Nonrigid External Fixation of the Elbow, Coxofemoral, and Tarsal Joints in Dogs

Zeev Schwartz, DVM
Dominique J. Griffon, DMV, MS, PhD, DACVS, DECVS
University of Illinois

ABSTRACT: Nonrigid external fixation of a joint is designed to restrict abnormal joint movement and facilitate healing of traumatized ligaments and capsule tissue while minimizing the impact of immobilization on articular homeostasis and cartilage metabolism. Weight bearing and joint motion minimize muscle atrophy and loss of bone mineral and allow controlled loading of the ligaments, thereby improving their strength and functionality. This article describes simple, cost-effective techniques for the percutaneous application of external fixators to the elbow, coxofemoral, and tarsal joints of dogs.

Ligament rupture and joint instability have been reported in 50% of traumatic joint luxations.1–4 Treatment of these injuries aims to restore joint alignment and stability while supporting structures and articular cartilage surfaces heal.5–8 Traditional treatment options involve open or closed reduction, joint immobilization, and exercise restriction for a minimum of 2 weeks.9 During the immobilization period, external coaptation consisting of a bandage, splint, sling, or rigid external fixator is typically used to fix the joint in a position that minimizes the risk of reluxation. However, prolonged immobilization (≥3 weeks) decreases synovial fluid production as well as cartilage stiffness and thickness and leads to degenerative joint disease and loss of muscle mass and bone mineral content.5–8 On the other hand, continuous passive motion has been shown to stimulate neochondrogenesis, promoting differentiation of mesenchymal cells toward a chondrogenic lineage, especially during the first few weeks of the healing process.10

Mobility is a prerequisite to joint homeostasis. It enhances the synthesis of glycosaminoglycans and hyaluronate and contributes to the circulation of synovial fluid, thereby improving the nutrition of articular cartilage.11 Maintaining the range of motion of a traumatized joint helps to clear intraarticular hematomas, minimizes the formation of periarticular adhesions, and improves the alignment of newly formed collagen fibers in the joint capsule.11 Nonrigid or flexible external fixation uses pins and elastic bands or hinges to allow early postoperative weight bearing and biomechanical loading of the bones, thereby minimizing muscle atrophy and loss of bone mineral content while providing adjunctive stabilization.12 The advantages and disadvantages of nonrigid external fixation are listed in Box I.

The goals of nonrigid external fixation are to prevent reluxation and promote healing of supportive structures while minimizing the impact of immobilization on articular homeostasis and cartilage metabolism.7,13,14 These goals should ideally be achieved via techniques that are simple, cost effective, and minimally invasive. The aim of this article is to describe the indications and surgical techniques for, and the perioperative management and potential complications of, nonrigid external fixation of the elbow, hip, and tarsus in dogs.
FLEXIBLE FIXATION OF THE ELBOW
Mediolateral instabilities of the elbow typically result from traumatic elbow luxations. They are directed laterally in more than 90% of cases because the medial epicondyle of the humerus usually prevents medial luxation of the ulna.1,2,9,14 The initial step in the management of this condition is to restore the alignment of articular surfaces within the elbow joint. Closed reduction has been recommended for treatment of traumatic luxations within the first few days or of congenital elbow luxation in dogs younger than 3 months. Open reduction is indicated to manage congenital elbow luxation in dogs older than 4 months, traumatic elbow luxation with fractures, traumatic luxation with postreduction mediolateral instability, chronic luxations, or failure of a closed reduction.3,9

After reduction, the elbow is traditionally immobilized in extension so that the anconeal process engages the supratrochlear foramen of the humerus, thereby preventing reluxation of the joint. This immobilization also enhances formation of scar tissue and, to a lesser extent, healing of ligaments, contributing to the mediolateral stability of the joint. The current standard for postoperative management of elbow luxation is application of a spica splint for 2 to 3 weeks,1–3 although placement of a transarticular pin has also been described.2,3,15 Alternatively, flexible external fixation can be used in the management of mediolateral instabilities of the elbow. Unlike a spica splint, the flexible external fixator does not compress the limb or cause abrasions,3 and it permits motion of the elbow joint.

