Management of distal humeral fractures in dogs with unilateral semicircular external skeletal fixators: prospective clinical trial and results in twelve cases

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SUMMARY

The aim of the present study is to present an alternative technique for the treatment of distal humeral fractures in young or small breed dogs, and to evaluate the effectiveness of the technique. 12 dogs of varying breeds, age, and sex with 9 supracondylar and 3 intracondylar humeral fractures were used in this study. A semicircular external skeletal fixation system was used for the fixation of the distal humeral fractures by open reduction. Configuration of the system, complications, time to limb usage, fixator removal time, and functional outcomes were evaluated clinically and radiographically. Clinical lameness score and evidence of pathologic changes in the elbow joints were evaluated at the final follow up examinations. All fractures obtained radiographic union. Three of the dogs started to use their limbs immediately after waking up from anesthesia. In the other 9 dogs the time ranged from 2 to 7 days. The most common complication was pin tract discharge during the convalescence period. (Time to fixator removal) ranged from 30 to 48 days (mean 37 days). At the final clinical examination, there was no observable convalescence. (Time to fixator removal) ranged from 30 to 48 days (mean 37 days). At the final clinical examination, there was no observable convalescence. Le temps de retrait du fixateur a varié de 30 à 48 jours (moyenne 37 jours). À l'examen clinique final, il n'y avait aucune boiterie observée sur 9 et boiterie légère en charge sur 3 chiens. Cette étude suggère que la technique employée peut-être une méthode alternative pour la fixation des fractures distales de l'humérus chez les chiens de petite races ou chez les jeunes chiens.

Keywords: Carbon-fibre, dog, external skeletal fixation, humerus.

RÉSUMÉ

Gestion des fractures de l’huméros distal chez les chiens par utilisation de fixateur unilatéral externe semi-circulaire : prospective clinique et résultats de douze cas

Le but de cette étude est de présenter une technique alternative au traitement des fractures de l’huméros distal chez les chiens de petite races ou chez les jeunes chiens, et d’évaluer l’efficacité de la technique. Douze chiens de différentes races, âges et sexes avec 9 fractures supracondyliennes et 3 fractures humérales intracondyliennes ont été utilisés dans cette étude. Un système externe de fixation semi-circulaire du squelette a été utilisé pour la fixation des fractures de l’huméros distal après réduction. La configuration du système, les complications, le temps nécessaire à l’utilisation d’abord, le moment de retrait du fixateur, et les résultats fonctionnels ont été évalués cliniquement et radiologiquement. Le score de boiterie clinique et la nature des changements pathologiques dans les articulations des coudes ont été évalués. Toutes les fractures ont montré une réparation radiographique. Trois des chiens ont commencé à utiliser leurs membres immédiatement après le réveil. Pour les 9 autres chiens, le délai de réutilisation a varié de 2 à 7 jours. La complication la plus fréquente a été un décrochage des broches au cours de la période de convalescence. Le temps de retrait du fixateur a varié de 30 à 48 jours (moyenne 37 jours). À l’examen clinique final, il n’y avait aucune boiterie observée sur 9 et boiterie légère en charge sur 3 chiens. Cette étude suggère que la technique employée peut-être une méthode alternative pour la fixation des fractures distales de l’huméros chez les chiens de petite races ou chez les jeunes chiens.

Mots clés : Fibre de carbone, chien, fixation externe du squelette, huméros.

Introduction

Fractures of the distal humerus are divided into distal dia-physseal, supracondylar, unicondylar, intracondylar and epi-condylar fractures. In a review of 130 humeral fractures, 46.6% of the fractures occurred in the distal humerus [1]. In another study of 129 distal humeral fractures in dogs, 29.5% were supracondylar fractures [2]. The difference between distal shaft and supracondylar fractures of humerus is that fractures of the distal shaft do not involve the supracondylar foramen. Distal humeral fractures most often result from severe trauma, such as motor vehicle accidents and can be either simple two piece fractures or comminuted fractures [1].

Fractures of the distal humerus can be challenging to manage. The presence of a large muscle mass and important neurovascular structures and the complex shape of the bone create technical difficulties [3]. The complex conformation of the distal humerus and small size of the juxtaarticular condylar fracture segments complicate implant placement [4,5]. The lack of bone for implant placement in distal fragments limits the usage of bone plates in fixation of distal humeral fractures [6,7].

External skeletal fixation can occasionally be used as a primary or solitary method for the fixation of humeral fractures, particularly in comminuted, open fractures with severe soft tissue disruption in which the use of large implants might be contraindicated [7]. Treatment of humeral fractures with external fixation alone or in combination with an intramedullary pin system is technically easier and considerably less expensive than plating [8].
External skeletal fixation has the advantage of adjustibility after surgery a unique advantage over plate- or pin fixation, frames may be adjusted or reinforced in the postoperative period. The technique is also less invasive than plate fixation, and allows better access to wounds than external coaptation does [9]. Application of traditional circular external fixation systems is limited proximal to the elbow and stifle, as the proximity of the trunk interferes with placement of complete rings [10].

