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Research Article

Management of Humeral Fractures in Dogs By Using Semicircular External Fixator and Intramedullary Pin Tie-in Combination

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Abstract

The purpose of present study was to report our experience with use of semicircular external skeletal fixator-intramedullary pin tie-in configurations for management of various types of humeral fractures in 33 dogs. Fracture description, history, frame configuration, complications, limb use, fixator removal time, and functional outcome were evaluated. All of the fractures except one with sufficient follow up healed. Twenty-six dogs started to use the operated limb in 1 to 3 days after the operation whereas initial limb use was 4 to 9 days in the other 7 dogs. Destabilization of the frame was performed between 21 to 42 days (median, 32 days) by removal of the IM pin. Time to fixator removal ranged from 42 to 96 days (mean, 56 days). Functional outcome was excellent in 26 cases, good in 6, and poor in 1 dog. As a result of this study, in which all the fractures except one healed, we believe that the unilateral semicircular ESF-IM pin tie-in configurations can be used as an alternative fixation method for the management of humeral fractures in dogs. The patients used the operated limb early in the postoperative period and limb use was improved throughout the healing period.

Keywords: *Dog, External skeletal fixation, Fracture, Humerus, Intramedullary pin*

Köpeklerin Humerus Kırıklarının Semisirküler Eksternal Fiksatör ve İntramedullar Bağlamalı Pin Kombinasyonu İle Sağaltımı

Öz

Bu çalışmanın amacı değişik tipteki köpek humerus kırıklarının sağaltımında semisirküler eksternal fiksatör intramedullar bağlamalı pin kombinasyonu ile ilgili tecrübelerin aktarılmasıdır. Kırığın tipi, anamnez, çerçeve konfigürasyonu, komplikasyonlar, bacağın kullanımı, fiksatörün çıkarılma zamanı ve sonuçlar değerlendirildi. Bir olgu haricindeki tüm kırıklarda kaynama şekillendi. Yirmi altı olgu operasyondan sonraki 1-3 gün arasında ilgili bacağını kullanmaya başladı. Geriye kalan 7 olguda bu sürenin 4- 9 gün arasında değiştiği gözlendi. Postoperatif 21-42. günlerde IM pin uzaklaştırılarak sistemde bilinçli zayıflatma uygulandı. Fiksatörün uzaklaştırılma süresi 42 ila 96 gün (ortalama 56 gün) arasında değişim gösterdi. Fonsiyonel değerlendirmede, olguların 26'sında çok iyi, 6'sında iyi ve 1'inde ise zayıf olarak değerlendirildi. Sonuç olarak, bir olgu haricinde tüm kırıkların iyileştiği göz önünde bulundurulduğunda, bize göre unilateral semisirküler eksternal fiksatör ve intramedullar bağlamalı pin kombinasyonu köpeklerin humerus kırıklarının sağaltımında alternatif bir yöntem olarak kullanılabilir. Hastalar operasyonlardan kısa zaman sonra ilgili ekstremitelerini kullanmaya başlamış ve iyileşme sürecinde ilgili eksremitenin kullanımı daha da iyi hale gelmiştir.

Anahtar sözcükler: *Köpek, Eksternal fiksasyon, Kırık, Humerus, İntramedullar pin*

INTRODUCTION

The humerus is the least commonly fractured long bone in the dog. The fracture incidence ranges from 5 to 13% and most of the fractures involve the middle and distal one third of the bone [1,2]. Because humerus has an S-shape from the lateral perspective -a cranial bow proximally and a caudal bow distally- with large surrounding muscle mass, management of this bone's fractures are challenging [3,4]. This shape can cause difficulty in application of dense intramedullary pins and contouring of the plates. Humerus is in relation to the thorax, so concurrent injuries such as pneumothorax, pulmonary contusions, hemothorax, diaphragmatic hernia, rib fractures, and brachial plexus injuries may be encountered in patients with humeral fractures [4,5]. Reported treatment options include intra-

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medullary (IM) pins and cerclage wires, bone plates, interlocking nails, tie-in IM-external skeletal fixator (ESF) combinations, and IM rod/bone plate combination [2-9]. External skeletal fixators can be used alone or in combination with intramedullary pins in the repair of humeral fractures of dogs and have several advantages compared with other fixation methods. Versatility and requiring minimal soft tissue damage are two featured benefits of ESF [7].

