provided by the manufacturer of the tomographic unit was taken in consid-

Patient No.	Recipient Site	Donor Site	Age	Sex	Healing Period (mo)	No. of Implants	Type of Provisional Restorations
1	#7-#11	Chin	60	M	9	5	RPD
2	#6 and #7	Ramus	70	M	6	2	FPD
3	#6-#11	Ramus	67	F	6	6	None
4	#30 and #31	Ramus	54	F	8	2	None
5	#2 and #3	Chin	69	M	6	2	None
6	#8-#10	Chin	44	M	6	3	None
7	#2-#4	Extraction socket	77	F	13	3	None
8	#6 and #7	Mandibular tori	73	M	10	2	RPD
9	#8-#10	Chin	60	M	7	3	RPD
10	#18 and #19	Chin	63	F	13	2	None
11	#10	Maxillary tuberosity	18	F	9	1	RPD
12	#10	Extraction socket	19	F	8	1	RPD
13	#22	Ramus	18	M	5	1	None
14	#12-#14	Ramus	83	M	10	3	None
15	#7	Chin	29	M	5	1	RPD
16	#8-#10	Chin	39	M	8	3	RPD
17	#9	Chin	18	F	15	1	RPD
Average	NA	NA	50.64	NA	8.47	NA	NA
SD			22.70		2.83		
Range			18-83		5-15		

\*RPD indicates interim removable partial denture; NA, not applicable.

eration when the measurements were made.

