# Mandibular reconstruction after gunshot trauma in a dog by use of recombinant human bone morphogenetic protein-2

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**Case Description**—A 6-year-old German Shorthaired Pointer was evaluated for possible reconstruction of a mandibular defect resulting from gunshot trauma.

**Clinical Findings**—A 5-cm defect of the right mandibular body was evident. A segment of the mandibular body was removed 9 weeks earlier because of severe contamination and comminution associated with gunshot trauma. Subsequent right-sided mandibular drift resulted in malocclusion in which the left mandibular canine tooth caused trauma to mucosa of the hard palate medial to the left maxillary canine tooth. The right maxillary canine tooth caused trauma to gingiva lingual to the right mandibular canine tooth.

**Treatment and Outcome**—The right mandible was stabilized with a 2.0-mm maxillofacial miniplate positioned along the lateral alveolar margin and a 2.4-mm locking mandibular reconstruction plate placed along the ventrolateral mandible. An absorbable compression-resistant matrix containing collagen, hydroxyapatite, and tricalcium phosphate was soaked in recombinant human bone morphogenetic protein-2 (rhBMP-2; 7.2 mL of a 0.5 mg/mL solution for a dose of 3.6 mg) and placed in the defect. By 4 weeks after surgery, an exuberant callus was evident at the site of the defect. By 7 months after surgery, the callus had remodeled, resulting in normal appearance, normal occlusion, and excellent function of the jaw.

**Clinical Relevance**—Mandibular defects resulting from gunshot trauma can be treated by removal of contaminated tissue and comminuted bone fragments, followed by staged reconstruction. The combination of rhBMP-2 and compression-resistant matrix was effective in a staged mandibular reconstruction in a dog with a severe traumatic mandibular defect. (*J Am Vet Med Assoc* 2008;233:1598–1604)

A 6-year-old 30-kg male neutered German Shorthaired Pointer was evaluated by the Dentistry and Oral Surgery Service of the Matthew J. Ryan Veterinary Hospital of the University of Pennsylvania for reconstruction of a 5-cm defect of the right mandibular body. Nine weeks earlier, the dog sustained gunshot trauma to the right mandible, right maxilla, and musculature of the left shoulder from 2 bullets fired from a 9-mm handgun. Severe comminution and contamination of the right mandible were treated by removal of bullet, bone, and tooth fragments, resulting in a defect extending from the third premolar to the second molar (**Figure 1**). Multiple wounds of the tongue and a large defect of the left sublingual mucosa were lavaged, debrided, and closed after removal of bullet fragments. A 2-cm full-thickness skin wound ventral to the right eye was explored, debrided, lavaged, and closed. A Penrose drain[a] was placed caudal to this defect and positioned so that it exited ventrally. A wound in the left shoulder was explored and debrided, and a drain was placed. All drains were removed 2 days later. Thoracic and abdominal radiographs revealed bullet fragments within the stomach. Serial radiographs revealed that these fragments had passed through the gastrointestinal tract and were excreted. Whole blood lead concentrations measured 2 and 13 days after evaluation at the hospital (5.4 µg/dL and 5.0 µg/dL, respectively) were within the reference range (< 10 µg/dL).

Subsequent right-sided mandibular drift resulted in malocclusal trauma of the mucosa palatal to the left maxillary canine tooth and alveolar mucosa lingual to the right mandibular canine tooth. These injuries were caused by the left mandibular canine tooth and right maxillary canine tooth, respectively (**Figure 2**). Treatment options for traumatic malocclusion were discussed with the owner and included selective extraction or crown reduction and vital pulp therapy to relieve malocclusive trauma. Alternatively, mandibular reconstruction

**Abbreviations**

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| CRM | Compression-resistant matrix |
| rhBMP | Recombinant human bone morphogenetic protein |
| TCP | Tricalcium phosphate |

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Dr. Seeherman is an employee of Wyeth Pharmaceuticals, which provided the rhBMP-2. Medtronic Sofamor Danek supplied the compression-resistant matrix.

