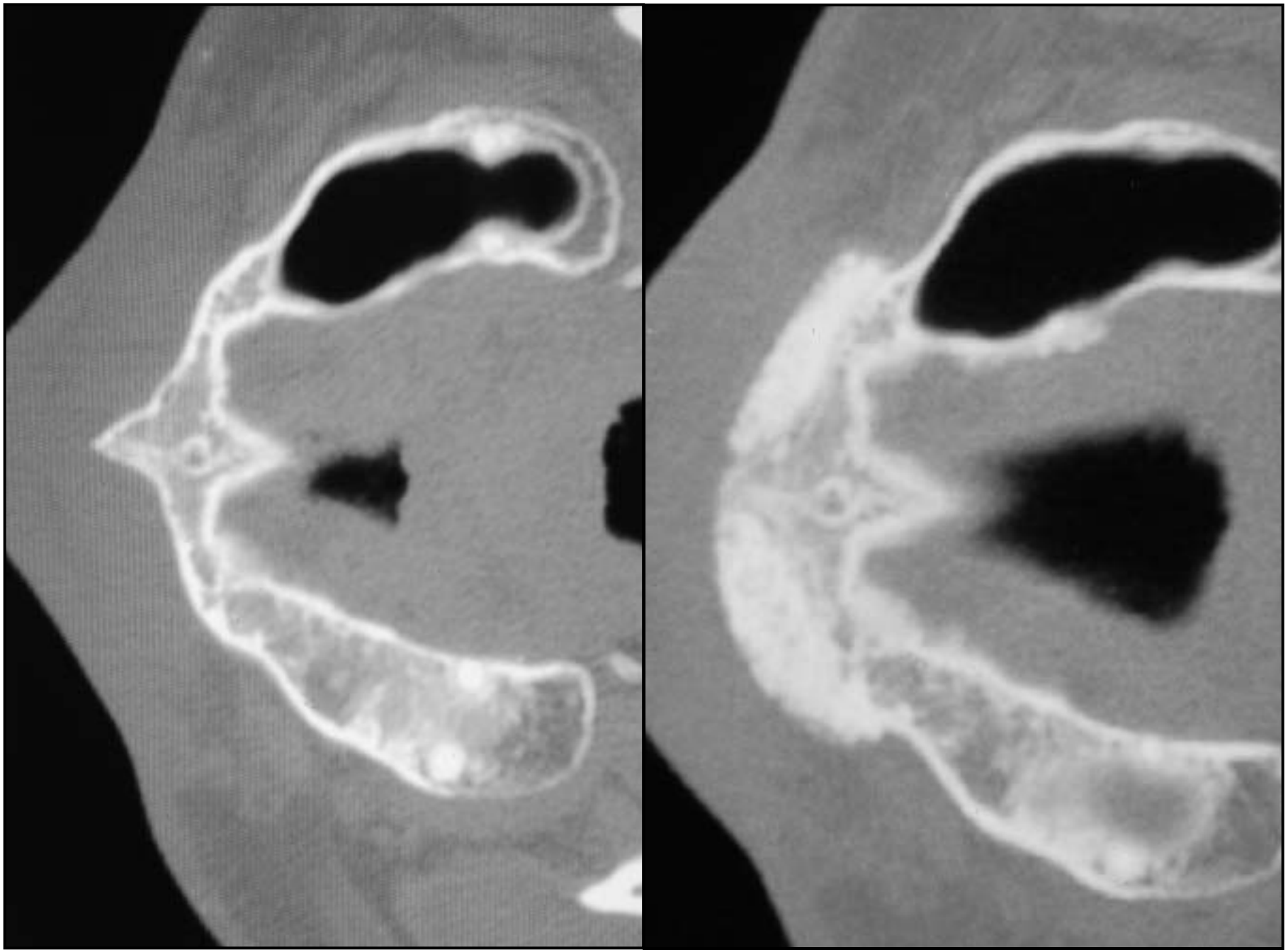

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The Use of Titanium Mesh in Conjunction with Autogenous Bone Graft and Inorganic Bovine Bone Mineral (Bio-Oss) for Localized Alveolar Ridge Augmentation: A Human Study

