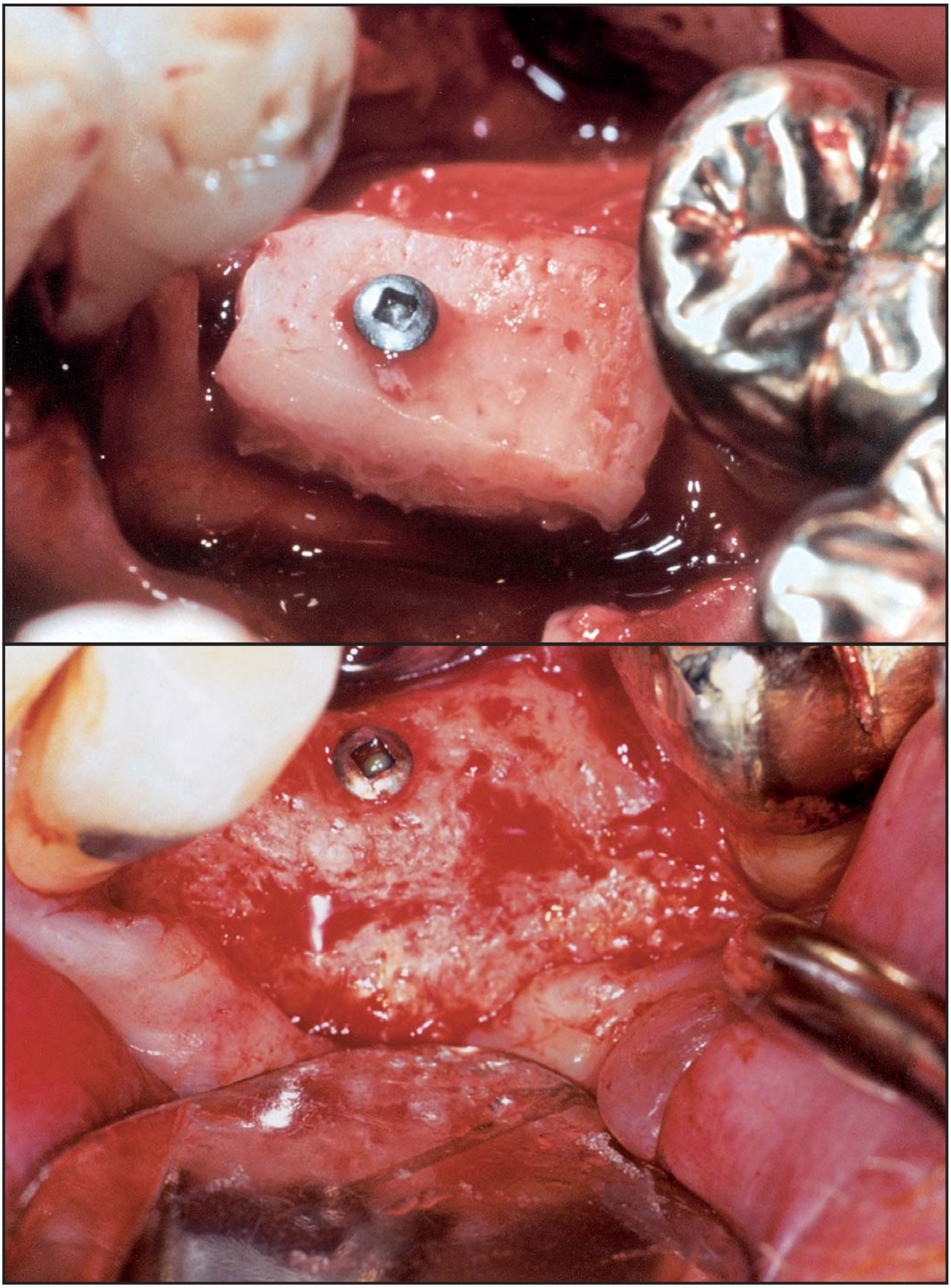
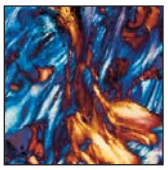


The Use of Intraorally Harvested Autogenous Block Grafts for Vertical Alveolar Ridge Augmentation: A Human Study