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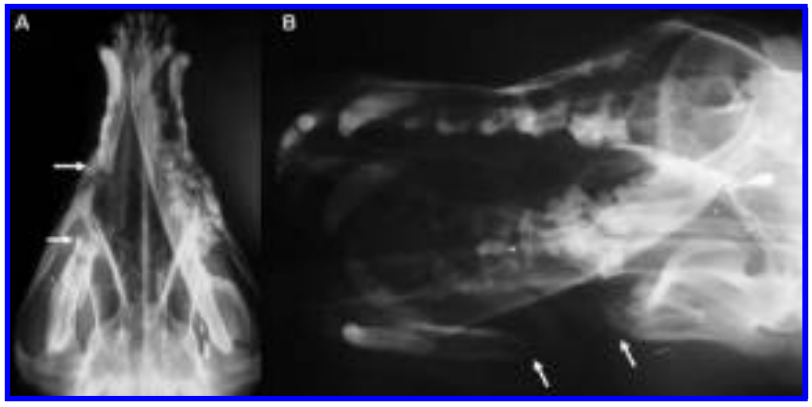


Figure 1—Radiographs showing a right mandibular defect immediately prior to reconstruction in a 6-year-old dog that sustained a gunshot wound of the right mandible 9 weeks previously. Premolars and molars of the right mandible were extracted at the time of trauma or shortly thereafter. A—Dorsoventral view; extent of defect is indicated by arrows. B—Oblique view; extent of defect is indicated by arrows.


Figure 2—Photographs of rostral occlusion immediately before and after mandibular reconstruction in the dog in Figure 1. A—Right mandibular drift prior to reconstruction. B—Normal occlusion immediately after reconstruction.

could be attempted to restore normal occlusion, and the owner opted for that course of action.

Remaining right mandibular premolars and molars rostral and caudal to the defect were extracted 9 weeks prior to reconstruction to allow for placement of plates and screws without impingement of tooth roots. Teeth in the right maxillary quadrant with severe crown damage as a result of gunshot trauma (right maxillary fourth premolar and first molar) were also extracted. The dog was reevaluated 6 weeks after initial trauma. The gingiva and mucosa covering the right mandibular defect had healed, and no abnormalities were detected except for malocclusion and soft tissue trauma resulting from the malocclusion (**Figure 3**). Head radiographs, dental radiographs, and full-mouth dental impressions were obtained to plan for the reconstructive surgery.

Three weeks later, the dog was returned to the hospital for mandibular reconstruction. Results of serum biochemical analysis and CBC performed at that time were unremarkable except for a mild increase in serum alanine aminotransferase activity (120 U/L; reference range, 16 to 91 U/L). The patient was anesthetized and monitored via continuous ECG, direct blood pressure measurement, capnography, and pulse oximetry. An isotonic balanced electrolyte solution[b] was administered IV at a rate of 10 mL/kg/h (4.5 mL/lb/h). A right inferior alveolar nerve block was administered with 2.5 mg (0.082 mg/kg [0.037 mg/lb]) of 0.5% bupivacaine.[c]

A pharyngotomy incision was made caudoventral to the angular process of the left mandible with a No. 10 scalpel blade. A size 11, wire-reinforced endotracheal tube[d] was placed after removal of the orally placed tube, allowing for intraoperative determination of occlusion without interference.[1] The dog was positioned in dorsal recumbency, and a ventrolateral approach to the right mandible was made.

Full access was obtained to the mandible rostral and caudal to the defect, and edges of the bone and the mandibular canal were exposed. While maintaining the desired occlusion of the rostral mandible based on canine and incisor relationships, a 16-hole, 2.0-mm miniplate[e] was positioned at the lateral alveolar margin with 4 screws placed rostral to the defect and 5 screws placed caudal to the defect. The plate was contoured caudally to conform to the rostral surface of the mandibular ramus along the coronoid crest. A 13-hole, 2.4-mm titanium locking mandibular reconstruction plate[f] was positioned in bridging fashion along the ventrolateral surface of the mandible. This plate was contoured to the shape of the mandible. Three locking screws were placed rostral and 4 locking screws were placed caudal to the defect (**Figure 4**). Screws placed rostral to the defect were caudal to the root of the right mandibular canine tooth.

