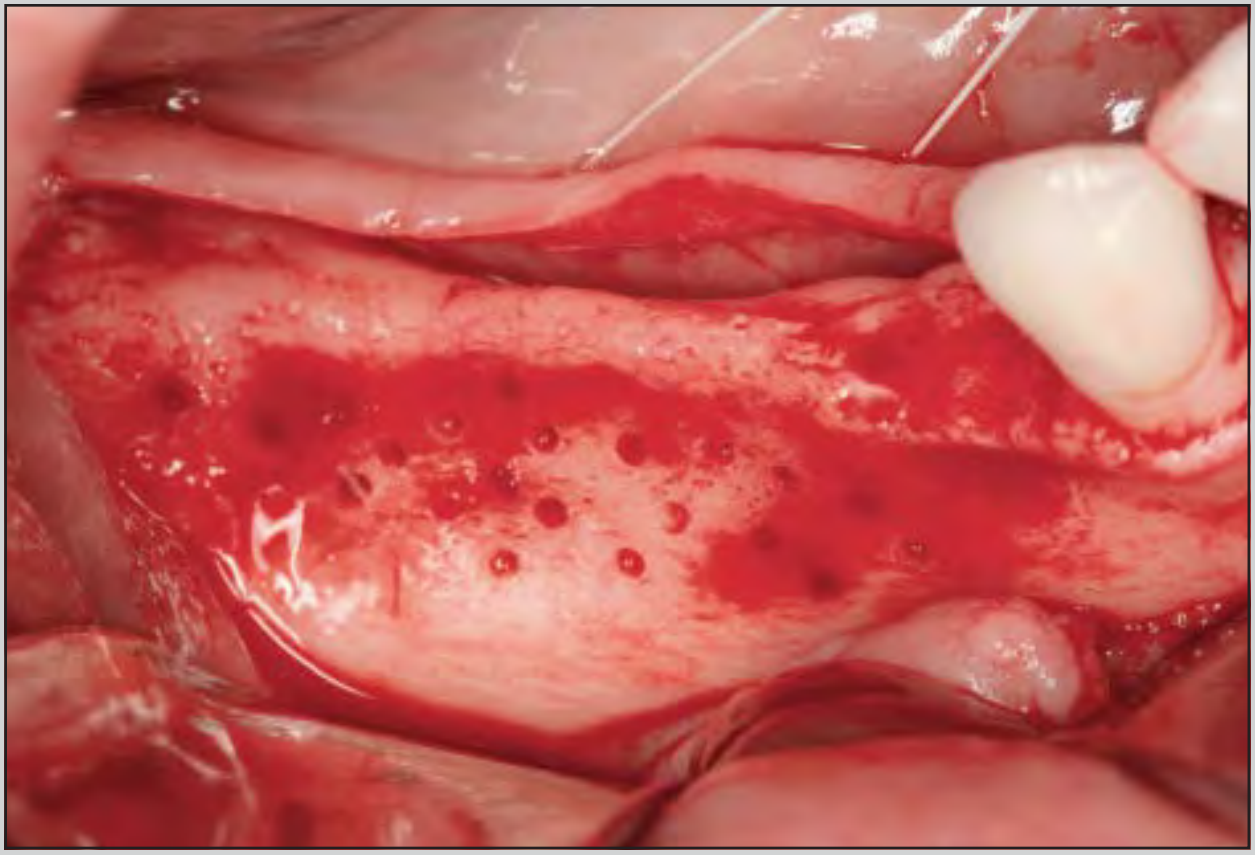
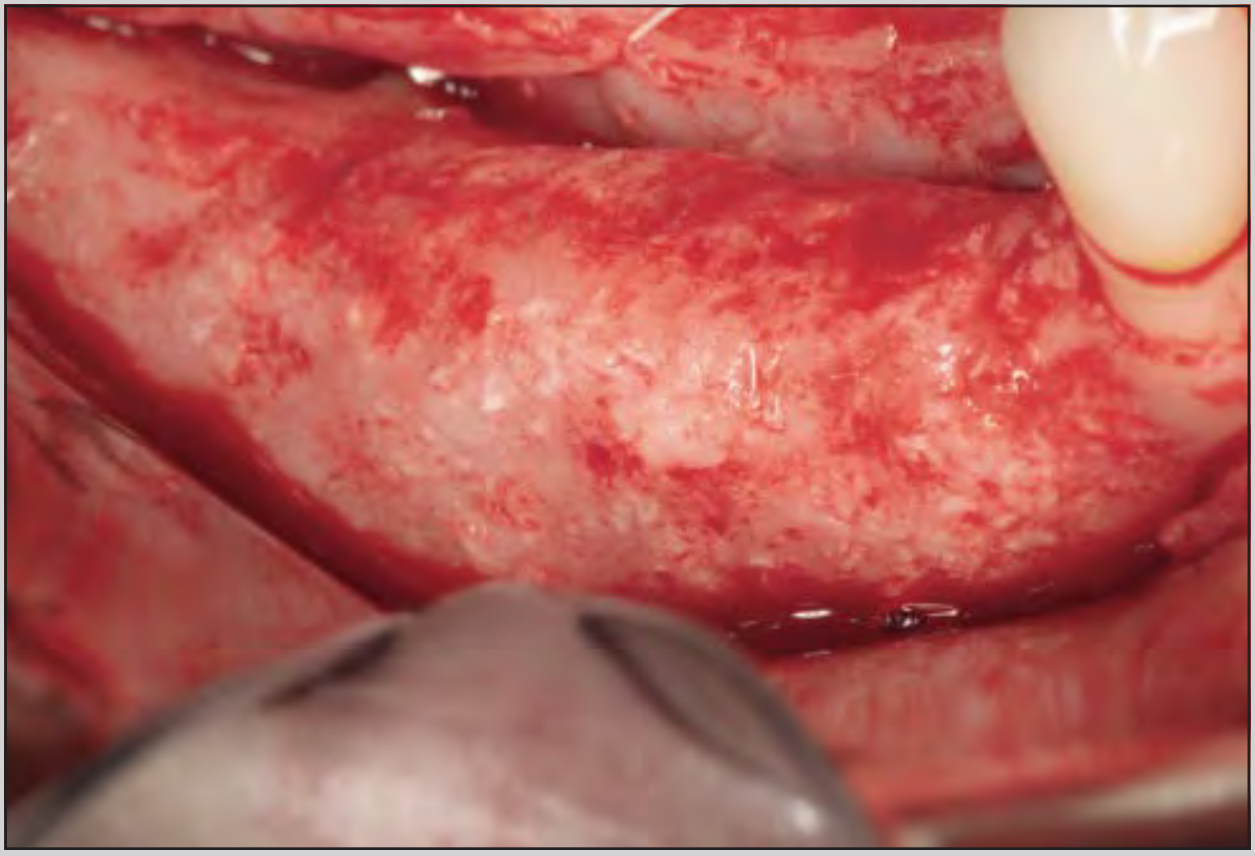
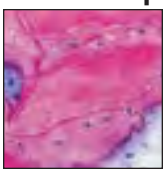




