Vertical Ridge Augmentation Around Implants by e-PTFE Titanium-Reinforced Membrane and Bovine Bone Matrix: A 24- to 54-Month Study of 10 Consecutive Cases

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Purpose: *The objective of the present study was to clinically and histologically evaluate the effectiveness of deproteinized bovine bone as the augmentation material in vertical ridge augmentation of the inserted implants.* ***Materials and Methods:*** *This retrospective study was performed on 10 vertically augmented ridges in which 24 dental implants were inserted. Deproteinized bovine bone (Bio-Oss) was used as the only augmentation material and was covered with a titanium-reinforced expanded polytetrafluoroethylene (e-PTFE) membrane (Gore-Tex). For 3 augmented areas, bone samples were retrieved for histologic and histomorphometric examination.* ***Results:*** *Clinical evaluations showed bone defects around the implants of 2 to 9 mm (average −5.1 mm; SD = 2.1). Bone height gain at 6 to 8 months after augmentation was 3 to 9 mm (average 5.3 mm; SD= 1.7). Differences between pre- and postaugmentation were statistically significant, for a mean value of > 4 mm (P < .005). The obtained bone biopsy specimens showed significant new bone formation and remodeling of the deproteinized bovine bone material. The radiographic data and the clinical stability showed that all implants were successfully osseointegrated. The radiographic and clinical follow-up indicated that the generated bone crest levels were stable.* ***Conclusion:*** *This clinical study suggests that vertical ridge augmentation with an e-PTFE membrane and deproteinized bovine bone is predictable and can lead to long-term success.* Int J Oral Maxillofac Implants 2008;23:858–866

Key words: *barrier membranes, bovine bone matrix, vertical ridge augmentation*

Vertical ridge augmentation (VRA) is the challenge in bone reconstruction. Relevant vertical defects of alveolar ridge may render the use of dental implants unfavorable in accordance with the principles of Albrektsson and Brånemark.[1,2]

The first study utilizing guided bone regeneration to augment bone vertically was carried out by Simion et al[3] in 1994. Fifteen implants were inserted in 6 different sites in 5 patients. The implants protruded 4 to 7 mm from the bone crest and were covered with a titanium-reinforced membrane. Membranes were removed after 9 months of healing and 3 to 4 mm of regenerated bone was obtained using only the blood clot as filler material. Jovanovic et al[4] later confirmed these results in an experimental study in dogs. Histologic evaluation of the defects confirmed the 4-mm vertical bone regeneration.

Trying to improve the performance of the blood clot as filler material, Jensen et al[5] and Renvert et al[6] used a canine model and filled the space underneath the membrane with autogenous bone chips or demineralized freeze-dried bone allograft (DFDBA). They showed that the autogenous bone could produce significantly more bone tissue.

Subsequently, Tinti et al[7] showed improved results in humans (up to 7 mm) using the same technique. Simion et al[8] then tested DFDBA or autogenous

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bone as a filler material in a group of 20 patients. Results confirmed that adding grafting materials rather than using a titanium-reinforced membrane on its own achieves significantly more regenerated bone. Additionally, it was shown that the outcome of the VRA procedure is more predictable if grafting materials are used. These findings were supported and summarized in a clinical protocol by Tinti and Parma-Benfenati.[9]

Simion et al[10] presented a long-term retrospective multicenter study covering up to 5 years of follow-up in which they inserted 123 implants using the aforementioned VRA procedure.[3] Again, the results demonstrated that VRA has a positive long-term effect and can be predictable and successful, given that a nonresorbable titanium-reinforced membrane is used with a healing period of at least 6 months and an adequate filler material is chosen.