An absorbable collagen sponge containing hydroxyapatite and TCP granules (CRM carrier)[g] was cut to the size of the defect and soaked in reconstituted rhBMP-2.[h] The volume of the defect was 12 $cm^3$ (5 × 2 × 1.2 cm). A 60% soak volume of rhBMP-2 was determined to be 7.2 mL, which at a concentration of 0.5 mg/mL resulted in delivery of 3.6 mg of rhBMP-2. The carrier was placed in the defect (Figure 4), and the adjacent tissue was apposed over the ventral mandible with a simple interrupted suture pattern of 3-0 poliglecaprone 25.[i] Subcutaneous tissue was closed by means of a simple continuous suture pattern of 3-0 poliglecaprone 25. The skin was closed with 3-0 nylon[j] by use of a Ford interlocking suture pattern. Postoperative evaluation revealed normal occlusion (Figure 2).

Head and dental radiographs were obtained immediately after surgery (Figures 3 and 5), revealing that the grainy opacity of the CRM carrier filled the entire defect. Subcutaneous hydromorphone[k] (0.1 mg/kg [0.045 mg/lb]) was administered at extubation and was continued every 6 hours for the next 24 hours. A fentanyl transdermal patch[l] (release rate, 100 µg/h) was applied to the shaved skin over the caudal dorsum after anesthetic recovery. Cold compresses were applied every 4 hours to the right mandibular area to preemptively minimize swelling.

The morning after surgery, the dog appeared comfortable and ate a small amount of canned dog food. Medications were prescribed, including cephalexin[m] (24.6 mg/kg [11.2 mg/lb], PO, q 8 h for 2 weeks) and

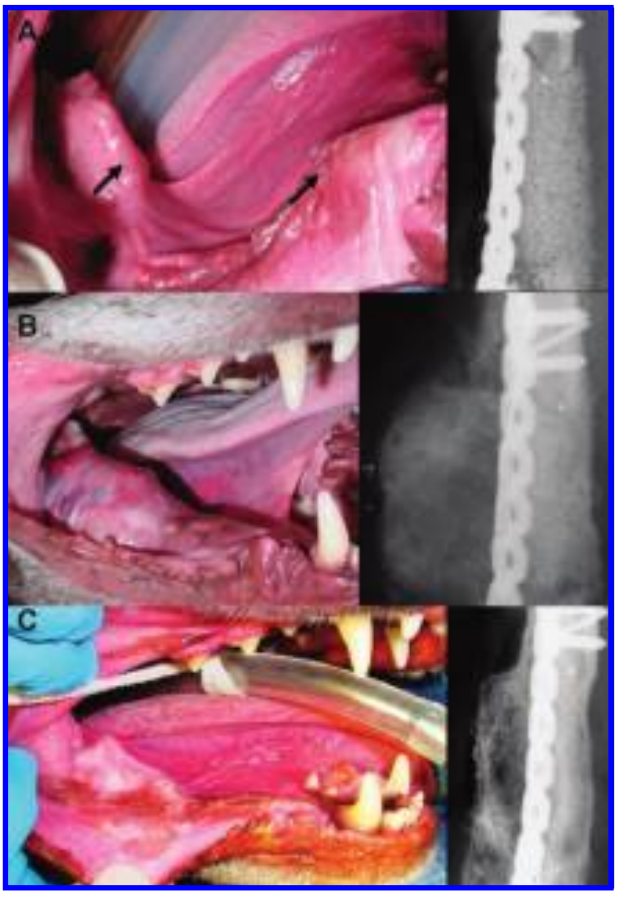


Figure 3—Intraoral photographs and radiographs of the right mandible of the dog in Figure 1 before and after mandibular reconstruction. A—Photograph shows a 5-cm defect of the right mandible (arrows indicate bone rostral and caudal to the defect). All soft tissues have healed 9 weeks after initial debridement. Intraoral dental radiograph obtained immediately after mandibular reconstruction shows grainy radiopaque material that represents an absorbable CRM carrier and a 2.4-mm locking mandibular reconstruction plate. B—Four weeks after mandibular reconstruction, a firm swelling is evident across the reconstructed defect, extending dorsally and laterally. Radiographically, evidence of new bone formation and some initial absorption of the CRM carrier can be seen. C—Right mandible 28 weeks after mandibular reconstruction. Radiographically, the carrier has been completely absorbed and considerable bone consolidation has occurred.

