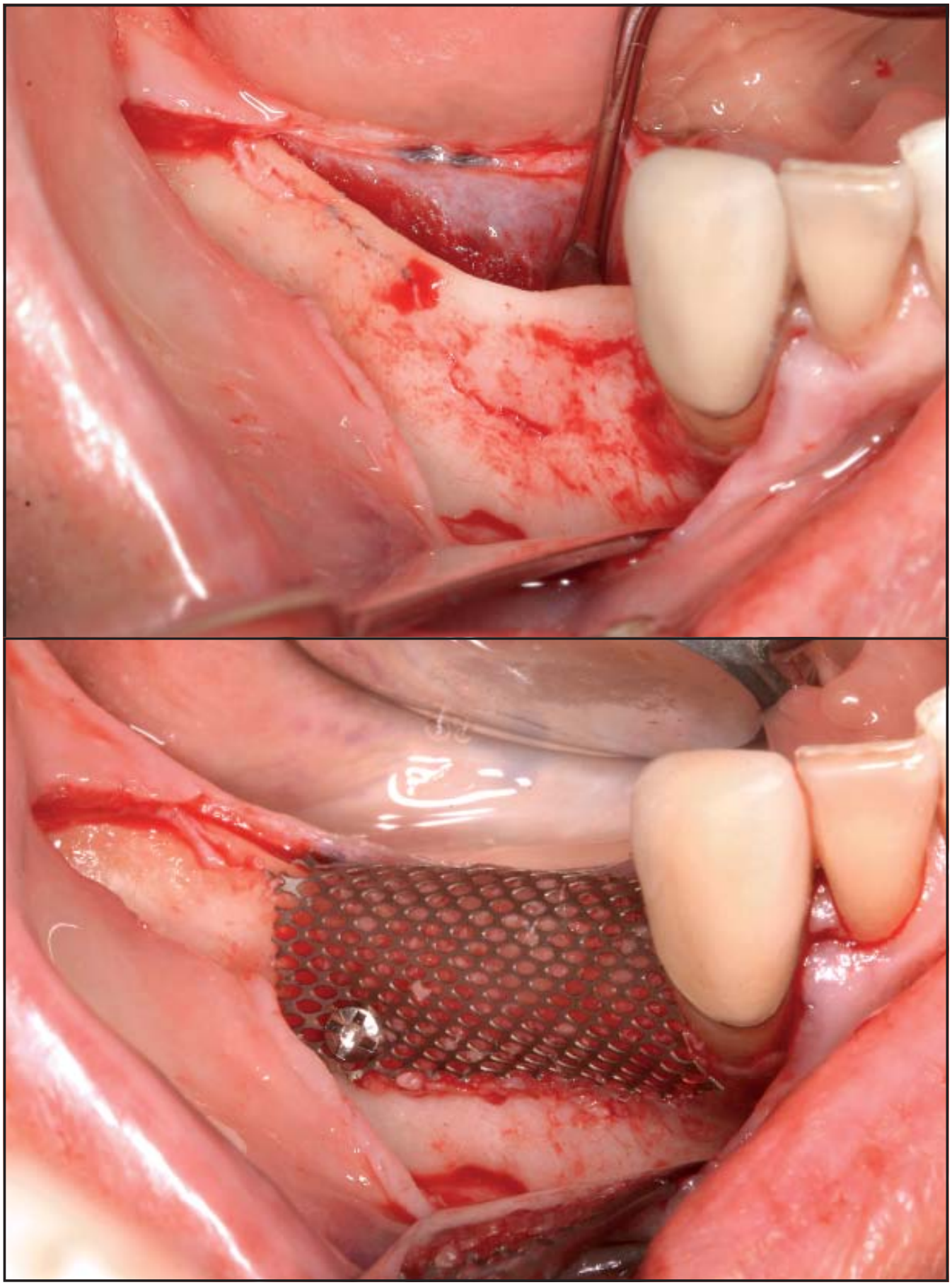
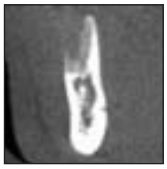