Horizontal Ridge Augmentation with a Collagen Membrane and a Combination of Particulated Autogenous Bone and Anorganic Bovine Bone–Derived Mineral: A Prospective Case Series in 25 Patients



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This prospective case series evaluated the use of a resorbable natural collagen membrane with a mixture of autogenous bone and anorganic bovine bone–derived mineral (ABBM) for lateral ridge augmentation and subsequent implant placement. A mixture (1:1) of particulated autogenous bone and ABBM was used for lateral ridge augmentation and covered with a resorbable, natural collagen bilayer membrane to treat knife-edge ridges and prepare them for implant placement. Ridge measurements were obtained pre- and postsurgery, complications recorded, and biopsy specimens examined histologically. Seventy-six implants were placed in 25 patients with 31 knife-edge ridge surgical sites. One defect had a bone graft complication (3.2%; exact 95% confidence interval: 0.1%, 16.7%). Clinical measurements revealed an average of 5.68 mm (standard deviation [SD] = 1.42 mm) of lateral ridge augmentation after a mean 8.9-month (SD = 2.1 months) graft healing period. Clinically, all treated ridges were sufficient in width for subsequent implant placement. All implants survived with an average follow-up of 20.88 months (SD = 9.49 months). Histologic analysis of nine surgical sites showed that ABBM was connected with a dense network of newly formed bone with varying degrees of maturation. Histomorphometric analysis demonstrated that autogenous bone represented a mean of 31.0% of the specimens, ABBM 25.8%, and marrow space 43.2%. The treatment of horizontally deficient alveolar ridges with the guided bone regeneration technique using autogenous bone mixed with ABBM and a natural collagen resorbable barrier membrane can be regarded as successful. Implant success and survival need to be confirmed with long-term follow-up examinations. (Int J Periodontics Restorative Dent 2013;33:299–307. doi: 10.11607/prd.1407)

