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*Clinical Reports*

# Repair of a Coracoid Luxation and a Tibiotarsal Fracture in a Bald Eagle (*Haliaeetus leucocephalus*)

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*Abstract:* A 4.5-kg, adult bald eagle (*Haliaeetus leucocephalus*) was presented after being found unable to fly. Crepitus was palpated in the left shoulder; however, the wing position was normal. Radiographs revealed caudoventral luxation of the left coracoid, affecting its distal articulation with the clavicle and its proximal articulation with the sternum. The luxation affecting the coracoid-sternum articulation was repaired by using a 4-hole, 1.5-mm T-plate and a 6-hole, 2.0-mm dynamic compression plate (DCP) placed side by side. The luxation affecting the coracoid and the clavicle was repaired by 2 cerclage wires in a simple interrupted pattern. Before a scheduled release, the bird sustained a closed, complete mid diaphyseal transverse fracture of the right tibiotarsus, which most likely occurred during recapture from the flight cage. The fracture was surgically repaired with 2 circumferential cerclage wires, an intramedullary Kirschner wire and one 10-hole, 2.7-mm DCP. The bird was successfully released, 105 days after the first surgery, near the location where it was found.

*Key words:* Coracoid, luxation, tibiotarsus, fracture, plate fixation, avian, bald eagle, *Haliaeetus leucocephalus*

## Clinical Report

A 4.5-kg adult bald eagle (*Haliaeetus leucocephalus*) was presented to the Wildlife Hospital of Louisiana (Louisiana State University, Baton Rouge, LA, USA) after being found unable to fly. On presentation, the bird was bright, alert, and responsive. Physical examination revealed good body condition (body score 3/5) and hydration status. Crepitus was noted in the left shoulder on palpation; however, the wing positioning was normal. A blood sample was collected from the right jugular vein for a complete blood cell (CBC) count and plasma biochemical analysis. Results revealed leukocytosis ($27.5 \times 10^3$ cells/µl; reference range, $6.2–21.5 \times 10^3$ cells/µl), with absolute heterophilia ($22.0 \times 10^3$ cells/µl; reference range, $3.3–13.0 \times 10^3$ cells/µl) and monocytosis ($1.1 \times 10^3$ cells/µl; reference range, $0.1–0.9 \times 10^3$ cells/µl).[1] High concentrations of glucose (526 mg/dl; reference range, 249–305 mg/dl), aspartate aminotransferase (943 U/L; reference range, 131–183 U/L), and creatine kinase (8200 U/L; reference range, 343–1637 U/L) were present on the plasma biochemical panel.[1]

The eagle was induced with 5% isoflurane in oxygen delivered by a face mask, intubated with a 5.0-mm uncuffed endotracheal tube, and maintained on 2% isoflurane for radiographs. The radiographs revealed a caudoventral luxation of the left coracoid (Figs 1 and 2), affecting its distal articulation with the clavicle and its proximal articulation with the sternum. The eagle recovered uneventfully from anesthesia. Initial therapy consisted of cage rest, meloxicam (0.2 mg/kg PO q24h; Boehringer Ingelheim Vetmedica, St Joseph, MO, USA), and offering frozen-thawed rats (50 g/kg q24h) until surgery was scheduled.

Before surgery, the bird was premedicated with butorphanol (0.2 mg/kg IM; Fort Dodge Animal Health, Fort Dodge, IA, USA) and diazepam (0.2 mg/kg IM), and anesthesia was induced as