Bone Augmentation of the Atrophic Posterior Mandible for Dental Implants Using rhBMP-2 and Titanium Mesh: Clinical Technique and Early Results



*Craig M. Misch, DDS, MDS**

The atrophic posterior mandible has unique challenges when implant placement is planned. The purpose of this case series was to evaluate the use of recombinant human bone morphogenetic protein 2/acelluar collagen sponge (rhBMP-2/ACS) and titanium mesh for augmentation of the atrophic posterior mandible prior to implant insertion. The case series included five patients with inadequate bone in the posterior mandible for implant placement. The residual ridges were augmented with rhBMP-2/ACS and a small amount of bone substitute. Titanium mesh was used to protect the graft sites. Dental implants were inserted after 6 months of healing. Healing of the grafted ridges was uneventful. Dental implants were placed in all grafted sites without the need for further bone augmentation. All 10 implants integrated well and were restored with single crowns. The use of rhBMP-2/ACS with titanium mesh was effective in this case series for augmentation of the atrophic posterior mandible prior to implant placement. This approach offers many advantages, including technical ease, no need for bone harvesting, decreased morbidity, and reduced surgical time. (Int J Periodontics Restorative Dent 2011;31:581–589.)

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The atrophic posterior mandible continues to be a challenging area for dental implant treatment. Various approaches have been evaluated, including using short implants,[1] lateral nerve repositioning,[2] block bone grafting,[3] distraction osteogenesis,[4] guided bone regeneration,[5] titanium mesh with bone grafting,[6] and interpositional grafts.[7] In some cases, the removal of the mandibular anterior teeth simplifies the overall treatment plan since implants can be inserted into the symphysis region to support a posterior cantilevered prosthetic replacement.[8] If vertical bone augmentation is planned, the resulting bone volume must allow implant placement at a safe distance from the mandibular canal. A 2.0-mm "zone of safety" has been recommended.[9] Therefore, a minimum vertical dimension of 8 to 12 mm is needed above the canal to place short implants (6 to 10 mm).

The use of the titanium mesh technique offers many advantages for augmentation of the posterior mandible. The mesh is easy to cut, shape, and adapt to the residual

ridge. The concave morphology of the atrophic posterior mandible supports the anterior and posterior aspects of the mesh, leaving space underneath. Bone graft is packed into the formed mesh and simply molded onto the site. The monocortical fixation screws used to secure the mesh are short with low risk of injuring the inferior alveolar nerve. Exposure of the mesh during healing does not appear to have a significant negative influence on the underlying bone formation.[6]

Traditionally, the titanium mesh technique uses cancellous autogenous bone graft from the iliac crest.[10] This approach can produce significant vertical bone augmentation exceeding 1 cm.[6] Intraoral autograft has been combined with bone substitutes using titanium mesh, but the reported volume gains are modest.[11] Recombinant human bone morphogenetic protein 2 (rhBMP-2) has been actively studied as an alternative to harvesting autogenous bone grafts. The use of rhBMP-2 has been investigated in socket bone repair,[12] sinus bone grafting,[13] continuity defects,[14] and alveolar clefts.[15] These early clinical studies found that rhBMP-2 can be safely and successfully used for bone augmentation prior to dental implant placement. One of the optimal rhBMP-2 carriers that has been identified is type I bovine absorbable collagen sponge (ACS). However, the collagen sponge has poor scaffolding properties to resist flap compression when used for onlay ridge augmentation. Titanium mesh has been proposed as a method to provide support and protection of the rhBMP-2/ACS during healing. This article describes the use of titanium mesh and rhBMP-2/ACS to augment the atrophic posterior mandible prior to dental implant placement. The grafted sites were reentered after approximately 6 months of healing for implant placement.