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Augmentation using guided bone regeneration (GBR) has become a major treatment option to provide optimal bone support for osseointegrated dental implants. Simple defects were initially treated with GBR, including dehiscence and fenestration defects.[1–9] In addition, GBR has been used for horizontal and vertical ridge augmentations[4–14] and has demonstrated reproducible outcomes with high implant survival and low complication rates.[15]

The so-called knife-edge ridges, or Cawood and Howell Class IV edentulous jaws,[16] present a unique problem for horizontal augmentation. The necessary height of the ridge is adequate on the lingual/palatal aspect, but the width is insufficient, thereby making implant placement often impossible without prior treatment.[17] However, there is good prognosis for this treatment as the residual ridge can be used to stabilize the bone graft, making it less subject to movement, one of the factors that may lead to a failure. To avoid movement of the bone graft, autogenous bone blocks are often screwed onto the ridge to ensure stability and subsequent new bone

formation.[18–21] However, block bone grafts are associated with varying morbidity depending on the harvest site[22–24] and early resorption, which could compromise the clinical outcome.[18,25] Thus, for partially edentulous patients, GBR has been used as an alternative grafting procedure for patients presenting with advanced ridge atrophies.[26]

Clinical studies using GBR for the treatment of knife-edge ridges employed both nonresorbable and resorbable membranes.[11,12,27] Resorbable membranes have shown better soft tissue compatibility compared with nonresorbable membranes.[8,28,29] Hämmerle et al used anorganic bovine bone–derived mineral (ABBM) in combination with a more rapidly resorbing, natural collagen membrane and concluded that this was an effective treatment for horizontal ridge augmentation.[27] Similarly, Zitzmann et al performed a histologic analysis in defects that had been filled with ABBM and covered with the same collagen membrane.[30] Their results indicated that ABBM may be a suitable material for staged localized ridge augmentation.

A recent prospective case series reported on the use of a more slowly resorbing, synthetic membrane in combination with autogenous particulated bone mixed with ABBM.[12] In this case series,[12] the amount of horizontal bone gain was more than in the previously reported case series.[27] However, it is not clear whether the difference in results can be attributed to the faster resorption time of the membrane or the lack of autogenous bone in the graft. Results of nonclinical studies that compared nonresorbable and resorbable membranes[31,32] and the case series using the natural collagen membrane[27] may indicate that a slowly resorbing membrane is not necessary for horizontal augmentation.

The use of a more rapidly resorbing natural collagen membrane and 1:1 mixture of autogenous particulated bone/ABBM as grafting material for horizontal augmentation has not yet been investigated prospectively. Accordingly, the purpose of this clinical series was to evaluate clinically and histologically the use of a more rapidly resorbing natural collagen membrane in combination with a mixture of ABBM and autogenous particulated bone in horizontal augmentation of knife-edge ridges to confirm the acceptability of the osteoconductive material and to limit the amount of harvested autogenous bone required.

Method and materials

This case series reports on patients presenting to a clinical practice and requiring horizontal bone augmentation for the purpose of implant placement. The indication for horizontal ridge augmentation generally resulted from a lack of horizontal bone width in the posterior maxilla or mandible. Patients in this case series were consecutively treated in the posterior mandible or maxilla with horizontal augmentation using GBR and particulated autografts from March 2007 through February 2010. All patients required augmentation of a knife-edge ridge for subsequent implant placement (Cawood-Howell Class IV), including some patients who also required a sinus floor elevation. All patients presented with a horizontal ridge of 4 mm or less and in need of horizontal ridge augmentation prior to dental implant placement (Table 1). Patients in good physical health and able to maintain good oral hygiene were treated with the resorbable collagen membrane and bone graft. All patients were fully informed about the treatment prior to the first surgical procedure and gave written consent. Patients were not eligible for this treatment if they were current smokers, engaged in excessive alcohol consumption, or had uncontrolled systemic conditions or periodontal disease. All patients were treated with horizontal ridge augmentation using a bilayer resorbable membrane derived from natural collagen (Bio-Gide Resorbable Bilayer Membrane, Geistlich Pharma) and a combination of autogenous bone and ABBM (Bio-Oss, Geistlich Pharma) (Figs 1 and 2). The medications, flap design and sutures, and bone harvesting procedure used in this case series have been described previously.[12] Maxillary cases were combined with sinus augmentation as indicated to achieve adequate bone height for implant placement. All patients in this case series were treated with a composite bone graft (ie, harvested bone mixed 1:1 with ABBM). Measurements of the alveolar ridge width were taken at the time of grafting and then at implant placement. The same caliper