The chosen filler material significantly influences the outcome of the augmentation procedure. Up to now, autogenous bone has been considered the gold standard. However, it involves a second surgical site to harvest the bone, and therefore, additional morbidity for the patient. The use of deproteinized bovine bone (DBB) as the filler material, either in combination with autogenous bone or by itself, has shown good and reproducible results in a variety of bone augmentation procedures.[11–13]

In 2006, Merli et al[14] evaluated the efficacy of and complications associated with 2 different techniques for vertical bone augmentation at implant placement. Autogenous bone covered by titanium-reinforced expanded polytetrafluoroethylene (e-PTFE) barriers and autogenous bone with resorbable collagen membranes supported by osteosynthesis plates were evaluated. No statistically significant differences between the 2 groups with respect to the amount of regenerated tissue or the number of complications were observed between the 2 techniques.[14]

On the other hand, in 2006, Canullo et al[15] showed clinically and histologically verifiable vertical bone rebuilding using a Gore-Tex titanium-reinforced membrane and DBB as the only filler material. This procedure used a biopsy specimen composed of low-density trabecular bone with numerous interspersed graft particles.

The aim of the present retrospective study was to evaluate the status of dental implants 24 to 54 months after insertion into alveolar ridges vertically augmented with DBB and covered by a titanium-reinforced e-PTFE membrane.

The technique presented here avoids a second surgical site for bone harvesting and therefore reduces morbidity and postoperative discomfort for the patient.[16]

MATERIALS AND METHODS

Patient Enrollment

The following patient inclusion criteria were applied for this retrospective study:

- Vertical bone defect
- Patient physically able to tolerate conventional surgical and restorative procedures

The exclusion criteria were

- Teeth with acute infection
- A Full Mouth Plaque Score or a Full Mouth Bleeding Score (FMBS) > 25%
- Smoking more than 10 cigarettes per day
- Uncontrolled diabetes
- Pregnancy or lactation
- Treatment with therapeutic radiation to the head (and neck area) within the past 12 months
- Active infection or inflammation in the area intended for implant placement

All patients received and signed an informed consent form. The age and gender of each patient were noted.

Surgical Protocol

First-Stage Surgery. All patients received antibiotic prophylaxis (amoxicillin and clavulonic acid, 1 g every 8 hours, starting 1 day preoperatively) in association with 0.2% chlorhexidine gluconate mouthrinse (every 12 hours, starting 1 day preoperatively for 7 days.

Local anesthesia (Ultracain DS Forte, Hoechs, Frankfurt am Main, Germany) was combined with a sedative premedication (diazepam, 5 mg administered orally 30 minutes before surgery). The surgical procedure was carried out as described in the literature.[3,7–10] A full-thickness incision was made within the keratinized gingiva from the distal aspect of the first tooth contiguous to edentulous space to the distal end of the edentulous ridge. The incision was extended intrasulcularly and anteriorly to the mesial aspect of the second last existing tooth. Vertical releasing incisions were made at the mesiobuccal line angle of the second to last existing tooth and at the distal aspect of the crestal incision. The buccal and lingual flaps were reflected with a periosteal elevator, avoiding damage to the anatomic structures. Once exposed, the cortical bone was curetted with a back-action chisel to remove all residual connective tissue and the periosteum.

Using a surgical stent, 1 to 3 implants (Defcon Implant System, Barcelona, Spain) were placed as needed. The implant head was positioned in an ideal

Fig 1 *A single patient (LG) is used as a representative to demonstrate the surgical procedure.*

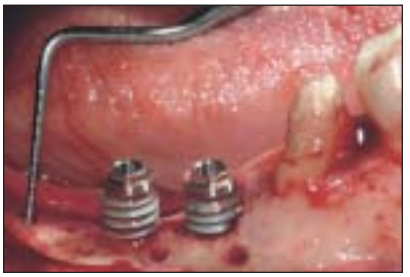


Fig 1a Implants placed in a severely atrophic mandible.

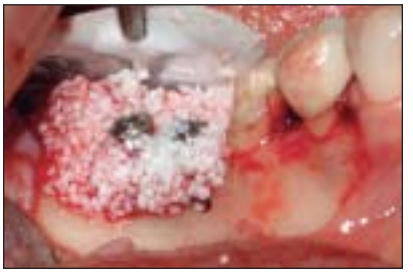


Fig 1b Bone defect grafted with DBB.

