CASE REPORT

Surgical correction of severe strabismus and enophthalmos secondary to zygomatic arch fracture in a dog

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Abstract
A grossly displaced segmental zygomatic arch fracture with marked ventro-lateral deviation of the left globe was diagnosed in a 3-month-old male German Shepherd dog following a bite injury. The fracture was approached via a modified lateral orbitotomy and a fragment of the lacrimal bone removed. The rostral portion of the fracture was stabilized with a 5-hole 2.0 dynamic compression plate bone plate. The surgical correction achieved sufficient skeletal fixation for proper anatomical reduction of the globe and excellent cosmetic and functional outcomes.

Key Words: dog, fracture, miniplate fixation, orbital rim

INTRODUCTION
Fractures involving facial bones, specifically mandibular and maxillary bones, are common in veterinary patients. Mandibular fractures account for 2.5–6% of all fractures in dogs, but maxillary fractures occur less frequently. These fractures are often caused by falls, gunshot wounds, animal bites and most commonly, automobile trauma. Orbital rim fractures often disrupt the normal structural support of the eye, causing severe caudal or ventral globe displacement if the lateral support of the zygomatic bone is lost. Few reports exist in the veterinary literature detailing surgical fixation of maxillary fractures, with only a single report of successful repair of zygomatic arch fractures affecting the orbital rim in the dog. The purpose of this report is to describe a case of orbital rim trauma in a young dog, and the surgical fixation of the zygomatic bone to correct globe position, with good cosmetic and functional outcomes.

CASE REPORT
A 3-month-old sexually intact male German Shepherd dog was referred to the North Carolina State University VTH for evaluation of facial trauma involving the OS sustained secondary to a bite from an adult dog. Skull radiographs, performed by the referring veterinarian, revealed fractures of the left zygomatic arch and left coronoid process of the mandible. Carprofen (20 mg subcutaneous [SQ]) and butorphanol (5 mg intravenous [IV]) were administered for pain control prior to referral. The dog was previously healthy, had received his first set of vaccinations and deworming at 2 months of age, and was fed a high quality canine puppy diet.

Initial clinical findings
Upon presentation, the dog was tachycardic (heart rate [HR] 188 [bpm]) and tachypneic (respiratory rate [RR] 84 [bpm]), with weak femoral pulses and a normal capillary refill time (CRT) of 2 s. The dog was normothermic with a rectal temperature of 101.2° F (38.4 °C). Blood pressure (BP) was 88 (systolic) mmHg/62 (diastolic) mmHg with a mean of 78 mmHg (Cardell Veterinary BP monitor, Sharn Veterinary Inc., Branford, CT, #5 cuff right antebrachium). To improve blood pressure and cardiac output, the dog received systemic fluid therapy (Lactated Ringer Solution, Hospira, Inc., Lake Fores, IL, IV bolus 20 mL/kg for 30 min × 2 followed by a maintenance rate of 38 mL/h), resulting in normalization of the patient's vital parameters after 30 min (HR 100 bpm, RR 34 bpm, BP 105/69 [84] mm/Hg).

Ocular examination revealed severe periorbital edema, moderate enophthalmos, and severe ventro-lateral globe displacement OS (Fig. 1). Crepitus was palpated over the zygomatic arch. The lower palpebral conjunctiva was edematous and hyperemic. A small puncture wound was present in the superficial ventral palpebral conjunctiva. Menace responses were positive OU, although mild lagophthalmos was noted OS, likely due to periocular edema. Direct and indirect pupillary light (PLRs) and dazzle reflexes were positive OU.
Saccadic movements were normal OU. Vestibulo-ocular reflexes appeared appropriate OU, although accurate assessment was difficult OS due to periocular swelling. Tear production, as assessed by Schirmer Tear Test-I (STT) test (Schering-Plough Animal Health, Union, NJ), was within normal range OU. The corneas appeared normal when examined using slit-lamp biomicroscopy (SL-15, Kowa, Japan) and did not retain fluorescein dye OU (Akorn, Inc., Buffalo Grove, IL). No abnormalities were noted on intraocular examination by slit-lamp biomicroscopy and indirect ophthalmoscopy. No abnormalities were detected in the OD. Mild edema was noted over the left proximal maxilla and no wounds were noted in the oral cavity. The remainder of the cranial nerve examination and physical examination were unremarkable.