Table 1 Surgical sites treated with horizontal ridge augmentation for subsequent implant placement

Patient (surgical site no.)	Sex	Age (y) (n = 25)	Arch	Healing time (mo)		Histology
				Grafts (n = 31)	Implants (n = 30)	
1 (1)	M	62	Maxilla	8.00	6.00	Yes
2 (1)	M	58	Maxilla	8.00	7.75	Yes
2 (2)			Mandible	9.25	6.00	Yes
3 (1)	F	72	Maxilla	13.00	6.00	
4 (1)	F	37	Mandible	13.25	5.25	
5 (1)	M	57	Maxilla	8.00	6.25	
5 (2)			Maxilla	8.00	6.25	
6 (1)	F	49	Mandible	7.5	4.25	
7 (1)	M	50	Maxilla	7.00	6.25	
8 (1)	M	62	Mandible	8.00	5.75	
9 (1)	F	61	Maxilla	8.25	5.75	Yes
9 (2)			Maxilla	10.25	5.75	
10 (1)	M	34	Maxilla	7.00	20.25	Yes
11 (1)	F	57	Mandible	6.50	3.50	
12 (1)	F	53	Mandible	6.00	7.75	Yes
13 (1)	F	62	Mandible	8.00	4.75	
14 (1)	M	59	Maxilla	10.00	6.00	Yes
15 (1)	F	30	Maxilla	7.75	5.50	
16 (1)	F	47	Mandible	7.50	9.00	
16 (2)			Mandible	7.50	9.00	
17 (1)	F	39	Maxilla	8.25	14.75	Yes
17 (2)			Mandible	13.00	14.00	
18 (1)	F	71	Maxilla	10.00	6.00	
19 (1)	F	55	Mandible	9.25	10.00	
20 (1)	F	54	Maxilla	11.25	6.00	Yes
21 (1)	F	61	Maxilla	8.50	6.00	
21 (2)			Maxilla	8.50	6.00	
22 (1)	M	38	Maxilla	9.25	5.25	
23 (1)	M	61	Mandible	8.00	6.00	
24 (1)	M	51	Maxilla	7.00	4.50	
25 (1)*	F	37	Mandible	14.00	NR*	
Mean (SD)		52.7 (11.4)		8.90 (2.06)	7.18 (3.51)	
Median		55.0		8.00	6.00	
Interquartile range		(47.0, 61.0)		(7.5, 10.0)	(5.75, 7.75)	
Range		(30, 72)		(6.0, 14.0)	(3.50, 20.25)	

SD = standard deviation; NR = not reported.
*Case no. 25 had the bone graft complication. Since the complication led to minimal bone gain, the procedure was subsequently repeated with successful results allowing for the placement and loading of two implants. Because the procedure was repeated, no implant healing time is reported for the initial procedure and this patient is not included in the cohort with implant healing times.