*Periklis Proussaefs, DDS, MS**
*Jaime Lozada, DDS***

This study presents a clinical, radiographic, laboratory, and histologic/histomorphometric analysis of the use of mandibular block autografts for vertical alveolar ridge augmentation. Twelve patients were included in the study. The autogenous block autografts were fixated at the recipient sites with screws, and a mixture of autogenous bone marrow and inorganic bovine mineral (Bio-Oss) was used at the periphery. At re-entry surgery, all the grafts appeared well incorporated at the recipient sites. Radiographic measurements revealed an average of 5.75 ± 1.29 mm vertical ridge augmentation at 1 month after surgery and 4.75 ± 1.29 mm at 4 to 6 months after surgery. This indicated 17.4% resorption. Laboratory volumetric measurements revealed an average of 0.84 ± 0.34 mL of alveolar ridge augmentation 1 month after surgery and 0.71 ± 0.28 mL at 6 months postoperatively. The resorption rate according to the laboratory volumetric measurements was 15.5%. Linear laboratory measurements revealed 5.92 ± 1.38 mm of vertical ridge augmentation 1 month postoperatively and 4.08 ± 1.01 mm at 4 to 6 months after surgery. Histologic evaluation of the block autografts indicated signs of active remodeling activity in 10 of the 12 specimens. In one case the block graft became exposed and infected, and in another case the block autograft became dislodged during implant placement surgery. Histomorphometric analysis of the peripheral particulate bone indicated bone present at 33.99% ± 8.82% of the graft surface, while 42.43% ± 11.06% of the area was occupied by fibrous tissue and 23.89% ± 9.12% was made up of residual Bio-Oss particles. Residual Bio-Oss particles were in tight contact with newly formed bone along 58.57% ± 15.22% of their perimeter. (Int J Periodontics Restorative Dent 2005;25:351–363.)

*Assistant Professor, Graduate Program in Implant Dentistry, Loma Linda University, Loma Linda, California; and Private Practice limited to Implant and Prosthetic Dentistry, Encino, California.
**Professor and Director, Graduate Program in Implant Dentistry, Loma Linda University, Loma Linda, California.

Correspondence to: Dr Periklis Proussaefs, Loma Linda University, School of Dentistry, Graduate Program in Implant Dentistry, Loma Linda, CA 92350. Fax: (909) 558-4803.
E-mail: pproussaef@hotmail.com

Since the acceptance of dental implants as a valid treatment modality for the completely[1,2] or partially[3,4] edentulous patient, bone grafting has been proposed, either before[5–15] or simultaneously with[16–19] the placement of dental implants, so that implants may be placed in patients lacking adequate bone volume. While xenografts,[15,20–25] alloplastic bone grafts,[26,27] and allografts[13,14,28,29] have been proposed and studied for alveolar ridge augmentation, the use of autogenous bone remains the gold standard for bone augmentation procedures.

Autogenous bone graft has been used as a block,[5,7–12,18,19] in particulate form,[13,30–32] or in combinations of block and particulate forms.[15,33] When autogenous bone graft is used in particulate form, various techniques have been applied to secure the graft material at the recipient site. Nonresorbable membrane barriers[7,29–33] and titanium mesh[34–37] have been proposed as securing devices for particulate bone graft. Block grafts can be secured at the recipient site with fixation screws[5,8–12,15,33] or dental implants.[16–19]

Autogenous block grafts, in comparison to particulate bone marrow, have been associated with

Table 1 Patient distribution

Patient no.	Age	Sex	Recipient site	Donor site	Healing period (months)	Implants (N)	Fixation screws (N)
1	63	F	18-20 (35-37)	Ramus	8	2	1
2	67	M	12-13 (24-25)	Ramus	5	3	1
3	59	M	3-5 (14-16)	Ramus	14	3	1
4	56	F	29-30 (45-46)	Ramus	7	2	2
5	54	M	19-21 (34-36)	Chin	6	2	1
6	71	F	18-21 (34-37)	Ramus	4	2	2
7	71	F	21-23 (32-34)	Ramus	5	2	1
8	51	M	28-30 (44-46)	Chin	4	N/A*	1
9	68	F	18-20 (35-37)	Ramus	5	N/A*	2
10	67	F	18-20 (35-37)	Ramus	6	2	2
11	63	M	19 (36)	Chin	9	1	1
12	67	F	28-30 (44-46)	Ramus	5	2	2
Average	60.15	N/A	N/A	N/A	6.5	N/A	N/A
SD	7.34	N/A	N/A	N/A	2.81	N/A	N/A
Range	51–71	N/A	N/A	N/A	4–14	N/A	N/A

Tooth numbers are listed as Universal (FDI).
*The block graft was dislodged during implant placement surgery.

reduced osteogenic activity[38] and slow revascularization.[39,40] Regarding the source of the autogenous bone, both extraoral[6,8,16,17,19,35] and intraoral[5,7–13,15,18,31–34] donor sites have been proposed. Several studies have demonstrated that intraorally harvested intramembraneous bone grafts, in comparison to extraorally harvested endochondral bone grafts, demonstrate less resorption,[41–44] enhanced revascularization,[42] and better incorporation at the donor site.[43]

The current study provides clinical, radiographic, laboratory, and histologic/histomorphometric analyses of the use of mandibular 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.