Method and materials

The case series included five patients with unilateral atrophic posterior mandibles requiring bone augmentation for implant placement. All patients were healthy and nonsmokers. Cone beam computed tomography (CBCT) scans of the mandible were obtained preoperatively (Figs 1a, 1b, and 2a). All patients received a loading dose of antibiotics (amoxicillin or clindamycin), dexamethasone, and 0.12% chlorhexidine mouthrinse. Local anesthesia was obtained using a mandibular nerve block and buccal infiltration with 2% lidocaine (1:100,000 epinephrine). The rhBMP-2/ACS was prepared just prior to surgery since the protein binding of the growth factor is time-sensitive. Four extra-small and one small Infuse bone graft kits (Medtronic) were used. The included 1 × 2-inch collagen sponge was evenly saturated with reconstituted rhBMP-2 (1.5 mg/mL). Fifteen minutes were allowed to pass for binding of the growth factor to the collagen carrier. The collagen sponge was then cut into smaller pieces and mixed with a small quantity of mineralized bone allograft (20% by volume).

An incision was made along the ridge crest through the keratinized gingiva in the posterior mandible, and a lateral releasing incision was made at the base of the retromolar pad. A short anterior releasing incision was made mesial to the most posterior tooth bordering the defect. Then, a mucoperiosteal flap was reflected to completely expose the atrophic ridge and identify the mental foramen (Fig 1c). The lingual reflection extended to the mylohyoid ridge. Future implant sites were planned, and the size of the mesh needed for graft coverage was assessed. The 0.2-mm-thick mesh was cut to extend well posterior to the distal implant site. The lateral borders of the mesh extended slightly beyond the desired area of augmentation to contact the residual ridge. The piece of mesh was formed into a U-shape and molded to the atrophic mandible with a periosteal elevator. The formed mesh was then removed, and the overextended areas were trimmed with scissors. Care was taken to remove sharp edges or unsupported metal struts. The cortex of the mandibular crest was generously perforated to produce bleeding in multiple sites with a no. 6 round carbide bur (Fig 2b). The pilot holes for the fixation screws were also prepared at this time. The concave portion of the mesh was packed with the rhBMP-2/ACS and allograft mixture (Fig 1d). The mesh with graft was reinserted over the mandible and

compressed into place, and the 1.5 × 4.0-mm monocortical fixation screws were inserted. At least two screws were placed anterior and posterior along the buccal cortex (Figs 1e and 2c). If needed, a lingual screw was also used for additional mesh stability. The buccal flap was retracted, and a no. 12 scalpel blade was used to incise the periosteum along the base of the flap. The periosteal incision was started posteriorly and continued laterally over the mental nerve area. Care was taken to remain superficial over the nerve but extend through the thin periosteal layer. The lingual flap release was accomplished by placing a gloved finger along the mylohyoid ridge and stretching the thin periosteum and soft tissue. The flap margins were then advanced over the mesh and approximated to evaluate for tension-free closure. If flap resistance was found, a small curved mosquito hemostat was used to separate the margins of the buccal periosteal releasing incision. The closed tips of the hemostat were inserted into the incision and then opened to spread the cut edges apart. If needed, additional lingual flap release was obtained by reflecting the mylohyoid muscle with a periosteal elevator. The flaps were closed primarily with 4-0 Vicryl (Ethicon) interrupted and horizontal mattress sutures (Fig 2d).