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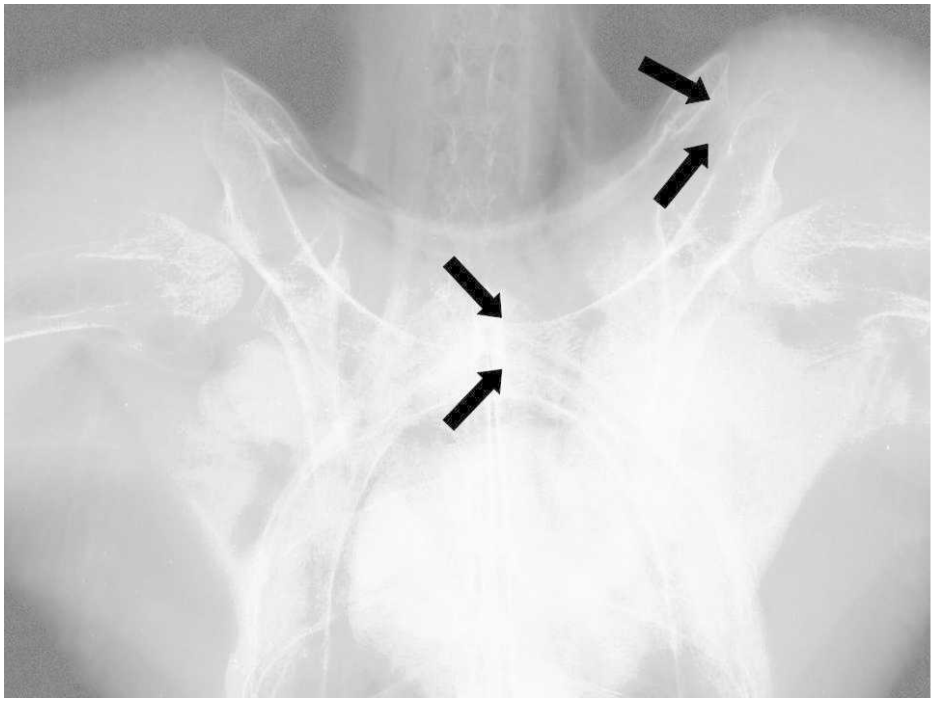


**Figure 1.** Ventrodorsal radiographic view of a bald eagle that presented for inability to fly. A luxation of the left coracoid is present (arrows).

described before. During the procedure, the eagle received fluids (5 ml/kg per hour; Normosol, Abbott Laboratories, Abbott Park, IL, USA) through an intravenous catheter placed in the medial metatarsal vein. The heart rate (Doppler, electrocardiogram), respiratory rate, and body temperature (cloacal temperature) were monitored during anesthesia. Heat was provided with a forced-air warmer system (Bair Hugger Warming System, model 505 with model 530 Pediatric Long Blanket, Augustine Medical, Eden Prairie, MN, USA). The bird received cefazolin (50 mg/kg IV q2h) perioperatively.

