Horizontal Ridge Augmentation with a Resorbable Membrane and Particulated Autogenous Bone With or Without Anorganic Bovine Bone–Derived Mineral: A Prospective Case Series in 22 Patients

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Purpose: *This prospective case series evaluated the use of a new synthetic resorbable membrane with autogenous bone, either alone or in combination with anorganic bovine bone–derived mineral, for horizontal ridge augmentation and subsequent implant placement.* ***Materials and Methods:*** *Particulated autogenous bone, either alone or in combination with anorganic bovine bone–derived mineral, was used for lateral ridge augmentation and covered with a new synthetic resorbable membrane (glycolide and trimethylene carbonate) to treat knife-edged ridges and prepare them for implant placement. Ridge measurements were obtained before and after augmentation, complications were recorded, and biopsy specimens were examined histologically.* ***Results:*** *Fifty-eight implants were placed in 22 patients with 25 surgical sites in knife-edged ridges. No complications were associated with this treatment. Clinical measurements revealed an average of 5.56 mm (± 1.45 mm) of lateral ridge augmentation after an average of 8.12 months (± 2.32 months) of graft healing. Clinically, all treated ridges were sufficient in width for subsequent implant placement. All implants have survived, with an average follow-up period of 45.88 months (± 12.43 months). Histologic analysis of the selected augmentation sites showed new bone formation and good incorporation of the bovine bone mineral particles.* ***Conclusion:*** *The high implant survival rate and the low complication rate show the potential of this technique for the treatment of horizontal augmentation of lateral ridges and the efficacy of the new resorbable synthetic membrane.* Int J Oral Maxillofac Implants 2011;26:404–414

Key words: *anorganic bovine bone–derived mineral, autogenous bone, guided bone regeneration, horizontal augmentation, resorbable membrane, sinus graft*

Augmentation through guided bone regeneration (GBR) has become a major treatment option to provide optimal bone support for osseointegrated dental implants. Initially, only simple defects, including dehiscence and fenestration defects, were treated with GBR.[1–9] In addition, GBR has been used for horizontal and vertical ridge augmentation[4–13] and has demonstrated reproducible outcomes with high implant survival rates and low complication rates.[14]

The so-called "knife-edged" ridge, or Cawood and Howell Class IV edentulous arch,[15] presents a unique problem for horizontal augmentation. The necessary height of the ridge is adequate, but the width is insufficient, often making implant placement impossible without prior treatment.[16] However, there is a good prognosis for this treatment, as the residual ridge can be used to stabilize a bone graft, making it less subject to movement, one of the factors that may lead to graft failure. To prevent movement of the bone graft, autogenous bone blocks are often screwed onto the ridge to ensure stability and subsequent new bone formation.[17–20] Bone blocks (also referred to as "onlay bone

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grafts") can be fixated onto the residual ridge, providing a limited number of additional bone-forming cells at the augmentation site, and may eliminate the need for a nonresorbable titanium-reinforced membrane.[21] Studies of onlay bone grafting have reported 60% to 100% implant survival rates, with the majority of reported survival rates above 90%.[1,22] However, block bone grafts are associated with varying morbidity depending on the harvest site[23–25] and early resorption, which could compromise the clinical outcome.[17,26] Thus, for partially edentulous patients, it has been recommended that GBR may be an alternative for patients presenting with advanced ridge atrophy.[22]

Clinical studies employing GBR for the treatment of knife-edged ridges have used both nonresorbable and resorbable membranes.[11,27] To obtain the necessary ridge volume with GBR, autogenous bone or bone substitutes are placed under the barrier membrane to prevent collapse of the augmented volume.[28]

Resorbable membranes show better soft tissue compatibility compared to nonresorbable membranes.[8,29,30] Reports of clinical and preclinical animal studies have demonstrated that a resorbable membrane in combination with particulated bone or bone substitute can be used for the treatment of knife-edged ridges. Friedmann et al reported on a clinical study that used a slowly resorbing collagen membrane in combination with anorganic bovine bone–derived bone mineral (ABBM) for the augmentation of horizontally deficient ridges.[30] Good results were obtained, but the handling of the collagen membrane was technique-sensitive, as has been observed with nonresorbable membranes.[21] Hämmerle et al used ABBM in combination with a collagen membrane and concluded that this was an effective treatment for horizontal ridge augmentation.[27] Similarly, Zitzmann et al performed a histologic analysis of defects that had been filled with ABBM and covered with a collagen membrane.[31] Their results indicated that ABBM may be a suitable material for staged localized ridge augmentation. As an additional osteogenic component, particulated autogenous bone can be mixed with bone substitutes to add more osteogenic factors and a limited number of osteogenic cells to the augmentation site. The potential advantages of this treatment modality compared to autogenous bone block application are increased exposure to osteoinductive growth factors and greater osteoconductive surface. Autogenous bone can be mixed with ABBM, and harvesting a smaller amount of autogenous bone may result in decreased morbidity from this procedure.