**Laboratory and ancillary diagnostic tests**

A complete blood count identified normocytic, normochromic, nonregenerative anemia (hematocrit 24.9%; reference range, 39.2–55.9, MCV 24.9 FL; reference range, 64–75.2 FL, MCH 23.6 PG; reference range, 22.7–26.8 PG, RBC 3, 710/UL; reference range, 5700–801/UL, reticulocyte 1.05%; reference range, 0.11–1.26%), and mild lymphocytosis (3,155/UL; reference range, 480–2,941/UL). A biochemistry panel revealed hypoproteinemia (3.9 g/dL; reference range, 5.5–7.2 g/dL), with normal albumin (2.6 g/dL; reference range, 2.4–8 g/dL), and decreased globulin (1.3 g/dL; reference range, 2–4.1 g/dL). Alkaline phosphatase was increased (187 IU/L; reference range, 14–120 IU/L), as was creatinine phosphokinase (626 IU/L; reference range, 48–380 IU/L). The nonregenerative anemia was attributed to acute blood loss from trauma and/or hemodilution from IV fluid therapy. The mild increase in ALP was attributed to the dog being a young growing puppy and the increased creatinine phosphokinase was likely due to the tissue damage from the trauma sustained from the bite.

A computed tomographic (CT) scan of the skull was performed with the dog anesthetized to further assess and characterize the facial fractures. A transverse multislice dataset was acquired and reconstructed into 3 and 1 mm transverse, sagittal, and dorsal plane sequences. The sequences revealed a mildly comminuted segmental fracture of the left zygomatic bone with lateral displacement of the fragments (Fig. 2a). The fragment of the lacrimal bone was displaced dorsally. A mildly comminuted fracture with slight medial displacement of the left coronoid process of the mandible was present (Fig. 2a).
Treatment and surgical management

Due to severe displacement and possible entrapment of the globe by bone fragments, surgical repair of the fractures was indicated. The surgical goals included anatomical reduction and fixation of the orbital rim with careful globe preservation to ensure proper function and cosmetic appearance of periorbital and maxillofacial structures. Before surgical fracture repair, the dog received a constant rate infusion (CRI) of 0.45% NaCl (Baxter Healthcare Corporation, Deerfield, IL) with 0.05 mEq KCl/kg/h and 3 μg/kg/h fentanyl (Hospira, Inc.) at 38 mLh for systemic hydration and pain control. Systemic antibiotics were administered (ampicillin sodium/sulbactam sodium 285 mg IV q8 h, Unasyn, Lek Pharmaceuticals Inc., Princeton, NJ) for infection prophylaxis. Triple antibiotic ophthalmic ointment was also applied (1/4 inch strip OS q6 h, neomycin and polymyxin B sulfates and bacitracin zinc, E. Fougera & Co., Melville, NY) to prevent infection of the conjunctival wound and to protect the cornea from further trauma. A 50 μg/h (5 mg content) fentanyl patch (Mylan Pharmaceuticals Inc., Morgantown, WV) was placed on the distal left hindlimb 12 h before surgery for perioperative pain control. After premedication with hydromorphone (1 mg IV; Baxter Healthcare Corporation) and glycopyrrolate (0.05 mg IV; Baxter Healthcare Corporation), general anesthesia was induced with propofol (50 mg IV; Teva Pharmaceuticals, North Wales, PA) and maintained with isoflurane (Minrad Inc., Bethlehem, PA) and oxygen on a circle system following intubation. The patient was placed in right lateral recumbency and the area over the left zygomatic bone and surrounding structures were prepped for surgery in a routine manner.7