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This study evaluated the effects of using a titanium mesh for localized alveolar ridge augmentation. Seven consecutively treated human subjects participated in the study. Clinical, radiographic, laboratory, and histologic/histomorphometric analysis revealed the efficacy of using the titanium mesh in conjunction with intraorally harvested autogenous bone graft and inorganic bovine bone mineral (Bio-Oss). Radiographic measurements detected that a 2.86-mm vertical and 3.71-mm buccolabial ridge augmentation was achieved, while histomorphometry demonstrated that 36.4% of the grafted area consisted of bone. Laboratory measurements revealed 15.08% resorption of the graft for the first 6 months, which appeared to consolidate after placement of the implants. Exposure of the mesh did not appear to compromise the result. (Int J Periodontics Restorative Dent 2003;23:185–195.)

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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 before[5–10] or simultaneously[6,10–12] with the placement of dental implants to allow their use in patients lacking adequate bone volume. Several methods, materials, and techniques have been used for bone grafting. Extraoral[6,11,12] and intraoral[5–10,13] donor sites have been used when autogenous bone grafting is selected, while xenografts,[14,15] alloplastic bone grafts,[16,17] and allografts[18,19] have also been proposed. Various techniques have been applied to secure the graft material at the recipient site. Membranes,[5,7] fixation screws,[9,8,13] dental implants,[11,12] or titanium mesh[20–29] are the most common securing devices.

The current article provides a clinical, radiographic, laboratory, and histologic/histomorphometric analysis of the use of titanium mesh for localized alveolar ridge augmentation in conjunction with intraorally harvested intramembraneous autogenous bone graft

Table 1 Patient distribution

Case	Age (y)	Sex	Recipient site*	Donor site	Healing (mo)	No. of implants	Type of provisional restorations
1	60	M	12–23	Chin	9	5	Removable partial denture
2	70	M	13–12	Ramus	6	2	Fixed partial denture
3	67	F	13–23	Ramus	6	6	None
4	54	F	46–47	Ramus	8	2	None
5	69	M	17–16	Chin	6	2	None
6	44	M	11–22	Chin	6	3	None
7	77	F	17–15	Extraction site	13	3	None
Mean	63				7.71		
SD	11.16				2.62		
Range	44–77				6–13		

*Fédération Dentaire Internationale tooth-numbering system.
SD = standard deviation.

and inorganic bovine bone mineral.

Method and materials

Seven consecutively treated subjects participated in this study (Table 1). The subjects required a bone grafting procedure before the placement of dental implants. For all subjects, a titanium mesh (Osteo-Tram, Osteomed) was used during the bone grafting procedure in conjunction with an intraorally harvested intramembraneous bone graft and inorganic bovine bone mineral (Bio-Oss, Osteohealth). The bone grafting procedures were performed from July 1998 to April 1999. Treatment was performed 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 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 *(1)* local anesthesia only, *(2)* local anesthesia with oral sedation (Halcion 0.25 mg, Upjohn), or *(3)* local anesthesia with intravenous sedation. Full-thickness buccolabial and linguopalatal flaps were reflected at the recipient site (Fig 1). The donor site was the chin area (three cases), the ascending ramus area (three cases), or an extraction socket (one case) (Table 1). Harvesting of the bone graft was performed according to the standard procedure described elsewhere.[5,8] For the chin and ascending ramus donor sites, the autogenous bone graft was removed in the form of a block (Fig 2) and then particulated with a rongeur instrument (Blemental Rongeur, H & H).

The autogenous graft particles were mixed with inorganic bovine bone mineral particles (Bio-Oss). The recipient site was perforated to induce bleeding and promote incorporation of the graft.[30] The particulate graft was then placed at the recipient site (Fig 3). A titanium mesh (Osteo-Tram) was subsequently trimmed to cover the recipient site (Fig 4). Periosteal fenestration[31,32] was performed along the buccolabial flap to enable primary closure. The mesh was secured with fixation screws (Fig 5). The flap was then sutured.

