The Use of Ramus Autogenous Block Grafts for Vertical Alveolar Ridge Augmentation and Implant Placement: A Pilot Study

Periklis Proussaefs, DDS, MS[1]/Jaime Lozada, DDS[2]/Alejandro Kleinman, DDS[3]/Michael D. Rohrer, DDS, MS[4]

Purpose: *This study presents a clinical, radiographic, laboratory, and histologic/histomorphometric analysis of the use of mandibular ramus block autografts for vertical alveolar ridge augmentation and implant placement.* ***Materials and Methods:*** *Autogenous block autografts were fixed at the recipient site with fixation screws while a mixture of autogenous bone marrow and inorganic bovine material (Bio-Oss) was used at the periphery. All grafts appeared well incorporated at the recipient site during reentry surgery.* ***Results:*** *Radiographic measurements revealed an average of 6.12 mm vertical ridge augmentation 1 month after surgery and 5.12 mm 4 to 6 months after surgery. Laboratory volumetric measurements revealed an average of 0.91 mL alveolar ridge augmentation 1 month after surgery and 0.75 mL 6 months postoperatively. Linear laboratory measurements revealed 6.12 mm of vertical ridge augmentation 1 month postoperatively and 4.37 mm 4 to 6 months after surgery. Histologic evaluation indicated signs of active remodeling in all the specimens. Histomorphometric analysis of the peripheral particulate bone indicated bone present at 34.33% of the grafted area, while 42.17% of the area was occupied by fibrous tissue and 23.50% by residual Bio-Oss particles.* ***Discussion:*** *The results demonstrated the potential of mandibular block autografts harvested from the ascending ramus to maintain their vitality. Volumetric resorption rate of 17.58% and radiographic resorption rate of 16.34% were in accordance with previously published literature. Early exposure appeared to compromise the results, while late exposures did not affect the vitality of the block autografts.* ***Conclusion:*** *Mandibular block autografts can maintain their vitality when used for vertical alveolar ridge augmentation. Inorganic bovine mineral (Bio-Oss) can be used at the periphery of the block graft when mixed with autogenous bone marrow.* (INT J ORAL MAXILLOFAC IMPLANTS 17:238–248)

Key words: *block grafts, vertical ridge augmentation*

Following acceptance of endosseous dental implants as a valid treatment modality for totally[1,2] or partially[3,4] edentulous patients, bone grafting has been proposed before[5–14] or simultaneously[15–18] with the placement of dental implants in patients lacking adequate bone volume. While xenografts,[19–24] alloplastic bone grafts,[25,26] and allografts[13,14,27,28] have been proposed and studied for alveolar ridge augmentation, the use of autogenous bone grafts represents the "gold standard" for bone augmentation procedures.

Autogenous bone grafts have been used in block[5,7–12,17,18] and particulate forms.[13,28–32] Various techniques have been applied to secure the graft material at the recipient site. Nonresorbable membrane barriers[7,28–31] and titanium mesh[32,33] have been used as securing devices for the particulate bone graft, while the block grafts can be stabilized at the recipient site with fixation screws[5,8–12] or dental implants.[15–18] Autogenous block grafts, when compared to particulate bone marrow, have been associated with reduced osteogenic activity[34] and slow revascularization.[35,36] Both extraoral[6,8,15,16,18,33] and intraoral[5,7–13,17,30–32] donor

[1]Assistant Professor, Graduate Program in Implant Dentistry, Loma Linda University, Loma Linda, and Private Practice, Implant and Prosthetic Dentistry, Santa Clarita, California.
[2]Professor and Director, Graduate Program in Implant Dentistry, Loma Linda University, Loma Linda, California.
[3]Assistant Professor, Graduate Program in Implant Dentistry, Loma Linda University, Loma Linda, California.
[4]Presidential Professor and Director, Hard Tissue Research Laboratory, University of Oklahoma College of Dentistry, Oklahoma City, Oklahoma.

Reprint requests: Dr Periklis Proussaefs, School of Dentistry, Graduate Program in Implant Dentistry, Loma Linda University, Loma Linda, CA 92350. Fax: 909-397-8861.
E-mail: pProussaefs@hotmail.com

Table 1 Patient Data*

Patient	Age	Sex	Recipient site	Healing period (mo)	No. of implants	No. of fixation screws
1	63	F	18–20	8	2	1
2	67	M	12–13	5	3	1
3	59	M	3–5	14	3	1
4	56	F	29–30	7	2	2
5	71	F	18–21	4	2	2
6	71	F	21–23	5	2	1
7	68	F	18–20	5	N/A	2
8	67	F	18–20	6	2	2
Average	65.25			6.75		
SD	5.47			3.20		
Range	51–71			4–14		

*US tooth numbers used.

sites have been proposed. Several studies have confirmed that intraorally harvested intramembraneous bone grafts, when compared to extraorally harvested endochondral bone grafts, may have minimal resorption,[37–40] enhanced revascularization,[41] and better incorporation at the donor site.[39]

There is a paucity of information in the literature regarding histologic evidence of the healing and maturation of mandibular block autografts in humans. In addition, mandibular block autografts have been studied for lateral alveolar ridge augmentation procedures. Excluding some published case reports,[42–43] and to the authors' knowledge, there has been no clinical study to evaluate the resorption and healing process of intramembraneous block autografts when used for vertical alveolar ridge augmentation.

This study provides a clinical, radiographic, laboratory, and histologic/histomorphometric analysis of the use of mandibular ramus block autografts for vertical alveolar ridge augmentation when a mixture of particulate bone marrow and inorganic bovine mineral was used at the periphery of the block autograft.