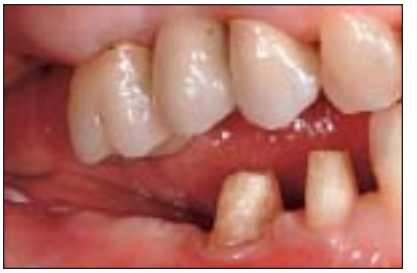


Fig 1c Mandible after flap closure and removal of sutures.

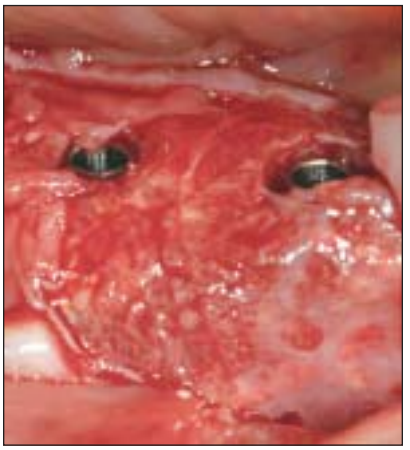


Fig 1d Overview of vertical bone augmentation after reopening 6 months later.

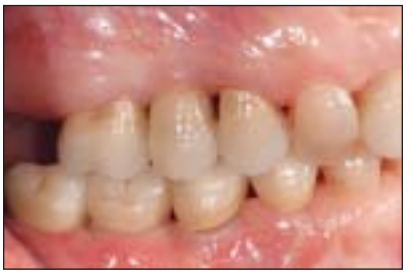


Fig 1e Final restoration in place, with satisfying esthetic results.

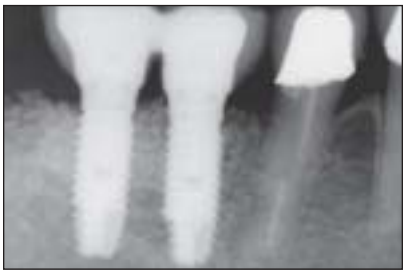


Fig 1f Periapical radiograph after 30 months of prosthetic loading demonstrates well-integrated implants and successful vertical bone augmentation.

vertical position located at the highest mesial bone crest (Fig 1a).

The distance between the bone crest and the most coronal portion of the implant platform were assessed. In the 2 cases in which it was not possible to insert implants during the first surgery, 1 or 2 screws (Cizeta, Florence, Italy) were inserted in order to generate a tent effect under the membrane. In these cases, the distance between bone crest and screw heads was assessed.

An appropriate titanium-reinforced GTAM Gore-Tex membrane (WL Gore & Associates, Flagstaff, AZ) was shaped to adapt to the vertical defect; this membrane did not touch the distal margin of the mesial teeth. Two miniscrews (Cizeta, Florence, Italy) were used to lingually fix the membrane to achieve optimal stabilization. The DBB (Bio-Oss; Geistlich Pharma, Wolhusen, Switzerland) was mixed with an antibiotic solution (Lincocin 600 mg, Pharmacia Italia, Milan, Italy) and placed under the membrane (Fig 1b). Mixing Bio-Oss with an antibiotic solution allows for easier packing of the graft, since the DBB by itself tends to flow when it is placed in a 1-wall bone defect. The defect was completely filled and covered by the membrane, and the membrane was fixed buccally with 2 miniscrews.

Releasing incisions in the periosteum were made at the base of the buccal flap to enhance the elasticity of the flap and to achieve a tension-free adaptation of the soft tissue at closure.

The flap was closed by horizontal mattress sutures alternated by interrupted sutures. In order to decrease swelling and pain, the patient received appropriate cortisonic corticosteroid therapy (Bentelan 1 mg, Sigma Tau, Rome, Italy) for 3 days and nonsteroidal anti-inflammatory drugs for 4 days (Aulin 100 mg, Helsinn Healthcare, Pambio-Noranco, Switzerland).

The sutures were removed after 10 days following application of 0.2% chlorhexidine gel for 2 minutes to reduce bacterial contamination of the wound. After suture removal, the patient was checked once a week for the first month and then once a month until second-stage surgery (Fig 1c).