A postoperative CBCT scan of the mandible was obtained (Fig 2e). Patients were not allowed to wear any soft tissue–borne prosthesis, continued on 1 week of antibiotic therapy and twice daily 0.12% chlorhexidine rinses, and were prescribed a narcotic analgesic. All patients also received a tapering dose of dexamethasone for 3 days. Patients were seen 10 to 14 days postoperatively for suture removal and follow-up care. The grafted sites were allowed to heal for 6 months. CBCT scans were obtained prior to implant surgery to evaluate the graft healing and select the appropriate size implants. Under local anesthesia, an incision was made along the ridge crest. A mucoperiosteal flap was elevated to expose the mesh and fixation screws. The screws were removed, and the edge of the mesh was freed and held with a hemostat to facilitate the dissection from the soft tissue. The fibrous tissue that typically encapsulates the mesh was reflected from the bone. Implant osteotomies were prepared according to the manufacturer's drilling sequence. A Lindemann bur (Hu-Friedy) was also used to prepare the sites. The bone density was recorded as D1 to D4.[16] Ten 4.0-mm-diameter Astra Tech Osseospeed implants (Astra Tech) were inserted (Figs 1f to 1h and 2f). The lengths ranged from 8.0 to 13.0 mm. In softer bone quality, implants were left to heal submerged; in sites that had favorable implant stability, healing abutments were inserted for single-stage healing. Periapical radiographs of the implants were obtained. Following a 2- to 4-month healing period, the submerged implants were uncovered for prosthetic restoration. Periapical radiographs were taken to evaluate implant healing. Implants were restored with independent cement-retained crowns (Fig 2g).

Fig 1 *Case 1.*

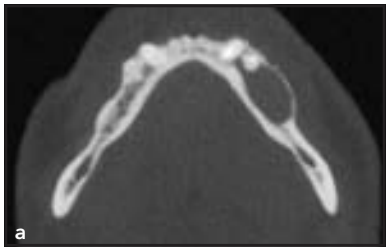


Fig 1a *Axial view of CT scan image revealed a large cyst in the right posterior mandible.*

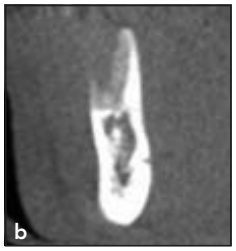


Fig 1b *Preoperative cross-sectional view of the CT scan following cyst removal and healing.*

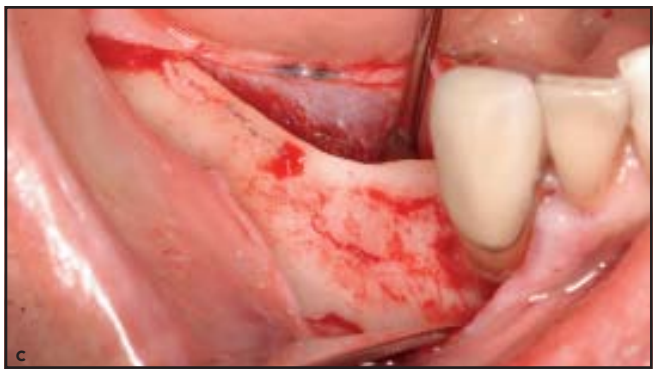


Fig 1c *Flap reflected to expose the atrophic posterior mandible after healing from cyst removal.*

Fig 1d *rhBMP-2/ACS mixed with allograft packed into the concave area of the titanium mesh.*

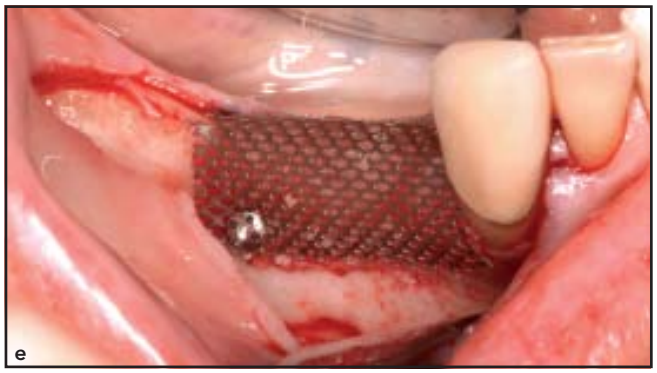


Fig 1e *Titanium mesh secured over the atrophic ridge with monocortical fixation screws.*