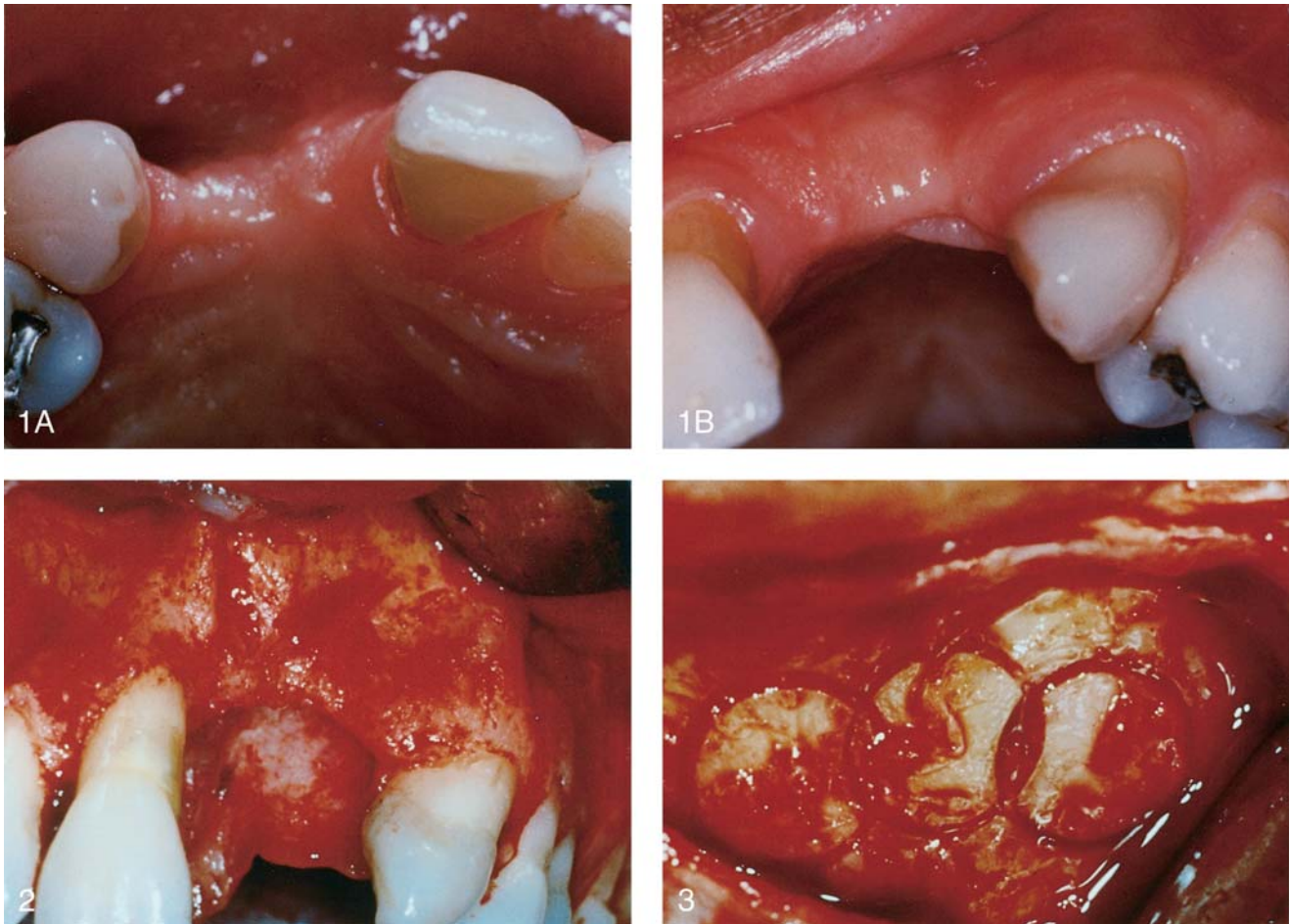
### Laboratory evaluation

Impressions were taken around the grafted area with a custom tray made from photopolymerized acrylic resin (Triad, Densply International Inc, York, Pa) with irreversible hydrocolloid as impression material (Coe Alginate, GC America Inc, Alsip, Ill). The impressions were taken before bone grafting, 1 month after bone grafting, 6 months after bone grafting, and 6 months after implant placement and were poured with type III dental stone (Microstone, Whip-Mix Co, Louisville, Ky).

The postoperative stone casts were used to quantitatively assess the volume of the alveolar ridge augmentation by the following technique: A custom tray was

fabricated by photopolymerized acrylic resin. An impression was taken from the postoperative stone cast with the custom tray and silicone (Lab-putty, Coltene/Whaledent Inc, Mahawan, NJ). The custom tray was removed. Polyvinylsiloxane bite registration material (BRM) (Exabite II NDS, GC America Inc) was loaded in the tray, which was then placed on the preoperative stone cast and the BRM was allowed to polymerize. The BRM was then removed from the tray. The excess material was trimmed. The weight of the BRM was assessed. By considering the special weight provided by the manufacturer, it was possible to calculate the volume of the alveolar ridge augmentation. In addition, linear measurements were made by evaluating the labial-buccal thickness and height of the BRM. Linear measurements were made with a caliper (Darby Dental Supply Inc,





FIGURES 1–3. FIGURE 1. Preoperative view, occlusal (A) and facial aspect (B). FIGURE 2. After full-thickness labial-palatal flap reflection, the residual alveolar ridge is exposed. FIGURE 3. Autogenous bone graft is harvested from the chin area.

Rockville, NY) at the location where preoperative clinical and radiographic evaluation revealed the maximum bone deficiency. For the 1-month postoperative data where the mesh was still in place, the thickness of the mesh (0.2 mm) was deducted from the caliper's measurements. The accuracy and reproducibility of this method have been evaluated in a different study that has been published elsewhere.<sup>34</sup> This laboratory method has been used in other studies involving localized alveolar ridge augmentation.<sup>7,28,35</sup>

#### *Specimen harvesting*

During implant surgery, a biopsy was taken from the grafted area

with a 2-mm internal-diameter trephine bur (ACE Surgical Supply Co) as the first drill during the osteotomy preparation for implant placement. The area that had the more pronounced preoperative bone deficiency was selected for the biopsy. The specimens were fixed in 10% buffered formalin.