The purpose of this paper was to describe the repair of various types of humeral fractures using semicircular external skeletal fixator and IM pin tie-in combination and to report the outcome in 33 medium/large breed dogs.

MATERIAL and METHODS

Inclusion Criteria and Medications

Between January 2009 and September 2016, dogs (>15 kg) with humeral metaphyseal or diaphyseal fractures (n = 33) with complete clinical and radiographic follow up of at least 24 weeks duration were included in the study. Signalment and history, description of the fracture, frame configuration, concomitant injuries, complications, time to first use of the limb, time to fixator removal and functional outcome was recorded.

Cefazolin (20 mg/kg intravenously, Cefozin 500 mg, Bilim, Istanbul, Turkey) was administered at anaesthetic induction and every 2 hours throughout the surgical procedure. Dogs were premedicated with diazepam (0.1 mg/kg IV, Diazem, Deva, Istanbul, Turkey), induced with propofol (6 mg/kg IV, Propofol 1%, Fresenius Kabi, Upsala, Sweden), and anaesthesia maintained with isoflurane (Isoflurane-Usp, Adeka, Samsun, Turkey) in oxygen. Transdermal fentanyl patch (25-50 µg/h, Durogesic transdermal patch, Janssen-Cilag, Beerse, Belgium) was adhered to the inguinal area 2 h before the surgery and stayed in place for 48 h. Meloxicam (0.2 mg/kg/day subcutaneously, Maxicam, Sanovel, Istanbul, Turkey) was administered for 3 days after surgery.

Frame Design and Features

The ESF system used in this study was composed of 7-holed 60° (180 mm inside Ø, 1/6 ring arch, 7x20x95 mm) carbon-fiber arches, 6 mm Ø threaded rods, cannulated pin and wire fixation bolts, and 4 mm Ø negative profile end-threaded half pins. 3 or 4 mm Ø Steinmann pins were used for intramedullary pinning. Depending on fracture type and length of fractured bone, either 3 or 4 arched frame configurations were used. Size of the IM pins were adjusted to a diameter not exceeding 30% of the medullary canal of the distal humerus [10]. The edge holes of the arches were used to secure to the threaded rods and the other holes for the half pin fixation bolts. Caudal rod was adjusted 3-4 cm longer than the cranial rod in order to attach the IM pin to the ESF frame in "tie-in" fashion. Another carbon-fiber arch was used as a connector for the linkage of the two fixation systems *(Fig. 1)*.

Surgical Technique

Fracture reduction was accomplished using an open or limited open approach from the cranio-lateral border of the humerus [11]. Following exposition of the fracture, a 3 or 4 mm Ø Steinmann pin was inserted to the medullary cavity via retrograde technique. After achieving axial reduction, half pins were perpendicularly and bicortically placed with a low speed (<150 rpm) power-drill. The proximal pin was placed at the level of the base of the greater tuberculum while the distal pin was placed from cranio-distal to the lateral epicondyle to exit the bone medially at a similar point halfway between the epicondyle and the articular surface [5]. Once acceptable reduction of the fracture was achieved, the construct was completed by inserting additional fixation pins (depending of the fracture type and localization) to the humeral shaft by avoiding muscles and radial nerve *(Fig. 2)*. Before skin closure half pin fixation bolts were firmly secured to the carbon fiber arches and then IM pin was tied-in to the caudal rod.