Two weeks after the bone graft surgery, the sutures were removed. Six to 9 months were allowed for the bone graft to heal before the

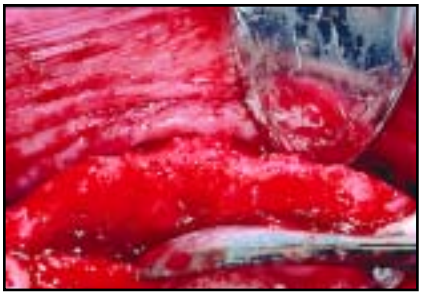

Fig 1 *Full-thickness labiopalatal flaps are reflected to expose the residual alveolar ridge.*

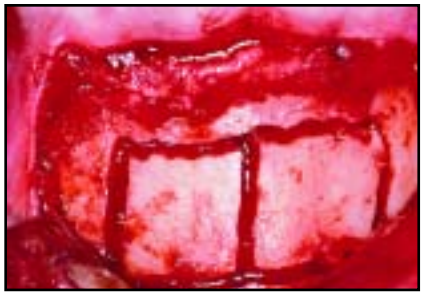

Fig 2 *Autogenous bone graft is harvested from the chin area.*

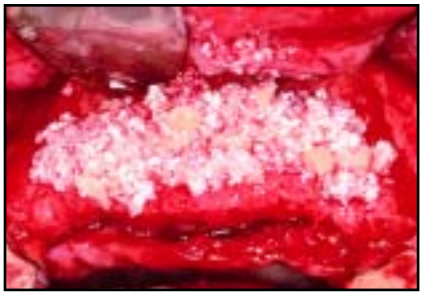

Fig 3 *Autogenous bone graft is mixed with inorganic bovine bone mineral (Bio-Oss) and placed at the recipient site.*

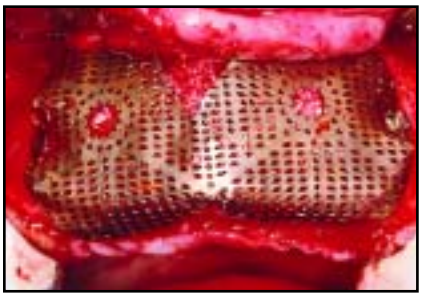

Fig 4 *Titanium mesh is trimmed and placed over the graft material.*

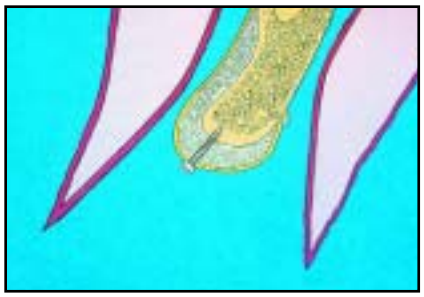

Fig 5 *Titanium mesh is secured in place by three fixation screws.*

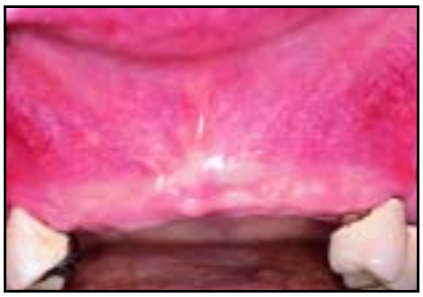

Fig 6 *Healing of the grafted area 6 months after the bone augmentation procedure. No mesh exposure or mucosa irritation is noted.*

placement of the implants (Fig 6 and Table 1). One subject (case 7) received the implants 13 months after the bone grafting procedure because she was unable to return earlier for personal reasons. The titanium mesh was removed 1 to 2 months before the placement of the implants in a separate procedure. Full-thickness buccolabial and linguopalatal flaps were reflected, and the mesh was removed after unscrewing the fixation screws (Fig 7). Hydroxyapatite-coated root-form implants (Steri-Oss, Nobel Biocare) were placed 1 to 2 months after the removal of the mesh with the aid of a surgical stent (Fig 8). All cases were treatment planned to receive an implant-supported screw-retained fixed partial denture (Figs 9 and 10).

Radiographic evaluation

All subjects received preoperative and postoperative panoramic radiographs. In addition, periapical radiographs were taken before the bone grafting procedure and before the placement of the implants (after the bone grafting had healed). For three subjects, a computed tomographic (CT) scan was taken before the bone grafting procedure and before placement of the implants (Figs 11 and 12), whereas for the other four subjects, linear tomographs were taken at the same intervals.