MATERIALS AND METHODS

Patient Selection

Eight consecutively treated patients (2 men and 6 women, mean age: 65.25 years, range: 51 to 71) participated in this study (Table 1). The subjects required vertical alveolar ridge augmentation before the placement of endosseous dental implants. In all the patients, an autogenous block autograft was harvested intraorally from the ascending ramus area (Fig 1) and used during the bone-grafting procedure. The bone-grafting procedures were performed between May 1998 and February 2000. Treatment was performed by graduate students at the Center for Prosthodontics and Implant Dentistry at Loma Linda University (LLU). All subjects signed the corresponding informed consent form approved by the Institutional Review Board at Loma Linda University to have a biopsy taken during implant surgery.

Surgical Protocol

At the time of the bone-grafting procedure or implant placement, the subjects were given a choice of local anesthesia (LA) only, LA with oral sedation, or LA with intravenous sedation.

Full-thickness labial/buccal and lingual/palatal flaps were reflected at the recipient site. The donor site was the ascending ramus area. Harvesting of the bone graft was performed according to the standard procedure described elsewhere.[5,10] After administering block anesthesia for the inferior alveolar canal, a crestal incision was made distal to the third molar. The incision followed the direction of the ramus and a vertical releasing incision was placed distal to the third molar in the ramus area. Full-thickness buccolingual flaps were reflected. Under copious irrigation and with a fissure bur, a block graft was harvested. A bone chisel was used to detach the block autograft. Additional bone marrow was harvested with a curette and was used in conjunction with inorganic bovine mineral (Bio-Oss, Osteohealth, Shirley, NY) around the block autograft (Fig 2).

The recipient site was perforated with a fissure bur to induce bleeding and promote the incorporation of the graft.[44,45] The block autograft was then

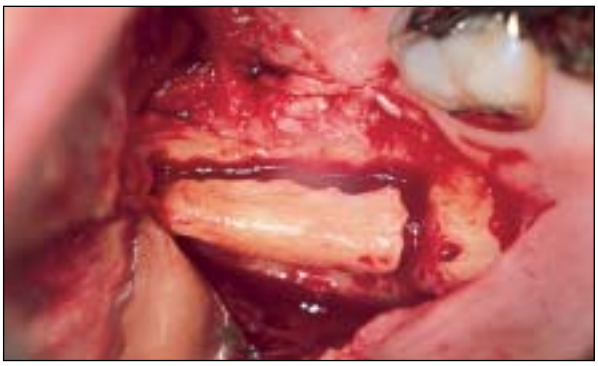


Fig 1 A mandibular block autograft is harvested from the ascending ramus area.

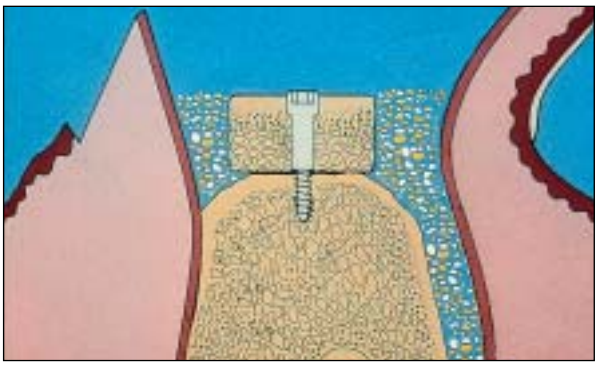


Fig 2 A mixture of autogenous marrow bone graft and Bio-Oss is placed at the periphery of the block graft.

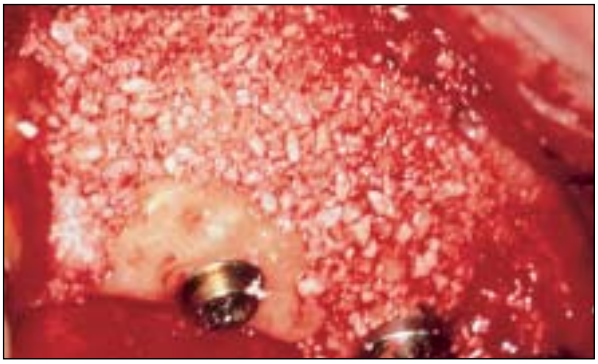


Fig 3 Placement of the block graft and particulate bone graft at the periphery of the block.

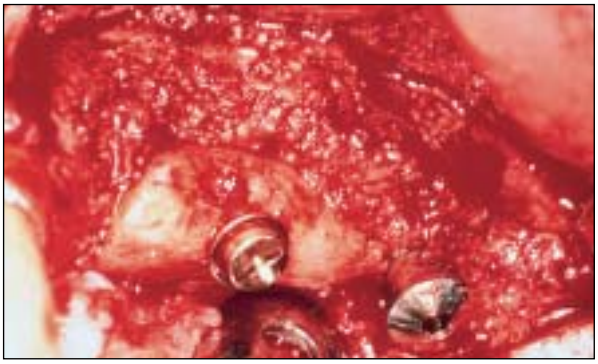


Fig 4 Full-thickness buccal-palatal flaps are reflected to expose the graft and fixation screw 4 to 8 months after the bone-grafting procedure.

fixated at the recipient site with 1 or 2 fixation screws (Osteomed, Addison, TX) and an additional mixture of autogenous bone marrow and Bio-Oss was placed at the periphery (Fig 3). Periosteal fenestration[46,47] was performed along the labial/buccal flap to enable primary closure. The recipient area was then sutured without a membrane barrier (Fig 2). Two weeks after the bone-grafting surgery, the sutures were removed.