Postoperative Period and Evaluation of Outcome

Clients were informed regarding wound care and strongly adviced to clean the pin-skin interface with 10% povidone iodine solution (Batticon 10% sol: Adeka, Samsun, Turkey) every day until the removal of the fixator. Recheck clinical and radiographic evaluations were performed for two/

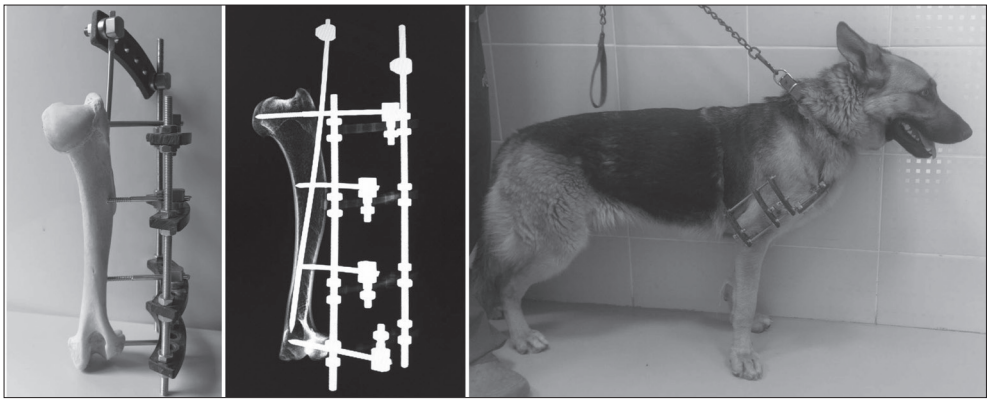


Fig 1. A four arched semicircular external fixator - IM pin tie-in combination and its clinical view on a standing dog

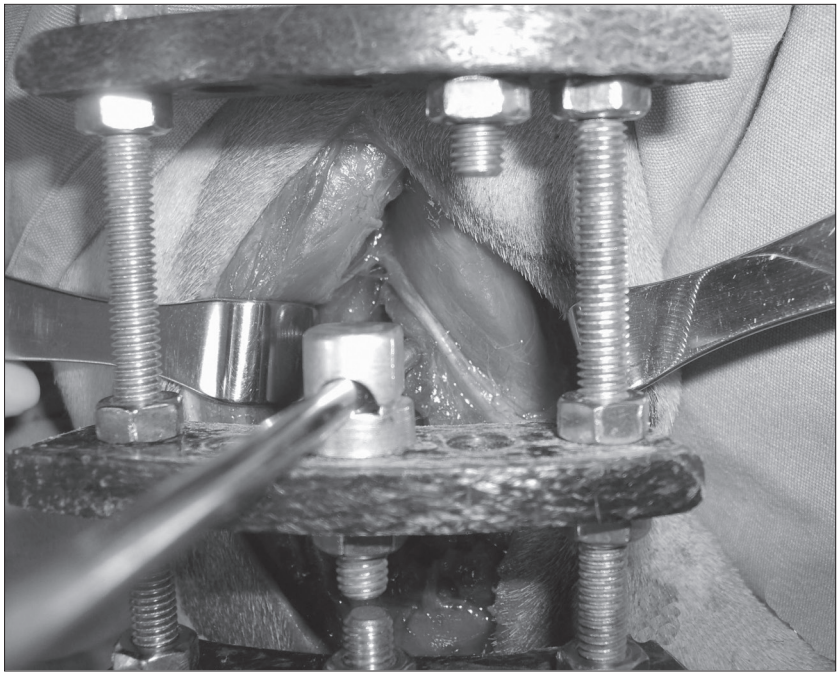


Fig 2. The most important advantage of the multiplanar feature of a semicircular arch is possibility of avoidance of the muscles, vessels and nerve injury during pin insertion. Note that the avoidance of the radial nerve with brachial and triceps muscles in a distal humeral fracture