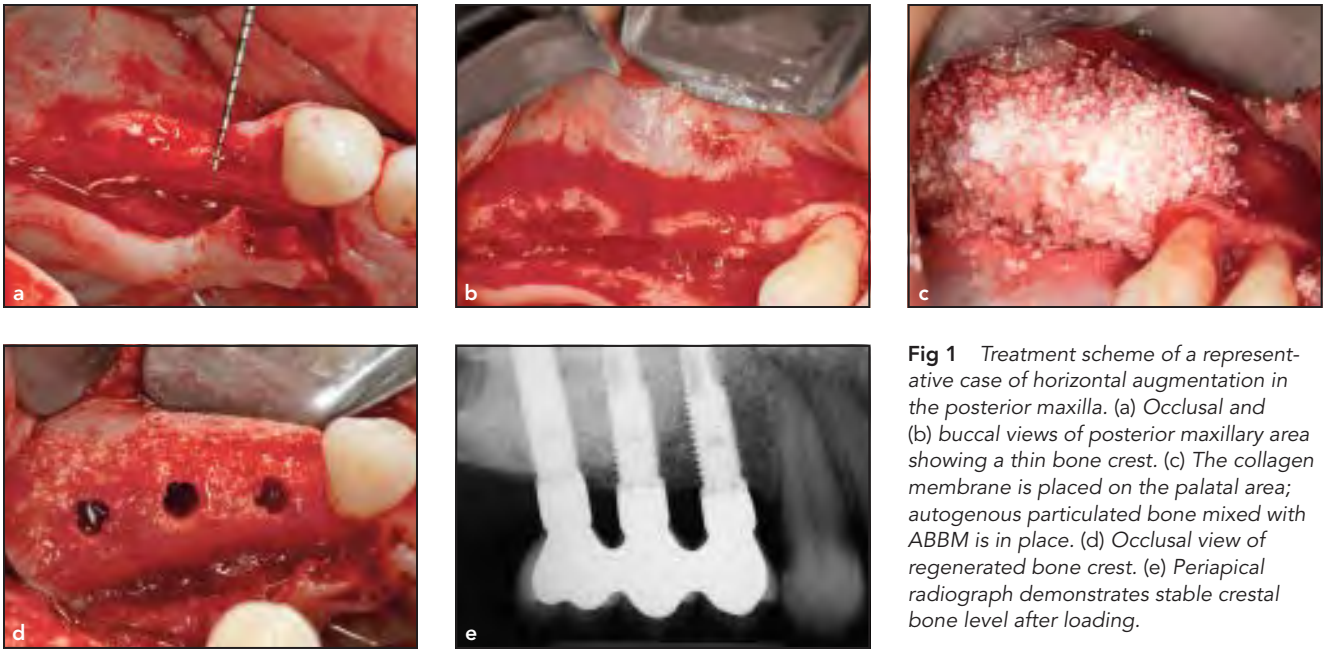

Fig 1 *Treatment scheme of a representative case of horizontal augmentation in the posterior maxilla.* (a) *Occlusal and* (b) *buccal views of posterior maxillary area showing a thin bone crest.* (c) *The collagen membrane is placed on the palatal area; autogenous particulated bone mixed with ABBM is in place.* (d) *Occlusal view of regenerated bone crest.* (e) *Periapical radiograph demonstrates stable crestal bone level after loading.*