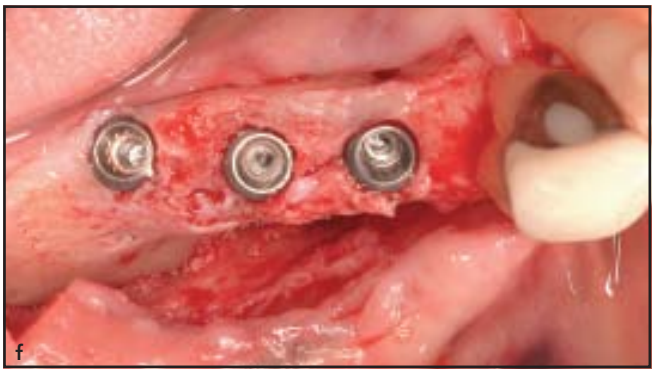


Fig 1f *After 6 months, the mesh was removed and three 4.0-mm-diameter implants were inserted.*

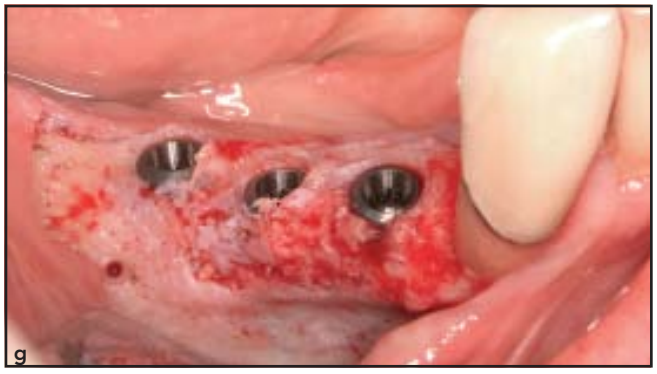


Fig 1g *Lateral view of implant placement in the right posterior mandible.*

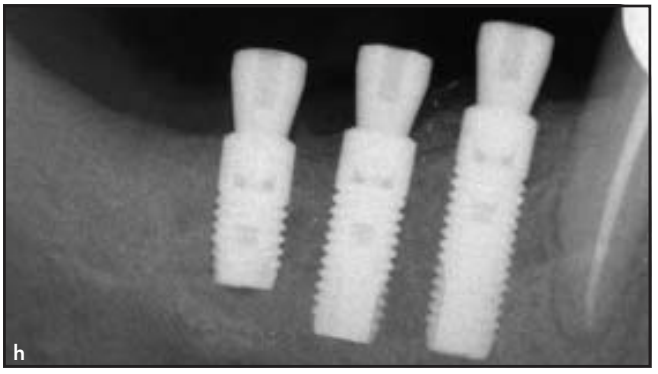


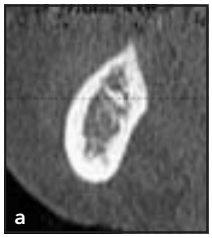
Fig 1h *Periapical radiograph taken after 2 months of implant healing reveals favorable integration.*

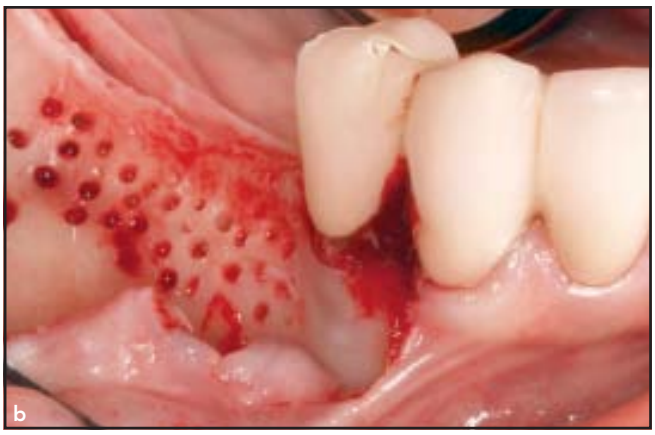
Fig 2 *Case 2.*

Fig 2a *Preoperative cross-sectional view of the CT scan in the right posterior mandible.*