three weeks intervals. Postoperative complications were classified as "*major"* which were defined as morbidities that require further medical or surgical interventions or "*minor"* which were defined as no need for an additional surgical or medical intervention to resolve. The frame was removed in two stages; first destabilization by removal of the IM pin and then removal of the ESF frame. Time to remove the IM pins varied depended on the presence of radiographically visible active bridging callus tissue. Clinical union was defined as the radiographic evidence of a bony callus bridging on at least one cortex on both medio-lateral and cranio-caudal views [12]; at this stage, EFSs were entirely removed. Treatment success was based on clinical evaluation of the operated limb, including willingness to use the limb in daily activities. Final clinical outcomes were graded as: *excellent*; willingness to use the limb at a walk and run, no evidence of obvious lameness, no pain on palpation - *good*; willingness to use the limb at all times but slight lameness evident when running, no pain on palpation - *fair*; reluctance to use the operated limb, moderate lameness evident, obvious pain on palpation - and *poor*; unwilling to use the limb, constant non-weight-bearing lameness.

RESULTS

Ages and bodyweights of the dogs ranged from 6 months to 10 years (mean, 24 months) and 15 to 39 kg (mean, 24 kg) respectively. Of the 33 dogs 21 were male and 12 were female. Fracture types were; oblique (n=15), transverse (n=11), and comminuted (n=7) and involved at the distal (n=18), diaphyseal (n=13), and proximal (n=2) part of the humerus. Fractures were caused by road accidents (n=28), gunshot injury (n=2), and unknown causes (3). Frame configuratios were IM pin + 3 arched ESF in 12 dogs and IM pin + 4 arched ESF in 21 dogs. Depending on the diameter of the distal humeral medullary canal 3 (n=10) or 4 mm Ø (n=23) IM pins were used. In all dogs - especially in dogs with early active limb use - mild serosanguineous discharge was observed at the point where IM pin protruded from the skin. Following removal of the IM pin, this minor complication was completely resolved. As seen in all ESF cases, discharge from the pin-skin interfaces during the convalescence period was seen in most of the dogs. Discharge was more apparent in proximal pins which were surrounded by bulky muscle groups. Serosanguineous or serohemorrhagic discharge responded to improved cleaning of the pin-skin interfaces with povidone iodine solutions, but in 6 cases with purulent discharge oral 12.5 mg/kg amoxicillin-clavulonate (Synulox 250 mg tablet, Pfizer, Italy) was administered for 10 days. In one case with extensive soft tissue loss after gunshot injury, purulent pin tract discharge due to osteomyelitis was observed. Despite the aggressive broad spectrum antibiotic use we could not resolve the infection and amputation was performed.

Pin breakage was seen in one dog in the early post-operative period. According to the information given by the client, the dog could use the affected limb but after running away from the house in the 3rd day and being found on the postoperative 4th day it had a non-weight bearing lameness. The radiographic examination performed after this revealed a broken half pin on the proximal fragment *(Fig. 3a-b)*. Fortunately, the fragments were still in alignment so the insertion of a half pin percutaneously salvaged the complication *(Fig. 3c)*. After-this application, the patient started using the afore-mentioned limb without showing any obvious signs