Second-Stage Surgery

Re-entry was performed after 6 to 8 months of healing. After membrane removal, the thickness of the soft tissue layer was measured with a periodontal probe (Fig 1d). In 1 case in which an additional implant had to be placed, a histologic biopsy specimen was taken at the place of implant insertion.

In the 2 cases for which implants were not inserted in the first surgery procedure, biopsy specimens were collected with a small trephine before implant insertion. Each patient from whom a biopsy was taken provided written informed consent. Vertical and horizontal bone regeneration were assessed with a periodontal probe.

After the final prosthetic restoration was in place (Fig 1e), the patients were included in a recall program. They were treated every 6 months for oral hygiene, and clinical evaluations were obtained by digital periapical standardized radiographs using a parallel technique (Fig 1f). The distance between the top of the implant shoulder and the coronal bone crest was assessed (DIB) as well as the distance between the top of implant head and the first visible bone-implant contact (DIBC).

An image analysis software application (Scion Image 4.02 Win, Scion, Frederick, MD) evaluated the marginal bone levels around implants with the ability to compensate for radiographic distortion. The software calculated bone remodeling at the mesial and distal aspects of the implants.

Statistical comparisons of the pre- and postoperative bone heights were performed with a paired *t* test.

Histologic Analysis

The 3 biopsy specimens were prepared for light microscopy without prior demineralization by the method of Donath and Breuner.[17] Dehydration was accomplished by increasing ethanol concentrations using a dehydration system with agitation and vacuum. The blocks were embedded in Kulzer Technovit 7200 VLC-resin and sliced longitudinally on an Exakt cutting unit (Exakt, Norderstedt, Germany). The slices were reduced by microgrinding and polishing using an Exakt grinding unit to an even thickness of 20 µm. These were stained with toluidine blue/pyronine G. Histometric measurements of the tissue types (DBB, newly formed bone, and marrow and/or connective tissue) in the augmented area were performed using a Leica DM6000B light microscope (Leica, Glattbrugg, Switzerland) for the entire specimen surface. Subsequently, the digitized images were analyzed by the image analysis software (Imagic, Glattbrugg, Switzerland). For each specimen the most central section was analyzed, and for each the amount of tissue was expressed as a percentage of the total length of the specimen.

The parameters calculated using the IAS 2000 (Imagic) software were the following:

- % Bone volume (BV), indicating the area occupied by the bone matrix over the entire microscopic field. This was measured by outlining the bone surface area to determine the surface area of bone in the microscopic field and expressed as percentage of the total biopsy area.
- % Graft volume (Graft), indicating the amount of graft still present and expressed as a percentage of the total surface.

RESULTS

Clinical Results

Ten patients were enrolled (mean age of 57.1 years). There were no dropouts.

Eight patients received implant insertion at the time of VRA. Two patients received implants in second-stage surgery, as no primary stability could be obtained. In these 2 patients, biopsy specimens were obtained with a small trephine.

One day after surgery, patients showed a moderate swelling in the submandibular region without experiencing pain. After 1 week, no symptoms of inflammation were detectable. After 10 to 14 days, sutures were removed. Healing was uneventful in almost all patients (Table 1), with the exception of a single membrane exposure occurring 5 months after first-stage surgery. The dehiscence was caused by mechanical failure of the temporary restoration. The provisional prosthesis was removed and the patient was instructed to rinse twice a day with chlorhexidine until the completion of the bone maturation period.

The e-PTFE membranes were removed after a 6- to 8-month period (Fig 1d). At that time the membranes appeared to be integrated into the surrounding tissues. Under every membrane, scarcely bleeding soft tissue was present.

The exposure surgery showed clinically new bony formation. In some cases it was necessary to perform an osteotomy to remove bone that had grown over the cover screw in order to insert the healing abutment (Table 1).

After second-stage surgery, an allowance of 1 month was given for gingival maturation before delivery of the definitive prosthetic impression. Afterward a metal-ceramic rehabilitation was put into place within 2 weeks (Fig 1e).