tepoxalin[n] (6.5 mg/kg [3.0 mg/lb], PO, q 24 h for 5 days). Substantial swelling of soft tissues lateral to the surgical site was evident, which was treated via application of continued cold compresses and oral administration of tepoxalin. The dog's appetite and activity level continued to improve, and it was discharged from the hospital 2 days after surgery. The fentanyl transdermal patch was removed 4 days after application.

Outpatient reevaluations were performed at 2, 4, 6, 8, 10, 12, 16, and 28 weeks after surgery. During the 2-, 4-, 6-, 12-, and 28-week reexaminations, the dog was sedated and oral examinations and dental radiographs were obtained. The 2-week reexamination revealed complete healing at the mandibular skin incision and appropriate second-intention healing of the pharyngotomy site. Skin sutures were removed from the healed incision. A firm, nonpainful swelling was evident lateral and dorsal to the surgical site, with 2 fluctuant areas beneath the oral mucosa. A small, partial-thickness defect of the oral mucosa attributable to impingement of the cusp of the right maxillary third premolar was evident on the dorsomedial aspect of the swelling. Dental radiographs were obtained, which revealed diffusion of the CRM carrier and early evidence of new bone formation at the periphery of the swelling.

Figure 4—Intraoperative photograph of the ventral right mandible of the dog in Figure 1. A 13-hole, 2.4-mm locking mandibular reconstruction plate can be seen along the ventrolateral surface of the mandible (screws placed in the caudal mandible are not visible). A 16-hole, 2.0-mm miniplate (not seen in photograph) is dorsal to the reconstruction plate at the lateral alveolar margin. The CRM, cut to the appropriate size and soaked with the rhBMP-2, is shown being inserted into the mandibular defect.

At the 4-week reevaluation, the mandibular swelling lateral and dorsal to the surgical site had enlarged. Intraoral examination revealed fluctuant areas beneath thin and inflamed but intact oral mucosa dorsally (Figure 3). Hard tissue was palpable beneath the mucosa laterally and medially. The thin mucosa overlying the fluid-filled area was traumatized during endotracheal intubation, and fluid from this area was submitted for cytologic analysis. Findings of that analysis were compatible with a diagnosis of seroma. No ulceration of the mucosa overlying the plates was detected. Intraoral and head radiographs were obtained to assess healing, which revealed continued replacement of the CRM carrier and development of a prominent callus lateral to the mandibular defect.

Two weeks later (6 weeks after surgery), the dog was reexamined. The area of thin, inflamed mucosa was intact, and the degree of mandibular swelling was slightly decreased in size. Dental radiographs revealed new bone formation in the previously fluid-filled areas and continuing replacement of the CRM carrier.

A reexamination was performed 4 months after surgery, revealing continued remodeling of the bony callus and no evidence of plate exposure. The previously detected fluid-filled areas were no longer evident, and the overlying mucosa appeared normal. Seven months after surgery, the dog was returned to the hospital and anesthesthetized for reexamination. Oral examination revealed intact mucosa over both plates, with no exposure of the plates or screws on the buccal or lingual surface of the mandible. The bony callus had remodeled substantially, particularly on the lateral aspect of the previous defect. The bone height of the alveolar margin was raised in the area of the missing right mandibular