Four to 8 months were allowed for the bone graft to heal before placement of the implants (Table 1). One patient (3) received the implants 14 months after the bone-grafting procedure; he was unable to return earlier for personal reasons. During implant surgery, full-thickness labial/buccal and palatal/lingual flaps were reflected (Fig 4) and the fixation screws were removed. Hydroxyapatite-coated root-form implants (Steri-Oss, Nobel Biocare, Yorba Linda, CA) were placed using a surgical guide. All patients were treatment-planned to receive an implant-supported, screw-retained fixed partial denture. A biopsy was taken from the grafted area during implant placement.

Specimen Harvesting

During implant surgery, a biopsy was taken from the grafted area by using a 2-mm internal-diameter trephine bur (ACE Surgical Supply, Brockton, MA) 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 biopsy was taken through the autogenous block autograft. The specimens were fixed in 10% buffered formalin.

Radiographic Evaluation

Measurements for the vertical bone augmentation were made by evaluating the preoperative, 1-month

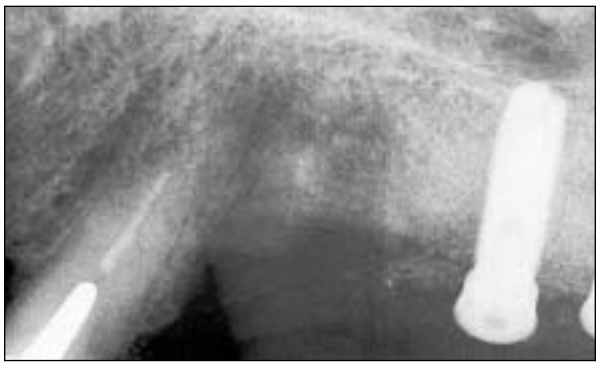


Fig 5a Periapical radiograph; preoperative view.

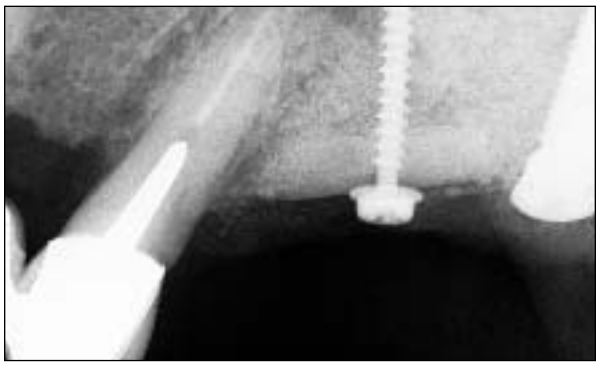


Fig 5b Periapical radiograph taken 6 months after bone-grafting procedure.

postoperative, and 4- to 6-month postoperative periapical nonstandardized radiographs (Figs 5a and 5b). A panoramic radiograph was obtained in all cases immediately after the bone-grafting surgery. No periapical radiographs were taken immediately after the bone-grafting procedure to avoid stretching of the tissue, especially in cases where the posterior mandible was the recipient site. All measurements were made by 1 investigator (PP).

Laboratory Evaluation

The volume and linear assessment of the vertical alveolar ridge augmentation was made with a technique that has been developed at the Graduate Program in Implant Dentistry, LLU.[48] Briefly, impressions were made around the grafted area with a custom tray made from photopolymerized acrylic resin (Triad, Dentsply, York, PA) and using irreversible hydrocolloid (Coe Alginate, GC America, Alsip, IL). The impressions were made preoperatively and 1 and 6 months after the bone-grafting procedure. The impressions were poured with Type III dental stone (Microstone, Whip-Mix, Louisville, KY).

An impression was made from the postoperative stone casts using the custom tray and silicone (Labputty, Coltene/Whaledent, Mahawan, NJ). Polyvinylsiloxane bite registration material (Exabite II NDS, GC America) was then loaded in the tray, which was placed on the preoperative stone cast, and the bite registration material was allowed to polymerize (Fig 6). The bite registration material was then removed from the tray. The excess material was trimmed. The weight of the material was assessed and 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 height of the bite registration material. Linear measurements were made with a caliper

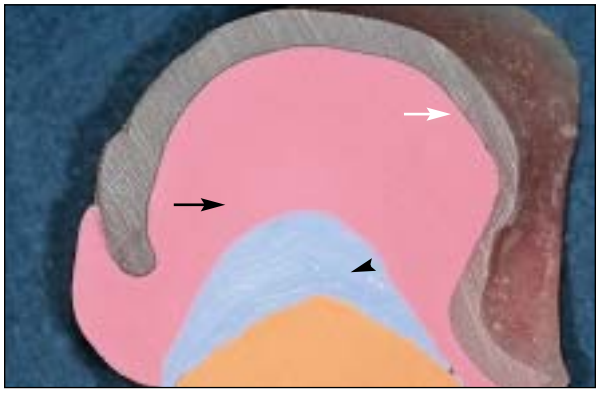


Fig 6 Laboratory measurements allowed linear and volumetric measurements of the grafted area. The blue area (bite registration material, *arrowhead*) represents the augmented alveolar ridge. The white arrow represents the custom tray and the black arrow represents the silicone impression made on the postoperative stone cast.

(Darby Dental Supply, Rockville, NY) at the location where preoperative clinical and radiographic evaluation revealed the maximum bone deficiency.