Fig 2b *The cortex of the mandible perforated with a round bur to gain access to the marrow.*

Fig 2c *rhBMP-2/ACS mixed with allograft protected by the titanium mesh.*





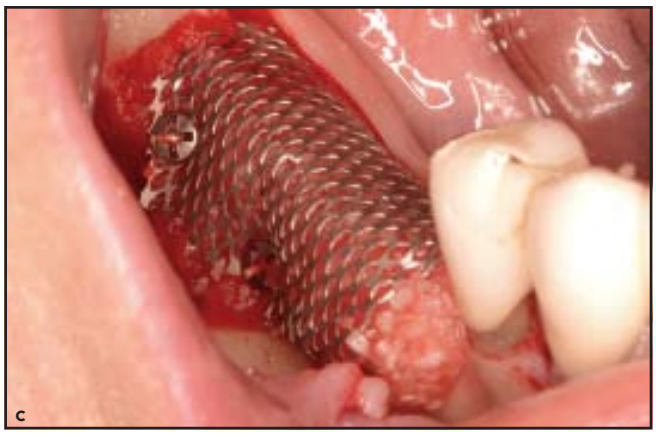
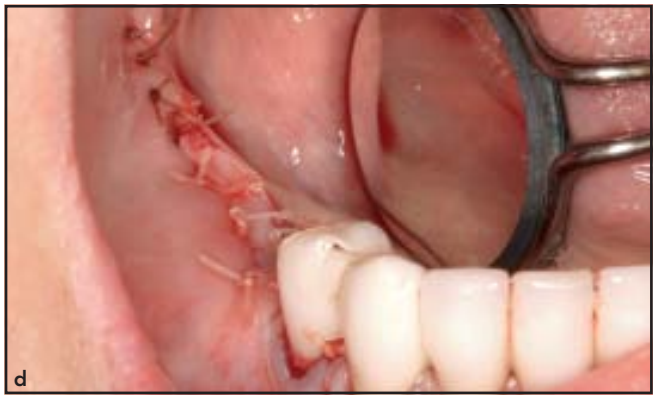


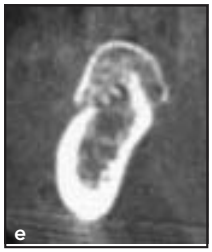
Fig 2d *Facial and lingual flaps advanced over the titanium mesh for primary closure with horizontal mattress sutures.*

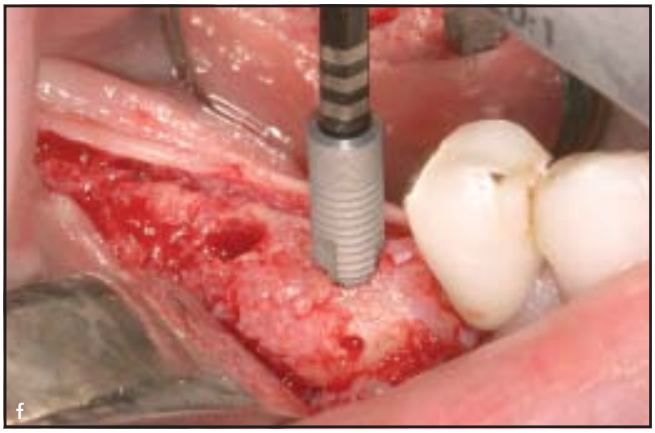
Fig 2e *Sagittal view of a CT scan image revealing the titanium mesh adapted to the right posterior mandible.*