Traditional synthetic membranes have demonstrated therapeutic problems with traditional polymers, eg, polylactic acid, because they provoke inflammatory and foreign-body reactions upon degradation.[32] More recent experimental results with a newly developed synthetic resorbable membrane made of polyglycolic acid and trimethylene carbonate have yielded positive results. Recent studies in an animal model with this membrane demonstrated no histologic foreign-body or inflammatory reactions.[33] This synthetic resorbable membrane has been designed to slowly resorb over 4 to 6 months, providing a prolonged barrier function to ensure that newly formed bone has sufficient time to mature before soft tissue can grow into it.

The purpose of the clinical series presented herein was to evaluate clinically and histologically the possibility of using this new synthetic resorbable membrane in combination with a mixture of ABBM and autogenous particulated bone for the horizontal augmentation of knife-edged ridges.

MATERIALS AND METHODS

This case series reports on patients who were consecutively treated in the posterior mandible or maxilla with horizontal augmentation using GBR and particulated autografts from January 2003 through May 2006. All patients required augmentation of a "knife-edged" ridge for subsequent implant placement (Cawood-Howell Class IV[15]), and some patients also required sinus floor elevation. All patients were treated in a private practice in Budapest, Hungary, and all surgical procedures were performed by the same practitioner, who has more than 15 years of experience in oral surgery and implant therapies. The prosthetic treatments were performed and restored by the first author and other private practitioners. All patients presented with a ridge that was 4 mm or less horizontally (Table 1).

Patients in good physical health and possessing the ability to maintain good oral hygiene were treated with the new resorbable membrane and bone grafting. All patients were fully informed about the treatment prior to the first surgical procedure and gave written consent for the procedure. Patients were not eligible for this treatment if they were current smokers, engaged in excessive alcohol consumption, or had uncontrolled systemic conditions or uncontrolled periodontal disease.

Treatment Protocol

All patients were treated with horizontal ridge augmentation using a recently developed synthetic barrier membrane composed of a microporous structure of synthetic bioabsorbable glycolide and trimethylene carbonate copolymer fiber (GORE RESOLUT ADAPT LT Regenerative Membrane, WL Gore & Associates). This membrane was developed with a new chemical

Table 1 Clinical Data of Surgical Sites Treated with Horizontal Ridge Augmentation for Subsequent Implant Placement

Patient no. (site no.)	Gender	Age (y)	Arch	Graft type	Healing time (mo)		Histology
					Graft	Implant	
1 (1)	M	50	Maxilla	Autograft	6.5	6.8	Yes
2 (2)	F	52	Maxilla	Autograft	6.3	6.0	–
3 (3)	F	57	Maxilla	Autograft	6.3	5.6	Yes
4 (4)	F	52	Maxilla	Autograft	10.8	5.8	Yes
5 (5, 6)	F	47	Maxilla	Autograft	6.4	6.0	–
			Maxilla	Autograft + ABBM	6.3	6.0	–
6 (7)	M	59	Maxilla	Autograft	6.3	5.4	–
7 (8)	F	30	Maxilla	Autograft	6.5	6.0	–
8 (9)	F	50	Maxilla	Autograft + ABBM	11.4	7.5	–
9 (10)	F	48	Maxilla	Autograft + ABBM	6.0	8.1	–
10 (11)	F	42	Maxilla	Autograft + ABBM	6.0	5.3	–
11 (12)	F	52	Maxilla	Autograft + ABBM	6.4	5.3	Yes
12 (13)	F	60	Maxilla	Autograft + ABBM	6.6	6.7	Yes
13 (14)	F	38	Maxilla	Autograft + ABBM	5.8	4.9	–
14 (15, 16)	F	63	Maxilla	Autograft + ABBM	10.0	11.7	Yes
			Maxilla	Autograft + ABBM	10.0	11.7	–
15 (17)	F	42	Maxilla	Autograft + ABBM	13.1	10.4	–
16 (18)	F	58	Maxilla	Autograft + ABBM	10.2	6.0	–
17 (19)	F	51	Mandible	Autograft + ABBM	6.3	6.4	–
18 (20)	M	51	Maxilla	Autograft + ABBM	7.1	8.2	–
19 (21, 22)	M	47	Mandible	Autograft + ABBM	11.3	6.0	–
			Maxilla	Autograft + ABBM	10.0	7.5	–
20 (23)	F	50	Mandible	Autograft + ABBM	7.3	5.1	–
21 (24)	F	45	Mandible	Autograft + ABBM	8.0	7.0	–
22 (25)	M	54	Maxilla	Autograft + ABBM	12.0	6.0	–
N (data available)		22			25	25	6
Mean (SD)	–	49.91 (7.60)	–	–	8.12 (2.32)	6.86 (1.89)	–
Median	–	50.50	–	–	6.60	6.00	–
Interquartile range		47.0–54.0			6.3– 10.0	5.8–7.5	–
Range		30– 63			5.8– 13.1	4.9–11.7	–

SD = standard deviation; autograft = autogenous bone; ABBM = anorganic bovine bone–derived mineral.

composition and ratio of the components, with the aim of a longer resorption time (4 to 6 months) than other resorbable membranes. Either autogenous bone or a combination of autogenous bone and ABBM (Bio-Oss, Geistlich Pharma) was used. The first seven patients were treated with autogenous bone alone to confirm the technique and use of the new membrane. Subsequent patients were treated with a combination of autogenous bone and ABBM to confirm the acceptability of a new osteoconductive material in the procedure and to limit the amount of harvested autogenous bone required for the procedure (Figs 1 and 2).