To provide access to the fractures for stabilization and fragment removal, an approach similar to a modified lateral orbitotomy technique was performed.8 A curved skin incision was made with a #10 Bard-Parker blade beginning about 1 cm ventral to the lateral canthus, extending caudally over the zygomatic arch fracture sites to a point 4 cm rostral and ventral to the base of the ear. The incision was extended rostrally and the subcutaneous tissues were separated bluntly to expose the fracture fragments and allow dorsal retraction of the palpebral branch of the auriculopalpebral nerve (CN VII). The aponeurosis of the temporalis muscle was transected 5 mm dorsal and parallel to the zygomatic arch, providing sufficient exposure for manual reduction of the rostral portion of the displaced zygomatic bone to its normal anatomical position, and removal of the 1 cm by 3 cm fragment of dorsal lacrimal bone positioned ventral to the globe (Fig. 3). A 2.0 dynamic compression plate (DCP) made of 316 L steel was placed over the rostral fracture line and secured with three 2.0 mm bicortical bone screws rostral to the fracture line and two screws caudal to the fracture line. No contouring of the plate was necessary. Due to the excellent anatomical alignment of the orbit and surrounding structures, the caudal zygomatic bone fracture was left to heal by secondary bone healing. Forced duction tests, performed to evaluate eye movement before and after fracture reduction, revealed a freely moveable globe. The left nasolacrimal duct was irrigated to ensure patency. The fascia of the temporalis muscle aponeurosis was sutured with simple continuous sutures of 2-0 polydioxanone suture (PDS, violet monofilament, Ethicon Inc.), the subcutaneous layer was closed with simple continuous sutures of 3-0 poliglecaprone 25 suture (Monocryl, violet monofilament, Ethicon Inc.), and the skin was sutured with a simple interrupted pattern of 4-0 polypropylene suture (Prolene, blue monofilament, Ethicon Inc). A temporary tarsorrhaphy was performed OS using horizontal mattress sutures of 6-0 nylon (Monosof Nylon, Surgalloy) for postoperative protection of the globe.

An immediate postoperative CT scan of the skull showed fracture reduction with the bone plate on the lateral aspect of the zygomatic bone, and significantly decreased ventral and lateral globe displacement (Fig. 4a,b). The most rostral cortical bone screw penetrated the unerupted left maxillary fourth premolar, fracturing its buccal surface. The second screw penetrated the alveolus of the unerupted left maxillary first molar. The caudal zygomatic bone fragment was mildly abaxially displaced and the mandibular fracture was visible (Fig. 4a). The possibility existed that penetration of the screws in the caudal maxillary teeth would disrupt the supportive structures of the teeth and affect proper eruption, but the decision was made to monitor for tooth eruption abnormalities, rather than prolong anesthesia to remove the screws and replace the plate, and thus avoid risking additional trauma to the globe and periorbital structures, or compromising the patient’s systemic welfare.

Immediate postoperative therapy included topical triple antibiotic ophthalmic ointment (1/4 inch strip OS q8 h for 14 days), systemic antibiotics (ampicillin sodium/sulbactam sodium 285 mg IV q8 h), and a CRI of fentanyl (Hospira, Inc.) and ketamine (Ketaset, Fort Dodge Animal Health, Fort Dodge, IA). An Elizabethan collar (M3, St. Paul, MN) was placed before extubation to prevent self trauma. A cold pack was placed over the incision for 10 min every 8 h to decrease postoperative swelling. One day following surgery, the patient’s appetite was normal and feeding of dry kibble was resumed to encourage jaw movement to prevent the development of bridging callus between the zygomatic and mandibular fractures.9 Postoperative pain appeared well-controlled based on the patient’s ability to chew dry kibble, normal HR and RR, lack of vocalization upon palpation, and appropriate mentation and activity level. The temporary tarsorrhaphy was removed to allow examination of the globe OS. Moderate periorbital swelling, mild enophthalmia, and mild skin bruising over the incision were present. The severe ventro-lateral globe displacement and strabismus were resolved, and normal globe motility was regained, subsequent to orbital rim fracture reduction. The ventral palpebral superficial puncture wound was healing well. The remainder of the ocular examination was normal. The fentanyl/ketamine CRI was tapered and discontinued over the next 24 h, with initiation of an oral opiod (25 mg
tablet PO q8-12 h for 10 days, tramadol [Animal Pharmaceuticals, Paterson, NJ]) before final discontinuation of the CRI. Intravenous antibiotics were replaced by oral antibiotics (amoxicillin trihydrate/clavulanate potassium 250 mg PO q12h for 14 days; Clavamox, Pfizer Animal Health, Exton, PA). Jaw movement, consisting of biting hard food and toys, was encouraged.9