Histologic Processing

The specimens were fixed in 10% buffered formalin, dehydrated in alcohol, and embedded in specialized resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). Initial midaxial sections of 200 µm were made by means of the cutting-grinding system (EXACT Medical Technologies, Oklahoma City, OK). The sections were then ground to 40 to 50 µm and were stained with Stevenel's blue and Van Gieson's picro-fuchsin for light microscopy.[49,50]

Histomorphometric Evaluation

Histomorphometric evaluation was performed by 1 investigator (PP) through the use of a computer-assisted linear analysis program, Ribbon, developed

Fig 7 Histomorphometric analysis performed by using parallel lines. The first 2 lines are color-coded to demonstrate how the histomorphometry was performed. Blue segments represent soft tissue, yellow segments represent residual graft material (Bio-Oss), and the green lines represent bone. The specimens were stained with Stevenel's blue and Van Gieson's picro-fuchsin.

at LLU.[51] The histomorphometry was performed for the specimens where part of the peripheral particulate bone graft (mixture of autogenous bone marrow and Bio-Oss) was harvested during the biopsy procedure. Because the biopsy was taken through the block graft, 3 specimens represented only the block autograft with no peripheral particulate bone graft.

The Ribbon 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 lines were spaced 50 pixels apart in the object plane, and the first line was placed randomly at the top of the image. Keyboard entries and cursor clicks recorded the lengths of the line segments that crossed 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 (Fig 7). For each histologic specimen, 1 to 2 images were analyzed (depending on the size of the specimen). 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, or graft particles) to the total length of lines analyzed. The percent 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.

All histomorphometric analysis was performed by capturing images under 2× magnification (Olympus Microscope, Model BH-2, McBain Instruments, Chattworth, CA).

Table 2 Clinical Assessment

Patient no.	Bone quality of block graft	Complications at donor site	Complications at recipient site†
1	II	None	None
2	I	Pain	Exposure 1 × 3 mm
3	I	Pain	None
4	II	None	Exposure 2 × 4 mm
5	I	None	None
6	I	None	None
7	N/A*	None	Exposure 4 × 7 mm
8	I	None	None

*The block graft was dislodged during implant placement.
†Before implant placement.
In all cases, the Bio-Oss appeared well incorporated to the recipient site.

RESULTS

Clinical Evaluation

Exposure of the block graft during healing was observed in 3 of the 8 patients (Table 2). In 2 patients (2 and 4), the exposure occurred 3 months after the bone grafting, while in 1 (7), the exposure occurred 2 weeks after surgery. In that case, and 3 weeks after the exposure, the exposed part of the block graft revealed clinical signs of necrosis (discoloration, odor, and soft consistency when examined with an explorer). The clinically necrotic part was removed with a curette. Two months after the bone-grafting surgery, a new surgical procedure was performed—in this case, to attempt primary closure of the block graft. Despite the new surgical intervention, the block graft became reexposed 2 weeks later. The implant placement was then scheduled 5 months after the initial bone-grafting surgery. After implant placement, no further dehiscence occurred.

During reentry surgery for implant placement, all block grafts appeared to be fixed at the recipient site. However, during osteotomy preparation for implant placement, 1 of the block grafts (7) became dislodged and the area was scheduled for regrafting. All block grafts had Type I or II bone quality.[52] No complications occurred at the donor site except in 2 patients (2 and 3) where persistent pain followed surgery. All symptoms were resolved 3 weeks postoperatively.

The peripheral particulate bone graft (mixture of autogenous bone marrow and Bio-Oss) appeared well incorporated at the recipient site. The Bio-Oss particles were firmly attached to the newly formed bone. Primary stability was achieved during the placement of all implants.

Table 3 Radiographic Assessment (Periapical Radiographs) of Vertical Ridge Augmentation

Patient no.	1 month postoperatively	4–6 months postoperatively
1	7	6
2	9	8
3	5	4
4	5	4
5	7	6
6	6	5
7	5	4
8	5	4
Average	6.12	5.12
SD	1.46	1.46
Range	5–9	4–8

Measurements give in mm.

Table 4 Laboratory Volumetric Measurements

Patient no.	1 month postoperatively	6 months postoperatively
1	0.55	0.49
2	1.82	1.53
3	0.94	0.80
4	0.60	0.53
5	0.75	0.61
6	0.77	0.56
7	0.81	0.67
8	1.03	0.77
Average	0.91	0.75
SD	0.40	0.34
Range	0.55–1.82	0.49–1.53

Measurements given in mL.

Radiographic Evaluation

Radiographic measurements revealed that an average of 6.12 mm of vertical ridge augmentation (range = 5 to 9 mm, SD = 1.46) was achieved 1 month after surgery and 5.12 mm (range = 4 to 8 mm, SD = 1.46) 4 to 6 months after surgery (Table 3). The resorption rate according to the radiographic measurements was 16.34%.

Laboratory Evaluation

Laboratory volumetric measurements revealed that an average of 0.91 mL (range = 0.55 to 1.82 mL, SD = 0.40) of ridge augmentation was achieved 1 month postoperatively and 0.75 mL 6 months after surgery (range = 0.49 to 1.53 mL, SD = 0.34) (Table 4). These measurements revealed 17.58% resorption 6 months after the bone grafting.

Linear measurements revealed that 1 month after the bone-grafting procedure, an average of 6.12 mm of vertical ridge augmentation (range = 4 to 9 mm, SD = 1.64) was obtained, while 4.37 mm (range = 3 to 6 mm, SD = 1.22) was achieved 6 months after surgery (Table 5).

Histologic Evaluation

The specimens from the block grafts presented a solid core composed almost entirely of cortical bone (Fig 8a). All but 1 (patient 7) of the block grafts demonstrated histologic signs of remodeling activity. The bone stained at different intensity in the Haversian canals, indicating remodeling (Fig 8b). Polarized microscopy emphasized the remodeling pattern (Fig 8c). In the specimen from patient 7, areas of necrosis were seen close to the coronal aspect of the block graft (towards the exposed surface).