Methods and materials

Patient selection

Twelve consecutively treated subjects (5 men and 7 women with a mean age of 60.15 years; range 51 to 71) participated in this study (Table 1). The subjects required vertical alveolar ridge augmentation before the placement of dental implants (Fig 1). In all the cases, an autogenous block graft harvested intraorally from either the chin (Fig 2) or the ascending ramus area was used for grafting. The bone grafting procedures were performed during the period May 1998 to September 2001. Treatment was performed by graduate students at the Center for Prosthodontics and Implant Dentistry at Loma Linda University (LLU). All subjects were treated by residents of the Graduate Program in Implant Dentistry and signed the corresponding informed consent, which had been approved by the Institutional Review Board at Loma Linda University, to have a biopsy taken during implant surgery.

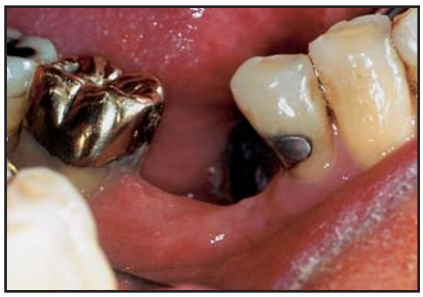


Fig 1 *Preoperative clinical view. A vertical alveolar defect is observed indicating a need for vertical ridge augmentation before implant placement can be attempted.*

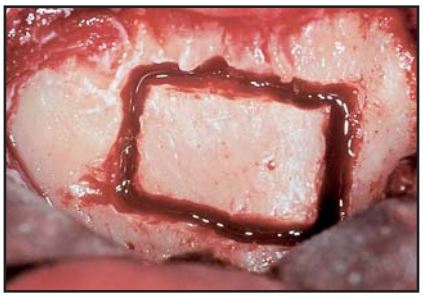


Fig 2 *A monocortical block autograft is harvested from the chin area.*

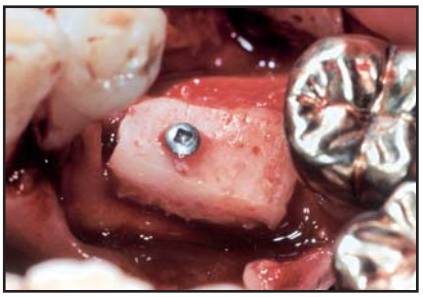


Fig 3 *The monocortical block autograft is secured at the recipient site with a fixation screw.*

Surgical protocol

At the time of bone grafting procedure or implant placement, the subjects were permitted to choose either local anesthesia (LA) only, LA with oral sedation (Halcion, 0.25 mg, Greenstone Ltd), or LA with intravenous sedation.

Full-thickness labiobuccal and linguopalatal flaps were reflected at the recipient site (Fig 3). The donor site was either the chin area (three patients) or the ascending ramus area (nine patients) (Table 1). Harvesting of the bone graft was performed according to the standard procedure described elsewhere.[5,10] Briefly, for the chin donor site, a vestibular incision was made at least 2 mm beyond the mucogingival junction. A full-thickness flap was reflected; 4 to 5 mm of periosteum were left intact at the most coronal part of the surgical site. The bone that would be harvested was defined 5 mm below the apex of the mandibular anterior teeth, 5 mm mesial to the mental foramen, and 5 mm above the inferior border of the mandible (Fig 2). A fissure bur and a chisel were used to remove a block autograft. Collagen hemostatic agent was placed at the donor site (Avitene; Alcon Pharmaceuticals) and the area was sutured.

For the ramus area, after administering block anesthesia for the inferior alveolar canal, a crestal incision was made distal to either of the mandibular third molar areas. The incision followed the direction of the ramus, and a vertical releasing incision was placed distal to the third molar areas and to 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. In the chin area, the donor site received collagen hemostatic agent and was then sutured. For both donor sites, additional bone marrow was harvested with a curette and was used in conjunction with inorganic bovine mineral (Bio-Oss, Geistlich Pharmaceuticals) around the block autograft.[15,33]

The recipient site was perforated to induce bleeding and promote incorporation of the graft.[45,46] The block autograft was then fixated at the recipient site with one or two fixation screws (Fig 3), and an additional mixture of autogenous bone marrow and Bio-Oss was placed at the periphery of the site. Periosteal fenestration[47,48] was performed along the labiobuccal flap to enable primary closure. The recipient area was then sutured without the use of any barrier membrane.