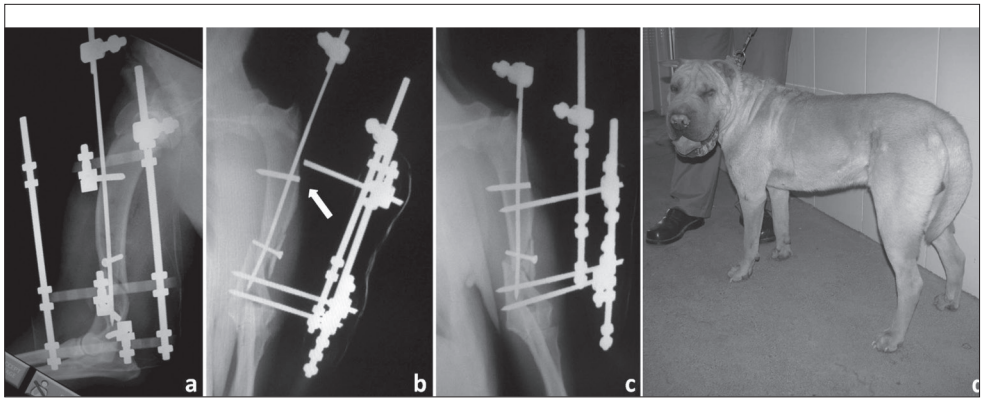
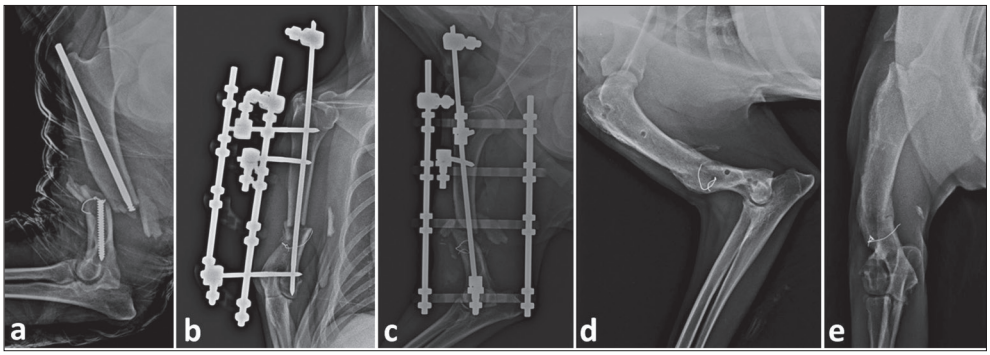


Fig 3. Immediate postoperative radiograph of a dog with a fixed comminuted distal diaphyseal humeral fracture (a). Note the broken half pin *(white arrow)* in the proximal fragment (b) in the early postoperative period. Because alignment of the fragments was not disturbed, fixation was performed with a new half pin inserted below the broken pin (c). Clinical view of the dog 4 weeks after fixator removal (d)

Fig 4. Radiographic view of the refracture of a diaphyseal humeral fracture due to early pin breakage (a). Stabilization with IM pin - ESF combination provided a rigid fixation (b-c) but fracture healing was longer compared to other dogs. Note that pin holes were still apparent despite the passed 36 weeks following removal of the fixator (d-e). This dog was a typical delayed union case



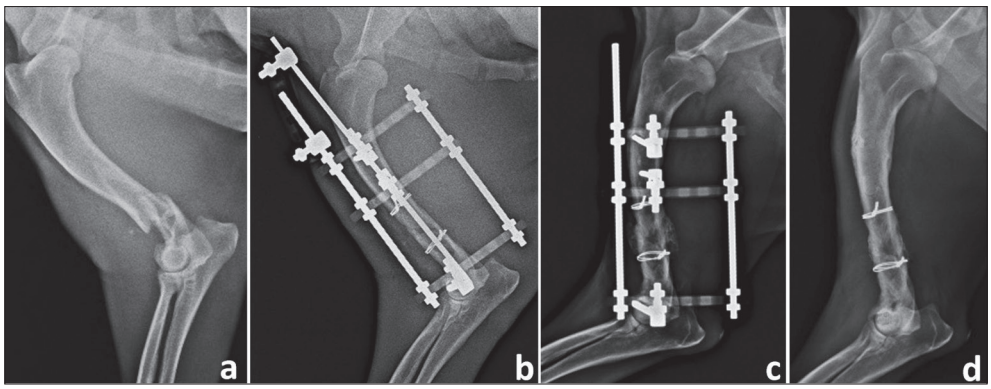
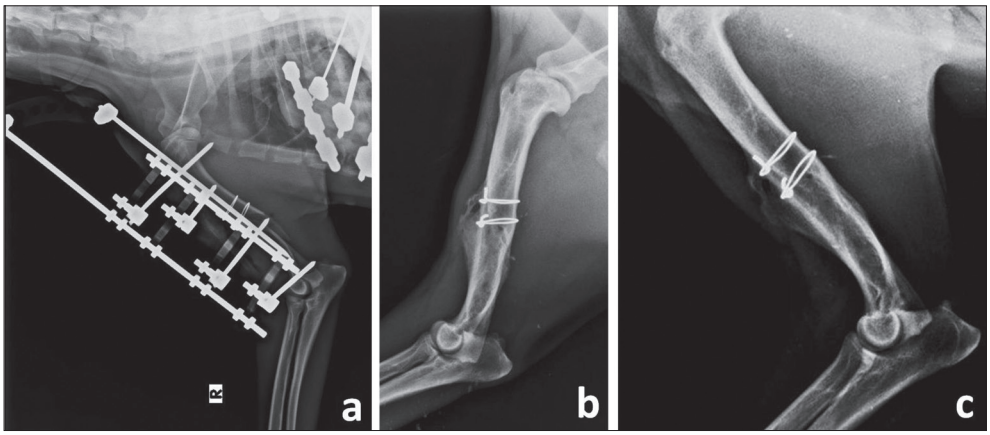