Measurements for the vertical and buccolabial bone augmentation were made by evaluating the preoperative and postoperative periapical radiographs in conjunction with the linear tomographs or CT

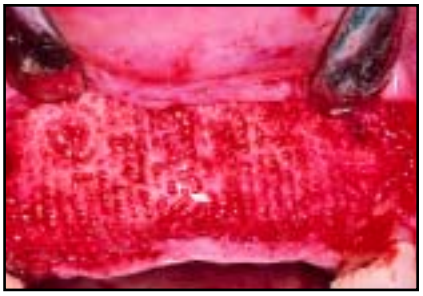

Fig 7 *Recipient site after the mesh is removed.*

Fig 8 *One month after mesh removal, dental implants are placed with the aid of a surgical stent.*

Fig 9 *Final result, facial view.*

Fig 10 *Patient's smile with the definitive prosthesis.*

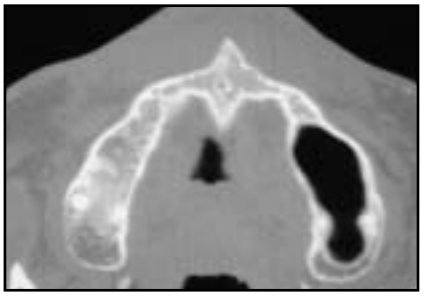

Fig 11 *CT scan, preoperative view.*

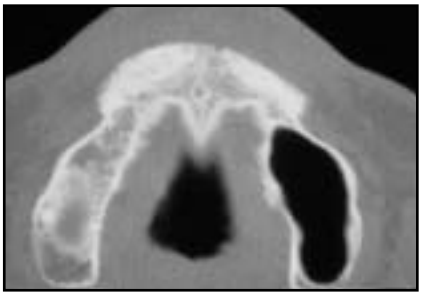

Fig 12 *CT scan, postoperative view.*

scans. All measurements were made by one investigator. For the linear tomographs, the distortion rate (1.7) provided by the manufacturer of the tomographic unit (Scanora type SBR 1C, Orion) was taken into consideration when the measurements were made. All tomographs were taken under the same series of linear projection (numbers provided by the manufacturer). The position of the subject's head was standardized by two light lines (one vertical and one horizontal) that are incorporated into the unit so the intersection of the two lines was located at the midline between the eyes of the subject (horizontal level reference) and at the midline between the eyebrows (vertical level reference).

Laboratory evaluation

Irreversible hydrocolloid impressions (Coe Alginate, GC) were made around the grafted area with a custom tray made from photopolymerized acrylic resin (Triad, Dentsply). The impressions were made preoperatively, 1 month after the bone grafting procedure, 6 months after bone grafting, and 6 months after implant surgery. The impressions were poured with type III dental stone (Microstone, Whip-Mix). The postoperative stone casts were used to quantitatively assess the volume of the alveolar ridge augmentation by adhering to a technique developed at LLU.[33,34] Briefly, a custom tray was fabricated from photopolymerized acrylic resin. An impression was made from the postoperative stone cast using the custom tray and silicone impression material (Labputty, Coltene/Whaledent). Polyvinyl siloxane bite registration material (Exabite II NDS, GC) was loaded in the tray, which was then placed on the preoperative stone cast, and the

Fig 13 *Laboratory measurements allow linear and volumetric measurements of the grafted area. The blue area (bite registration material) represents the augmented alveolar ridge. The white area represents the custom tray. An impression with silicone (pink) is made from the postoperative stone casts, bite registration material is internally applied, and the tray is reseated on the preoperative (before the bone augmentation) stone cast.*

Table 2 Clinical assessment*

Case	Bone quality	Complications, donor site	Complications, recipient site
1	II	Prolonged hypesthesia, finally resolved	None
2	III	None	Mesh exposure, 4 mm × 5 mm
3	II	None	None
4	III	None	Mesh exposure, 3 mm × 7 mm
5	IV	None	Mesh exposure, 4 mm × 5 mm
6	III	Incision line dehisced	Mesh exposure, 4 mm × 7 mm
7	IV	None	None

*In all cases, the Bio-Oss particles appeared well-attached to the surrounding grafted area and incorporated into the regenerated alveolar ridge.

registration material was allowed to polymerize (Fig 13). The weight of the registration material was assessed, and by considering the weight provided by the manufacturer, it was possible to calculate the volume of the alveolar ridge augmentation. In addition, linear measurements were made with a caliper (Darby Dental Supply) by evaluating the buccolabial thickness and vertical height of the registration material.