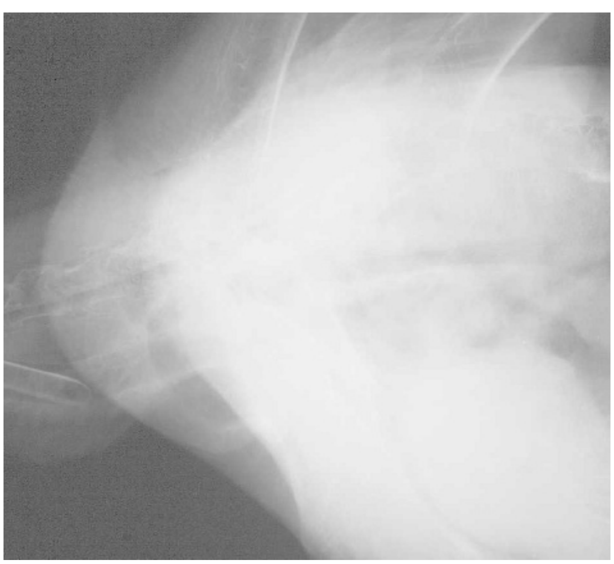


**Figure 2.** Lateral radiographic view of the eagle described in Figure 1, revealing left coracoid luxation.

The eagle was placed in dorsal recumbency, with the left wing partially extended. The feathers were plucked from the left pectoral region, and the surgical site was prepared routinely with alcohol and chlorhexidine. The skin was incised along the left clavicle and extended along the cranial half of the sternum. The superficial and deep pectoral muscles were severed from the cranial attachment to the clavicle and were retracted caudally, exposing the coracoid. The luxation affecting the coracoid-sternum articulation was repaired first by using a 4-hole, 1.5-mm T-plate and a 6-hole, 2.0-mm dynamic compression plate (DCP) (Synthes Inc, West Chester, PA, USA) placed side by side over the coracoid-sternum articulation. Each screw hole was predrilled with a 1.1- and 1.5-mm drill bit, respectively, for the 1.5- and 2.0-mm bone plates. The holes were then measured by using a depth gauge to determine appropriate screw length and then tapped by using a 1.5-mm or 2.0-mm tap. Each screw was placed in its respective hole before moving to the next screw. The luxation

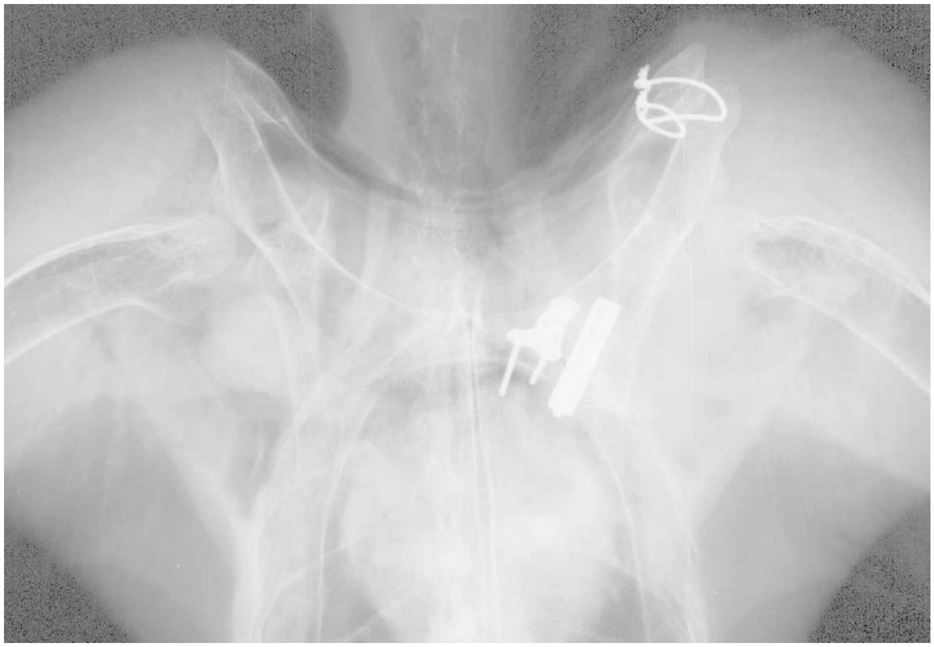


**Figure 3.** Ventrodorsal radiographic view of the eagle described in Figure 1, showing surgical repair of the left coracoid luxation with a T-plate, a compression plate, and cerclage wires.

affecting the coracoid and the clavicle was repaired by using 2 cerclage wires (22 gauge) in a simple interrupted pattern. Holes were drilled through the coracoid and the clavicle with a 1.5-mm drill bit, one for each wire. The ends of the cerclage wires were passed through the coracoid, around the clavicle, and tied. The surgical area was lavaged and then closed with absorbable monofilament polydioxanone (4.0 PDS, Ethicon Inc, Sommerville, NJ, USA) with a simple continuous pattern in 3 layers: deep and superficial pectorals, subcutaneous tissue, and intradermal tissue. The incision was covered with permeable wound dressing (Opsite, Smith and Nephew Medical Unlimited, Hull, England). The duration of the surgical procedure was 1 hour and 55 minutes.