Fig 5. Preoperative (a) and immediate postoperative (b) radiographs of a comminuted distal humeral fracture. System was destabilized by removal of the IM pin 4 weeks after the operation (c). Bridging callus tissue was seen to be resorbed related to the remodelling process at the radiographs taken 15 weeks following removal of the fixator

Fig 6. Postoperative immediate radiograph of a mid-diaphyseal long oblique humeral fracture after fixation (a). Diminution of the bridging callus and reorganization of the medullary cavity can be seen on the radiographs at 5th (b) and 12th (c) weeks following removal of the implants



of pain and lameness. The dog was able to bear full weight to the limb following removal of the fixator *(Fig. 3d)*.

One of the dog was operated due to early breakage of the intramedullary pin which was operated in a private veterinary clinic *(Fig. 4a)*. After removal of the cast, draining

operation wound was observed. After controlling of the wound infection, fixation was performed with ESF and IM pin combination *(Fig. 4b-c)*. Following the operation we performed, bone infection was recurred due to the necrotic bone fragments. Bone loss after removal of these necrotic fragments formed a large fracture gap and resulted with delayed union of the case. In this case, time for bone healing was longer compared with other cases. Fixator was removed on 96th day postoperatively and restricted activity for three months was advised to the clients. At long term radiographic controls -36th week after removal of the fixator- although remodeling was not properly completed *(Fig. 4d-e),* dog was able to use the limb without signs of obvious lameness.

In all dogs, semicircular ESF-IM pin combination provided a stable fixation and all of the cases tolerated this scaffold (weighing about 0.5 kg) well. In the dogs with purulent pin tract discharge volcano chimney image was observed in radiographs at the point where half pins protrudes from the bone. All of these periosteal reactions were improved after completion of remodelling process. Destabilization of the frame was performed between 21 to 42 days (median, 32 days) by removal of the IM pin *(Fig. 5)*. In most of the dogs limb use was significantly improved following removal of the IM pin.

All of the fractures but one with sufficient follow-up healed *(Fig. 6)*. Twenty six of the dogs bore weight on the operated limb within three days (median, 2 days) following the operation. In the other seven dogs time to first use of the limb ranged between four to nine days. These prolonged cases were the dogs with comminuted fractures and moderate to severe soft tissue loss. Time to ESF removal ranged from 42 to 96 days (mean, 56 days). All clinical evaluations were done by the same operators. Final clinical outcome was excellent in 26, good in six, and poor in one dog.