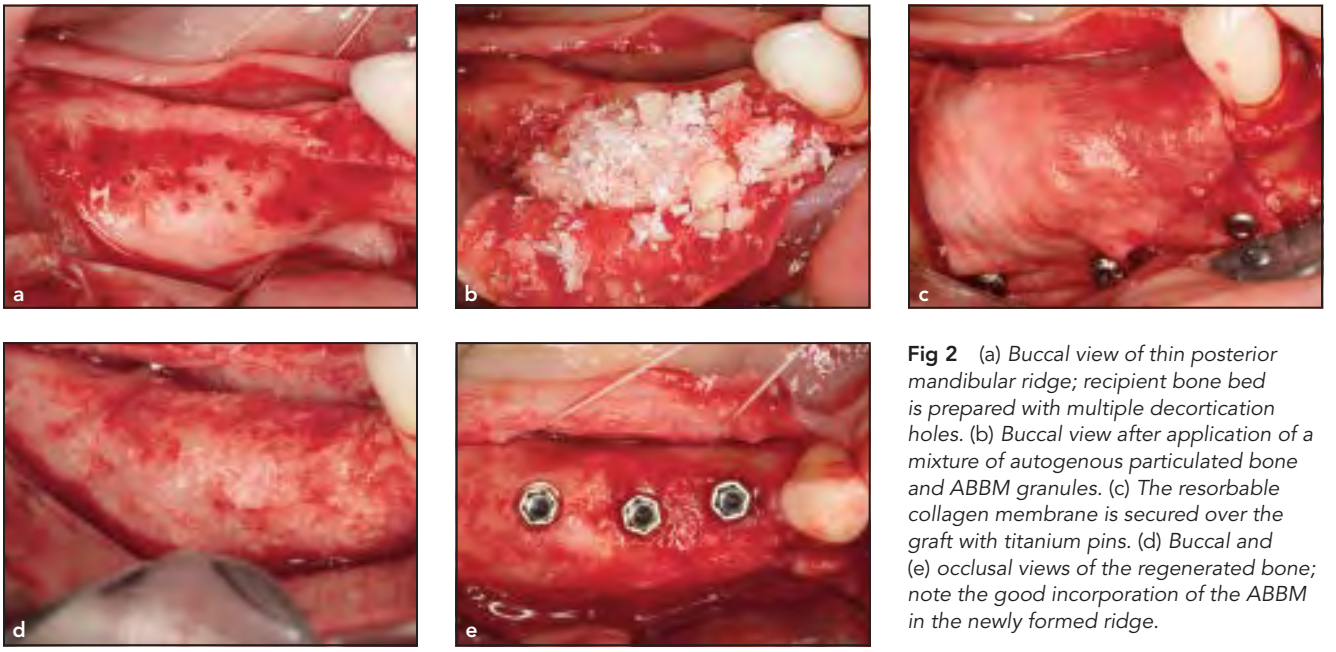

Fig 2 (a) *Buccal view of thin posterior mandibular ridge; recipient bone bed is prepared with multiple decortication holes.* (b) *Buccal view after application of a mixture of autogenous particulated bone and ABBM granules.* (c) *The resorbable collagen membrane is secured over the graft with titanium pins.* (d) *Buccal and* (e) *occlusal views of the regenerated bone; note the good incorporation of the ABBM in the newly formed ridge.*

was used to take all measurements 2 mm apically from the top of the crest. Periapical radiographs were taken at the abutment connection and every year thereafter with a long cone parallelling technique.

Complications in bone graft healing, such as membrane exposure, subsequent infection, and/or morbidity associated with the harvest site, were recorded. Functionally loaded implants were monitored to evaluate the following: absence of pain, foreign body sensation, dysesthesia; radiological contact between the host bone and the implant surface.

At the time of implant placement, nine cylindrical biopsy specimens were obtained from implant osteotomies of selected healed and augmented surgical sites using a trephine bur with an inner diameter of 2.0 mm. Specimens were fixated, stained with Azur II (Sigma-Aldrich Chemie), and prepared as described previously.[12]

All data were analyzed by descriptive methods and means, standard deviations [SDs], medians, ranges, and interquartile ranges using SAS statistical software (version 9.2, SAS). Implant survival was estimated using life table analysis.

Results

Seventy-six implants were placed in 25 patients with 31 knife-edge ridges (15 women and 10 men with a mean age of 52.7 years) (Table 1). For the maxillary cases, if an additional sinus proximity was present, a sinus floor augmentation was carried out simultaneously (16 of 18). Intraoperative measurements indicated an average residual bone width of 2.19 mm (SD = 0.64 mm; range 1 to 4 mm) (Table 2). All ridges were of insufficient width to place dental implants (generally at least 6 mm are required).[2] A comparison between the baseline ridge width for the maxilla (58.1%) and the mandible (41.9%) showed a mean residual ridge of 2.42 mm and 1.88 mm, respectively. After horizontal augmentation and a mean graft healing period of 8.9 months (SD = 2.1 months; range 6.0 to 14.0 months), the mean ridge width was 7.87 mm (SD = 1.61 mm), giving an increase of 5.68 mm (SD = 1.42 mm) in ridge width. There were no discernible statistical differences in bone width gain between maxillary and mandibular sites (P = .1399).

After the graft healing period, a total of 76 implants with an anodized TiUnite surface (Brånemark System, Nobel Biocare) were placed. Implants were either 3.5 mm, 3.75 mm, 4.0 mm, or 4.3 mm in diameter, and implant lengths ranged from 7 to 13 mm, with the majority of implants being 13 mm in length. With one exception, the graft and implant healing periods were uneventful in all cases. One patient developed an abscess at the graft site (3.2%; 95% confidence interval [CI]: 0.1%, 16.7%). The surgical site was opened and irrigated, and the patient was given antibiotics. The infection was treated effectively, but a major portion of the bone graft was lost and a minimal bone gain of 2 mm was achieved. The patient was successfully retreated with grafting and subsequent implant placement. The placed implants have been loaded for almost 2 years. Postoperative swelling of the donor sites was most pronounced 48 hours postsurgery. Swelling gradually subsided but was still visible at 1 week and disappeared completely after 10 days. Postoperative discomfort was primarily associated with tension from the swelling, but pain was minimal. No residual pieces of the membrane were observed at the stage-two surgeries. There were no device-related adverse effects associated with the use of the natural collagen membrane in these augmentation procedures.

Healing was similar for the mandibular and maxillary cases. Upon reopening of the surgical site at implant placement, the tissue beneath appeared healthy with a healthy periosteal layer between the soft tissue and bone, similar to results previously reported for nonresorbable and collagen membranes.[20,25] After a mean implant healing time of 7.18 months (SD = 3.51 months; range 3.50 to 20.25 months), the healing abutments were placed in the 30 surgical sites. In seven cases, primary implant stability was sufficient to place the healing abutments at implant placement. All implants appeared clinically stable upon reopening and were maintained for provisional and definitive prosthetic restoration. All 76 implants have survived to date (100.0% at all time points; life table analysis) with an average follow-up of 20.88 months (SD = 9.49 months). There does not appear to be any difference in implant survival between implants placed in the mandible or the maxilla.