Patients were premedicated with amoxicillin (2 g) 1 hour before surgery and took 500 mg penicillin three times a day for 1 week following surgery. In the event of a penicillin allergy, clindamycin (600 mg) was used for premedication and following surgery (300 mg four times a day for 1 week). Oral sedation, usually triazolam (0.50 mg), was also frequently administered 1 hour prior surgery. Patients were instructed to rinse with 0.2% chlorhexidine solution for 1 minute to disinfect the surgical site, and a sterile surgical drape was applied to minimize the potential contamination from extraoral sources. A local anesthetic (Septanest with adrenaline, 1/100,000, Septodont) was applied.

Fig 1 Representative site grafted with autogenous bone only.

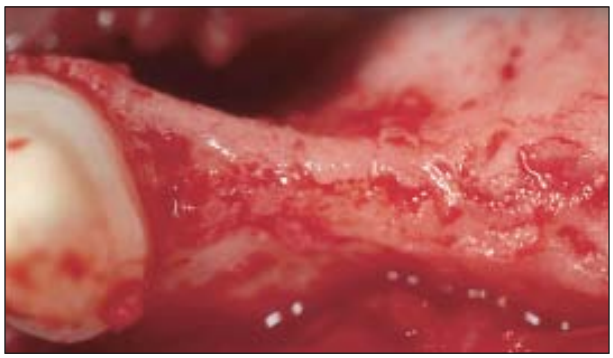


Fig 1a Occlusal view of posterior maxillary area shows the thin bone crest.

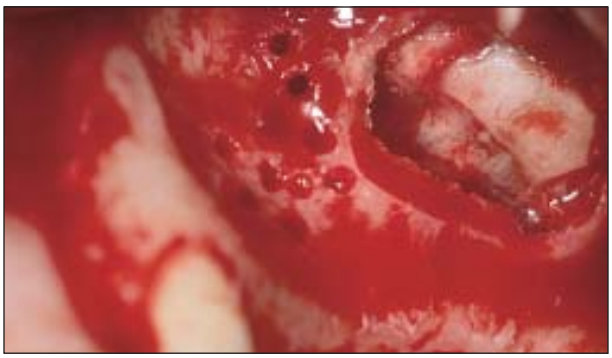


Fig 1b Buccal view of the defect area shows the elevated maxillary sinus. The recipient bone bed has been prepared with multiple decortication holes.

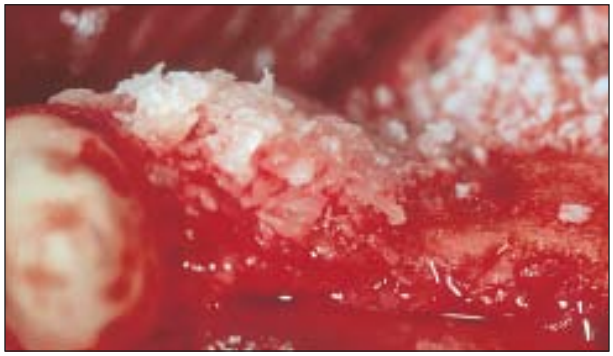


Fig 1c The autogenous particulated bone is in place.

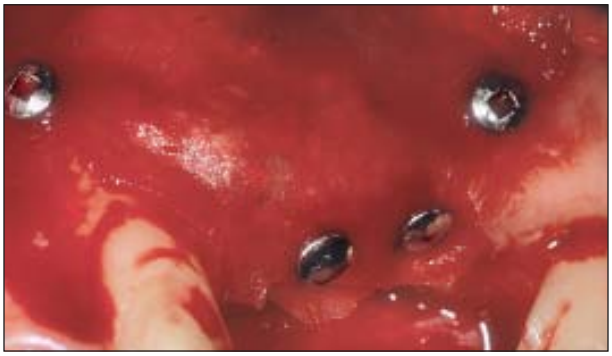
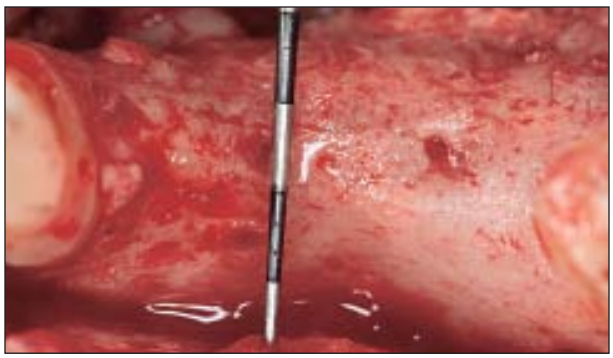
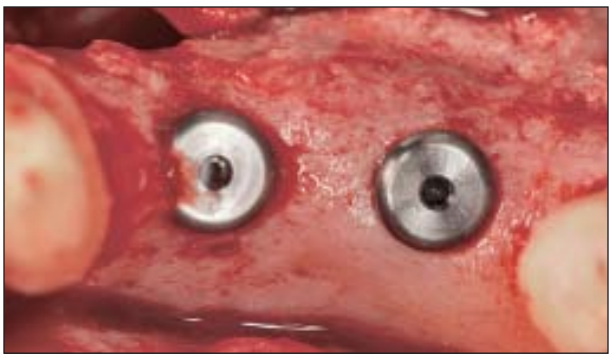


Fig 1d The membrane is fixated with titanium pins.