During implant surgery, a biopsy was taken from the grafted area using a 2-mm-internal-diameter trephine bur (ACE Surgical Supply) as the first drill during the osteotomy preparation for implant placement. The specimens were fixed in 10% buffered formalin. The specimens were dehydrated in alcohol and embedded in specialized resin (Technovit 7200 VLC, Heraeus Kulzer). Initial midaxial sections of 200 µm were made by means of the cutting-grinding system (Exakt Medical Instruments). The sections were then ground to 40 to 50 µm and stained with Stevenel's blue and van Gieson's picric fuchsin for histomorphometric analysis and light microscopy.[35,36]

Histomorphometric evaluation was performed by one investigator using a computer-assisted linear analysis program, Ribbon, developed at LLU.[37] For each specimen, the following parameters were measured: percentage composition of bone, connective tissue, and residual Bio-Oss, and percentage of the surface of the Bio-Oss surface in direct contact with bone. All histomorphometric analysis was performed by capturing an image under 2× magnification (Olympus Microscope, model BH-2, McBain Instruments). For each specimen, one to three images were analyzed, depending on the size of the specimen.

Results

Clinical evaluation

Exposure of the mesh during healing was observed in four of the seven cases (Table 2). In these cases, soft tissue proliferation and epithelialization was noticed to occur underneath the exposed mesh, an observation also made by others.[24] Oral hygiene instructions included to gently brush the exposed mesh with a T-ended toothbrush. Patients reported no pain or discomfort at the grafted area, even when the mesh was exposed. No clinical sign of

Table 3 Volume of alveolar ridge augmentation (mL)

Case	1 mo after grafting	6 mo after grafting	6 mo after implant placement
1	0.87	0.73	0.69
2	0.45	0.33	0.30
3	3.05	2.73	2.82
4	1.25	1.00	0.95
5	1.03	0.87	0.81
6	0.47	0.33	0.34
7	1.72	1.50	1.44
Mean	1.26	1.07	1.05
SD	0.99	0.90	0.87
Range	0.45–3.05	0.33–2.73	0.30–2.82

SD = standard deviation.

inflammation or infection was observed in any of the seven cases.

During the removal of the mesh, a layer of connective tissue was consistently observed underneath the mesh. Boyne et al[21] described this layer as "pseudoperiosteum." The mesh was surrounded by a thin layer of granulation tissue in most cases. 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 analysis revealed that a 2.86-mm vertical ridge augmentation (range 1 to 5 mm, standard deviation [SD] 1.77) and a 3.71-mm buccolabial augmentation (range 2 to 5 mm, SD 1.24) were achieved. In all cases, adequate bone volume was clinically observed for the placement of root-form implants in a prosthetically ideal position.

Laboratory evaluation

Laboratory volumetric measurements revealed that 1.26 mL of ridge augmentation was achieved 1 month postoperative, 1.07 mL was achieved 6 months after bone grafting, and 1.05 mL was achieved 6 months after implant placement (Table 3). These measurements dictated a 15.08% resorption 6 months after bone grafting, which appeared to consolidate after the placement of the implants. Linear measurements revealed that 1 month after the bone grafting procedure, 3.14 mm of vertical and 4.28 mm of buccolabial ridge augmentation were obtained (Table 4). The corresponding numbers for the 6-month postgrafting measurements were 2.57 mm of vertical and 3.86 mm of buccolabial alveolar ridge augmentation, while 6 months after implant placement, the corresponding numbers were 2.71 mm and 3.71 mm, respectively.