DISCUSSION

Intramedullary pinning is mainly used to treat simple fractures as a primary fixation method or as an ancillary fixation for plates or external skeletal fixators. But in humerus, medullary canal ends far proximal to the distal part of the bone limiting Steinmann pin purchase in the medial condyle of the bone which restricts the use of IM pins in communitued or juxta-articular fractures primarily. Steinmann pin serves to assist in fracture alignment and also protects the ancillary fixation from catastrophic fractures [4]. Although each technique has its advantages and disadvantages, plate fixation is the most commonly used method today [3,13-15]. Both reduction and fixation of the humerus pose a challenge due to its anatomical location and shape, being surrounded by bulky muscle groups, the radial nerve traversing close to the skin in the distal part and having a natural "S" shape because of its proximal and distal curvatures [4,5]. In this study, favourable results were obtained in 33 medium/large breed dogs treated for different types of humeral fractures, considering biological fixation criteria, by semicircular external fixation/ intramedullary pin combination using a limited open approach. Adequate stabilization was achieved with this technique and patients were able to use their affected limbs functionally in the early post-operative period.

The main purpose of fracture fixation is to achieve the fastest possible bone healing and encourge the patient for functional limb usage by promoting postoperative early ambulation [16]. The golden standart for a perfect ESF procedure is to construct frames that allow full weight-bearing without interfering with the use of the limb. Early ambulation accelerates bone healing by stimulating axial micromotion at the fracture line and also prevents fracture disease such as disuse atrophy and muscle contractures [17,18]. This is critical in large breed dogs with concomitant injuries. In present study 26 of the dogs bore weight on the operated limb within three days (median, 2 days) following the operation. According to the data received during the convalescence period, the dogs tolerated the frame well and this frame did not impede the daily activities of the dogs.

There are several advantages of external skeletal fixation over internal fixation techniques; they can be applied with minimal surgical exposure, limiting soft tissue, bone and periosteal damage. They are safer to apply on infected or compound fractures, the frames may be reinforced or destabilized after the initial surgery and they do not require bandages on the recovery period [19-21]. The semicircular arches offer the option of inserting half pins unilaterally, but in a multiplanar fashion owing to its novel design which enables half pin insertion up to five different planes. The semicircular arches allow the insertion of two pins with a single arch, one from a bolt placed over the arch and the other placed below it. This versatility makes the semicircular arch superior to linear fixators. This property allows preserving the muscles and the radial nerve depending on the shape of the fracture, unlike linear external fixators. This is particularly important in the fixation of distal fractures that may endanger the radial nerve. Optimal and safe fixation can be achieved by preserving muscle and nervous tissue with the semicircular arch, owing to its multiplanar pin insertion options. The distal region fractures in this study (n=18) healed without any major complications with the exception of one osteomyelitis case, which required amputation. Also, the pin breakage complication that was seen in one case could be easily corrected with the insertion of a half pin percutaneously in about 15 min duration. This property of the external frame which allows recovery of such complications should not be discounted.

There were several reports of complications due to mishaps or failed post operative maintenance of external

fixators [22,23]. These are pin tract lysis, haemorrhage, drainage, infection, pin loosening and breakage, osteomyelitis, malunion, malalignment and non-union. Pin tract drainage is the most common complication seen in almost every case and nature of the discharge is important. While serosanguinous or serohaemorrhagic discharge may be prevented with daily cleansing of the pin tract, discharge with purulent characteristics require the use of antibiotics to prevent possible bone infections. Pin tract discharge was seen in each of our cases and this finding correlated with previous studies. The intramedullary pin protruding from the dorsal trochanteric region enlarged the pin tract considerably due to repetitive cranio-caudal movement. The pin exiting this location provides direct access to the medullary tract from the outside, so the potential for bone infection should not be discounted if pin tract maintenance is not adequately performed. We did not encounter any such complication in this study, because pin tract maintenance was performed with utmost care with patient collaboration.

As a result of this study, in which all the fractures except one healed, we believe that the unilateral semicircular ESF-IM pin tie-in configurations can be used as an alternative fixation method for the management of humeral fractures in dogs. The patients used the operated limb early in the postoperative period and limb use was improved throughout the healing period.

Conflict of Interest

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. The authors declare that there is no conflict of interest regarding the publication of this article.

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