Table 5 Linear Laboratory Measurements

Patient no.	1 month postoperatively	4–6 months postoperatively
1	8	6
2	9	6
3	5	3
4	5	3
5	6	5
6	6	5
7	4	3
8	6	4
Average	6.12	4.37
SD	1.64	1.22
Range	4–9	3–6

Vertical augmentation in mm.

Regarding the peripheral particulate bone graft, a mixture of bone, connective tissue, and residual Bio-Oss particles was observed (Fig 9). In a majority of the cases, the Bio-Oss particles appeared to be in tight contact with bone (Figs 10a and 10b). No sign of resorption or active inflammation was identified in any of the specimens.

Histomorphometric Evaluation

Histomorphometric analysis of the specimens where peripheral particulate bone graft was harvested revealed bone to be 34.33% of the area (range = 29% to 45%, SD = 5.78); soft tissue was observed in 42.17% of the specimen area (range = 24% to 57%, SD = 12.80); and residual Bio-Oss particles made up 23.50% of the surface (range = 8% to 41%, SD = 10.78) (Table 6). The surface of

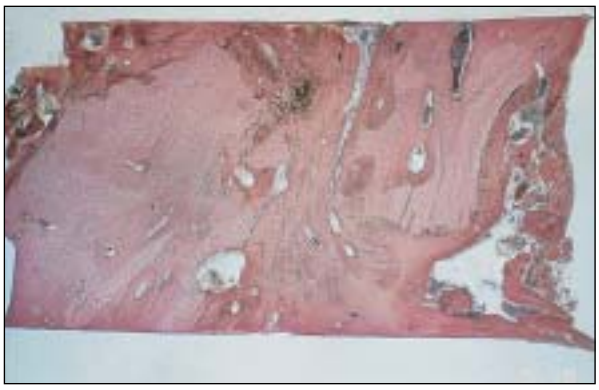


Fig 8a Histologic overview of a specimen representing a block graft (original magnification ×2.5; specimens stained with Stevenel's blue and Van Gieson's picro-fuchsin).

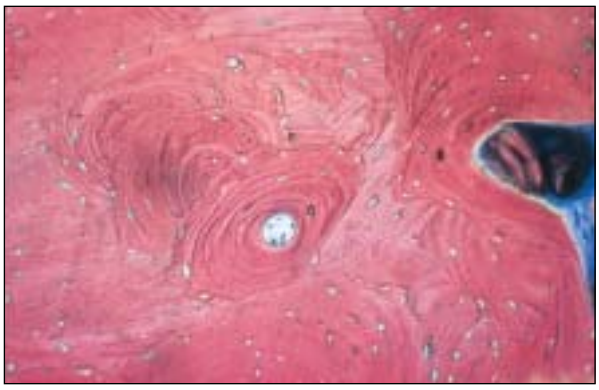


Fig 8b At a higher magnification, Haversian canals are observed within the area of the block graft (original magnification ×4; specimens stained with Stevenel's blue and Van Gieson's picro-fuchsin).

Fig 8c Under polarized microscopy, the remodeling activity of the autogenous mandibular block autograft is emphasized (original magnification ×4; specimens stained with Stevenel's blue and Van Gieson's picro-fuchsin).

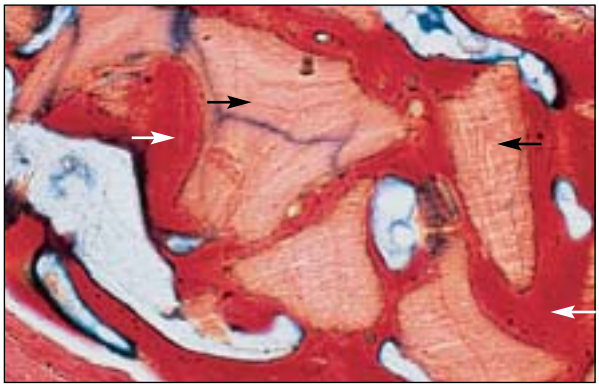
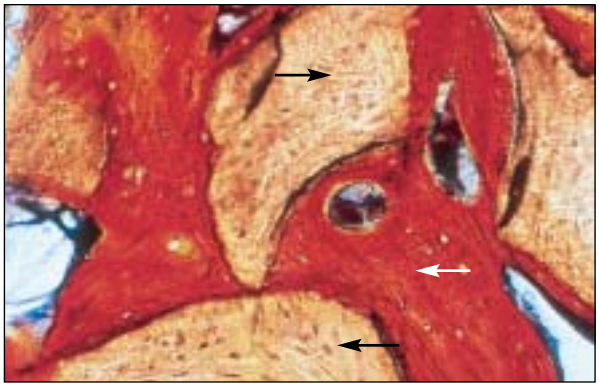
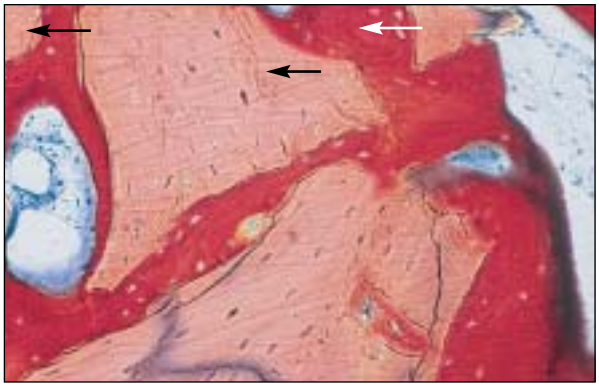


Fig 9 Histologic overview of the particulate peripheral bone graft. Black arrows indicate Bio-Oss particles; white arrows indicate bone (original magnification ×4; specimens stained with Stevenel's blue and Van Gieson's picro-fuchsin).