In all specimens, a mixture of bone, connective tissue, and residual Bio-Oss particles was observed (Fig 14). In the majority of the cases, the Bio-Oss particles appeared to be in tight contact with bone (Figs 15 and 16). No signs of resorption or active inflammatory processes were identified in any of the specimens.

The mean area of all seven core sections occupied by bone was 36.4% (Table 5). The comparable value for soft tissue was 51.6%, and for Bio-Oss particles it was 12.0%. The proportion of the surface of residual Bio-Oss particles that was in contact with bone was 36.7%.

Discussion

The current study provided histologic evidence in humans that the use of titanium mesh in conjunction with autogenous bone graft and inorganic bovine bone mineral (Bio-Oss) can result in new bone formation. In the literature, there is a scarcity of histologic evidence in humans of the results obtained using a titanium mesh for alveolar ridge augmentation. Although animal studies have offered the opportunity to histologically evaluate the results of this method of bone grafting,[20,23] few papers have reported histologic evidence of bone formation in humans after alveolar ridge

Table 4 Linear laboratory measurements (mm)

Case	1 mo after grafting		6 mo after grafting		6 mo after implant placement	
	Vertical	Buccolabial	Vertical	Buccolabial	Vertical	Buccolabial
1	2	5	1	4	1	4
2	3	4	3	4	3	4
3	2	6	2	6	2	6
4	4	3	3	2	3	2
5	4	2	3	2	4	2
6	3	4	2	4	2	3
7	4	6	4	5	4	5
Mean	3.14	4.28	2.57	3.86	2.71	3.71
SD	0.90	1.50	0.97	1.46	1.11	1.50
Range	2–4	2–6	1–4	2–6	1–4	2–6

SD = standard deviation.

Fig 14 *Histologic overview (Stevenel's blue–van Gieson's picric fuchsin stain; original magnification × 3).*

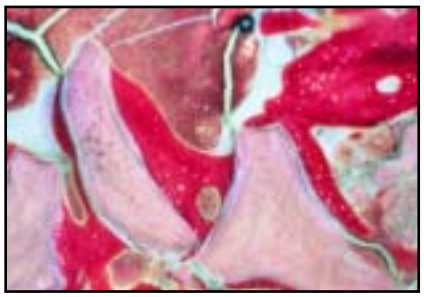

Fig 15 *Residual bovine bone mineral (Bio-Oss) particles are in tight contact with the surrounding bone. Particles appear interconnected with bony tissue. No sign of inflammation or resorption is observed (Stevenel's blue–van Gieson's picric fuchsin stain; original magnification × 10).*

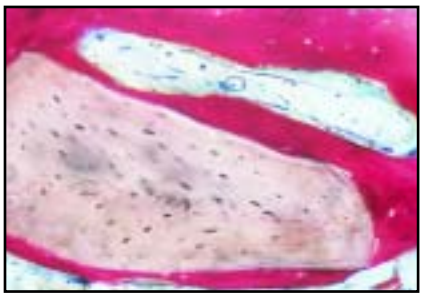

Fig 16 *At higher magnification, some of the residual Bio-Oss particles appear to have an intimate contact with the surrounding bone along the entire surface (Stevenel's blue–van Gieson's picric fuchsin stain; original magnification × 20).*

Table 5 Histomorphometric analysis (%)

Case	Bone	Fibrous tissue	Residual Bio-Oss particles	Bone–residual particles contact
1	40	52	8	22
2	24	62	14	0
3	36	54	10	35
4	34	53	13	45
5	30	57	13	63
6	53	45	2	50
7	38	38	24	42
Mean	36.4	51.6	12.0	36.7
SD	9.05	7.89	6.71	20.54
Range	24–53	38–62	2–24	0–63

SD = standard deviation.

augmentation using a titanium mesh.[25,26,28,29]

Regarding the type of bone grafting that has been used in conjunction with a titanium mesh, the majority of the reported cases involved the use of extraorally harvested autogenous endochondral bone grafts, typically from the iliac crest area.[20–23,25,28] However, hydroxyapatite[25] or Bio-Oss[29] mixed with autogenous bone has also been proposed, as has the use of intramembraneous autogenous bone grafts harvested intraorally from the chin or ascending ramus area.[24,26,27,29] Several publications have demonstrated a superiority of the intramembraneous autogenous bone graft to the extraorally harvested endochondral graft.[38–42] Intraorally harvested grafts have demonstrated a reduced resorption rate,[38,39,41] faster rate of revascularization,[40,41] and accelerated healing process[42] attributed to their embryogenic origin. A 15.08% 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 placement of the implants, an observation also made by others.[43] The occlusal or transmucosal loads of the implants may provide stimulus to the periimplant bone to maintain the bone volume.[44]