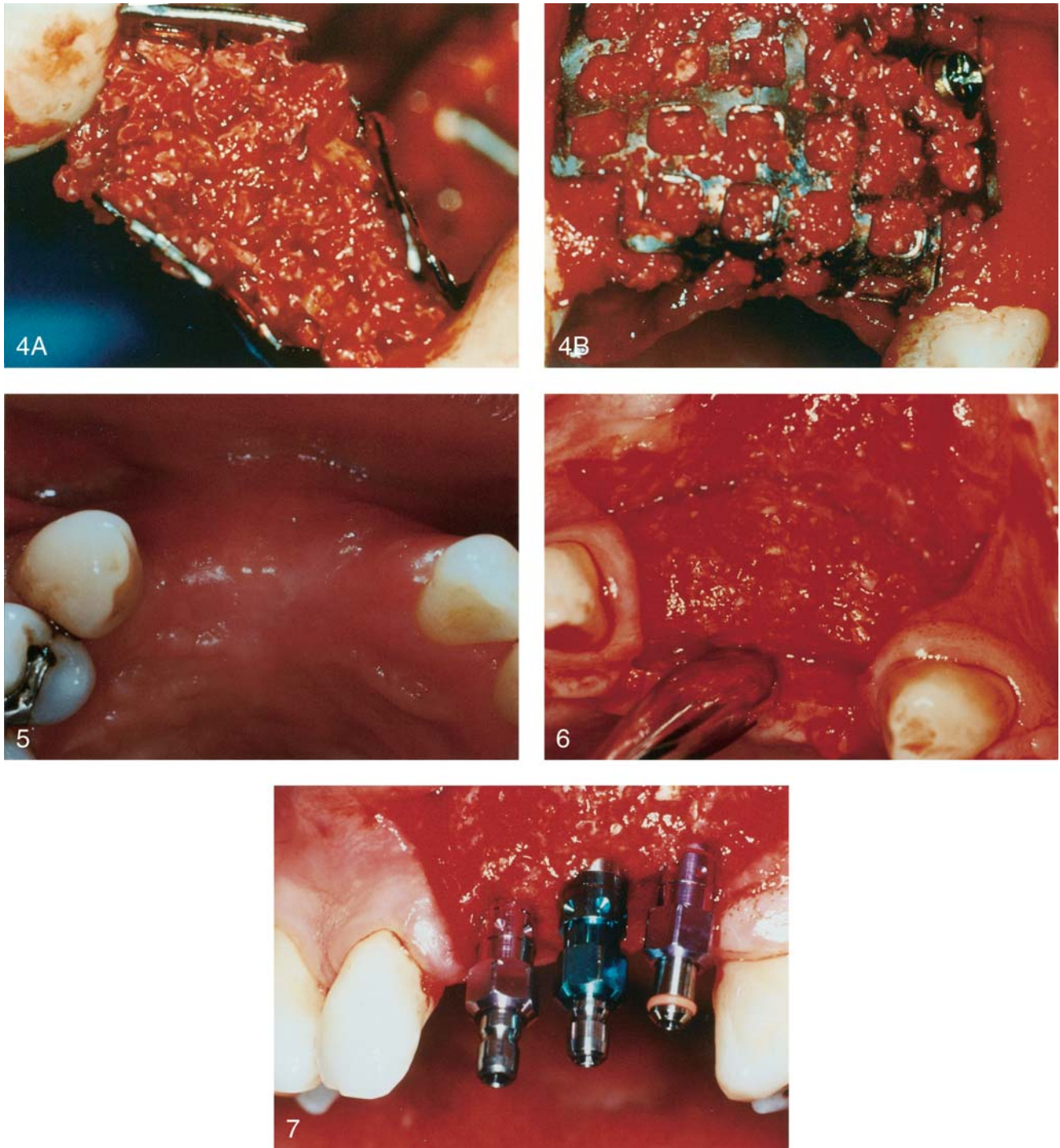
#### *Histologic processing*

The specimens were dehydrated in alcohol and embedded in specialized resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). Initial midaxial sections of 200  $\mu$ m were made by means of the cutting-grinding system (Exact Medical Instruments, Okla-

homa City, Okla). The sections were then ground to 40 to 50  $\mu$ m and were stained with Stevenel's blue and Van Gieson's picrofuchsin for histomorphometric evaluation and light fluorescent microscopy.<sup>36,37</sup>

#### *Histomorphometric evaluation*

One investigator (P.P.) used Ribbon, a computer-assisted linear analysis program developed at LLU,<sup>38</sup> to perform histomorphometric evaluation. This program uses a series of systematically spaced horizontal lines (each 2 pixels wide), one by one, on a vertically oriented image selected for analysis. In this study, the



FIGURES 4–7. FIGURE 4. (A) Autogenous bone graft mixed with Bio-Oss is loaded on the titanium mesh. (B) Titanium mesh is secured at the recipient site with fixation screws. FIGURE 5. Postoperative view, 8 months after bone grafting. FIGURE 6. After full-thickness flap reflection, the grafted alveolar ridge is exposed. FIGURE 7. In this case, 3 hydroxyapatite-coated root form implants were placed.

lines were spaced 50 pixels apart in the object plane, and the first line was placed randomly within 50 pixels of the top of the image.

Keyboard entries and cursor clicks recorded the lengths of the various types of tissue (bone, soft

tissue, or residual bone graft particles). Intersections of lines with residual bone graft particles were recorded as contacting bone



or soft tissue, depending on the type of tissue at the interface. One to 4 items were analyzed for each histologic specimen, depending on the size of the specimen. All histomorphometric evaluations were performed by capturing an image under  $\times 2$  magnification (Olympus Microscope, Model BH-2, McBain Instruments, Chatterworth, Calif).

Percent composition of the specimen was given by the ratio of the sum of the lengths of line segments falling on a given component (bone, soft tissue, graft particles) to the total length of lines analyzed. The percentage of residual xenograft surface occupied by bone was given by the ratio of the number of line intersections with bone-particle interfaces to the total number of graft xenograft surface intersections.

## RESULTS

### *Clinical evaluation*

Exposure of the titanium mesh during healing was observed in 6 of the 17 patients (Table 2). In these patients, soft tissue proliferation and epithelization was noticed to occur underneath the exposed mesh, an observation also made by others.<sup>26</sup> Oral hygiene instructions included to gently brush the exposed mesh with an end-T tooth brush. Patients reported no pain or discomfort at the grafted area, even when the mesh was exposed. The mesh was exposed within 2 weeks (early exposures) after bone grafting for 2 patients and within a few months (late exposures,  $>3$  months) after bone grafting for 4 patients. No clinical sign of inflammation or infection was observed in any of the 17 patients.

During the removal of the mesh, a layer of connective tissue was consistently observed underneath. Boyne et al<sup>20</sup> described this layer as "pseudoperiosteum." The mesh was surrounded by a thin layer of granulation tissue. The Bio-Oss particles appeared well incorporated into the grafted area. During implant placement, the grafted area had a type II to IV consistency. Primary stability was achieved during the placement of all implants.