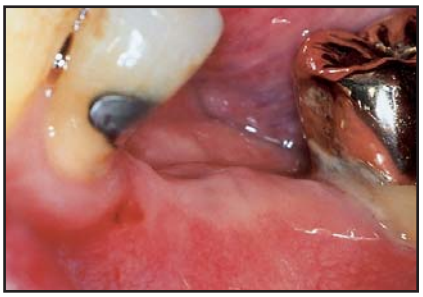


Fig 4 *Lateral view at 3 months after bone grafting.*

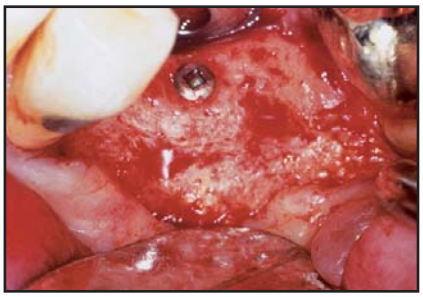


Fig 5 *Nine months after bone grafting, the block autograft and the peripheral particulate bone graft have been well incorporated into the recipient site.*

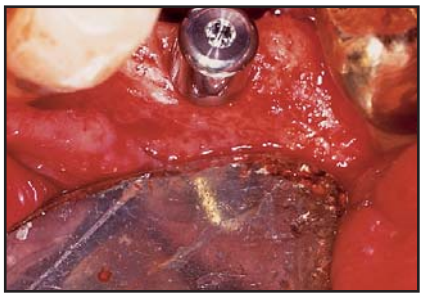


Fig 6 *After the fixation screw is removed, one threaded hydroxyapatite-coated implant is placed.*

Two weeks after the bone graft surgery, the sutures were removed. One subject (#9) received a removable provisional prosthesis 2 weeks after bone grafting. The remaining subjects did not receive any provisional prosthesis during the entire healing period.

Four to 8 months were allowed for the bone graft to heal before the placement of the implants (Fig 4, Table 1). One subject (#3) received implants 14 months after the bone grafting procedure, because she was unable to return earlier for personal reasons. During implant surgery, full-thickness labiobuccal and palatolingual flaps were reflected (Fig 5) and the fixation screws were removed. Hydroxyapatite-coated root-form implants (Steri-Oss; Nobel Biocare) were placed using a surgical stent (Fig 6). All patients were treatment-planned to receive an implant-supported screw-retained fixed partial denture. A biopsy specimen was taken from the grafted area during implant placement. A 2-mm internal-diameter trephine bur (ACE Surgical Supply) was used as the first drill during the osteotomy preparation for implant placement. The area with the more pronounced preoperative bone deficiency was selected for the biopsy. This biopsy specimen was taken through the autogenous block autograft.[15] The specimens were fixed in 10% buffered formalin.

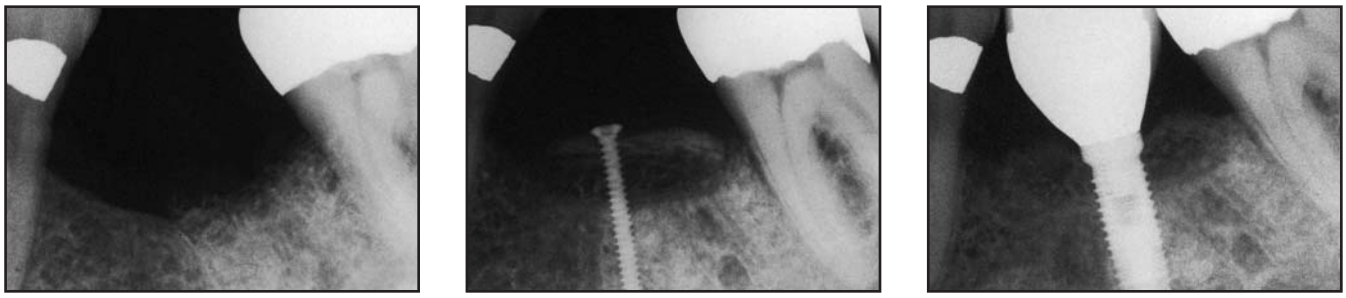
Radiographic evaluation

Measurements for the vertical bone augmentation were made by evaluating the preoperative, 1-month postoperative, and 4- to 6-month postoperative periapical radiographs (Figs 7a to 7c). A panoramic radiograph was taken in all cases immediately after bone grafting surgery. No periapical radiographs were taken immediately after bone grafting to avoid stretching of the tissue, especially in cases where the posterior mandible was the recipient site. All measurements were made by one investigator (PP) under 10× magnification.[49]

Laboratory evaluation

The volume and linear assessment of the vertical alveolar ridge augmentation were made with a technique developed at the Graduate Program in Implant Dentistry at LLU.[50] Briefly, impressions were made around the grafted area with a custom tray made from photopolymerized acrylic resin (Triad; Dentsply International) by using irreversible hydrocolloid as impression material (Coe Alginate; GC America). The impressions were made preoperatively and 1 and 6 months after bone grafting. The impressions were poured with Type m dental stone (Microstone; Whip-Mix).

An impression was made from the postoperative stone casts with the custom tray and silicone (Labputty; Coltene/Whaledent). Polyvinylsiloxane bite registration material (Exabite II NDS; GC America) was then loaded in the tray, which was then placed on the preoperative stone cast, and the bite registration material was allowed to polymerize.