Figs 1e and 1f Occlusal views of the augmented bone crest after 6 months of uneventful healing.

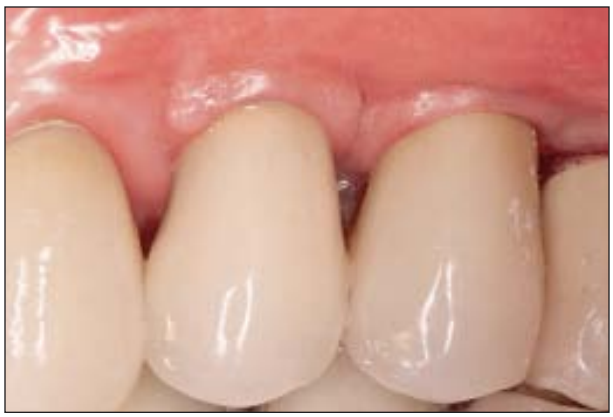


Fig 1g Definitive prosthetic reconstruction.

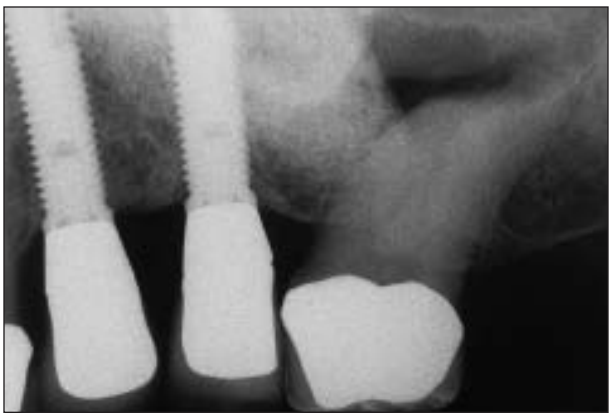


Fig 1h Periapical radiograph after 5 years of function.

Fig 2 Representative site grafted with a 1:1 mixture of autogenous particulated bone and ABBM in the posterior mandible.

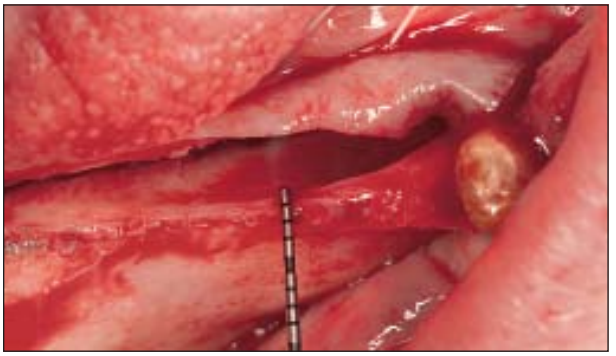


Fig 2a Occlusal view of the site showing the knife-edged ridge.

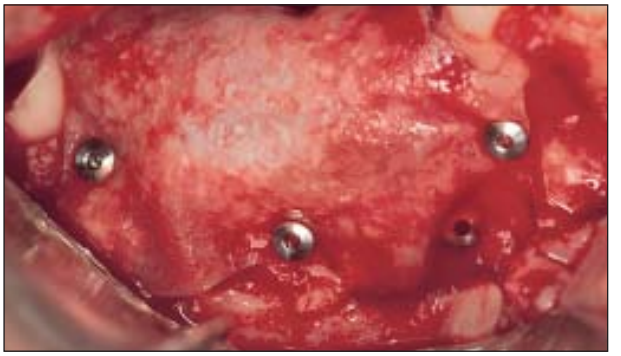


Fig 2b Buccal view after application of a mixture of autogenous particulated bone and ABBM granules. The synthetic resorbable membrane has been secured over the graft with titanium pins.

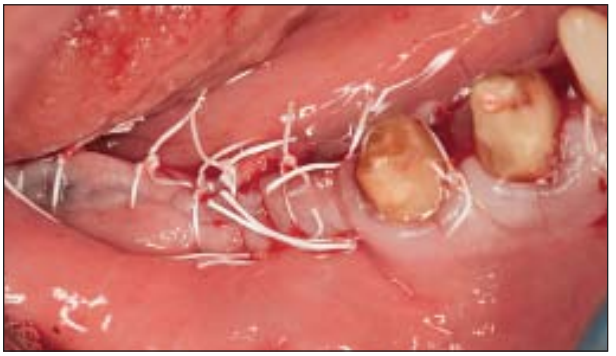


Fig 2c Sutured defect ensuring primary tension-free wound closure.