### *Radiographic evaluation*

Radiographic evaluation revealed that a 2.56-mm vertical ridge augmentation (range 1–5, SD 1.32) and a 3.75-mm labial-buccal augmentation (range 2–5, SD 1.33) were achieved. In all situations, adequate bone volume was clinically observed for the placement of root form implants at a prosthetically ideal position.

### *Laboratory evaluation*

Laboratory volumetric measurements revealed ridge augmentation of 0.86 cc (range 0.34–3.05, SD 0.69) 1 month after bone grafting, 0.73 cc (range 0.29–2.73, SD 0.60) 6 months after bone grafting, and 0.71 cc (range 0.28–2.82, SD 0.57) 6 months after implant placement (Table 3). These measurements dictated a 15.11% resorption 6 months after bone grafting, which appeared to consolidate after implant placement.

Linear laboratory measurements for vertical and labial-buccal alveolar ridge augmentation were 2.94 mm and 4.47 mm 1 month after bone grafting, 2.59 mm and 3.88 mm 6 months after bone grafting, and 2.65 mm and 3.82 mm 6 months after implant placement (Table 4).

### *Histologic evaluation*

A mixture of bone, connective tissue, and residual Bio-Oss particles was observed in all specimens (Figure 8). Polarized microscopy emphasized the active remodeling pattern of the bone around the xenograft material (Figure 9). Newly formed bone appeared in tight contact along the surfaces of the residual Bio-Oss particles (Figure 10). No sign of resorption or active inflammatory process was identified in any of the specimens.

### *Histomorphometric evaluation*

The average area of all 17 core sections occupied by bone was 36.47% (range 10–53, SD 10.05) (Table 5). The comparable values were 49.18% (range 38–68, SD 6.92) for soft tissue and 14.35% (range 2–24, SD 5.85) for Bio-Oss particles. The proportion of the surface of the residual Bio-Oss particles that was in contact with bone was 44.65% (range 0–63, SD 22.58). Situations where early exposure occurred (patients 2 and 14) had the lowest proportion of bone formation (24% and 10%) and represented the instances where Bio-Oss particles had the lowest percentage of their surface in contact with bone (0% and 5%).

## DISCUSSION

The current study provided histologic evidence in humans that using a titanium mesh in conjunction with autogenous bone graft and Bio-Oss can result in new bone formation. Few studies have reported histologic evidence of bone formation in humans after performing alveolar ridge augmentation with titanium mesh.<sup>22</sup> Shirota et al<sup>23</sup> presented

TABLE 2  
Clinical assessment

Patient No.	Bone Quality	Complications at Donor Site	Complications at Recipient Site	Bio-Oss Particles
1	II	Prolonged hypesthesia—finally resolved	None	The Bio-Oss particles appeared well attached to the surrounding grafted area and incorporated to the regenerated alveolar ridge.
2	III	None	Mesh exposure, 4 × 5 mm (early)	
3	II	None	None	
4	III	None	Mesh exposure, 3 × 7 mm	
5	IV	None	Mesh exposure, 4 × 5 mm	
6	III	Incision line dehiscid	Mesh exposure, 4 × 7 mm	
7	IV	None	None	
8	III	None	Mesh exposure, 2 × 4 mm	
9	III	None	None	
10	II	None	None	
11	III	None	None	
12	III	None	None	
13	II	Persistent pain	None	
14	IV	None	Mesh exposure, 2 × 4 mm (early)	
15	III	None	None	
16	III	None	None	
17	III	None	None	

the results of 10 biopsies harvested from humans where new bone trabeculae were observed within the grafted area. The new bone trabeculae contained numerous large lacunae and osteoid tissue lined by developing osteoblasts. The marrow was mature in character and had osteocytes. Malchiodi et al<sup>24</sup> performed a biopsy in 1 of the 25 cases reported in their study and discovered that the grafted area appeared to have signs of active bone remodeling. In a pilot study, Proussaefs et al<sup>28</sup> reported 36.4% new bone formation in 7 patients. Artzi et al<sup>29</sup> reported 81.2% bone formation in 10 patients.

Regarding the type of bone grafting that has been used in conjunction with titanium mesh, the majority of the reported cases involved the use of extraorally harvested autogenous endochondral bone graft, typically from the iliac crest area.<sup>20,21,23,27</sup> However,

the use of HA mixed with autogenous bone graft,<sup>23</sup> intramembraneous autogenous bone graft harvested intraorally from the chin or the ascending ramus area,<sup>22,24,25,28</sup> or Bio-Oss alone<sup>29</sup> have also been reported. Several publications have demonstrated a superiority of the intramembraneous autogenous bone graft in comparison with the extraorally harvested endochondral graft.<sup>39–41</sup> Intraorally harvested grafts have demonstrated a reduced resorption rate, faster rate of revascularization, and accelerated healing process attributed to their embryogenic origin.<sup>39–41</sup>

During harvesting of the autogenous bone graft, an effort was made to harvest bone marrow at the largest possible quantity. The chin area offers an increased amount of bone marrow compared with other intraoral donor sites.<sup>6</sup> Cancellous bone marrow offers enhanced bone formation at the recipient site.<sup>42,43</sup> Revascularization of cancellous bone is faster, and endosteal osteoblasts and marrow mesenchymal cells that are capable of bone induction are transplanted.