Technique
Flexible external fixation of the elbow requires two full pins,4 a rigid bar,5 elastic bands, clamps, and rubber stoppers. One pin is placed in the distal quarter of the humerus, proximal to the supratrochlear foramen and perpendicular to the long axis of the bone. A stab incision is made through the skin. Blunt dissection with a pair of mosquito forceps minimizes the risk of trauma to the radial nerve during pin insertion. The second pin is placed parallel to the first in the center of the olecranon, at the proximal aspect of the bone (Figure 1). The pins should be placed in an isometric manner to allow consistent tension of the elastic bands and avoid interference with the range of motion. If periarticular swelling prevents accurate palpation of these landmarks, a 22-gauge, 1.5-inch needle may be placed

Box 1. Advantages, Disadvantages, and Complications of Nonrigid External Fixation

Advantages
- Permits weight bearing and joint motion soon after surgery
- Minimizes loss of muscle mass and bone mineral content and density
- Allows physiologic loading, leading to stronger and more functional ligaments
- Encourages orderly deposition of collagen
- Limits the formation of adhesions between periarticular structures
- Improves joint nutrition
- Stimulates synthesis of glycosaminoglycans and hyaluronate
- Improves clearance of joint hematomas
- Is cost effective and technically simple
- Is minimally invasive (for closed reduction)
- Improves range of motion and return to function

Disadvantages and complications
- Superficial infection and drainage at pin sites
- Premature pin loosening
- Pin breakage
- Implant migration and failure
- Deterioration of elastic bands
- Potential injury to adjacent vessels or nerves (e.g., sciatic, radial, ulnar nerves)
- Spread of infection into deeper tissue, including bone
- Bone fracture
- Recurrent luxation of the affected joint
to allow range of motion (Figure 2). The elastic bands should have enough tension to allow the patient to keep the elbow in extension and allow good range of motion. A band that is too tight will interfere with joint motion and may damage the articular cartilage. Rubber plugs (such as blood sampling tube stoppers) are driven over the pins before and after placement of the elastic bands to prevent migration of the bands, friction against the skin, and other injuries.

Postoperative Care
Radiographs should be taken after surgery to evaluate joint alignment and implant positioning and again 3 to 4 weeks later. A soft, padded bandage should be applied to the limb and changed once daily until soft tissue swelling has resolved. The pin tracts should be cleaned daily initially and as needed after removal of the bandage, and the frame should be checked twice daily after the elastic bands are placed. Owners should be instructed to watch for migration of the bands or signs of wear and tear. At this point, physical therapy should include warm compresses, passive range of motion exercises, and cold packing. Only short leash walks are allowed, followed by massage of the limb. The pins and external fixators are usually removed within 3 to 4 weeks after surgery. Exercise remains restricted for 4 to 6 weeks after the elbow is stable.

Complications
The most common complication after a closed reduction is relaxation warranting open reduction and repair of the collateral ligaments. Owners should be informed of the likelihood of decreased range of motion and progressive osteoarthritis in the affected joint. Based on our experience, the most common complication specific to flexible fixation of the elbow is excessive drainage and infection around the pin tracts. Our impression is that this is more likely to occur when flexible fixation is applied within 2 to 3 days after surgery, before postoperative swelling has resolved. Other complications include fracture of the olecranon, premature pin loosening, pin breakage, and deterioration of the bands. Although we have not experienced issues related to the placement of the pins or postoperative relaxation, evaluation of this technique in a larger number of cases is warranted to evaluate the risk of this complication.

FLEXIBLE FIXATION OF THE COXOFEMORAL JOINT
Coxofemoral luxation is a common traumatic injury encountered in small animal practice, comprising up to 90% of all joint luxations. In most cases (78%),
Luxation occurs in a craniodorsal direction because of the strong pull of the gluteal and iliopsoas muscles. Maintenance of a closed reduction of a hip luxation most commonly relies on the application of an Ehmer sling or figure-of-eight bandage. In this method, the limb is held in abduction and internal rotation, maximizing coverage of the femoral head but preventing weight bearing during the recovery period. The flexible external fixator maintains the femur in a similar position, yet allows weight bearing and joint motion immediately after reduction and avoids the difficulties encountered in maintaining a sling. Because the femoral head is held in abduction and internal rotation, this technique is contraindicated in cases of cranioventral coxofemoral luxation and should not be applied in cases with intraarticular or pelvic fractures or with avulsion of the round ligament, for which open reduction is indicated.