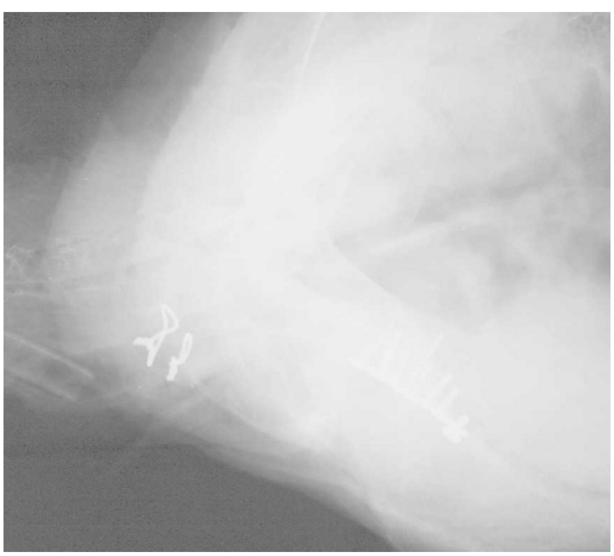


**Figure 4.** Lateral radiographic view of the eagle described in Figure 1, showing surgical repair of the left coracoid luxation with a T-plate, a compression plate, and cerclage wires.

Postoperative radiographs revealed reduction of the luxated coracoid by using bone plates side by side and cerclage wires (Figs 3 and 4). The wing was immobilized against the body with a stockinette and elastic tape. Recovery from anesthesia was uneventful.

The bird was cage rested (1.1 × 1.1 × 1.1 m) with a block perch for 45 days. During the first 21 days of the rehabilitation process, the stockinette was maintained to minimize movement of the wing. The bandage was removed once weekly for physical rehabilitation. Passive range of motion exercises were performed for all joints of the left wing (for 3–5 minutes) while the eagle was under general anesthesia. Meloxicam (0.2 mg/kg PO q24h) was given for 12 days after surgery. Blood tests and radiographs were repeated 3 weeks after surgery, and results were unremarkable. Radiographs showed no change in implant position and reduction of the coracoid.

Forty-five days after surgery, the bird was transferred to a flight cage (130 × 21 × 6 m) for 15 days to complete the rehabilitation process. The bird was capable of flight immediately after being placed in the cage.

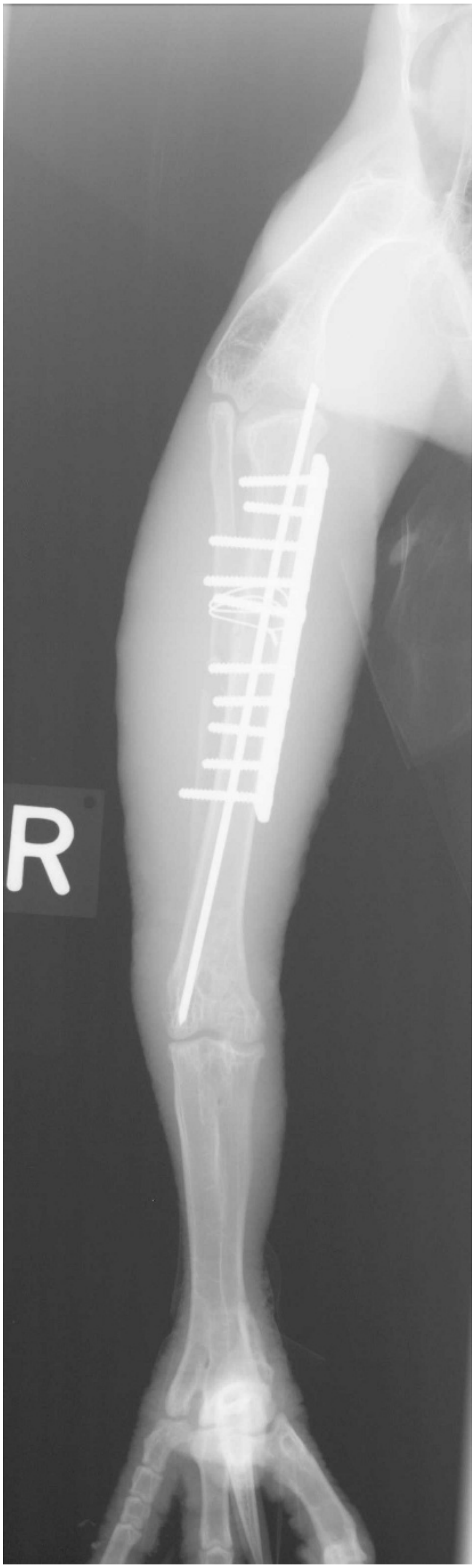
The bird was reexamined 60 days after surgery for a final CBC count and radiographs before release into the wild. During the procedure, it was noted that the bird had sustained a closed complete, mid diaphyseal transverse fracture of the right tibiotarsus (Figs 5 and 6). The injury most likely occurred during recapture from the flight cage. The fracture was stabilized with a modified Robert Jones splint, and the bird received butorphanol (1 mg/kg IM) for analgesia.