The distance between the implant head and the bone crest, before the regeneration procedure, was 3 to 9 mm (average –5.1 mm, SD 2.1). The distance between the implant head and bone crest after the regeneration procedure was between +2 and –3 mm (average +0.0 mm, SD 1.0). This represented a bone height gain between 3 and 9 mm (average 5.3 mm, SD 1.9) for the 10 sites. The differences between pre- and postoperative height were statistically significant, for a mean value greater than 4 mm ($P = .005$),

Table 1 Clinical Observation of the 10 Patients Enrolled

Patient	Age	Site no.	Location*	Implant surgery date	Abutment connection date	DIB 1 (mm)	P-L (tissue)	DIB 2 (mm)	Bone gain (mm)	DIBC (mm)	Healing
1. TC	56	1	19	12–03–01	20–10–01	–4	0	+2	+6	1.5	Uneventful
		2	18			–5	0	+1	+6	1.5	
2. LG	65	3	30	20–02–02	30–09–02	–4.5	0.5	+0.5	+5	1	Uneventful
		4	31			–4.5	0.5	+0.5	+5	1.5	
3. CF	67	5	11	21–04–02	5–12–02	–3	0.5	0	+3	1.5	Uneventful
		6	12			–4	0.5	+1	+5	1	
		7	13			–2	0.5	+1.5	+3.5	1.5	
		8	14			–5	0.5	0	+5	1	
4. LA	56	9	19	08–01–03	25–07–03	–4	0.5	+1.5	+5.5	1.5	Uneventful
		10	18			–4	0.5	+1	+5	1.5	
5. CP	54	11	21	15–01–03	02–09–03	–5	1	0	+5	1.5	Uneventful
		12	20			–6	1	+1	+7	1	
		13	19			–7	1	–1	+6	1.5	
6. MA	64	14	20	20–01–03	24–10– 03	–4	0	0	+4	1.5	Uneventful
		15	19			–3	0	0	+3	1.5	
		16	18			–3	0	0	+3	1.5	
7. VG	68	17	23	05–04–03	10–11–03	–5	1	0	+5	1	Late
		18	26			–5	1	0	+5	1	exposure
8. SR	43	19	23	12–05–03	10–03–04	–9	1	0	+9	1	Uneventful
		20	26			–9	1	0	+9	1	
9. PO	40	21	30	01–07–03	15–03–04	–7	2	–1	+6	1.5	Uneventful
		22	31			–7	4	–3	+4	3	
10. MF	58	23	29	10–05–03	20–03–04	–3	0.5	0	+3	1.5	Uneventful
		24	30			–7	0.5	0	+7	1.5	
Average	57.1 ± 9.1					–5.1 ± 2.1	0.8 ± 0.8	0.0 ± 0.9	5.3 ± 1.9	1.4 ± 0.4	

*Implant localization in accordance with World Health Organization (WHO) classification.
Patient: consecutive number and initials of patient.
Age: age of patient at the date of the first surgery.
Implant surgery date: the date of the first surgery.
DIB = distance between implant shoulder and coronal bone.
DIBC = distance between the top of the implant head and the first visible bone-implant contact.

showing that a highly significant increase in the vertical bone height was achieved by the VRA.

Implant Evaluations

Every 6 months, standardized periapical digital radiographs using a parallel technique were taken to evaluate bone resorption after loading. The mean follow-up period was 36 months. The radiographs showed a cone of bone resorption all around the implant neck. No other vertical resorption was detected along the augmented bone (Fig 1f).

Histology

The biopsy specimens showed local bone and an augmented area made up of DBB and new bone (Fig 2). They also showed bone remodeling and osteoclast activity at the periphery and resorption of the DBB particles (Figs 3 to 5). The specimens were composed of low-density trabecular bone with numerous interspersed graft particles.

The particles were uniformly and widely dispersed in the biopsy space and almost everywhere covered by layers of bone.

On one side of the biopsy specimens, a continuous thin trabecula of composite bone is visible similar to a cortex. Also, the trabeculae of the inner space were made of composite bone, with a central core of woven and external layers of lamellar bone. The bone surface was covered by osteoid bands with mature and plump osteoblasts; few signs of resorption were seen there.