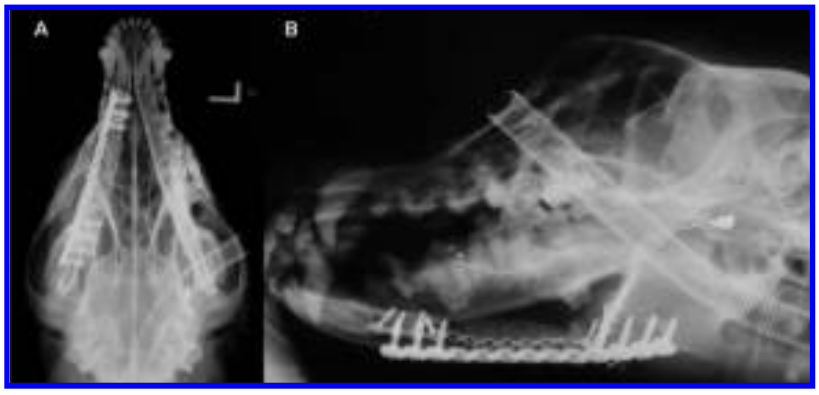


Figure 5—Dorsoventral (A) and oblique (B) radiographs obtained immediately after mandibular reconstruction in the dog in Figure 1 by means of 2 plates affixed to the right mandible. A 16-hole, 2.0-mm miniplate is evident along the lateral alveolar margin, and a 13-hole, 2.4-mm locking mandibular reconstruction plate is evident along the ventrolateral mandibular surface, spanning the 5-cm fracture gap. Within the gap is the radiopaque CRM. In the oblique view, the right mandible is situated ventrally.

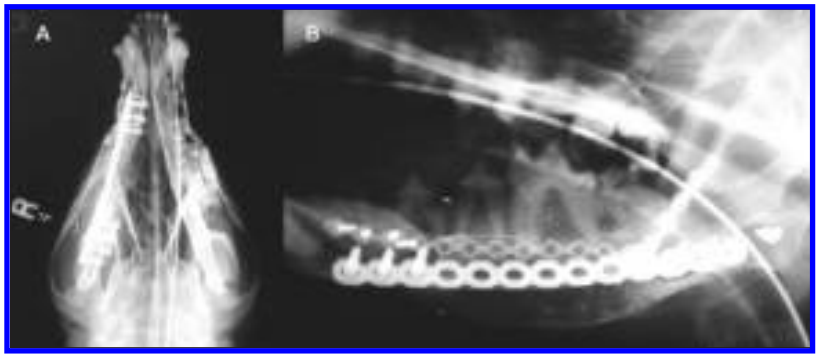


Figure 6—Dorsoventral (A) and lateral (B) radiographs obtained 28 weeks after mandibular reconstruction surgery in the dog in Figure 1. All implants are stable. The previously grainy opacity of the CRM (evident in Figure 3) has been replaced by new bone that spans the original defect. Lateral view is slightly oblique, with the right mandible situated ventrally.

first molar, but the rest of the previously raised alveolar margin had decreased to the height of the normal bone adjacent to the defect (Figure 3). Dental radiographs revealed complete bridging of the defect with new bone and complete resolution of previously detected fluid-filled areas. An occlusal dental radiograph revealed substantial decrease in callus size and increase in density of bone lateral to the defect, compared with characteristics detected in previous radiographs. Dental radiographs of the right mandibular incisors and canine teeth were obtained by means of the bisecting angle technique to assess tooth vitality. No teeth had radiographic evidence of endodontic or periodontal disease. Mild sclerosis of the apical alveolar bone of the canine tooth was evident.

Lateral and dorsoventral radiographs of the head were obtained and revealed no evidence of screw loosening or bone infection (**Figure 6**). Occlusion and range of mandibular motion were normal. Function was excellent according to the client, and aesthetics were similar to the appearance prior to the gunshot trauma. Moderate plaque and calculus accumulation was evident on the remaining maxillary teeth, which were scaled and polished. The dog continued to have excellent clinical function 18 months after the reconstructive procedure.

## Discussion

Recombinant human bone morphogenetic proteins have been used in experimental studies of mandibular reconstruction in dogs,[2] rabbits,[3] rats,[4,5] nonhuman primates,[6,7] sheep,[8,9] and miniature pigs.[10–12] Mandibular reconstruction with rhBMPs in human patients has also been described.[13] Reports of clinical use of rhBMPs for management of mandibular defects in domestic species are rare.[14] Three clinical cases exist describing treatment of mandibular defects after oncologic surgery,[14–16] but to our knowledge, the use of rhBMPs in mandibular reconstruction after gunshot trauma has not been reported.