Figs 7a to 7c *Periapical radiographs demonstrating the site (a) preoperatively, (b) 9 months after bone grafting, and (c) 6 months after implant loading.*

The bite registration material was then removed from the tray and 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 alveolar ridge augmentation. In addition, linear measurements were made by evaluating the vertical height of the bite registration material. Linear measurements were made with a caliper (Derby Dental Supply). Linear measurements were made at the location where preoperative clinical and radiographic evaluation revealed the maximum bone deficiency. This method for laboratory evaluation of alveolar ridge resorption has been utilized in previous studies.[51,52]

Histologic processing

The specimens were fixed in 10% buffered formalin, dehydrated in alcohol, and embedded in specialized resin (Technovit 7200 VLC; Kulzer). Initial midaxial sections of 200 µm were made by means of the cutting-grinding system (EXACT Medical Technologies). 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.[51,52]

Histomorphometric evaluation

Histomorphometric evaluation was performed by one investigator (PP) by using a computer-assisted linear analysis program (Ribbon) developed at LLU.[53] 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, three specimens represented only the block autograft, with no peripheral particulate bone graft.

The Ribbon program uses a series of systematically spaced horizontal lines (each two 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.[15] For each histologic specimen, one or two 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

Table 2 Clinical assessment

Patient no.	Bone quality of graft[54]	Complications at donor site	Complications at recipient site (before implant placement)
1	2	None	None
2	1	Persistent pain	Exposure 1 × 3 mm
3	1	Persistent pain	None
4	2	None	Exposure 2 × 4 mm
5	1	Dehiscence of incision line	None
6	1	None	None
7	1	None	None
8	N/A*	None	None
9	N/A*	None	Exposure 4 × 7 mm
10	1	None	None
11	1	None	None
12	1	None	None

In all cases, the Bio-Oss appeared to be well-incorporated at the recipient sites.
*The block graft was dislodged during implant placement.

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).

Results

Clinical evaluation

Exposure of the block graft during healing was observed in three of the 10 cases (Table 2). In two situations (#2 and #4) the exposure occurred 3 months after bone grafting, while in one case (patient #9) 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, soft consistency when examined with an explorer). The clinically necrotic part was removed with a curette. Two months after the bone graft 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 was re-exposed 2 weeks later. The necrotic bone graft was completely removed 5 months after the initial grafting surgery.

During re-entry surgery for implant placement, all block grafts appeared to be fixated at the recipient site. However, during osteotomy preparation for implant placement, two of the block grafts (#8 and #9) became dislodged. In one clinical situation (#8) short implants were utilized, while in the other situation (#9) the area was scheduled for re-grafting. For patient #9, repeated graft exposure had resulted in necrosis of the autograft. All block grafts had type 1 or 2 bone quality.[54] No complications occurred at the donor site, except in one patient (#5), where dehiscence of the incision was seen 3 weeks after surgery.

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.

Radiographic evaluation

Radiographic measurements revealed that 5.75 ± 1.29 mm of vertical ridge augmentation (range 5 to 9 mm) was achieved 1 month after surgery and 4.75 ± 1.29 mm (range 4 to 8 mm) of augmentation was achieved 4 to 6 months after surgery (Table 3). The resorption rate according to the radiographic measurements was 17.4%.

Table 3 Radiographic assessment (periapical radiographs) of vertical ridge augmentation (mm)

Patient no.	1 mo	4 to 6 mo
1	7	6
2	9	8
3	5	4
4	5	4
5	5	4
6	7	6
7	6	5
8	5	4
9	5	4
10	5	4
11	5	4
12	5	4
Mean	5.75	4.75
SD	1.29	1.29
Range	5–9	4–8

Table 4 Laboratory volumetric measurements (mL)

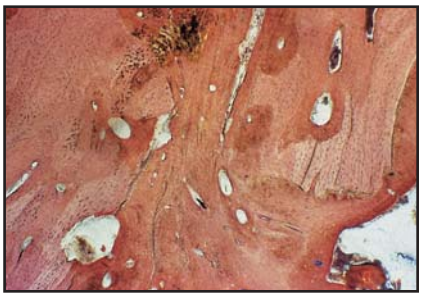
Patient no.	1 mo	6 mo
1	0.55	0.49
2	1.82	1.53
3	0.94	0.80
4	0.60	0.53
5	0.79	0.73
6	0.75	0.61
7	0.77	0.56
8	0.73	0.63
9	0.81	0.67
10	1.03	0.77
11	0.52	0.48
12	0.78	0.69
Mean	0.84	0.71
SD	0.34	0.28
Range	0.52–1.82	0.48–1.53