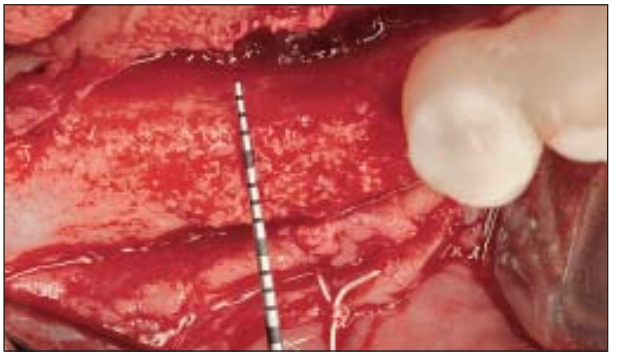


Fig 2d Re-entry surgery after 8 months reveals sufficient bone width to place dental implants.

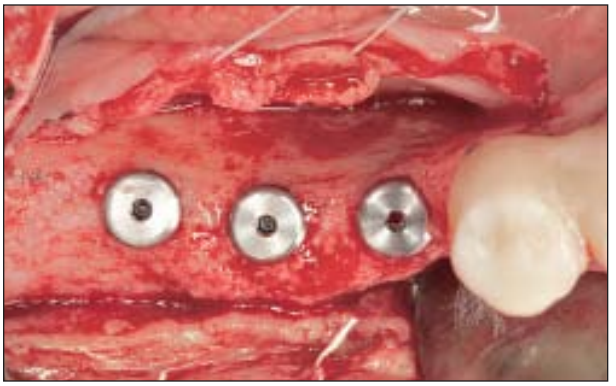


Fig 2e Implants in the augmented ridge.

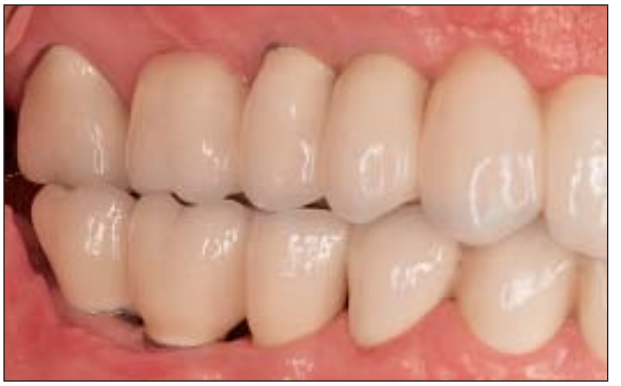


Fig 2f Definitive prosthetic reconstruction.

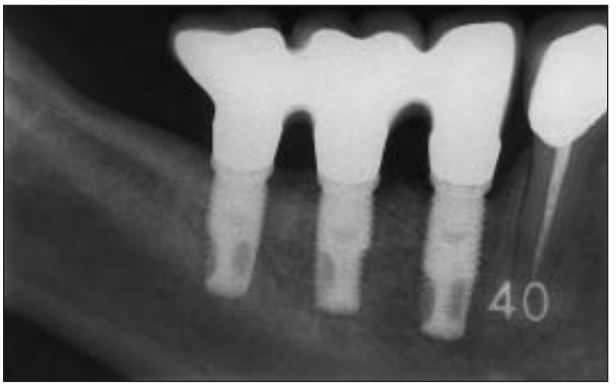


Fig 2g Radiographs after 12 months of loading.

The flap design was chosen to ensure primary tension-free closure after the bone grafting procedure despite the increased dimension of the ridge. A remote flap was raised that included crestal and vertical releasing incisions. A full-thickness, midcrestal incision into the keratinized gingiva was made with a surgical scalpel. The two divergent vertical incisions were placed at least one tooth away from the surgical site. In edentulous areas, the vertical incisions were placed at least 5 mm away from the augmentation site. After the primary incisions had been made, periosteal elevators were used to reflect a full-thickness flap beyond the mucogingival junction and at least 5 mm beyond the bone defect. In the posterior mandible, the lingual flap was elevated beyond the mylohyoid line, and sensitive anatomical locations, such as the mental and infraorbital nerves, were protected.

After flap elevation and evaluation of the defect size, autogenous bone was harvested from the retromolar regions using a trephine bur. In posterior mandibular sites, bone harvesting was performed on the same side and the harvest site preparation was included in the flap design. For maxillary sites, an additional flap was created in the posterior mandible for bone harvesting.

The harvested graft material was particulated in a bone mill (R. Quétin Bone-Mill, Roswitha Quétin Dental Products) and applied alone or mixed with ABBM in a 1:1 ratio (ie, a composite bone graft) and then applied. The bone at the exposed augmentation site was cleaned of all soft tissue remnants prior to grafting. Ridge measurements were made and are described later. The recipient bone bed was prepared with multiple decortication holes using a small round bur.

The new synthetic membrane was trimmed to the volume of the graft, and care was taken to avoid contact with the edges of the adjacent teeth. The membrane was fixed to at least two points on the lingual/palatal sides with titanium pins. The autogenous particulated bone graft or composite bone graft was placed into the defect, and the membrane was folded over and fixed into place with additional titanium pins on the vestibular side.

For maxillary sites with the sinus nearby, additional sinus floor augmentation was performed. No other combination grafting procedures were performed.