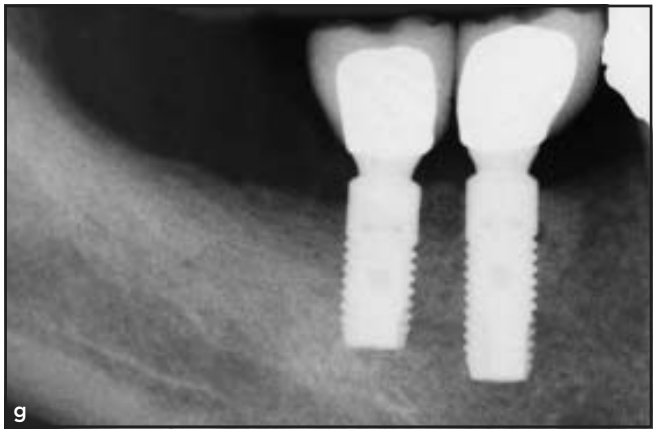
Fig 2f *Two 4.0-mm-diameter implants were placed into the grafted posterior mandible.*

Fig 2g *Periapical radiograph of the restored implants after 4 months of loading.*









Results

The grafted sites all healed without complication. Four patients experienced moderate unilateral swelling of the lower face; the other patient had minimal swelling. No significant lingual or tongue swelling was encountered. The soft tissue healing over the graft sites at 2 weeks was favorable. No incision dehiscence was found. There was mild erythema of the healing soft tissue noted in two cases.

Patients were allowed to heal for at least 6 months before implant surgery. The pre-implant CT scans revealed favorable bone fill under the mesh, but the density appeared less than that in the native mandible. No exposure of the mesh was found during healing.

There was adequate regenerated bone volume to place the implants in all the planned sites. The bone quality of the regenerated tissue was rated D3 in all sites. The implants were all stable upon insertion, but healing abutments were only inserted onto 4 implants. All 10 sites had adequate bone for planned implant placement, without the need for further bone augmentation. Stage-two exposure of the 6 submerged implants found that they were stable and appeared well integrated with no marginal bone defects. The regenerated bone volume appeared stable. Periapical radiographs confirmed favorable osseous healing. All implants were restored with independent cement-retained crowns.

Discussion

Initial human clinical reports on the use of rhBMP-2 for alveolar bone repair largely focused on product safety and technical feasibility. Fiorellini et al[12] performed a randomized multicenter study evaluating two concentrations of rhBMP-2 in the repair of extraction socket buccal wall defects for dental implant placement. At 4 months, patients treated with the higher concentration of rhBMP-2 (1.5 mg/mL) had significantly greater bone augmentation and adequate bone volume for implant placement. Human clinical trials led to the Food and Drug Administration's approval of a commercially available rhBMP-2/ACS for the repair of alveolar bone defects associated with tooth extraction. The use of Infuse for residual ridge augmentation is considered off-label.

ACS is a poor scaffold and lacks space maintenance under the compression of the soft tissue flaps. In spinal-fusion surgery, rhBMP-2/ACS has been placed into titanium cages to resist the compressive forces from the surrounding tissues.[17] Titanium mesh can be used with onlay bone augmentation to protect the collagen carrier and maintain the space for bone in-growth. Herford and Boyne[14] successfully used titanium mesh to maintain the periosteal envelope around large mandibular continuity defects treated with rhBMP-2/ACS. The mesh thickness should be adequate to resist flexing and micromovement during healing, but thin enough to mold easily. A 0.2-mm-thick mesh

appears to fulfill these requirements. The use of titanium mesh for bone augmentation should not be confused with guided bone regeneration techniques. Guided bone regeneration uses a cellular occlusive barrier membrane to impede soft tissue penetration and allow the slower-growing bone cells to repopulate the osseous defect.[18] Titanium mesh acts as a protective matrix to maintain space and facilitate bone in-growth, but is not cellular occlusive. Combining rhBMP-2/ACS with a barrier membrane does not seem to provide any additional value and actually may be biologically counterproductive since it occludes cells that may contribute to the bone-forming process and impedes vascularity from the soft tissue flap.[19–22] The use of rhBMP-2 with porous expanded polytetrafluoroethylene scaffolds, which provide space but are not occlusive, revealed favorable bony in-growth.[23] The existing human trials on rhBMP-2/ACS for bone augmentation have not relied on guided bone regeneration for bone formation.[12,13] The inclusion of a bulking agent or matrix has also been suggested to provide additional three-dimensional support for the collagen sponge.[17] Ceramic blocks and granules have been evaluated in the spinal-fusion model.[24] In this case series, a small amount of mineralized bone allograft (20%) was mixed with rhBMP-2/ACS. Although the allograft appeared to incorporate well, some of the graft particles could be identified on reentry for implant placement.