The bird was premedicated with butorphanol (1 mg/kg IM) and meloxicam (0.2 mg/kg IM) the next day for surgical stabilization of the fracture. Anesthesia was induced as described above. During the procedure, the eagle received fluids (10 ml/kg per hour, Normosol) through an intravenous catheter placed in the right basilic vein. During surgery, the bird received atropine (0.02 mg/kg) twice, because of bradycardia. Cefazolin (50 mg/kg IV) was given at the beginning of the procedure and repeated 90 minutes later.

**Figure 5.** Anteroposterior radiographic view of the eagle described in Figure 1, revealing mid diaphyseal transverse fracture of the right tibiotarsus.


**Figure 6.** Lateral radiographic view of the eagle described in Figure 1, revealing mid diaphyseal transverse fracture of the right tibiotarsus.

The eagle was placed in dorsal recumbency. The surrounding feathers of the distal femur, tibiotarsus, and tarsometatarsus were removed, and the surgical site was prepared routinely for sterile surgery. The skin was incised medially along the shaft of the tibiotarsus. The proximal tibiotarsus was exposed, separating the fascial planes between the cranial complex of muscles (fibularis longus and tibialis cranialis) and the medial head of the gastrocnemius to expose the fracture site. A longitudinal fissure extending from the fracture site into the proximal fragment observed. Two circumferential cerclage wires (22 gauge) were placed around the proximal fragment was to prevent further splitting of the fissure. An intramedullary (IM) Kirschner pin (3/32 inch) (Synthes Inc) was normograded from the nonarticular portion of the medial tibiotarsal plateau until it was seated in the distal tibiotarsal fragment. One 10-hole, 2.7-mm DCP (Synthes Inc) was contoured to the medial tibiotarsus and attached with 2.7-mm screws to the proximal (5 screws) and the distal (5 screws) fragments by using the technique described previously. The surgery site was closed with a simple continuous pattern by using polydioxanone (4–0 PDS) in 3 layers: muscles, subcutaneous, and cutaneous. The duration of the surgical procedure was 2 hours. Postoperative radiographs showed good




apposition and alignment of the fracture (Figs 7 and 8). The animal had a slow but uneventful recovery from anesthesia.

The bird was weight bearing in the affected leg after the surgery and cage rested for an additional 42 days. Enrofloxacin (15 mg/kg PO q24h; Bayer Health Care LLC, Shawnee Mission, KS, USA) and meloxicam (0.2 mg/kg PO q24h) were given for 12 days after surgery. Tibiotarsal radiographs at 3 and 6 weeks after surgery revealed no change in implant position, and appropriate callus formation at the fracture site. Six weeks after surgery, the IM pin was removed uneventfully with the bird under general anesthesia with isoflurane. The bird was successfully released, 105 days after the first surgery, near the location where it had been found.