The surfaces of the graft particles were mostly covered by newly formed bone. Some areas of these surfaces were exposed to the marrow soft tissue (indicated by a typical white unstained band), and sometimes macrophages could be observed.

The histomorphometric analysis of the 3 biopsy specimens showed visible formation of new bone. For the 2 biopsy specimens taken before implant placement, no connective tissue ingrowth was observed. However, for the biopsy specimen taken after additional implant placement, a smaller amount of DBB and new bone was measured, and a small amount of connective tissue had penetrated the augmentation area (Table 2).

Fig 2 *Overview of the round section through the biopsy specimens taken. They show local bone and the augmented area with DBB, newly formed bone (NB), and marrow spaces (M).*

Fig 2a MA2: The biopsy specimen shows a compact augmented area with a high volume of DBB.

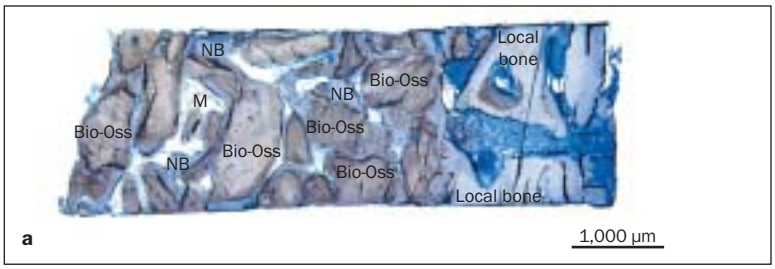


Fig 2b MA1: The biopsy specimen shows a compact formation of DBB and new bone. The biopsy specimen has broken into 2 pieces.

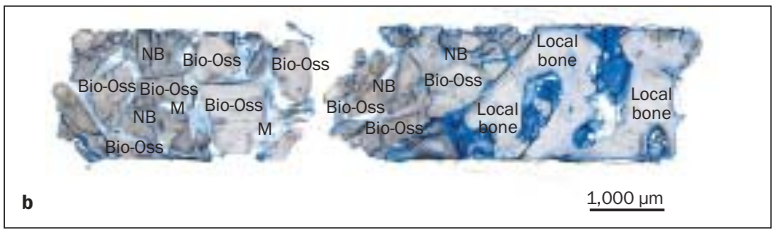


Fig 2c LG: The biopsy specimen shows a loose formation of new bone and a small volume of DBB particles.

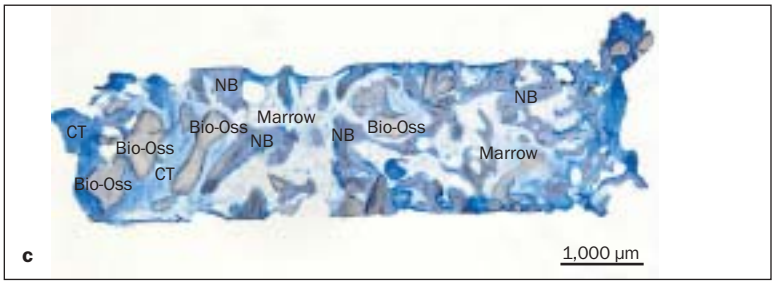
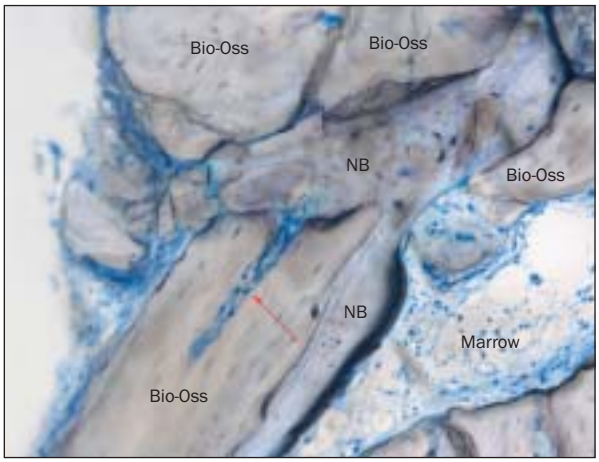


Fig 3 Higher magnification of an area in Fig 2b. The area shows DBB particles connected by newly formed bone (NB). The arrow indicates an area of DBB remodeling. The marrow shows a significant amount of cells.