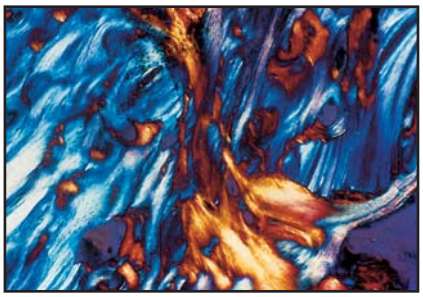
Laboratory evaluation

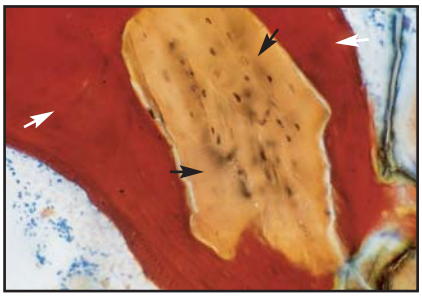
Laboratory volumetric measurements revealed that a mean of 0.84 ± 0.34 mL (range 0.52 to 1.82 mL) of ridge augmentation was achieved 1 month postoperatively, and a mean of 0.71 ± 0.28 mL of augmentation was seen 6 months after surgery (range 0.48 to 1.53 mL) (Table 4). These measurements dictated 15.5% resorption by 6 months after the bone grafting. Linear measurements revealed that 1 month after the grafting, 5.92 ± 1.38 mm (range 4 to 9 mm) of vertical ridge augmentation, and 4.08 ± 1.01 mm (range 3 to 6 mm) of augmentation was achieved by 6 months after surgery (Table 5).

Table 5 Linear laboratory measurements (vertical augmentation, in mm)

Patient no.	1 mo	4 to 6 mo
1	8	6
2	9	6
3	5	3
4	5	3
5	6	3
6	6	5
7	6	5
8	5	3
9	4	3
10	6	4
11	6	4
12	5	4
Mean	5.92	4.08
SD	1.38	1.01
Range	4–9	3–6







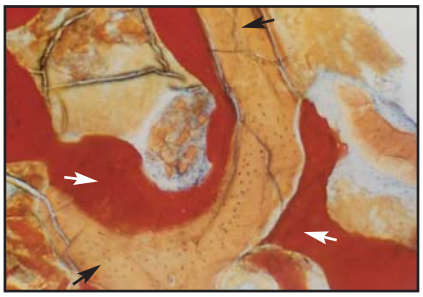


Fig 8 (top left) *Histologic overview of a specimen representing a block graft (original magnification ×2.5).*

Fig 9 (top center) *Under polarized microscopy, the remodeling activity of the autogenous mandibular block autograft is emphasized (original magnification ×4).*

Fig 10 (top right) *Histologic overview of the particulate peripheral bone graft (original magnification ×4).*

Fig 11 *At a higher magnification, Bio-Oss particles* (black arrows) *appear to be "amalgamated" within the surrounding newly formed bone* (white arrows) *(original magnification ×20).*

Fig 12 *Intimate contact between residual Bio-Oss particles* (black arrows) *and peripheral bone* (white arrows) *is apparent (original magnification ×20).*

Histologic evaluation

The specimens from the block grafts presented a solid core composed almost entirely of cortical bone (Fig 8). In all but one patient (#9), block grafts demonstrated histologic signs of remodeling activity. In the situation (#8) where the block autograft became dislodged during implant surgery, the block autograft appeared to have signs of vitality and remodeling activity. Polarized microscopy emphasized the remodeling pattern (Fig 9). In a specimen of grafting procedure, obtained from patient #9, areas of necrosis were seen close to the coronal aspect of the block graft (toward the exposed surface).

Regarding the peripheral particulate bone graft, a mixture of bone, connective tissue, and residual Bio-Oss particles was observed (Fig 10). In the majority of the cases, the Bio-Oss particles appeared to be in close contact with bone (Figs 11 and 12). No signs of resorption or active inflammatory process were identified in any of the specimens.

Histomorphometric evaluation

Histomorphometric analysis of the specimens from which peripheral particulate bone graft was harvested revealed bone in 33.99% ± 8.82% of the area (range 16% to 45%), soft tissue in 42.43% ± 11.06% of the specimen area (range 24% to 57%), and residual Bio-Oss particles in 23.89% ± 9.12% of the surface (range 8% to 41%) (Table 6). The surface of the residual Bio-Oss particles was in contact with bone at 58.57% ± 15.22% (range 42% to 79%) of the total surface of all particles.

Table 6 Histomorphometric analysis of particulate bone grafts

Patient no.	Bone %	Fibrous tissue %	Bio-Oss %	Bone/residual particles contact %
2	32	43	25	79
3	30	52	18	44
4	29	47	24	48
5	16	53	31	42
6	35	57	8	44
7	35	24	41	54
10	45	30	25	71
11	43	36	21	78
12	41	40	19	67
Average	33.99	42.43	23.89	58.57
SD	8.82	11.06	9.12	15.22
Range	16–45	24–57	8–41	42–79

For patients 1, 8, and 9, no particulate bone was harvested.