## Discussion

To the best of our knowledge, this case represents the first report of successful surgical repair of a coracoid luxation and the first case report of surgical repair of a tibiotarsal fracture with a system combining an IM pin and bone plate in a raptor.

The coracoid is a large bone that, along with the scapula and the clavicle, comprise the avian thoracic girdle.[2] It articulates proximally with the sternum and distally with the humerus, clavicle, and scapula. The coracoid acts as a strut between the wing and the sternum, preventing the collapse of the thorax when the pectoral muscles contract during the wing downstroke. During gliding flights, the coracoid helps to suspend the sternum along with other bones of the thoracic gridle.[2]

Coracoid luxations are uncommon in birds. These injuries are thought to occur in a similar way that coracoid fractures do, when the bird collides with a solid object.[3,4] Birds with a coracoid luxation or a coracoid fracture usually cannot fly or are only capable of flying minimal distances.[4,5] Diagnosing a coracoid luxation can be difficult on physical examination, because birds may only have a slight wing droop or may hold the wing in a normal position. In this case, the bird did not present with a wing droop, but crepitus could be palpated with manipulation of the left shoulder. Radiographs are required to confirm a coracoid

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**Figure 7.** Anteroposterior radiographic view of the eagle described in Figure 1, showing surgical repair of the right tibiotarsal fracture.


**Figure 8.** Lateral radiographic view of the eagle described in Figure 1, showing surgical repair of the right tibiotarsal fracture.

luxation and to differentiate it from other lesions of the pectoral girdle.

Because of the severity of the lesion, we thought that open reduction and internal plate fixation would provide the best chance for recovery of flight. Other potential treatment options include open reduction of the luxation and fixation of the coracoid to the sternum with intramedullary pins and nonsurgical treatment with external coaptation and cage rest. Potential complications associated with pinning are advancement of the pin into the coelomic cavity and penetration into important soft-tissue structures, damage to the shoulder joint resulting in periarticular fibrosis, shoulder joint ankylosis, and impaired shoulder function.[4,6] Periarticular fibrosis, shoulder joint ankylosis, and impaired function are also potential complications of nonsurgical management. The prognosis for return to full flight function was considered less favorable with nonsurgical than with surgical treatment.

The surgical approach to the coracoid has been described.[6,7] The clavicular artery is located within the pectoral muscles, and elevating the pectoral muscles close to the keel and clavicle is recommended to prevent transecting the artery (R. Aguilar, oral communication, 2005). Internal fixation of this coracoid luxation was completed by using a second plate placed adjacent to the first to obtain additional purchase of the cortical bone. Two cerclage wires were placed through the clavicle and the coracoid, stabilizing the triosseal canal formed by the coracoid, clavicle, and scapula. A body-wing bandage was maintained on the bird for 3 weeks after the surgery to immobilize the wing.

The tibiotarsus is formed from a fusion of the tibia and the proximal row of tarsal bones during the growth of the avian embryo. The fibula is attached to the tibiotarsus at the fibular crest (*crista fibularis*).[2] The arterial supply to the limb runs between the fibula and the tibia proximal and distal to the crest.[8] The proximal two thirds are well protected by soft tissue. The distal end of the tibiotarsus forms an ossified supratendinal bridge over the muscle extensor digitorum longus tendon, which runs through it with almost an S-shaped kink.[9] The primary loads borne during normal use are compressive.[10]

Tibiotarsal fractures are among the most common orthopedic problems encountered in raptors, especially in newly jessed hawks. In this case, it is not clear when the fracture occurred, but it most likely occurred during capture from the flight cage. This type of fracture is usually located a few millimeters distal to the fibular crest, where the tibiotarsus changes from an almost triangular form proximally to a more round portion distally.[9,11] The fractures are often simple transverse, as it was in this eagle. Damage to the tibial or fibular nerve or both is common with this type of fracture.[12]