Many factors affect the destructive capacity of a projectile, but velocity is one of the most important variables.[17] In the dog of this report, gunshot wounds were caused by a handgun firing projectiles at a medium-velocity range. Medium- and high-velocity projectiles are more likely to cause cavitation (rapid expansion of tissues adjacent to the course of the bullet), which may encompass an area 30 times the diameter of the bullet.[17] Tissues outside the path of the bullet may be disrupted, and their vascular supply may be irreversibly compromised.[17] Cavitation may result in delayed recognition of tissues that will become nonvital because of disruption of vascular supply. For the dog described here, knowledge of the type of firearm, severity of contamination, and potential for vascular compromise warranted aggressive debridement followed by reconstruction. The site of impact appeared to be the dorsal surface of the right mandibular body, resulting in fracture of teeth, which became secondary projectiles.

Not all bullet fragments, even those containing lead, require removal unless they are in the gastrointestinal tract or within a joint in which continued absorption of lead may occur. Bullet fragments embedded in soft tissue often become surrounded by fibrous connective tissue without consequence.[17] Most fragments were removed from the dog of this report, but a large fragment in the left caudal oropharynx was not removed because of difficulty in surgically accessing this location. In the authors' experiences, ingestion of bullet fragments is a common sequela of oropharyngeal gunshot wounds. Abdominal radiographs are warranted to look for bullet fragments within the stomach or small intestines. Whole blood is the recommended fluid sample for determination of lead toxicosis in living patients.[18]

Right-sided mandibular drift resulted from the gunshot trauma and its initial treatment. Treatment of dental trauma caused by malocclusion may be accomplished by selective extraction or crown reduction followed by vital pulp therapy to remove chronic discomfort of teeth impinging upon soft tissue structures. However, canine teeth are functionally important teeth.

Because the dog of this report was a sporting dog, the owner chose mandibular reconstruction in an effort to maintain function while correcting the malocclusion. Experimental evidence suggests that drift associated with mandibular defects results in chronic pathology of the temporomandibular joint, with histologic changes that are more severe in the joint contralateral to the mandibulectomy. These changes are presumed to be attributable to instability, abnormal loading, or both.[19] It has yet to be determined whether these changes eventually result in degenerative joint disease and discomfort in clinical mandibulectomy patients.

Treatment of mandibular fractures with plate fixation has been clearly described,[20–23] but special considerations are necessary in plating the mandible when large defects exist. Plate position along the mandible must be considered to avoid the tooth roots in the remaining intact bone. The tension surface is generally the desired surface for placement of a plate, although the existence of teeth and roots in the dorsal half of the mandible complicates such placement.

Miniplates have been suggested as a better option, compared with standard plate fixation, to minimize potential screw impingement upon the tooth roots.[23] However, miniplates alone would not be expected to provide acceptable outcomes when bridging a large defect because of their low strength as a buttress device. Therefore, supplementing the tension-band fixation with an additional larger plate placed ventrolaterally can be expected to provide the appropriate buttress support. Defects can easily be spanned with large buttress plate fixation along this position on the mandible; however, prolonged healing may occur over such large gaps, and standard fixation will not remain stable indefinitely. Bridging plates that span large defects may be at risk for early loosening because standard plates and screws obtain their stability via compressive forces generated between the plate and bone, while neutralizing all forces during healing.[24] Locking plates do not rely on these compressive forces because they are fixed-angle stable devices, and as such, they are expected to provide long-term stability when delayed healing is projected and large defects are spanned.[24] Successful reconstruction with locking plates for mandibular reconstruction of large defects in the dog has been described.[15,16] Rigid fixation and maintenance of normal occlusion were attained in 3 dogs in which the combination of locking plates and rhBMP-2 was used for mandibular reconstruction of large gaps, with long-term clinical follow-up from 18 to 48 months.[14–16]