The autogenous bone graft in the current study was particulate because particulate bone

TABLE 3

Laboratory volumetric measurements (cc) of alveolar ridge augmentation			
Patient No.	1 mo After Bone Grafting	6 mo After Bone Grafting	6 mo After Implant Placement
Average	0.86	0.73	0.71
SD	0.69	0.60	0.57
Range	0.34–3.05	0.29–2.73	0.28–2.82

TABLE 4

Linear laboratory measurements (mm) of alveolar ridge augmentation

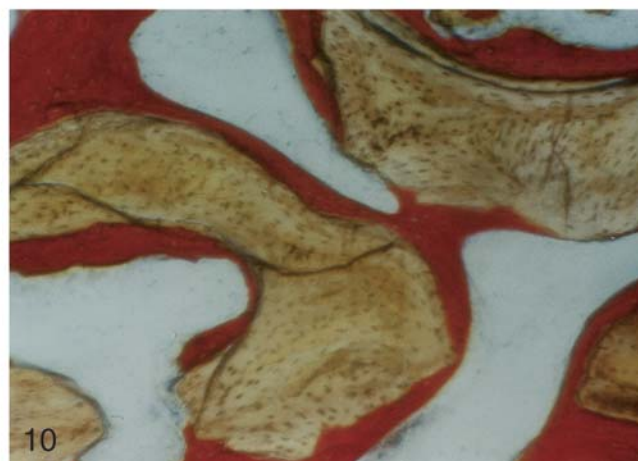
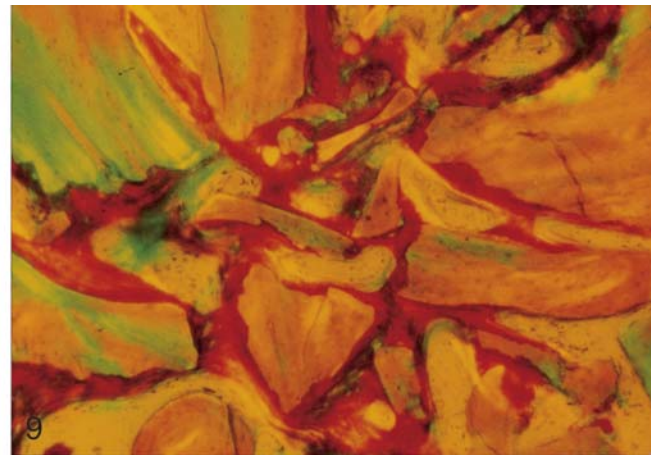
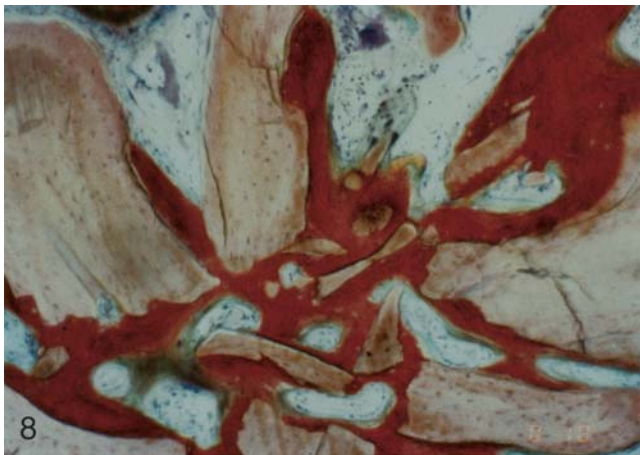
Patient	1 mo After Bone Grafting		6 mo After Bone Grafting		6 mo After Implant Placement	
	Vertical	Labial-buccal	Vertical	Labial-buccal	Vertical	Labial-buccal
Average	2.94	4.47	2.59	3.88	2.65	3.82
SD	0.86	1.55	0.91	1.43	1.14	1.47
Range	2-4	2-6	1-4	2-6	1-4	2-6

graft has been associated with enhanced healing and revascularization process.<sup>43</sup> However, several authors have demonstrated that bone graft particles exhibit an increased resorption rate if they are too small.<sup>44,45</sup> Because those studies were done in animals, it is difficult to define in a clinical situation the optimum

size of an autogenous bone graft particle. It has been the lead author's experience that a 0.5- × 0.5-mm to 1.0- × 1.0-mm particle size offers a consistent and fast incorporation of the bone graft. Further studies are needed that will assess the size of the autogenous bone particles that offer the maximum osteogenic potential.