After the membrane was completely secured, the flap was mobilized to permit tension-free primary closure. A periosteal releasing incision connecting the two vertical incisions was performed to achieve elasticity of the flap. The flap was then sutured in two layers: first, horizontal mattress sutures (GORE-TEX CV-5 Suture, WL Gore & Associates) were placed 4 mm from the incision line; then, single interrupted sutures with the same suturing material were placed to close the edges of the flap, with at least a 4-mm-thick connective tissue layer left between the membrane and the oral epithelium. This intimate connective tissue–connective tissue contact provided a barrier to prevent exposure of the membrane. Vertical incisions were closed with single interrupting sutures. The single interrupted sutures were removed between 10 and 14 days postsurgery, and mattress sutures were removed after 2 to 3 weeks.

Measurements of the alveolar ridge width were taken intrasurgically, at the time of the original surgery, and again after the healing phase prior to preparation of the implant bed. The same caliper was used to take all measurements 2 mm apical to the top of the crest.

Complications in bone graft healing, such as membrane exposure, subsequent infection, and/or morbidity associated with the harvest site, were recorded. Periapical radiographs were obtained at the time of abutment connection and every 12 months thereafter with a long-cone paralleling technique. Functionally loaded implants were monitored to evaluate the following: absence of pain, foreign-body sensation, and/or dysesthesia; and radiologic contact between the host bone and the implant surface.

Specimen Preparation

At the time of implant placement, cylindric biopsy specimens were obtained from selected healed and augmented surgical sites using a trephine bur with an inner diameter of 2.0 mm. Specimens were fixated in 4% formaldehyde. Before processing, they were rinsed in water, dehydrated in alcohol (70%, 80%, 90%, and 100%; 3 days in each concentration) and then defatted for 1 day in Xylol (Merck). Specimens were then placed for 2 weeks into a mixture of methyl methacrylate (MMA) (Merck) and 15% dibutylphthalate (Fluka) and then placed for 1 day in a mixture of MMA, 15% dibutylphthalate, and 1.5% dried benzoyl peroxide (Merck). Infiltration took place in an airproof sealed glass envelope for 2 weeks in a polymerization mixture of MMA, 15% dibutylphthalate, and 3% dried benzoyl peroxide at room temperature. Sections were then ground to a thickness of 80 µm on a rotating grinding plate (Struers).

Optical microscopy specimens were stained according to the procedure described by Richardson et al.[34] Azur II (Merck) was used for differentiation of the soft tissue and Pararosalin (Sigma-Aldrich) was used for the differentiation of native and new bone. Imaging was performed with a microscope (Carl Zeiss) and a digital camera (CC-12, Soft Imaging System). Images were optimized and evaluated with the analySIS program (Soft Imaging System).

Statistical Analysis

All data were analyzed by descriptive methods and means, standard deviations, medians, and interquartile ranges were calculated using SAS statistical software (version 9.1.3, SAS Institute). Implant survival was estimated using life table analysis.

Table 2 Measurements of the Ridges Before and After Augmentation

Site no.	Ridge width (mm) Baseline	Re-entry	Gain	No. of implants placed	Follow-up (months)
1	2	8	6	2	66
2	4	8	6	2	66
3	1	8	7	3	64
4	4	8	4	2	59
5	2	8	6	2	62
6	2	7	5	1	34
7	3	9	6	3	62
8	2	6	4	1	59
9	3	9	6	1	46
10	2	6	4	1	50
11	4	10	6	1	50
12	3	9	6	3	49
13	3	8	5	3	48
14	3	7	4	3	47
15	1	9	8	4	40
16	1	5	4	4	40
17	1	7	6	1	37
18	2	8	6	2	37
19	2	8	6	3	40
20	1	8	7	3	37
21	3	7	4	2	32
22	2	5	3	2	32
23	1	10	9	3	34
24	1	8	7	3	30
25	2	6	4	3	26
N (data available)	25	25	25	25	25
Mean (SD)	2.20 (1.00)	7.68 (1.35)	5.56 (1.45)	2.32 (0.95)	45.88 (12.43)
Median	2.00	8.00	6.00	2.00	46.00
Interquartile range	1.0–3.0	7.0–8.0	4.0–6.0	2.0–3.0	37.0–59.0
Range	1–4	5–10	3–9	1–4	26–66

SD = standard deviation.

RESULTS

Clinical Results

This case series reports on patients who presented to a clinical practice and required horizontal bone augmentation prior to implant placement. The indication for horizontal ridge augmentation generally resulted from a lack of horizontal bone width in the posterior maxilla or mandible. For maxillary sites, if a pneumatized sinus was also present at the planned implant site, a sinus floor augmentation was carried out simultaneously (17 of 21 maxillary sites).

Fifty-eight implants were placed in 22 patients with 25 knife-edge ridges (17 women and 5 men with a mean age of 50 years). Intraoperative measurements indicated an average residual bone width of 2.20 ± 1.00 mm (range, 1 to 4 mm) (Table 2). No ridges were wide enough to place dental implants as, generally, at least 6 mm are required.[2] Mean baseline ridge width was 2.29 mm for the maxilla (84% of surgical sites) and 1.75 mm for the mandible (16% of surgical sites).