DISCUSSION

The aim of this retrospective clinical study was to evaluate the possibility of promoting vertical ridge augmentation in atrophic partially edentulous ridges by using a titanium-reinforced e-PTFE membrane (Gore-Tex) in combination with DBB. A radiographic follow-up provided evidence regarding the implant and the success of the VRA for up to 54 months.

It has been shown previously that it is possible to generate new bone vertically when autogenous bone chips are used in association with an e-PTFE or resorbable membrane.[8–10,14,18] However, using a bone substitute allows the clinician to avoid bone harvesting from a donor site, thus reducing the invasiveness of the procedure and patient discomfort in the postoperative period.

DBB has shown to be highly biocompatible and osteoconductive. It has been demonstrated to be integrated into the newly formed bone and is slowly resorbed.[12,13,15] DBB has shown the capability to regenerate bone vertically in association with titanium mesh.[11]

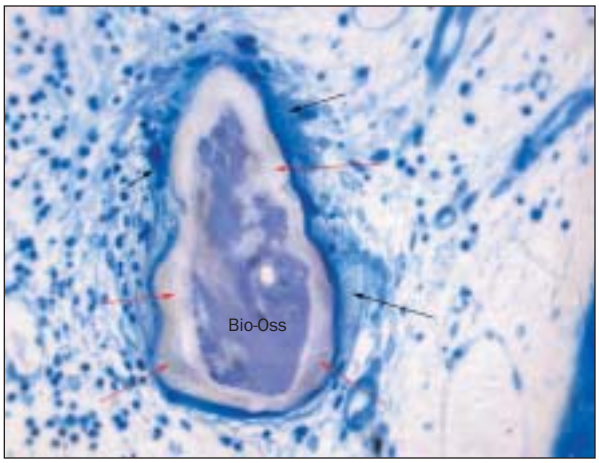


Fig 4a Remodeling of Bio-Oss. Note the formation of new bone in the resorption area *(red arrows)* and the presence of an osteoclast *(black arrows)*.

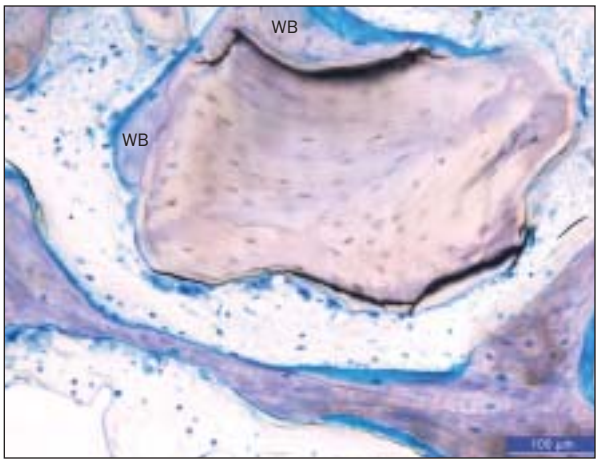


Fig 4b Remodeling of DBB. Note the formation of woven bone (WB).

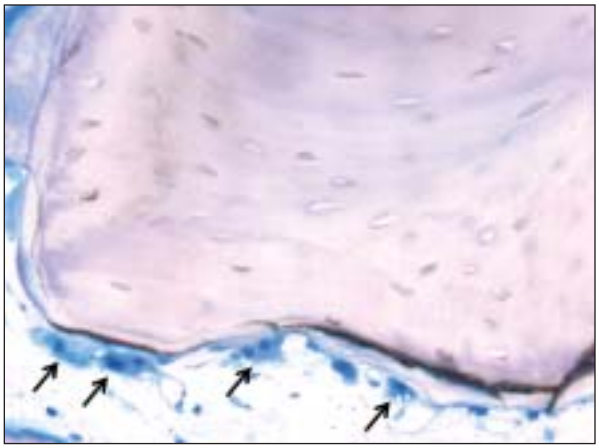


Fig 5 Remodeling of DBB. Note the presence of an osteoclast *(black arrows)*.