The surgical approach to the tibiotarsus has been described.[6] In this case, the fracture was approached through a craniomedial incision between the tibialis cranialis and the medial portion of gastrocnemius. A more lateral approach might result in an encounter with the cranial tibial vein and artery, and the fibular nerve.[8] The IM pin used in the repair was normograded from the fossa retropatellaris in the proximal segment of the tibiotarsus. Normograde IM pin insertion is preferred over retrograde pin insertion in the tibiotarsus, because the risk for stifle joint penetration is decreased.[4] Insertion through the intertarsal joint is not recommended, because the tendons of insertion of the digital flexor muscles pass through the tibiotarsal cartilage in this area and may be irreparably damaged.[8] The pin was left protruding approximately 1 cm from the craniomedial aspect of the femorotibial joint and had been passed through the fascial insertion of muscles femorotibialis externus and medius. Placing the pin through the fossa retropatellaris and the protrusion of the pin through the skin have not been associated with complications.[9] This procedure neatly avoids the cruciate ligaments, the menisci, and the femur.[9] Advantages of IM pin-plate fixations are the following: 1) the IM pin can assist the surgeon in reestablishing spatial alignment of the limb; 2) the IM pin maintains reduction of the main bone fragments as the plate is placed on the bone; 3) the IM pin reduces plate strain, thereby increasing fatigue life of the construct; and 4) the IM pin allows microstrain of the fracture plane if it occupies 35%–50% the diameter of the marrow cavity without increasing stiffness of the repair beyond that which is needed.[13] Other fixation methods for successful repair of similar tibiotarsal fractures are type 2 external skeletal fixation,[14] external skeletal fixation–tie-in fixation,[12] IM pin with adjunct cerclage fixation,[8] interlocking nail,[15] and type 1A hybrid external skeletal fixation.[16] In birds that weigh under 300 g, tibiotarsal fractures repaired with a combination of an IM pin or K-wire and external coaptation in the form of an Altman splint may heal very well.[12] Of the fixations mentioned, only external skeletal fixation–tie-in fixation has been biomechanically evaluated in birds.[17]

Bone plates provide rigid stability and maintain anatomic reduction, allowing early return to function. Plates counteract bending and rotational moments, and shear and compression forces.[18] In birds, an advantage of bone plates is excellent patient tolerance, because plates are completely internal and provide rigid fixation with less callus formation. Disadvantages of bone plating are high costs for instrumentation and implants, specialized training in placing the plates, prolonged anesthesia times, soft tissue disruption, and potential thermal conduction.[7]

Plate fixation has been applied successfully in different avian species and bones[19–23] but historically has been discouraged, because the cortices of avian bones were considered too thin for adequate screw purchase.[24] To our knowledge, there are no studies on the holding strength of screws in avian long bones, nor are there any mechanical data with regard to optimal plate size based on the bone or size of the bird. Plate fixation with intramedullary polymethylmethacrylate has been described and might improve screw purchase in avian bone.[25]

Guidelines for screw insertion in avian bone have been published.[4,21,26] If a screw is stripped, a nut may be fashioned from a small piece of a polypropylene syringe case, drilled, and tapped to hold screw threads.[4,27]

One complication associated with bone plating in birds is plate bending. It has been suggested that long bone fractures in birds need to be repaired with longer plates than similar canine and feline fractures.[21] Tension and compression surfaces of avian bones have not been determined.[26] Improper plate length and surface application may contribute to implant failure. A combination of an IM pin and bone plate reduces internal plate stress, and thereby increases fatigue life of the plate.[13] In general, plates are not removed unless they cause a problem.[18] In this case, plate removal would have required major surgery and additional rehabilitation. Because both plates were imbedded under muscles, thermal conduction would be unlikely.

For this eagle, early return to full function was the goal of the 2 surgical procedures. During rehabilitation the eagle was found to be flight ready after the coracoid repair and weight bearing after the tibiotarsal repair.

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