Histologic findings

Nine specimens were examined histologically. The histologic samples were taken at a mean of 8.4 months of graft healing during the implant placement from the implant osteotomies using a 2-mm trephine for implant site preparation. Histomorphometric analysis

Table 2 Ridge measurements before and after augmentation

Patient (surgical site no.)	Ridge width (mm) (n = 31)			No. of implants placed (n = 30)	Follow-up (mo)
	Baseline	Reentry	Gain		
1 (1)	3.5	11.0	7.5	2	28.25
2 (1)	2.0	8.0	6.0	3	23.50
2 (2)	2.0	7.5	5.5	2	27.25
3 (1)	1.5	7.0	5.5	3	23.75
4 (1)	2.0	7.0	5.0	1	14.25
5 (1)	2.0	7.0	5.0	3	29.50
5 (2)	2.0	8.0	6.0	3	29.50
6 (1)	2.0	10.5	8.5	3	22.00
7 (1)	2.0	6.0	4.0	3	14.25
8 (1)	1.0	5.0	4.0	3	3.00
9 (1)	2.0	12.0	10.0	4	24.00
9 (2)	2.0	10.0	8.0	3	24.00
10 (1)	3.5	8.0	4.5	2	7.00
11 (1)	2.0	7.5	5.5	3	9.25
12 (1)	2.0	8.0	6.0	2	31.00
13 (1)	1.5	7.0	5.5	2	16.00
14 (1)	2.0	7.0	5.0	3	34.00
15 (1)	3.0	8.0	5.0	1	11.75
16 (1)	2.0	7.0	5.0	2	29.25
16 (2)	2.5	8.0	5.5	2	29.25
17 (1)	3.0	9.0	6.0	3	16.25
17 (2)	1.5	6.5	5.0	3	2.25
18 (1)	2.0	8.0	6.0	2	13.25
19 (1)	1.5	7.5	6.0	1	30.75
20 (1)	4.0	10.0	6.0	2	27.75
21(1)	2.5	8.0	5.5	4	12.75
21 (2)	2.5	8.0	5.5	4	12.75
22 (1)	2.0	8.0	6.0	1	16.50
23 (1)	2.5	7.5	5.0	2	23.75
24 (1)	2.0	8.0	6.0	4	39.50
25 (1)	2.0	4.0	2.0	0*	NR*
Mean (SD)	2.19 (0.64)	7.87 (1.61)	5.68 (1.42)	2.53 (0.90)	20.88 (9.49)
Median	2.00	8.00	5.50	3.00	23.63
Interquartile range	(2.00, 2.50)	(7.00, 8.00)	(5.00, 6.00)	(2.00, 3.00)	(13.25, 29.25)
Range	(1.0, 4.0)	(4.0, 12.0)	(2.0, 10.0)	(1.0, 4.0)	(2.25, 39.50)

SD = standard deviation; NR = not reported.
*Case no. 25 had the bone graft complication, 2 mm of bone gain, and needed additional grafting. The second graft was successful but is not reported. Since no implants were placed from the initial procedure, this table indicates that 0 implants were placed. This patient is not included in summaries of the cohort with implants.