A 15.11% resorption of the graft was observed in the current study 6 months after the bone augmentation procedure according to the measurements performed in the laboratory. The volume of the grafted area appeared to consolidate after implant placement, an observation also made by others.<sup>46</sup> The occlusal or transmucosal loads of the implants may provide stimulus to the peri-implant bone to maintain the bone volume.<sup>47</sup>

Exposure of the titanium mesh was observed in 6 cases in the current study. This is a common phenomenon when titanium mesh is used for alveolar ridge augmentation. For example, von



FIGURES 8–10. FIGURE 8. Histologic overview revealing new bone formation around residual Bio-Oss particles (original magnification ×4). FIGURE 9. Polarized microscopy emphasizes remodeling pattern of the grafted area. FIGURE 10. At a higher magnification level, residual Bio-Oss particles appeared “amalgamated” within newly formed bone (original magnification ×10).



Arx et al<sup>22</sup> experienced exposure of the mesh in 50% of their cases. Despite the exposure, no infection was noticed in any of the patients. This offers an advantage as compared with nonresorbable membrane barriers, which result in infection when exposed.<sup>5,19</sup> When the clinical situations that had experienced exposure were histomorphometrically evaluated, early titanium mesh exposure offered compromised results (Table 5). Reduced bone formation was observed in patients 2 (24%) and 14 (10%), where early exposure preceded. Residual Bio-Oss particles had reduced contact with bone along their perimeter for patients 2 (0%) and 14 (5%). Late mesh exposure (patients 4, 5, 6, and 8) did not compromise new bone formation. Even though the number of patients is inadequate to make definitive conclusions, early mesh exposure may offer reduced new bone formation and compromised integration of residual xenograft particles with surrounding bone.

In the current study, the titanium mesh was removed 1 to 2 months before implant placement as a separate procedure. Removal of the mesh could be done at the same time with implant installation. The presence of a thin layer of connective and granulation tissue (pseudoperiosteum)<sup>20</sup> under the mesh dictated removal at a separate approach. A similar layer of pseudoperiosteum has been observed under nonresorbable membrane barriers.<sup>5,19</sup> The clinical significance of this connective and granulation tissue layer is unknown. The use of resorbable collagen barrier eliminates formation of this layer.<sup>35</sup>

Bio-Oss was used as a filler in the current study. This material appeared to be biocompatible and histologically demonstrated a tight contact with the surrounding

	Bone	Fibrous Tissue	Bio-Oss Residual Particles	Bone-Residual Particles Contact
Average	36.47	49.18	14.35	44.65
SD	10.05	6.92	5.85	22.58
Range	10-53	38-68	2-24	0-63

bone at 44.65% of its surface area. No sign of resorption or inflammation was observed under light microscopy.

There is a controversy regarding use of Bio-Oss as an onlay bone graft. Skoglund et al<sup>14</sup> evaluated 6 histologic specimens from humans where Bio-Oss had been used as onlay bone graft. Bone was found around the particles in 5 of these cases. Proussaefs et al<sup>7,28</sup> and Proussaefs and Lozada<sup>35,48</sup> have provided histologic evidence in humans regarding the potential of Bio-Oss to be used as an onlay bone graft filler in conjunction with intramembraneous intraorally harvested autogenous bone graft. On the other hand, Pinholt et al<sup>13</sup> failed to identify any bone formation around Bio-Oss particles when used as an onlay bone graft. This material appeared to have no osteoinductive properties, and connective tissue was surrounding the residual particles. Similarly, Young et al<sup>49</sup> found no bone formation around the Bio-Oss particles. However, when the Bio-Oss was mixed with autogenous bone graft, as in the current study, new bone formation was observed. The Bio-Oss acts as a scaffold for the formation of new bone. It appears that there is a need for autogenous bone graft that will have the osteogenic potential to induce new bone formation around the Bio-Oss particles. Further studies are needed that will assess the role

of this xenograft material when used as an onlay bone graft.

In summary, the present study demonstrated 36.47% bone formation when the titanium mesh was used in conjunction with autogenous bone graft and Bio-Oss. The augmented alveolar ridge had a solid consistency, and no sign of inflammation or resorption was seen under light microscopy. The grafted area demonstrated a 15.11% resorption 6 months after bone grafting; no further resorption occurred after implant placement. Early mesh exposure might compromise new bone formation. Further clinical studies and long-term follow-up are indicated before definitive conclusions can be made.

#### ACKNOWLEDGMENTS

The authors would like to acknowledge Osteomed Co and Nobel Biocare for supporting the study. They are also thankful to Michael Rohrer, DDS, MS, for the histologic evaluation and Hari Prasad, BS, MDT, for his technical assistance during the histologic processing.