Discussion

The present study provided histologic evidence in humans 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.[39,40] Enneking et al[40] 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. Burchardt[55] used the term "creeping substitution" to describe the dynamic reconstructive and healing process of bone transplantation. He reported that cortical bone transplants are not penetrated by blood vessels until the sixth day after transplantation and that the revascularization process may take twice as long as when particulate bone marrow is transplanted. According to his study, cancellous bone autografts were completely repaired, but in the cortical admixtures, both necrotic and viable bone were often observed. In this study, mandibular block autografts that were exposed after 3 months (patients #2 and #4) maintained their vitality. The block autograft that was exposed 2 weeks after bone grafting (patient #9) became necrotic. Within the limitations of the restricted number of cases, it could be suggested that early exposure may result in graft necrosis, potentially because the graft has not obtained adequate vascularity to maintain its vitality. With late exposures, block autografts seemed to have adequate vascularity to maintain their vitality by the time exposure occurred.

In the literature there is a scarcity of human histologic evidence of the potential of intramembranous mandibular block grafts to heal and demonstrate signs of vitality. Shirota et al,[6] in a study that included three cases with block autografts, signs of devitalized bone tissue were seen in the block grafts. Urbani et al,[12] in five clinical cases, demonstrated signs of vitality of the bone transplants. Matsumoto et al[56] demonstrated the potential of mandibular block autografts to maintain their vitality. In that study, in which biopsy specimens were taken from 10 patients, mandibular autografts appeared to have enhanced remodeling activity and vascularity as compared to extraorally harvested endochondral bone grafts. Proussaefs et al[15,33] have demonstrated in humans the potential of mandibular block autografts to maintain their vitality. Similar observations (histologic evidence of vital bone graft) have also been made in an animal study[46] in which intramembranous bone graft was utilized as a block.

The radiographic and laboratory volumetric measurements in the current study demonstrated similar resorption rates (17.4% and 15.5%, respectively). This is in agreement with other investigators. Misch et al[5] reported 0% to 25% resorption, while Raghoebar et al[9] reported 5% to 20% resorption with mandibular autogenous bone grafts. Proussaefs et al[15] reported 17% resorption at 4 to 6 months after bone grafting when the ascending ramus was used

as the donor site. However, Widmark et al[11] reported 25% resorption of the graft material during implant placement and 60% at the time of abutment connection. Although intramembranous mandibular bone grafts have been shown to have a reduced resorption rate versus extraorally harvested bone grafts,[41–44] it is unknown whether the resorption process is continuous. Some clinicians have reported that the resorption of the bone graft slows after implant placement.[57] Further research is required before definitive conclusions can be made.

In patient #8 of this study, the block autograft became dislodged during osteotomy for implant placement. No previous complication had been observed in that patient, and the block autograft appeared well attached at the recipient site after flap reflection. Nevertheless, De Carvalho et al[46] have shown the presence of a connective tissue layer between a mandibular block graft and the recipient bony site. This layer of connective tissue may offer reduced resistance to dislodgement of the block graft during implant site preparation. It has been recommended that the block graft be held firmly with two fingers by the surgeon during implant osteotomy procedure.[15] In the patient (#8) in whom the block graft was dislodged, 4 months of healing time were allowed before implant surgery. Further healing might have resulted in a firmer attachment of the graft to the recipient site. Certainly, studies of more cases are needed before definitive conclusions can be made.

In the present study, no membrane barriers were utilized. Nonresorbable membrane barriers have been used to mechanically protect and isolate the graft material.[7,29–31] However, nonresorbable membrane barriers have been associated with infection upon exposure,[7,32] incomplete healing,[29,30] and the presence of a connective tissue layer between the membrane and the newly formed bone.[29–31] Raghoebar et al[9] reported that when autogenous mandibular bone graft is used, a nonresorbable membrane barrier may not be needed because of the minimal resorption and high rate of revascularization of the intramembranous particulate bone graft. Proussaefs et al[15,33] have shown that when particulate bone graft (mixture of autogenous bone and Bio-Oss) is placed around a block autograft, newly formed bone can be created without the use of any barrier above the graft material. In the technique presented here, the assumption was made that the block graft would provide mechanical support for the surrounding particulate bone graft and no membrane barrier would be necessary.

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.[58,59] On the other hand, little is known about the use of this material as an onlay bone graft. While bone formation has been shown around and in tight contact with Bio-Oss particles at four-wall defects,[21,23] no bone formation was seen when Bio-Oss was used as an onlay graft material.[20] In the current study, the Bio-Oss particles were mixed with autogenous bone marrow, which contains abundant bone cells[38] to provide the necessary osteogenic potential to the graft material. Young et al[25] demonstrated that when Bio-Oss is used alone as a graft material, connective tissue will result, while when mixed with autogenous bone graft as a filler, newly formed bone will form that will be in close contact with the residual Bio-Oss particles. Proussaefs et al[15,33,36] have demonstrated bone formation around and in contact with Bio-Oss particles when used around block autografts[15,33] or under a titanium mesh.[36]

A newly developed laboratory measuring technique was used in this study to calculate the volume of the augmented alveolar ridge and to provide linear measurements of the augmented sites. This technique has been shown to be reproducible and accurate.[50] However, in this study the impressions were made preoperatively and postoperatively, and included measurements of the soft tissue as well. This imposes a limitation in the presented data; an impression made during the surgery from the bony defect would offer more valuable results.