After horizontal augmentation and a mean graft healing period of 8.12 ± 2.32 months (range, 5.8 to 13.1 months), the mean ridge width was 7.68 ± 1.35 mm, for a mean increase of 5.56 ± 1.45 mm in ridge width. After the graft healing period, 58 implants with an anodized TiUnite surface (Brånemark System, Nobel Biocare) were placed (Table 3).

Table 3 Dimensions and Locations of Implants Placed

Implant diameter/ length (mm)	Locations of implants				Total
	Maxilla		Mandible		
	Right	Left	Right	Left	
3.75					
8.5	–	–	1	2	3
10	–	–	3	1	4
11.5	2	1	2	–	5
13	8	11	–	–	19
15	–	1	–	–	1
4.0					
8.5	–	–	–	2	2
13	5	7	–	–	12
15	7	5	–	–	12
Total	22	25	6	5	58

Of the 58 implants placed, 43 were placed in sites augmented with a combination of ABBM and autogenous bone (74.1%) and 15 were placed into sites augmented with autogenous bone only (25.9%) (Table 1). Implants were either 3.75 or 4.0 mm in diameter, and implant lengths ranged from 8.5 to 15 mm, with the majority of implants being 13 or 15 mm in length (Table 3).

The graft and implant healing periods were uneventful in all patients, and no complications, such as membrane exposure, infections, or harvest site morbidity, were observed. No residual pieces of the membrane were observed at stage-two surgery.

Postoperative swelling of the donor sites was remarkable in most cases, with a maximum swelling at 48 hours postoperatively. Swelling gradually subsided; it was still apparent at 1 week but disappeared completely after 10 days. Postoperative discomfort was primarily associated with tension from the swelling, but pain was minimal. No major complications, such as hemorrhage, postoperative infection, mandibular fracture, or neurosensory disturbances, occurred in any patients in this case series.

The experimental membranes used in these augmentations showed no device-related side effects. Healing was similar for the mandibular and maxillary sites as well as for the cases augmented with autograft or with the composite graft. Upon reopening of the surgical site at implant placement, the tissue underneath appeared healthy, with a healthy periosteal layer between the soft tissue and the bone, similar to results previously reported for nonresorbable and collagen membranes.[20,27]

After an average of 6.86 months of implant healing time (SD, 1.89 months; range, 4.9 to 11.7 months), healing abutments were placed in the 25 surgical sites. In three cases, primary implant stability had been sufficient to place the healing abutments at implant placement. All implants appeared clinically stable upon reentry and were maintained for provisional and definitive prosthetic restoration.

All 58 implants have survived to date (100.0% at all examinations; life table analysis) with an average follow-up of 45.88 ± 12.43 months. There does not appear to be any difference in survival between implants placed in the mandible or the maxilla or between sites augmented solely with autograft or with the composite graft.

Histologic Findings

In all, six biopsy specimens were evaluated, three from surgical sites treated with autogenous bone only and three from surgical sites treated with a mixture of autogenous bone and ABBM. Representative histologic specimens are presented in Fig 3. The original intention was to evaluate biopsy specimens from every augmented surgical site. However, because of problems with staining and storage of the specimens, only six of the specimens could be histologically evaluated to differentiate between preexisting bone, newly formed bone, and membrane. Because several of the maxillary sites included simultaneous sinus elevation, this was always evident in the augmentation and was usually observed in the biopsy specimen. In two of the sites augmented with ABBM and autogenous bone, the horizontally augmented ridge could be distinguished in the histologic specimen. Both specimens demonstrated newly mineralized bone in various stages of maturation. In one histologic specimen, the cortical plate of the former knife-edged ridge

Fig 3 Histologic views of a regenerated area from the maxillary right canine area. It had healed for 6.6 months.

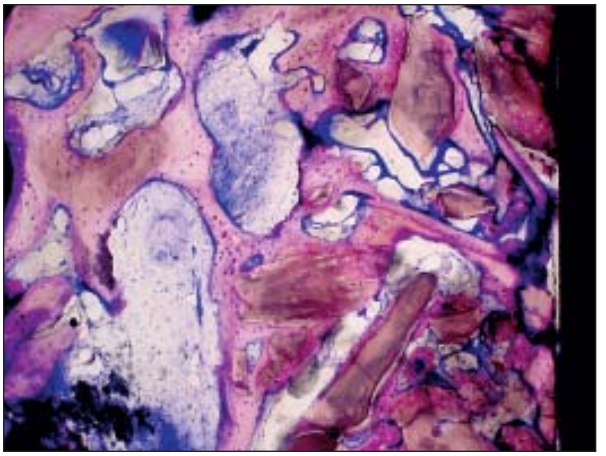


Fig 3a *(Left)* The original bone (knife-edged ridge) can be seen on the left side. The right side shows the mixture of autogenous bone and ABBM used for augmentation. The ABBM particles are connected by a dense network of newly formed bone (original magnification ×25).