Open reduction of coxofemoral luxation is indicated in cases with avulsion fractures of the fovea capitis or acetabulum, acetabular rim fractures, and an inability to reduce the joint in a closed fashion.

**Clinical Pearls**

- Nonrigid external fixation can be applied to the elbow, hip, and tarsus in a simple and cost-effective manner to maintain mobility while preventing relaxation of the joint.
- Flexible external fixation of the hip and elbow relies on two threaded pins placed percutaneously and tightly connected with an elastic band.
- Hinged transarticular braces or external fixators allow weight bearing and motion of the tarsus in a plane parallel to its axis while protecting injured medial and lateral collateral ligaments.

**Technique**

The flexible external fixator for the hip consists of two full pins placed in the proximal femur and ilium that are connected externally by a flexible band. Negative-profile tip-threaded Steinmann intramedullary pins have been used, but positive-profile tip-threaded intramedullary pins are now preferred. A stab incision is made through the skin lateral to the base of the tail in the palpable depression between the superficial and middle gluteal muscles and the sacrocaudalis lateralis and intertransversarius dorsalis caudalis muscles of the tail. The incision is made lateral to the transverse process of the sacrum and proximal and cranial to the greater trochanter of the femur directly over the dorsal edge of the iliac body.

A Steinmann intramedullary pin corresponding to the diameter of the selected threaded pin is inserted into the stab incision and oriented perpendicular to the axis of the dog’s spine. The pin is advanced through the gluteal muscles to locate the dorsal surface of the ilium. The pin should contact the body of the ilium in the greater ischiatic notch caudal to the caudal dorsal iliac spine. Adequate positioning of the pin may be verified via fluoroscopy or radiography. A tap sleeve is placed over the pin and pushed down to contact the ilium. This sleeve serves as a guide and minimizes soft tissue damage. The intramedullary pin is removed and the corresponding threaded pin inserted into the tap sleeve. The pin is oriented perpendicular to the axis of the spine and directed so that it exits the ventral ilial body cranial to the iliopubic eminence, near the tuberosity for the rectus femoris muscle. This ensures that the pin passes through the ilium cranial to the acetabulum, avoiding damage to the articular cartilage. The pin is inserted by hand or using a power drill at low speed until the tip exits the far cortex.

A second pin is inserted into the greater trochanter, using a guide wire and tap sleeve as guides. It enters the lateral, cranial, and proximal aspect of the greater trochanter and is directed distally, caudally, and medially so that it exits the femur distal to the lesser trochanter. Bands are cut from a bicycle inner tube to measure about 1 cm in width. A band is wrapped twice around the pins and its tightness subjectively assessed before cyanoacrylate adhesive is applied. The tension between the pins should keep the joint at a slight degree of internal rotation and abduction while preserving extension and flexion. SK clamps or rubber stops should be applied at the end of the pins to prevent the band from slipping. A band that is too tight will interfere with joint motion and may damage the articular cartilage. Pressure necrosis of the cartilage may result if the tension on the band creates excessive pressure between the femoral head and acetabulum.

**Postoperative Care**

Pin placement is assessed by postoperative radiographs (Figure 3). Daily care, including cleaning the pin tracts and short walks with the support of a sling, is necessary. The flexible bands should be monitored twice daily and are generally replaced every 2 to 4 days to avoid breakage. The external fixator is removed after 2 weeks, and strict exercise restriction is enforced for 4 to 6 weeks.
Complications
The most common complications associated with this technique are rupture of the bands and distal migration of the bands along the pins, predisposing pin sites to local dermatitis. Additionally, the cyanoacrylate may gradually dissolve the polyethylene tubing, and band deterioration or breakage may lead to relaxation of the hip. Other potential complications include septic arthritis, sciatic nerve injury, and decubital ulceration. Based on our experience, complications, including relaxation, seem to be more common in dogs with bilateral coxofemoral luxations.

NONRIGID FIXATION OF THE TARSUS
The tarsus is supported by a complex arrangement of ligaments. The tarsocrural joint is supported medially by the long medial collateral, short medial collateral, and tibiocentral ligaments. Lateral support is provided by the long lateral collateral ligament and the short calcaneofibular ligament. Tarsal instability results from traumatic sprains, juxtaarticular fractures, and shearing injuries. Shearing injuries of the canine hock most commonly result in the loss of the medial malleolus of the tibia and the rupture of the medial collateral ligament. Damage to both the medial and the lateral collateral ligament complexes, fractures of both malleoli, or fracture of one malleolus with injury to the contralateral collateral ligament complex can lead to tarsal luxations of the tibiotarsal, proximal intertarsal, and tarsometatarsal joints.