Conclusions

Mandibular block autografts can maintain their vitality when used for vertical alveolar ridge augmentation. An average of 4.75 ± 1.29 mm of vertical ridge augmentation can be expected, with 17.4% resorption at 4 to 6 months after bone grafting. Late graft exposure does not necessarily result in graft necrosis, while early exposure will probably result in compromised healing and partial or total graft necrosis. Inorganic bovine mineral (Bio-Oss) can be used at the periphery of the block graft when mixed with autogenous bone marrow. This mixture results in an average of 33.99% bone formation.

Acknowledgments

The authors would like to acknowledge Sammy Noumbissi, DDS, and Miguel Estrella, DDS, for their contribution. They are also thankful to Michael Rohrer, DDS, MS, for the histologic analysis of the specimens and Hari Prasad, BS, MDT, for his technical assistance during the histologic processing. They are thankful to Nobel Biocare for covering part of the expense for histologic analysis, Osteomed for providing the fixation screws, and ACE Surgical Supply for providing the trephine burs.

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 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; 54:1180–1185, discussion 1185–1186.
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. 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.
16. Breine U, Brånemark P-I. Reconstruction of alveolar jaw bone. Scand J Plast Reconstr Surg 1980;14:23–48.
17. 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.
18. 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.
19. Isaksson S, Alberius P. Maxillary alveolar ridge augmentation with onlay bonegrafts and immediate endosseous implants. J Craniomaxillofac Surg 1992;20:2–7.

20. Pinholt EM, Bang G, Haanaes HR. Alveolar ridge augmentation in rats by Bio-Oss. Scand J Dent Res 1991;99:154–161.
21. 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.
22. 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.
23. 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 1996;11:55–66.
24. 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.
25. 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.
26. 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.
27. Holmes R, Mooney V, Bucholz R, et al. A coralline hydroxyapatite bone graft substitute. Clin Orthop 1984;188:252–262.
28. 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.
29. Doblin JM, Salkin LM, Mellado IR, 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.
30. 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.
31. 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.
32. 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.
33. Proussaefs P, Lozada JL, Rohrer MD. 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 Periodontics Restorative Dent 2002;22:567–673.
34. 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.
35. 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.
36. 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 Periodontics Restorative Dent 2003;23:185–195.
37. Lozada JL, Proussaefs P. Clinical, radiographic, and histologic evaluation of maxillary bone reconstruction by using a titanium mesh and iliac graft: A case report. J Oral Implantol 2002;28:9–14.
38. Marciani RD, Conty AA, Synhorst JB, et al. Cancellous bone marrow grafts in irradiated dog and monkey mandibles. Oral Surg 1979;47:17–24.

39. Hammack BL, Enneking WF. Comparative vascularization of autogenous and homogenous bone transplants. J Bone Joint Surg [Am] 1960;42:811–817.
40. 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.
41. Smith JD, Abramsson M. Membranous vs endochondral bone autografts. Arch Laryngol 1974;99:203–205.
42. Zins JE, Whitaker LA. Membranous vs endochondral bone: Implications for craniofacial reconstruction. Plast Reconstr Surg 1983;72:778–784.
43. 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.
44. Lin KY, Bartlett SP, Yaremchak MT, 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.
45. 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.
46. 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.
47. Corn H. Periosteal separation; Its clinical significance. J Periodontol 1962;33: 140–153.
48. Carranza FA, Carraro JJ, Dotto CA. Effect of periosteal fenestration in gingival extension operations. J Periodontol 1966;37:335–340.
49. Rungcharassaeng K, Lozada JL, Kan JYK, Kim JS, Campagni WV, Munoz CA. Peri-implant tissue response of immediately loaded, threaded, HA-coated implants: 1-year results. J Prosthet Dent 2002;87: 173–181.
50. Proussaefs PT, Lozada JL, Valencia G, Tatakis DN. A method to assess clinical outcome of ridge augmentation procedures. J Periodontol 2002;73:302–306.
51. 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.
52. 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.
53. 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.
54. 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.
55. Burchardt H. The biology of bone graft repair. Clin Orthop 1983;174:28–42.
56. Matsumoto MA, Filho HN, Francischone CE, Consolaro A. Microscopic analysis of reconstructed maxillary alveolar ridges using autogenous bone grafts from the chin and iliac crest. Int J Oral Maxillofac Implants 2002;17:507–516.
57. Rubin CT, Lanyon LE. Regulation of bone formation by applied dynamic loads. J Bone Joint Surg [Am] 1984;66A:397–402.
58. 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.
59. 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.