Avoidance of tooth roots when placing screws is important for a number of reasons. First, trauma to the roots may result in pulpitis,[25] which may cause acute and chronic pain. Second, pulp necrosis may develop as a result of irreversible pulpitis or vascular disruption, which increases the potential for development of periapical abscess and osteomyelitis through direct contamination or by anachoresis (hematogenous bacterial migration and colonization). Avoidance of roots was accomplished in the dog of this report by preemptive extraction of the premolars and molars rostral and caudal to the defect. All teeth serve a function, but tooth extraction was considered the best solution to avoid complications of root perforation. Loss of shearing and grinding tooth surfaces on the right mandible was expected to adversely affect the self-cleansing interaction of opposing maxillary and mandibular teeth, and more thorough oral hygiene or more frequent professional cleanings may be necessary.

Although screw trauma to the periodontium of the right mandibular canine tooth was avoided, radiographic follow-up was advisable to monitor this tooth and adjacent incisors for loss of tooth vitality resulting from potential disruption of apical blood supply. Seven months after surgery (9 months after gunshot trauma), no evidence of tooth death was apparent clinically or radiographically in the dog of this report. Pulp death and periapical disease may require months or years to manifest radiographically.

The normal blood supply to the canine mandible has been extensively evaluated.[26–28] Small arterioles derived from the mandibular artery supply alveolar bone and teeth with multiple dental, interdental, and interradicular branching arterioles. These branches supply the endosteal surface of cortical bone adjacent to the symphysis. Periosteal arteries primarily feeding the ventral cortex of the rostral mandible have also been detected via microangiography.[26] A study[21] of healing mandibular osteotomy sites in dogs revealed that blood supply to the rostral portion of the mandible is restored by extraosseous arterioles penetrating the mandibular cortex near the symphysis. Thus, the integrity of the soft tissues surrounding the rostral segment is important for maintaining viability.

Although both dental and head radiographs were used to monitor healing, dental radiographs provided more information than head radiographs when assessing new bone production. Dental radiographs were obtained with size 4 intraoral films by means of parallel and occlusal techniques, which prevented superimposition encountered with head radiographs and allowed for better determination of new bone formation. Intraoral radiography requires deep sedation or general anesthesia. Sedation also was necessary in the dog of this report to allow for thorough intraoral examination to evaluate mucosa for plate exposure. Mucosal erosion and exposure of plates placed on the dorsolateral surface of the mandible can be a long-term complication,[15,16,25] but mucosal erosion did not develop in this situation.

One unique aspect of the dog of this report was the degree of response, compared with reported responses of other dogs to rhBMP-2 in mandibular reconstruction.[14–16] It is unclear why our patient had an exuberant response to rhBMP-2 and others treated with a similar dose did not. We used a 60% soak volume with an rhBMP-2 concentration of 0.5 mg/mL, whereas other authors used a 50% or 60% soak volume with an rhBMP-2 concentration of 0.4 to 0.5 mg/mL.[14–16] The amount of rhBMP-2 we used was only marginally higher than that reported elsewhere but was consistent with the most common dosage that one of the authors (RJB) has used in all other dogs undergoing mandibular reconstruction.[14] Marked swelling in the region of the surgical site was evident within 24 hours after surgery, and this swelling reached maximal size at 48 hours after surgery, which likely was related to development of a hematoma

at the surgical site. Particular attention to hemostasis may be important in situations in which rhBMP-2 is used because it has a high affinity for serum proteins. These proteins may compete with the CRM for rhBMP-2 binding, which may result in elution of rhBMP-2 from the CRM, as evidenced by the effectiveness of using a fibrin glue coating of collagen carriers to prevent diffusion.[29] Bone morphogenetic proteins upregulate vascular endothelial growth factors[30] and are associated with a high degree of neovascularization, which may result in substantial swelling after surgery when rhBMPs are used at pharmacologic doses. In the dog of this report, degree of swelling decreased to half its maximum 48 hours after surgery and then remained fairly unchanged for several months, unlike a typical hematoma. Substantial mineralization at the periphery of this swelling was evident at the 2-week reexamination, also suggesting that rhBMP-2 diffused from the CRM carrier.