Figs 10a and 10b At a higher magnification, the residual Bio-Oss particles appear to be in tight contact with the surrounding bone. Black arrows indicate Bio-Oss particles; white arrows indicate bone (original magnification ×10; specimens stained with Stevenel's blue and Van Gieson's picro-fuchsin).

Table 6 Histomorphometric Analysis of Particulate Bone Graft

Patient no.	Bone %	Fibrous tissue %	Bio-Oss %	Bone residual particles contact %
1	N/A	N/A	N/A	N/A
2	32	43	25	79
3	30	52	18	44
4	29	47	24	48
5	35	57	8	44
6	35	24	41	54
7	N/A	N/A	N/A	N/A
8	45	30	25	71
Average	34.33	42.17	23.50	56.67
SD	5.78	12.80	10.78	14.89
Range	29–45	24–57	8–41	44–79

*N/A = No particulate bone was harvested.

residual Bio-Oss particles was in contact with bone in 56.67% (range = 44% to 79%, SD = 14.89) of the total surface of all particles.

DISCUSSION

The present study provided human histologic evidence regarding the potential of mandibular block autografts to maintain their vitality after bone grafting. Corticocancellous block grafts have been associated with a reduced rate of revascularization.[35,36] Enneking and associates[36] reported that in cortical bone autografts, most of the interior of such grafts was never revascularized or replaced by viable bone. As a result, they are prone to infection, and if infected, they may never recover. Burchad[53] described the term "creeping substitution," which is a dynamic reconstructive and healing process of bone transplantation. According to his study, the cancellous bone autograft is completely repaired wherein cortical admixtures of necrotic and viable bone are often observed.

Nevertheless, a distinction should be made between endochondral bone grafts and intraorally harvested intramembranous bone grafts. It has been shown[41] that intramembranous bone grafts demonstrate accelerated revascularization and healing as compared to endochondral bone grafts. It is questionable whether or not the above-mentioned concerns regarding the vitality and revascularization of cortical block autografts apply for the intramembranous mandibular block autografts as well. The observations made in the specimens of the current study support the hypothesis that, because of their embryogenic origin, mandibular block autografts can maintain their vitality.

There is little information in the literature regarding histologic evidence in humans of the potential of intramembranous mandibular block grafts to heal and demonstrate signs of vitality. Shirota and associates,[6] in a study of 3 cases with block autografts, demonstrated signs of devitalized bone tissue in the block grafts. Urbani and coworkers,[12] in 5 clinical cases, demonstrated signs of vitality of the bone transplants. Similar observations (histologic evidence of vital bone graft) have also been made in an animal study,[45] where intramembranous bone graft was utilized as a block.

Vertical alveolar ridge augmentation procedures were performed in the current study. The radiographic measurements demonstrated 5.12 mm vertical augmentation 4 to 6 months after the bone-grafting procedure and 6.12 mm 1 month postoperatively. These results are similar to those reported by Simion and colleagues.[30]

Controversy exists regarding the potential for dental implants to be placed simultaneously with bone grafting. Several other authors have utilized block grafts, harvested either extraorally[15,16,18] or intraorally,[17] placed simultaneously with the dental implants as well. One-stage surgery (bone graft and implant placement) offers the advantage of a single surgical intervention and potentially reduced healing time. However, several authors have reported better results when the 2-stage approach is followed.[8,54] In addition, with the 2-stage protocol the surgeon can achieve prosthetically better implant placement and superior esthetics.[55] It has been demonstrated that the revascularization process of a block graft is gradual and increases with time.[56] Implant placement in a revascularized and well healed grafted area may offer enhanced potential for osseointegration and remodeling.

The radiographic and laboratory volumetric measurements in the current study demonstrated a similar resorption rate (16.34% and 17.58%, respectively), which is in agreement with other investigators.[5,9,11] Even though intramembranous mandibular bone grafts have been shown to have a reduced resorption rate as compared to extraorally harvested bone grafts,[37–40] it is unknown whether the resorption process is continuous. Some clinicians have reported that resorption of the bone graft consolidates after implant placement,[57] as a result of occlusal or transmucosal stimuli the implants may provide to the peri-implant bone for maintaining the bone volume.[58] Further research is required before definitive conclusions can be made.

In 1 of the patients in the present study (7), the block graft dislodged during the osteotomy preparation for implant placement. Only 1 screw was used for graft fixation. Clinicians have supported the use of at least 2 fixation screws for proper graft immobilization,[42,43] while animal studies have shown the importance of good graft immobilization.[40] It has been the primary author's experience that in vertical ridge augmentation cases, the block graft needs to be held firmly with 2 fingers by the surgeon during the implant osteotomy procedure to avoid possible dislodgement of the graft, even in cases where no sign of pathosis or lack of graft integration can be clinically observed.

Exposure of the block graft was evident in 3 patients. In patients 2 and 4, the exposure occurred late (more than 3 months after the bone-grafting procedure), while in 1 case (7), the exposure occurred 2 weeks after the surgery. The 2 patients with the late exposure demonstrated no clinical or histologic signs of pathosis or necrosis, while the patient with the early exposure demonstrated partial necrosis of the graft under light and polarized microscopy. While the number of cases precludes drawing definitive conclusions, it seems that the time of exposure may be the key factor that determines the result of a graft exposure. Lozano and colleagues[56] have shown that revascularization is an ongoing process; even though it is unknown when an intramembranous bone graft will completely heal, early exposure occurs at a time when the graft material has not yet been revascularized, resulting in susceptibility to infection.