Fig 3b *(Above)* Compact augmentation with well-integrated ABBM particles. The bone surrounding the particles is of variable degrees of maturity (original magnification ×50).

was observed, and the augmentation area showed that the ABBM was connected by a dense network of newly formed bone. In this specimen, only very small amounts of the harvested autogenous bone could be observed. Since there was no sign of resorption of the ABBM particles, it was assumed that the autogenous bone used for augmentation had been resorbed and replaced by newly formed bone. There was no histologic evidence of the GBR membrane.

Although there was a limited number of histologic specimens that could be analyzed, no difference in the amount of newly formed bone observed between the apical and coronal parts of the biopsies was detected.

DISCUSSION

The case series presented herein demonstrates that the combination of particulated augmentation material (either autogenous bone alone or a combination of autogenous bone and ABBM) and a resorbable membrane can be used safely and effectively for horizontal augmentation of knife-edged ridges in the posterior maxilla or mandible. Although the healing time between grafting and implant placement can be regarded as a compromise between the time to form a sufficient amount of new bone and the need for a timely prosthetic solution for a patient, the benefit of this two-stage procedure is that it provides the horizontal ridge width necessary to successfully place an implant.

Healing of the bone graft was uneventful in all patients in this prospective case series. The synthetic membrane reported herein showed good soft tissue compatibility, and no membrane exposures or infections occurred at any of the surgical sites. Similar results for soft tissue healing have been reported for both nonresorbable expanded polytetrafluoroethylene (e-PTFE) and resorbable synthetic and collagen membranes.[12,13,27,35] Recently, a new synthetic membrane composed of different resorbable materials has been used in preclinical animal models and clinical studies with similar results and comparable soft tissue healing.[36–39] Other authors, however, have reported spontaneous exposures of collagen and e-PTFE membranes.[9,28] Nonresorbable e-PTFE membranes are still regarded as the gold standard in GBR; however, frequently reported soft tissue problems, as well as the need to remove the membrane, have led to the development and use of resorbable membranes.[9,28] The lack of titanium reinforcement for the resorbable membrane can be overcome by secure fixation of the membrane on both the lingual/palatal and the vestibular side. This technique immobilizes the graft material, allowing for the formation of the desired amount of bone.

In this case series, there was a mean horizontal bone increase of 5.52 mm (± 1.40 mm), with some sites gaining up to 9 mm. Overall, only two sites resulted in a horizontal ridge width of less than 6 mm; however, in both cases, implant placement was achieved and the

implants have survived for more than 32 months. Similarly, 4.6 mm of horizontal bone gain was reported in a study that used autogenous bone blocks covered with ABBM particles and resorbable collagen membranes,[17] whereas a somewhat less favorable result of 3.6 mm horizontal bone gain was achieved when using ABBM particles alone as grafting material with collagen membranes.[27] The differences may be attributed to the use of autogenous particles mixed with ABBM, which may have resulted in a more osteogenic graft. Also, the membrane used in this report has a longer resorption time, which may have allowed more time for the graft to mature.

Within the sites treated in this patient series, no differences could be detected between the sites augmented with autogenous bone only and those augmented with a mixture of autogenous bone and ABBM. However, the number of sites treated with autogenous bone alone is limited. In the sites treated with the mixture of autogenous bone and ABBM, the ABBM particles showed good incorporation with the newly formed ridge. This is supported by the available histologic evidence of the augmentation area showing that the ABBM was connected by a dense network of newly formed bone. In another published report in which autogenous bone blocks were covered with ABBM particles and collagen membranes, at re-entry, the ABBM particles showed fibrous encapsulation only and no evidence of osseous integration.[17] This may further support the use of particulated autogenous bone mixed with ABBM rather than ABBM layered onto autogenous bone blocks.

Because all implants have survived to date, this case series demonstrates the feasibility of using a new resorbable membrane in GBR for horizontal ridge augmentation. However, the high rate of implant survival reported in this case series has to be viewed cautiously, since implant success according to established methods has not yet been investigated.

Recent reports in the literature indicate that the standard treatment for knife-edged ridges has changed in recent years.[27] The use of bone grafting materials and resorbable membranes to treat knife-edged defects with horizontal augmentation may lead to less morbidity in the treatment of patients with these defects. In addition, the use of ABBM in these procedures may lessen the need for harvested autogenous bone and may generally lead to decreased morbidity and therefore increased patient comfort and satisfaction associated with these regenerative procedures. The absence of major complications in any of the harvest sites in this case series supports the potential benefit of ABBM for these types of procedures. However, the positive results obtained in this case series need to be proven by larger randomized and controlled clinical trials.

CONCLUSION

Within the limitations of this case series, the treatment of horizontally deficient alveolar ridges with the GBR technique using autogenous bone, with or without ABBM, and a resorbable barrier membrane can be regarded as successful and may lead to implant survival. The regenerated bone can provide good osseointegration of the dental implant. Histologic evaluation of the regenerated bone has shown that the autogenous bone is mostly resorbed and replaced by vital bone and the bone substitute particles are connected by new vital bone. Nevertheless, randomized controlled clinical studies are necessary to prove that other resorbable membranes, as well as other bone substitutes, can support healing in the same way as has been demonstrated in this case series.

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