The formation of fluid-filled areas at the site of reconstruction suggested the exuberant response was attributable to administration of a higher pharmacologic dose than necessary.[31] A study[31] in which researchers used rhBMP-2 in dogs with experimentally induced segmental radial defects evaluated delivery of a collagen sponge material soaked in equal volumes of varying concentrations of 0.05, 0.2, or 0.8 mg/mL of rhBMP-2 into a 3-cm radial defect. Although bone formed in the defects regardless of concentration of rhBMP-2 used, formation of cyst-like voids that appeared to be dose-related was detected histologically and radiographically. Minimal void formation was evident at the 0.05 mg/mL dose, and voids were most common at the highest dose. Histologically, these voids were not true cysts lined by epithelium but were, rather, seromas, analogous to the cytologic diagnosis obtained from the fluid-filled area of the dog in the present report. With higher doses of rhBMP-2, voids are believed to form as a result of rapid influx of vessels and fluid early in the healing process rather than as a result of resorption of previously formed bone.[31] The chronologic progression and resolution of the clinically and radiographically detectable fluid-filled areas evident in the dog of our report suggest these voids develop early and eventually remodel to become filled with bone or decrease in size to become clinically undetectable.

Reported adverse effects in humans treated with rhBMP-2 are rare but include local erythema, swelling, heterotopic ossification, and immune response.[32] The exuberant proliferation of bone in the dog of the present report caused no complications other than esthetic problems, but similar procedures in a more caudal location might affect range of mandibular motion.

The dosage of rhBMP-2 for use in clinical mandibular reconstruction in dogs has not been definitively determined, although one of the current authors (RJB) has consistently used a third of the concentration (0.5 mg/mL) recommended for humans with excellent results. The results obtained in the dog of this report suggest that a lower dose of rhBMP-2 may be sufficient to provide the desired effect. Experimental studies may support this supposition.[2,33]

The ability to use lower concentrations of rhBMP-2 may be important because expense is an important limitation for the use of rhBMPs in veterinary surgery. Coupled with the expense of locking plates and screws, a procedure such as that described here may be cost prohibitive for many clients. Reconstituted liquid rhBMP-2 can be used at a later date if frozen at –70°C, such that the expense resulting from the initial purchase can be distributed over multiple patients; however, this practice is beyond that recommended in the product insert.[14] Regardless, any use of rhBMP-2 in the dog is considered extralabel use.

The dog in the present report is the fourth dog with a clinical mandibular defect and the first dog with gunshot trauma that has been reportedly treated with rhBMP-2. Use of rhBMP-2 appears to be a viable option for staged reconstruction of mandibular defects. The responsiveness to rhBMP-2 reported here was similar to that described in other reports of mandibular reconstruction, despite its application 9 weeks after substantial trauma. The proliferative bone response of our patient and evidence of fluid-filled voids suggested that lesser concentrations of rhBMP-2 may be sufficient to achieve satisfactory results in some situations.

a. CR Bard Inc, Covington, Ga.
b. Normosol-R, Abbott Laboratories, Chicago, Ill.
c. Marcaine, Hospira Inc, Lake Forest, Ill.
d. Fome Cuf, Bivona Inc, Gary, Ind.
e. Synthes Maxillofacial, West Chester, Pa.
f. UniLOCK, Synthes Maxillofacial, West Chester, Pa.
g. Mastergraft Matrix, Medtronic Sofamor Danek, Memphis, Tenn.
h. Wyeth Pharmaceuticals, Cambridge, Mass.
i. Monocryl, Ethicon, Somerville, NJ.
j. Ethilon, Ethicon, Somerville, NJ.
k. Dilaudid, Knoll Pharmaceuticals, Mount Olive, NJ.
l. Duragesic transdermal patch, Janssen Pharmaceutica, Beerse, Belgium.
m. Ranbaxy Laboratories Ltd, Jacksonville, Fla.
n. Zubrin, Intervet/Schering-Plough, Kenilworth, NJ.

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