Clinical signs of tarsal luxation include deviation of the paw, non–weight-bearing lameness, pain, swelling, and crepitus. Ligament deficiencies result in abnormal laxity, allowing increased deviation of the joint away from the damaged ligament. Injuries isolated to the long band of a collateral ligament are suspected when laxity is palpated with the joint held in extension but not in flexion. The short band of the collateral ligament is taut during flexion of the tarsus and provides support to the joint.

The initial management of these injuries should be aimed at preventing further damage to stabilizing structures and articular surfaces, as well as debridement of any associated wound. Treatment goals should then focus on restoring joint congruity and stability while preserving range of motion. Nonrigid fixation of the tarsus stabilizes the joint while maintaining its freedom of movement within the natural plane of flexion and extension of the joint, which is especially relevant to the conservative or postoperative management of mediolateral instabilities.

Unlike the techniques described for the elbow and hip, nonrigid fixation of the tarsus is not achieved with dynamic compression from elastic bands but rather with a hinge that restricts the motion of the joint to a single plane parallel to its axis.

Nonrigid external fixation of the tarsus provides mediolateral support to the joint and avoids the deleterious effects of prolonged immobilization while the soft tissues surrounding the hock heal. Hinged transarticular braces or external fixators can be used. Transarticular hinged braces are made of polyethylene incorporated into padded wraps. One wrap is placed around the tibia, and a second is...
positioned distal to the tibiotalar joint, extending to the metatarsus. The two wraps are connected by a hinge at the level of the tibiotalar joint that allows adjustment of the degree of flexion and extension. The hinge is placed over the joint so that its plane of motion is parallel to that of the joint and its axis of rotation is aligned with the joint. Hinged transarticular braces are especially useful in the conservative management of closed tarsal ligament sprains. Tarsal injuries requiring surgical repair and shearing injuries are more amenable to hinged transarticular external fixation (HTEF). HTEF consists of linear frames connected by a hinge centered over the talar ridges.

Technique
An HTEF frame can be placed after exploration and primary repair of the talocrural joint. Hinge kits are commercially available. Positive-profile end-threaded pins are placed on the lateral aspect of the tibia and metatarsal bones and on the medial aspect of the tibia, central tarsal bone, and metatarsal bones to stabilize the tarsus. The pins are inserted in predrilled pilot holes and should be long enough to allow the threads to engage both cortices. The most proximal and distal pins are placed first, followed by mounting the bars and positioning the hinge at the level of the talus. End-threaded titanium hybrid rods are used with small SK clamps and internally threaded female hinges to form all-metal articulated frames. The hinge should be centered medially over the talar ridges so that its plane of motion is parallel to that of the tarsocural joint, with the connecting bars along the axes of the metatarsal bones and tibia (Figure 4). This is accomplished by slowly taking the joint through its range of motion while the clamps are tightened on the connecting rods.

Postoperative Care
Maintenance of the HTEF frame includes daily cleansing of the pin tracts and application of a triple antimicrobial ointment. Patients should be reevaluated at 4 and 8 weeks after surgery. Radiographs should be taken to assess frame integrity, possible mechanical complications, fracture healing, and potential osteomyelitis. The hinges should be loosened to assess the varus-valgus stability of affected joints. The flexion and extension angles of affected and contralateral joints should be measured after application and removal of the frame, with the uninjured contralateral joint used for comparison. Moderate activity, including leash walks and climbing or walking downstairs, is recommended 8 weeks after surgery. Complications include loosening of the metatarsal pins and hinge, breaking of the distal metatarsal pins and connecting rods, and malpositioning of the hinge so that it does not control motion properly.

CONCLUSION
Nonrigid external fixation provides support and stability to injured joints while allowing range of motion. Early mobility of joints after a traumatic injury stimulates neochondrogenesis, increases synthesis of glycosaminoglycans and hyaluronate, and decreases the formation of adhesions between periarticular structures. The methods reported here are cost-effective, simple adjuncts to the treatment of elbow, coxofemoral, and tarsal instabilities.

REFERENCES
Surgical Views (continued from p. 653)