#### REFERENCES

1. Adell R, Lekholm U, Rockler B, Branemark P-I. A 15 year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg.* 1981;10:387-416.
2. Adell R, Eriksson B, Lekholm U, Branemark P-I, Jemt T. Long-term

- follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. *Int J Oral Maxillofac Implants.* 1990;5:347-359.
3. Jemt T, Lekholm U, Adell R. Osseointegration in the treatment of partially edentulous patients: a preliminary study of 876 consecutively installed fixtures. *Int J Oral Maxillofac Implants.* 1989;4:211-217.
  4. Jemt T, Petterson P. A 3-year follow-up study on single implant treatment. *J Dent.* 1993;21:203-208.
  5. Buser D, Dula K, Hirt HP, Schenk RK. Lateral ridge augmentation using autografts and barrier membranes: a clinical study with 40 partially edentulous patients. *J Oral Maxillofac Surg.* 1996;54:420-432.
  6. Misch CM. Comparison of intra-oral donor sites for onlay grafting prior to implant placement. *Int J Oral Maxillofac Implants.* 1997;12:767-776.
  7. Proussaefs P, Lozada JL, Kleinman A, Rohrer M. The use of ramus autogenous block grafts for vertical alveolar ridge augmentation and implant placement: a pilot study. *Int J Oral Maxillofac Implants.* 2002;17:238-248.
  8. Urbani G, Lombardo G, Santi E, Tarnow D. Localized ridge augmentation with chin grafts and resorbable pins: case reports. *Int J Periodont Restor Dent.* 1998;18:363-375.
  9. Nevins M, Melloning JT, Clem DS, Reiser GM, Buser DA. Implants in regenerated bone: long-term survival. *Int J Periodont Restor Dent.* 1998;18:35-45.
  10. Breine U, Branemark PI. Reconstruction of alveolar jaw bone. *Scand J Plast Reconstr Surg.* 1980;14:23-48.
  11. Triplett RG, Schow S. Autologous bone grafts and endosseous implants: complementary techniques. *J Oral Maxillofac Surg.* 1996;54:486-494.
  12. Verhoeven JW, Cune MS, Terlou M, Zoon MAOW, de Putter C. The combined use of endosteal implants and iliac crest onlay grafts in the severely atrophic mandible: a longitudinal study. *Int J Oral Maxillofac Surg.* 1997;26:351-357.
  13. Pinholt EM, Bang G, Haanaes HR. Alveolar ridge augmentation in rats by Bio-Oss. *Scand J Dent Res.* 1991;99:154-161.
  14. Skoglund A, Hising P, Young C. A clinical and histologic examination in humans of the osseous response to implanted natural bone mineral. *Int J Oral Maxillofac Implants.* 1997;12:194-199.
  15. Kent JN, Quinn JH, Zide MF, Guerra LR, Boyne PJ. Alveolar ridge augmentation using nonresorbable hydroxyapatite with or without autogenous cancellous bone. *J Oral Maxillofac Surg.* 1983;41:629-642.
  16. Holmes R, Mooney V, Bucholz R, et al. A coralline hydroxyapatite bone graft substitute. *Clin Orthop.* 1984;188:252-262.
  17. Fonseca RJ, Nelson JF, Clark PJ, Frost DE, Olson RA. Revascularization and healing of onlay particulate allogenic bone grafts in primates. *J Oral Maxillofac Surg.* 1983;41:153-162.
  18. Doblin JM, Salkin LM, Mellado JR, Freedman AL, Stein MD. A histologic evaluation of localized ridge augmentation utilizing DFDBA in combination with e-PTFE membranes and stainless steel bone pins in humans. *Int J Periodont Restor Dent.* 1996;16:120-129.
  19. Simion M, Jovanovic SA, Trisi P, Scarano A, Piatelli A. Vertical ridge augmentation around dental implants using a membrane technique and autogenous bone or allografts in humans. *Int J Periodont Restor Dent.* 1998;18:9-23.
  20. Boyne PJ, Cole MD, Stringer D, Shafiqat JP. A technique for osseous restoration of deficient edentulous maxillary ridges. *J Oral Maxillofac Surg.* 1985;43:87-91.
  21. Cobb CM, Eick JD, Barker BF, Mosby EL, Hiatt WR. Restoration of mandibular continuity defects using combination of hydroxyapatite and autogenous bone: microscopic observations. *J Oral Maxillofac Surg.* 1990;48:268-275.
  22. von Arx T, Hardt N, Wallkamm B. The TIME technique: a new method for localized alveolar ridge augmentation prior to placement of dental implants. *Int J Oral Maxillofac Implants.* 1996;11:387-394.
  23. Shiota T, Ohno K, Motohashi N, Mich K. Histologic and microradiologic comparison of block and particulate cancellous bone and marrow grafts in reconstructed mandibles being considered for dental implant placement. *J Oral Maxillofac Surg.* 1996;54:15-20.
  24. Malchioldi L, Scarano A, Quaranta M, Piattelli A. Rigid fixation by means of titanium mesh in edentulous ridge expansion for horizontal ridge augmentation in the maxilla. *Int J Oral Maxillofac Implants.* 1998;13:701-705.
  25. von Arx T, Wallkamm B, Hardt N. Localized ridge augmentation using a micro titanium mesh: a report of 27 implants followed from 1 to 3 years after functional loading. *Clin Oral Implant Res.* 1998;9:123-130.
  26. von Arx T, Kurt B. Implant placement and simultaneous ridge augmentation using autogenous bone and a micro titanium mesh: a prospective clinical study with 20 implants. *Clin Oral Implant Res.* 1999;10:24-33.
  27. Lozada JL, Proussaefs P. Clinical, radiographic, and histologic evaluation of maxillary bone reconstruction by using a titanium mesh and autogenous iliac graft. A case report. *J Oral Implantol.* 2002;28:9-14.
  28. Proussaefs P, Lozada LJ, Kleinman A, Rohrer M. The use of titanium mesh in conjunction with autogenous bone graft and inorganic bovine mineral (Bio-Oss) for localized alveolar ridge augmentation. A human study. *Int J Periodont Restor Dent.* 2003;23:185-195.
  29. Artzi Z, Dayan D, Alpern Y, Nemcovsky CE. Vertical ridge augmentation using xenogenic material supported by a configured titanium mesh: clinicohistopathologic and histochemical study. *Int J Oral Maxillofac Implants.* 2003;18:440-446.
  30. Ganz SD. Mandibular Tori as a source for onlay bone graft augmentation: a surgical procedure. *Pract Periodont Aesthetic Dent.* 1997;9:973-982.
  31. De Carvalho PS, Vasconcellos LW, Pi J. Influence of bed preparation on the incorporation of autogenous bone grafts: a study in dogs. *Int J Oral Maxillofac Implants.* 2000;15:565-570.
  32. Corn H. Periosteal separation; its clinical significance. *J Periodontol.* 1962;33:140-153.
  33. Carranza FA, Carraro JJ, Dotto CA. Effect of periosteal fenestration in gingival extension operations. *J Periodontol.* 1966;37:335-340.
  34. Proussaefs P, Valencia G, Lozada JL, Tatakis DN. A method to assess the clinical outcome of ridge augmentation procedures. *J Periodontol.* 2002;73:302-306.
  35. Proussaefs P, Lozada JL. The use of resorbable collagen membrane (Bio-Guide) in conjunction with autogenous bone graft and inorganic bovine mineral (Bio-Oss) for buccal/labial alveolar ridge augmentation. *J Prosthet Dent.* 2003;90:530-538.
  36. Donath K, Breuner G. A method for the study of undercalcified bones and teeth with attached soft tissues. The Sage-Schliff (sawing and grinding) technique. *J Oral Pathol.* 1982;11:318-326.
  37. Rohrer MD, Schubert CC. The cutting-grinding technique for histological preparation of undercalcified bone and bone-anchored implants. Improvements in instrumentation and procedures. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1992;74:73-78.