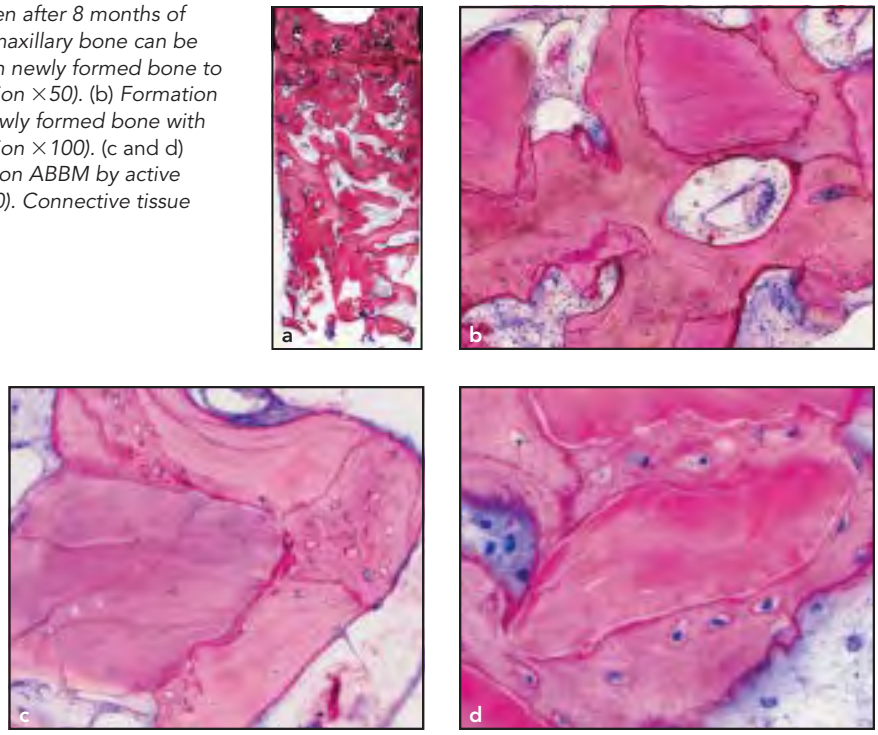

Fig 3 (a) *Overview of a histologic section taken after 8 months of graft healing (patient 1, Table 1). The original maxillary bone can be seen. The augmentation area is connected with newly formed bone to the original maxillary bone (original magnification ×50).* (b) *Formation of dense trabecular structures composed of newly formed bone with integrated ABBM granules (original magnification ×100).* (c and d) *Mixed deposition of lamellar and woven bone on ABBM by active osteoblasts (original magnification ×200, ×400). Connective tissue shows no sign of inflammatory reactions.*

demonstrated that autogenous or regenerated bone represented a mean of 31.0% of the specimens, ABBM 25.8%, and marrow space 43.2%. Representative histology is presented in Fig 3. In all biopsy specimens evaluated, ABBM was connected with a dense network of newly formed bone of various degrees of maturation. In two histologic specimens, the original cortical plate of the knife-edge ridge was observed and the augmentation area was connected with a dense network of newly formed bone connected with the original bone. There was no histologic evidence of the GBR membrane.

Discussion

The present case series demonstrates that the combination of particulated autogenous bone mixed with ABBM and a short-term resorbable, collagen membrane can be safely and effectively used for horizontal augmentation of knife-edge ridges in the posterior maxilla or mandible. With one exception involving infection of the bone graft (3.2%), healing of the bone graft was uneventful. The collagen membrane has shown good soft tissue compatibility, and no membrane exposures occurred at any of the surgical sites. Similar results of soft tissue healing have been reported for both nonresorbable expanded polytetrafluoroethylene (e-PTFE) and resorbable synthetic and collagen membranes.[12–14,27,34] Other authors, however, have reported more spontaneous exposures of collagen and e-PTFE membranes.[9,35] 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 encouraged the development and use of resorbable membranes.[9,35] The stability of the resorbable membrane can be improved by secure fixation on both the lingual/palatal and the vestibular sides. 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 5.68 mm (SD = 1.42 mm), with some sites gaining up to 10.0 mm. All cases resulted in a horizontal ridge width of at least 5 mm, and implant placement was achieved. All implants have survived to date and are in function (2 to 40 months).

Compared to other approaches for GBR, a 4.6-mm horizontal

bone gain was reported in a study using autogenous bone blocks covered with ABBM particles and resorbable collagen membranes,[18] whereas a somewhat less favorable result of 3.6 mm of horizontal bone gain was achieved when using ABBM particles alone as grafting material with short-term resorbable 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.

In this case series 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 histology of the augmentation area showing that the ABBM was connected by a dense network of newly formed bone. Similar histologic findings were reported in another study in which a mixture of ABBM and autograft was used for periodontal regeneration.[36] In another report in which autogenous bone blocks were covered with ABBM particles and collagen membranes, at reentry the ABBM particles showed fibrous incapsulation only and no evidence of osseous integration.[18] This may further support the use of particulated autogenous bone mixed with ABBM rather than ABBM layered on autogenous bone blocks. Since all implants have survived to date, this case series demonstrates the feasibility of using a more rapidly resorbing 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 and the implants were followed for only a short time period.

Recent reports in the literature indicate that the standard treatment of knife-edge ridges has changed in recent years.[12,27] The use of bone grafting materials and resorbable membranes to treat knife-edge 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 use in 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 mixed with ABBM and a natural collagen resorbable barrier membrane can be regarded as successful and may lead to implant survival.

Within the timeframe of the study, the regenerated bone led to osseointegration of the dental implant. Histologic evaluation showed that ABBM was connected with a dense network of newly formed bone of various degrees of maturation. 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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