rhBMP-2 is a locally acting factor that induces bone formation at the site of application. The growth factor is chemotactic for mesenchymal stem cells, osteoprogenitor cells, and osteoblasts.[20] Preparation of the osseous recipient site is therefore important since these cells are found in bone marrow and, to a lesser degree, in soft tissue. The cortex of the recipient site should be perforated generously in multiple sites with a bur to allow access to the marrow. Primary tension-free closure of the soft tissue flaps over the grafted site is necessary to prevent wound dehiscence and early exposure of the mesh. The healing of the soft tissue over the rhBMP-2–grafted sites appears to be accelerated by the growth factor. In the repair of open tibial fractures with rhBMP-2, accelerated soft tissue healing was observed and thought to be related to an increased vascular supply.[25] The processes of osteogenesis and angiogenesis are intimately linked during bone repair. Although BMPs are involved in bone development, they are pleiotropic growth factors that play a role in the growth and differentiation of various organs.[20] BMPs have been found to be chemotactic for endothelial cells and can also stimulate angiogenesis through the production of vascular endothelial growth factor A by osteoblasts.[26,27] Since wound dehiscence is one of the most detrimental postoperative events associated with onlay bone augmentation, the growth factor may reduce this complication. Exposure

of the titanium mesh during healing has been reported.[6,11] However, this finding does not seem to significantly influence the outcome of the augmentation. No early or late exposure of the mesh occurred in this case series.

Based on preclinical studies, rhBMP-2 initially induces woven trabecular bone formation and then remodels it into lamellar bone consistent with the anatomical location.[20] The quality of the rhBMP-2–regenerated bone is initially softer but improves over time. In the sinus bone graft study by Boyne et al,[13] the rhBMP-2 grafts had significantly less radiographic bone density than autograft sites after 4 months of healing. This difference is likely because of the mechanism of bone formation. The de novo bone induction by rhBMP-2 requires greater time for mineralization. At implant insertion, later in the sinus study (mean, 6.9 ± 1 months), the investigators rated the clinical bone quality as similar between the autograft and 1.5 mg/mL–rhBMP-2 group. A longer healing period of at least 6 months appears to be beneficial when using rhBMP-2 for onlay augmentation. It is unclear if the addition of a mineralized bone substitute would favorably influence the quality of regenerated bone. In this case series, the preparation of the implant osteotomies was complicated by the difference in quality between the native and newly formed bone. The native mandibular bone was dense (D1/D2), and the regenerated bone was softer (D3). In width-augmented sites, the handpiece would favor displacement into the softer buccal bone; in height-augmented sites, the handpiece would easily pass through the soft bone and then encounter the resistance of the dense native bone above the mandibular canal. A Lindemann side-cutting bur was useful in width-augmented sites to prepare the dense native bone prior to inserting the next larger-diameter implant drill.

Ridge augmentation using rhBMP-2/ACS with titanium mesh offers another approach to managing the atrophic residual ridge. From a patient's perspective, there are significant benefits since there is no bone graft harvesting and associated morbidity. The technical procedure has relative ease and, as such, requires minimal surgical time. However, the ability to manage the surgical flaps to attain tension-free primary closure is still a requisite. The disadvantages of this technique compared to the use of autograft include longer graft healing times, softer bone quality, and higher material costs. Although the preliminary results appear promising, there are questions regarding the long-term stability of the onlay grafted bone under loading. Additional studies will be helpful in determining the specific indications and limitations of this technique.

Disclosure

Dr Misch is a consultant for Medtronic, the manufacturer of the Infuse bone graft kits used in this study.

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