38. McMillan PJ, Kim J, Garrett S, Crigger M. Evaluation of bone-implant integration: efficiency and precision of 3 methods. *Int J Oral Maxillofac Implants.* 1999;14:631–638.
39. Smith JD, Abramsson M. Membranous vs endochondral bone autografts. *Arch Laryngol.* 1974;99:203–205.
40. Zins JE, Whitaker LA. Membranous vs endochondral bone: implications for craniofacial reconstruction. *Plast Reconstr Surg.* 1983;72:778–784.
41. Kusiak JF, Zins JE, Whitaker LA. The early revascularization of membranous bone. *Plast Reconstr Surg.* 1985;76:510–514.
42. Boyne PJ. Autogenous cancellous bone and marrow transplants. *Clin Orthop.* 1970;73:199–209.
43. Shiota T, Ohno K, Motohashi N, Mich K. Histologic and microradiologic comparison of block and particulate cancellous bone and marrow grafts in reconstructed mandibles being considered for dental implant placement. *J Oral Maxillofac Surg.* 1996;54:15–20.
44. Fonseca RJ, Clark PJ, Burkes EJ, Baker RD. Revascularization and healing of onlay particulate autologous bone grafts in primates. *J Oral Surg.* 1980;38:572–577.
45. Dado DV, Izquierdo R. Absorption of onlay bone grafts in immature rabbits: membranous versus endochondral bone and bone struts versus paste. *Ann Plast Surg.* 1989;23:39–48.
46. Schenk RK. Bone regeneration: biologic basis. In: Buser D, Dahlin C, Schenk RK, eds. *Guided Bone Regeneration in Implant Dentistry.* Chicago, Ill: Quintessence; 1994:49–100.
47. Rubin CT, Lanyon LE. Regulation of bone formation by applied dynamic loads. *J Bone Joint Surg Am.* 1984;66A:397–402.
48. Proussaefs P, Lozada JL. A clinical and histologic evaluation of block onlay graft in conjunction with autogenous particulate and inorganic bovine mineral (Bio-Oss). A case report. *Int J Periodont Restor Dent.* 2002;22:567–673.
49. Young C, Sandstedt P, Skoglund A. A comparative study of anorganic xenogenic bone and autogenous bone implants for bone regeneration in rabbits. *Int J Oral Maxillofac Implants.* 1999;14:72–76.