In the present study, no membrane barriers were utilized. Nonresorbable membrane barriers have been used to mechanically protect and isolate the graft material.[7,28–31] However, nonresorbable membrane barriers have been associated with infection upon exposure,[7,31] incomplete healing,[28,29] and the presence of a connective tissue layer between the membrane and the newly formed bone.[28–30] In the presented technique, the assumption was made that the block graft provided the mechanical support for the particulate bone graft (which was placed around the block) without the need of any membrane barrier.

In the presented technique, the particulate bone graft that was placed at the periphery of the block was a mixture of autogenous bone marrow and inorganic bovine mineral (Bio-Oss). The use of Bio-Oss has been well documented as an inlay bone graft for sinus-grafting procedures.[59,60] However, little is known regarding the use of this material as an onlay bone graft. While bone formation has been shown around and in tight contact with the Bio-Oss particles in 4-wall defects,[20,22] no bone formation was seen when the Bio-Oss was used as an onlay graft material.[19] In the current study, the Bio-Oss particles were mixed with autogenous bone marrow that contains abundant bone cells[34] that would provide the necessary osteogenic potential for the graft material. Young and coworkers[24] demonstrated that when Bio-Oss is mixed with autogenous bone graft, newly formed bone will be observed that will be in tight contact with the residual Bio-Oss particles, as seen in the current study.

A newly developed laboratory measuring technique was used in this study to measure the volume of the augmented alveolar ridge and provide linear measurements of the augmented sites. This technique has been shown to be reproducible end accurate.[48] However, in this study the impressions were made preoperatively and postoperatively that included measurements of the soft tissue as well. This imposes a limitation in the presented data; an impression made during the surgery of the bony defect would offer more valuable results.

CONCLUSIONS

1. Mandibular block autografts can maintain their vitality when used for vertical alveolar ridge augmentation.
2. An average of 5.12 mm of vertical ridge augmentation was achieved and 17% resorption was seen 4 to 6 months after bone grafting.
3. Late graft exposure may not necessarily result in graft necrosis, while early exposure may result in compromised healing and partial graft necrosis.
4. Inorganic bovine mineral (Bio-Oss) can be used at the periphery of the block graft when mixed with autogenous bone marrow. This mixture resulted in an average of 34.33% bone formation in this series.

ACKNOWLEDGMENTS

The authors would like to acknowledge Nobel Biocare for supporting the study and ACE Surgical Supply for providing the trephine burs. They would also like to thank Greg Kammeyer, DDS, for his clinical contribution. Hari Prasad, BS, MDT, is thanked for his technical assistance during the histologic processing. The first author (PP) is much obliged to Gloria Valencia, DDS, Cert Pros, for her overall assistance.

REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark 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, Brånemark 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 Res 1993;21:203–208.
5. 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 Implants 1992;7:360–366.
6. Shirota 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.
7. 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.
8. Triplett RG, Schow S. Autologous bone grafts and endosseous implants: Complementary techniques. J Oral Maxillofac Surg 1996;54:486–494.
9. 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;54:1180–1186.
10. Misch CM. Comparison of intraoral donor sites for onlay grafting prior to implant placement. Int J Oral Maxillofac Implants 1997;12:767–776.
11. Widmark G, Andersson B, Ivanoff CJ. Mandibular bone graft in the anterior maxilla for single-tooth implants. Presentation of surgical method. Int J Oral Maxillofac Surg 1997;26:106–109.
12. Urbani G, Lombardo G, Santi E, Tarnow D. Localized ridge augmentation with chin grafts and resorbable pins: Case reports. Int J Periodontics Restorative Dent 1998;18:363–375.
13. Nevins M, Mellonig JT, Clem DS, Reiser GM, Buser DA. Implants in regenerated bone: Long-term survival. Int J Periodontics Restorative Dent 1998;18:35–45.
14. Simion M, Jovanovic SA, Trisi P, Scarano A, Piattelli A. Vertical ridge augmentation around dental implants using a membrane technique and autogenous bone or allografts in humans. Int J Periodontics Restorative Dent 1998;18:9–23.
15. Breine U, Brånemark P-I. Reconstruction of alveolar jaw bone. Scand J Plast Reconstr Surg 1980;14:23–48.
16. Adell R, Lekholm U, Grondahl K, Brånemark P-I, Lindstrom J, Jacobsson M. Reconstruction of severely resorbed edentulous maxillae using osseointegrated fixtures in immediate autogenous bone grafts. Int J Oral Maxillofac Implants 1990;5:233–246.
17. Jensen J, Sindet-Pedersen S. Autogenous mandibular bone grafts and osseointegrated implants for reconstruction of the severely atrophied maxilla: A preliminary report. J Oral Maxillofac Surg 1991;49:1277–1287.
18. Isaksson S, Alberius P. Maxillary alveolar ridge augmentation with onlay bone-grafts and immediate endosseous implants. J Craniomaxillofac Surg 1992;20:2–7.
19. Pinholt EM, Bang G, Haanæs HR. Alveolar ridge augmentation in rats by Bio-Oss. Scand J Dent Res 1991;99:154–161.
20. Klinge B, Alberius P, Isaksson S, Jonsson J. Osseous response to implanted natural bone mineral and synthetic hydroxyapatite ceramic in the repair of experimental skull bone defects. J Oral Maxillofac Surg 1992;50:241–249.
21. Callan DP, Rohrer MD. Use of bovine-derived hydroxyapatite in the treatment of edentulous ridge defects: A human clinical and histologic case report. J Periodontol 1993;64:575–582.
22. Jensen SS, Aeboe M, Pinholt EM, Hjørting-Hansen E, Melsen F, Ruyter IE. Tissue reaction and material characteristics of four bone substitutes. Int J Oral Maxillofac Implants l996;11:55–66.
23. 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.
24. 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.
25. 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.
26. Holmes R, Mooney V, Bucholz R, et al. A coralline hydroxyapatite bone graft substitute. Clin Orthop 1984;188:252–262.
27. 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.
28. 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 Periodontics Restorative Dent 1996;16:120–129.
29. Simion M, Trisi P, Piattelli A. Vertical ridge augmentation using a membrane technique associated with osseointegrated implants. Int J Periodontics Restorative Dent 1994;14:497–511.
30. 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 Periodontics Restorative Dent 1998;18:9–23.
31. Tinti C, Benfenati SP. Vertical ridge augmentation: Surgical protocol and retrospective evaluation of 48 consecutively inserted implants. Int J Periodontics Restorative Dent 1998;18:435–443.