Outcome/Follow-up

Two weeks following surgery, there was mild subcutaneous swelling ventro-lateral to the globe (dorsal to the incision site) OS, which was expected from the trauma and surgical procedure. The globe was mildly enophthalmic but no strabismus or abnormal ventro-lateral displacement of the globe was noted OS. No epiphora or abnormal lacrimal drainage was noted OU. Menace response and saccadic movements were normal OU. The palpebral reflex was normal and complete OU. Normal ocular movements OU were elicited with movement of the head. STT-I, IOP, dazzle response, PLR were normal OU. The cornea did not retain fluorescein dye and the intraocular examination was unremarkable OU. Cranial nerve examination was normal. The skin incision had healed without complication and skin sutures were removed. Jaw opening measurement was 9 cm (as measured from the occlusal surface of the dorsal canine tooth to the occlusal surface of the ventral canine tooth). This measurement was performed to monitor appropriate jaw movement due to the possibility of callus formation from the uniting of the zygomatic and coronoid fractures and thus preventing normal jaw motion, as any decrease from the baseline measurement of 9–10 cm could be a sign of early bridging of the fractures.9

Three months following surgery, periorbital swelling and mild enophthalmia were resolved OS. Neither epiphora nor abnormal lacrimal drainage were noted OU and good facial symmetry was apparent. Menace response and saccadic movements were normal OU. The palpebral reflex was normal and complete OU. STT-I, IOP, dazzle response, and PLR were normal OU. The cornea did not retain fluorescein dye and intraocular examination was unremarkable OU. A firm proliferation of bony tissue was palpated over the previous zygomatic arch fracture. Oral examination revealed delayed eruption of the left maxillary fourth premolar as compared to the right side.

CT scan was performed to evaluate fracture healing and revealed bony union of the zygomatic fractures with extensive osseous proliferation surrounding the bone plate. The left coronoid fracture was healed (Fig. 5). There was persistent penetration of the left maxillary fourth premolar by a cortical bone screw, which was probably the cause of the delayed tooth eruption. Resolution of previously evident periocular soft tissue swelling and lateral displacement of the left globe was noted.

Because the zygomatic fractures were healed and the bone plate was interfering with eruption of the left maxillary fourth premolar, surgical removal of the plate was performed. The patient was anesthetized and prepared for surgery as described previously. An incision was made over the previous incision site. Proliferative bone, which prevented visualization of the bone plate, was removed with small bone rongeurs. The screws and bone plate were removed and the incision was closed as before. The screws, plate, and proliferative tissue were placed in thioglycollate medium (Becton, Dickinson and Company, Sparks, MD) for bacterial...
culture. The left maxillary third and fourth premolars were extracted with standard exodontic technique without complication.\textsuperscript{10} The patient recovered from anesthesia uneventfully and was discharged one day postoperatively with an oral nonsteroidal anti-inflammatory medication (Rimadyl, Pfizer Animal Health, 50 mg PO q12h for 5 days), tramadol (Animal Pharmaceuticals, 50 mg PO q8 h for 5 days) and an oral antibiotic (cephalexin, TEVA Pharmaceuticals, Sellersville, PA, 500 mg q8 h for 12 days). The sutures were removed 14 days later. Culture results revealed no bacterial growth.

A 4-month follow-up visit revealed good facial symmetry and no enophthalmos or strabismus OU (Fig. 6). No epiphora was noted OU. Normal saccadic movements, menace response, and palpebral reflex were noted OU. STT-I, IOP, dazzle response, and PLR were normal OU. The cornea did not retain fluorescein dye and intraocular examination was unremarkable OU. The skin and dental incisions healed without complications. Jaw movement was appropriate and jaw opening measured (as described above) 10 cm.

DISCUSSION

This case report describes surgical fixation of an orbital rim fracture in a young dog using a miniplate system, resulting in excellent functional and cosmetic outcomes. Severe ventro-lateral globe displacement and presence of a fragment of lacrimal bone were indications for early surgical repair of the zygomatic arch fracture. Due to the rostral location and comminution of the zygomatic bone fracture, bone plating offered the best surgical fixation technique\textsuperscript{4} and immediate fracture fixation permitted early restoration of function.\textsuperscript{11} Removal of the lacrimal bone fragment prevented sequestrum formation and penetration or entrapment of the globe.\textsuperscript{12,13} Additionally, early return to normal jaw function likely prevented ankylosis and bridging of the zygomatic and mandibular fractures.\textsuperscript{9,14,15} Without surgical intervention, this dog may have had vision deficits and globe compromise OS as well as functional and mechanical maxillo-mandibular abnormalities. Early surgical intervention using stable plate fixation should be routinely considered when treating comminuted fractures of the orbital rim affecting globe placement and integrity.