During harvesting of the autogenous bone graft, an effort was made to harvest bone marrow in the largest possible quantity. The chin area appears to offer an increased amount of bone marrow compared to other intraoral donor sites.[8] Cancellous bone marrow offers enhanced bone formation at the recipient site.[45,46] Revascularization of cancellous bone is faster, and endosteal osteoblasts and marrow mesenchymal cells that are capable of bone induction are transplanted. In addition, the autogenous bone grafts in the current study were particulated, since particulate bone grafts have been associated with enhanced healing and revascularization processes.[46]

Inorganic bovine bone mineral (Bio-Oss) was used as a filler in the current study. This material appeared to be biocompatible and histologically demonstrated tight contact with the surrounding bone at 36.7% of its surface area. In one case (case 2), the Bio-Oss particles had no contact with the surrounding bone. In that case, the fixed temporary prosthesis had fractured, impinging on the grafted area during function. It can be hypothesized that the micromovement induced on the Bio-Oss particles in that case prevented bone formation in tight contact with the particles. No sign of resorption or inflammation was observed under light microscopy.

The effectiveness and biocompatibility of Bio-Oss when used as an inlay bone graft has been well-documented in both animal[47,48] and human studies.[49,50] However, little is known about the use of Bio-Oss as an onlay bone graft. In a four-walled defect in rabbits, the use of Bio-Oss resulted in the formation of new bone between the particles of the graft that were in tight contact with the surrounding bone, with no sign of resorption or inflammation.[51] Similar observations have been made in humans.[15,29,52] On the other hand, some studies[14,53] failed to identify any bone formation around Bio-Oss particles when used as an onlay bone graft. However, when Bio-Oss is mixed with an autogenous bone graft, as in the current study, new bone formation is observed. The inorganic bovine bone mineral acts as a scaffold for the formation of new bone. It appears that there is a need for an autogenous bone graft with the osteogenic potential to induce new bone formation around the Bio-Oss particles.[29,52] Further studies are needed to assess the role of this xenograft when used as an onlay bone graft.

Exposure of the titanium mesh was observed in four of the cases in the current study. This is a common phenomenon when a titanium mesh is used for alveolar ridge augmentation, and von Arx et al[24] experienced exposure of the mesh in 50% of their cases. However, clinically and histologically, the exposure did not appear to affect the final outcome. This offers an advantage compared to nonresorbable membrane barriers, which result in infection when exposed.[7] In the current study, the titanium mesh was removed 1 to 2 months before the placement of the implants as a separate procedure. The presence of a thin layer of granulation tissue around the mesh dictated the removal in a separate approach.

Multiple surgical procedures (bone grafting, titanium mesh removal, implant placement, implant uncovering) increase the time, cost, and discomfort associated with the treatment.

The laboratory technique used in the current study to provide volumetric and linear measurements of the alveolar ridge augmentation has been shown to be both reproducible and accurate.[33,34] However, for the current study, the impressions were made from the residual alveolar ridge before and after the bone grafting procedure. The major limitation is that this does not include measurements of the soft tissue thickness. Alternatively, the impressions could be made directly from the bone and during the surgery, excluding the variability induced by the soft tissue thickness.

The present study demonstrated 36.4% bone formation when titanium mesh was used in conjunction with an autogenous bone graft and Bio-Oss. The augmented alveolar ridges had a solid consistency, and no sign of inflammation or resorption was seen under light microscopy. The grafted areas demonstrated a 15.08% resorption in the 6 months after bone grafting, which appeared to consolidate after implant placement. Radiographic assessment revealed a 2.86-mm vertical and 3.71-mm buccolabial ridge augmentation, and exposure of the mesh did not appear to compromise the result.

Acknowledgments

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