Table 2 Histomorphometric Analysis of the Bone Biopsy Specimens Taken from the VRA Areas

	DBB (%)	New bone (%)	Marrow (%)	Connective tissue (%)
MA 14	54.9%	30.6%	14.5%	–
MA 15	46.6%	40.6%	12.8%	_
LG4	11.8%	22.6%	50.3%	15.3%

*The biopsy specimen from LG was taken from the periphery of the augmentation area where the implants were placed previously.

Simion et al[10] have shown in a long-term retrospective clinical study that jaw bone augmented vertically by means of GBR techniques in association with autogenous bone chips has the tendency to show bone remodeling that is slightly higher (1.71 mm; SD = 0.97) than those generated with autogenous bone clot grafts. From this point of view, the slow resorption process of DBB can be of benefit in maintaining the stability of the regenerated bone.

The results of this study provide data on implants placed in bone vertically regenerated with e-PTFE membrane and DBB following 24 to 54 months of functional loading. None of the 24 implants placed in this study failed, and none demonstrated significant bone loss as evidenced by radiographs. Only the physiologic cone resorption after abutment connection was observed.

Clinical findings have demonstrated new bone formation up to the implant shoulder level. Only one case demonstrated incomplete bone filling, which was probably due to an inadequate filling of the space between membrane and bone crest with the DBB or insufficient cortical perforations to generate sufficient cell invasion from the marrow space.

At the membrane removal, a soft tissue layer (0.5 to 1 mm thick) was observed between the membrane and the regenerated hard bone-like tissue (Table 1). This finding is in accordance with previous reports[3,7–10,18] demonstrating a periosteal-like soft tissue.

The histologic evaluation of the vertically augmented ridges showed that the DBB particles, which were used as the only filler material, were well integrated into newly formed bone (Fig 2, Table 2). Analysis of the histologic samples revealed that new bone

formation was approximately the same volume as the amount of DBB added (Table 2). A more detailed view of the augmented area shows ongoing remodeling of the DBB (Fig 3), which itself is evidence for the incorporation of the material in the physiologic maturation process. Further evidence of the physiologic incorporation of the DBB is given by the presence of osteoblasts and osteoclasts within the augmented area (Fig 5). The presence of the cells up to 9 mm away from the local bone suggests that DBB is highly osteoconductive and can bridge a distance of up to 9 mm without the necessity to add autogenous bone or growth factors to initiate new bone growth.

Overall, the clinical findings presented here are in agreement with previous observations by other investigators, who demonstrated that DBB particles are capable of being well integrated by new bone and their remodeling appears to be a slow but steady process.[11,15,19–23]

Radiographic examinations showed the physiologic cone of bone resorption around the implant neck (Table 1). No vertical resorption was detected along the interproximal or distal augmentation site. However, the biometric evaluation of the present study should be interpreted with caution, as bone levels were evaluated only by means of digital standardized periapical radiographs.

CONCLUSION

Histologic and clinical results demonstrated that vertical ridge augmentation using a Gore-Tex titanium-reinforced membrane in combination with deproteinized bovine bone can be a successful and predictable procedure for rebuilding a resorbed ridge to accommodate implants.

Three years after loading, radiologic measurements showed a physiologic bone resorption cone all around the implant-abutment connection. However, no decrease of the bone level was detected along the crest. The histologic data presented here confirm the previous literature (ie, that the association of a Gore-Tex membrane with deproteinized bovine bone allows a vertical ridge augmentation of up to 9 mm without the use of autogenous bone). This presents a significant reduction of the patient's morbidity. A mean follow-up of 36 months suggested that this procedure allowed the achievement of a long-term stability of the implant.

On the basis of these results, it can be concluded that vertical ridge augmentation using deproteinized bovine bone supports implant placement in a manner similar to autogenous bone.

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