Maxillofacial and mandibular fractures are common injuries\textsuperscript{1,3,4} requiring immediate veterinary care and often surgical correction.\textsuperscript{1,3,5,6,16} Indications for surgical repair of maxillofacial fractures include dental malocclusion, facial deformity, globe displacement, respiratory compromise, and possibility of bone sequestrum development.\textsuperscript{1,3,4,6,13} The objectives of treatment are to provide ideal anatomical reduction and early return to function with minimal surgical trauma,\textsuperscript{1,4} which are provided by rigid skeletal fixation using miniplates and screws, especially when reducing comminuted bone fragments or fracture gaps.\textsuperscript{3} In humans, use of specialty miniplates and screws has become a preferred method for fracture fixation involving the zygomatic arch and other fractures involving the fronto-zygomatic arch due to excellent outcomes.\textsuperscript{17,18} Other techniques described in veterinary literature for maxillofacial fracture repair include external fixators, various wiring and splinting methods, and muzzles.\textsuperscript{3,6} Few reports exist in the veterinary literature of repair of maxillofacial fractures involving the lateral orbital rim.\textsuperscript{1,5,6,17}

Diagnosis of peri-orbital fractures is often based on history, clinical signs and advanced imaging. Deformation of normal facial contours with swelling and pain on palpation, with or without instability or crepitus, may suggest fracture.\textsuperscript{4,12,13} In the case presented here, ventro-lateral orbital rim deformation, causing severe ventro-lateral globe displacement, and crepitus over the zygomatic arch were present. CT was the diagnostic modality of choice due to its superior resolution of both bony and soft tissue periorcular structures.\textsuperscript{19} Specific disadvantages of plate fixation include the necessity for an open procedure, risk to neuromuscular structures,
malunion or malocclusion due to misplacement, dental trauma, and abnormal extracapsular ankylosis of the temporomandibular joint.\textsuperscript{9,14–16,20} In the presented case, dental trauma occurred due to screw misplacement through the root of the left maxillary fourth premolar resulting in abnormal eruption and possible devitalization of the tooth. Miniaturized plate and screw systems, developed to provide accurate stability to thin maxillary bone fragments and adequate screw purchase in thin bone,\textsuperscript{4} were used in this case. Perhaps use of even smaller screws with monocortical, rather than bicortical, placement\textsuperscript{20} would have prevented tooth root penetration. The penetration of the tooth roots was a minor complication in this case and monitoring for delayed tooth eruption allowed for early removal of the teeth and prevention of further complications such as inflammation or infection.\textsuperscript{21}

Possible complications prevented with careful removal of the displaced lacrimal bone fragment in this patient include absence of bone sequestrum formation, penetration or entrapment of the globe, and abnormal tear drainage.\textsuperscript{12,13} Lacrimal bone fracture may lead to nasolacrimal duct disruption, as the nasolacrimal sac and duct are partially encased by the lacrimal bone,\textsuperscript{22} which may subsequently lead to chronic or intermittent epiphora.\textsuperscript{12} In this case, careful removal of the bone without extensive exploration may have favored the positive outcome as the dog has not developed nasolacrimal abnormalities.

Mechanical interference of jaw movement is a noted complication of maxillofacial fractures.\textsuperscript{9,14,15} Extracapsular or false temporomandibular joint ankylosis is caused by extracapsular pathology such as adhesions of the arch to components of the mandible.\textsuperscript{9,14,15} In the case presented here, healing of the comminuted zygomatic bone fracture and the coronoid fracture could have resulted in bridging by bony callus formation. For this reason, jaw movement was encouraged by offering hard food and toys in the immediate and distant postoperative period. This immediate return to normal jaw function may not have been possible with other fracture repair techniques. The baseline jaw opening measurement of around 10 cm did not vary throughout the recovery period.

Fractures of the zygomatic bone affecting lateral orbital rim can lead to exophthalmus, enophthalmus, and severe caudal and/or ventral displacement of the eye.\textsuperscript{4} Early repair of zygomatic bone fractures affecting the stability of the orbital rim is essential in attaining a favorable cosmetic and functional outcome. The use of miniplates and screws with the lateral orbitotomy approach, as described in the presented case, is an effective method to repair comminuted zygomatic bone orbital rim fractures, acquire proper anatomical reduction of the globe, and provide good cosmetic results.

REFERENCES


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