32. Boyne PJ, Cole MD, Stringer D, Shafqat JP. A technique for osseous restoration of deficient edentulous maxillary ridges. J Oral Maxillofac Surg 1985;43:87–91.
33. 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.
34. Marciani RD, Conty AA, Synhorst JB, et al. Cancellous bone marrow grafts in irradiated dog and monkey mandibles. Oral Surg Oral Med Oral Pathol 1979;47:17–24.
35. Hammack BL, Enneking WF. Comparative vascularization of autogenous and homogenous bone transplants. J Bone Joint Surg [Am] 1960;42:811–817.
36. Enneking WF, Eady JL, Burchardt H. Autogenous cortical bone grafts in the reconstruction of segmental skeletal defects. J Bone Joint Surg [Am] 1980;62:1039–1058.
37. Smith JD, Abramsson M. Membranous vs endochondral bone autografts. Arch Laryngol 1974;99:203–205.
38. Zins JE, Whitaker LA. Membranous vs endochondral bone: Implications for craniofacial reconstruction. Plast Reconstr Surg 1983;72:778–784.
39. Borstlap WA, Heidbuchel KLWM, Freihofer HPM, Kuijpers-Jagtman AM. Early secondary bone grafting of alveolar cleft defects: A comparison between chin and rib grafts. J Craniomaxillofac Surg 1990;18:210–215.
40. Lin KY, Bartlett SP, Yaremchuk MJ, Fallon M, Grossman RF, Whitaker LA. The effect of rigid fixation on the survival of onlay bone grafts: An experimental study. Plast Reconstr Surg 1990;86:449–456.
41. Kusiak JF, Zins JE, Whitaker LA. The early revascularization of membranous bone. Plast Reconstr Surg 1985;76: 510–514.
42. Pikos MA. Block autografts for localized ridge augmentation: Part I. The posterior maxilla. Implant Dent 1999;8: 279–285.
43. Pikos MA. Block autografts for localized ridge augmentation: Part II. The posterior mandible. Implant Dent 2000;9: 67–75.
44. Rompen EH, Biewer R, Vanheusden A, Zahedi S, Nusgens B. The influence of cortical perforations and of space filling with peripheral blood on the kinetics of guided bone regeneration. Clin Oral Implants Res 1999;10:85–94.
45. 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.
46. Corn H. Periosteal separation: Its clinical significance. J Periodontol 1962;33:140–153.
47. Carranza FA, Carraro JJ, Dotto CA. Effect of periosteal fenestration in gingival extension operations. J Periodontol 1966;37:335–340.
48. Proussaefs PT, Lozada JL, Valencia G, Tatakis DN. A method to assess clinical outcome of ridge augmentation procedures [abstract]. J Dent Res 2001;80:163.
49. Donath K, Breuner G. A method for the study of undecalcified bones and teeth with attached soft tissues. The Sage-Schliff (sawing and grinding) technique. J Oral Pathol 1982;11:318–326.
50. Rohrer MD, Schubert CC. The cutting-grinding technique for histological preparation of undecalcified bone and bone-anchored implants. Improvements in instrumentation and procedures. Oral Surg Oral Med Oral Pathol 1992;74: 73–78.
51. 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.
52. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.
53. Burchad H. The biology of bone graft repair. Clin Orthop 1983;174:28–42.
54. Lundgren S, Rasmusson L, Sjostrom M, Sennerby L. Simultaneous or delayed placement of titanium implants in free autogenous iliac bone grafts. Int J Oral Maxillofac Surg 1998;28:31–37.
55. Nevins M, Mellonig JT. The advantages of localized ridge augmentation prior to implant placement: A staged event. Int J Periodontics Restorative Dent 1994;14:96–111.
56. Lozano AJ, Cestero HJ, Salyer KE. The early revascularization of onlay bone grafts. Plast Reconstr Surg 1976;99: 203–205.
57. Schenk RK. Bone regeneration: Biologic basis. In: Buser D, Dahlin C, Schenk RK (eds). Guided Bone Regeneration in Implant Dentistry. Chicago: Quintessence, 1994:49–100.
58. Rubin CT, Lanyon LE. Regulation of bone formation by applied dynamic loads. J Bone Joint Surg [Am] 1984;66: 397–402.
59. Wetzel AC, Stich H, Caffesse RG. Bone apposition onto oral implants in the sinus area filled with different grafting materials. Clin Oral Implants Res 1995;6:155–163.
60. Hanisch O, Lozada JL, Holmes RE, Calhoun CJ, Kan JYK, Spiekermann H. Maxillary sinus augmentation prior to placement of endosseous implants. Int J Oral Maxillofac Implants 1999;14:329–336.