As there is an absence of clear, longitudinal safe corridors in the canine humerus and as the regional anatomy of the forelimb is complex, it is not possible to maintain a direct axial alignment of the pins inserted in the safe areas and lines [11]. This hampers the use of conventional linear external fixation systems in humeral fractures. Because of this limitation a semicircular external skeletal fixation system (SESFS) has been developed which enables multi-plane half pin insertion [12]. Three or 4 half pins may be connected to each arch of the SESFS. In this system, because half pins can only perpendicularly be inserted to the bone, in order to avoid of encountering of the pins at the same arch, only two pin application (one above, one below) is possible if bicortical application is desired. But the system allows more than two half pin insertions in unicortical applications.

Our purpose is to report the clinical features and outcome of 12 dogs with supracondylar or intracondylar humeral fractures that were stabilized with SESFS to provide an alternative method for management of the distal humeral fractures in young or small breed dogs.

Material and Methods

The material of the study consisted of 12 dogs of different breeds, age, and sex with supracondylar or intracondylar humeral fractures. For inclusion criteria although there was no age or bodyweight restriction for small breeds, bodyweights were limited with 13 kg in medium-sized or large breed dogs. The medical records and radiographs of the dogs managed with SESFS between October 2006 and September 2009 were reviewed. The following information was recorded for each dog: the animal’s signalment and history, a description of the fracture, a description of the fixator configuration, time elapsed between fracture occurrence and repair, postoperative complications, concurrent injuries, time to limb usage as well as fixator removal, osteoarthritis score, and the lameness score at the final follow up examination.

All animals received perioperative cefazolin sodium1 (20 mg/kg, IV) at the time of anesthetic induction and every 2 hours throughout the surgical procedure. All dogs were premedicated with diazepam2 (0.1 mg/kg, IV) induced with propofol3 (6 mg/kg, IV), and maintained with isoflurane4. In all dogs carprofen5 (4 mg/kg/day, SC) injection was administered immediately before- and for 3 days following surgery. Further, the owners of the animals were advised to use local antibiotic spray6 for possible pin tract infections during the convalescence period. Postoperative external coaptation and exercise restriction was not carried out in any of the dogs.

The principal connecting elements of SESFS are the 6-holed 45° (180 mm Ø, 1/8 ring arch, 7x18x85 mm) or 5-holed 40° (180 mm Ø, 1/9 ring arch, 7x18x80 mm) carbon-fibre arches. The other components of the system composed of 6 mm Ø threaded rods (80, 100, 120, 150 mm length), half pin fixation bolts for 3 and 4 mm Ø half pins, 6 mm Ø hex nuts, and 3 and 4 mm Ø negative profile end-threaded half pins. In some dogs 3 mm Ø biopsy punch was used for circular stab incision of skin for closed application of the half pins (figure 1). All the components except arches were made of 316L stainless steel. Depending on fracture type, and body weight of the patient, 3 or 4 arched configurations were used. The 40° and 45° carbon-fibre arches were used in dogs weighing <10 kg and ≥10 kg respectively. In the preoperative planning procedure, the configuration of the fixator was prepared according to the radiographs obtained in both medio-lateral and cranio-caudal projections. The level of the arches were determined according to the level of suitable and safe pin insertion point.

Fracture reduction was accomplished using an open approach in all dogs. In the approach procedure, the skin incision was made along the cranialateral border of the shaft of the humerus from level of the mid-diaphysis to the level of the lateral...
The deep fascia of the brachium was incised along the cranial border of the triceps. The deep fascia was undermined to allow cranial retraction of the brachiocephalicus muscle and the cephalic vein and exposure of the radial nerve (figure 2.a). To obtain a better exposure of the distal portion of the bone, brachiocephalicus muscle retracted cranially and brachialis muscle and radial nerve retracted caudally [13]. In intracondylar fractures, fracture area was exposed following osteotomy of the tuber olecrani. Then fracture was identified, debrided, and anatomically reduced and maintained with bone-holding forceps. Then Kirshner wires or an intercondylar lag screw was applied from slight proximal of the lateral epicondyle in order not to interfere with the condylar half pin.

Following reduction of the fracture, the first half pin was perpendicularly and bicortically applied from slightly distal of bony protuberance of lateral epicondyle with low speed power-drill after predrilling with with 2,7mm Ø drill for 3mm Ø half pin and 3,5 mm Ø drill for 4 mm Ø half pin. The diameter of the half pin chosen was, in general, the largest that was thought could be placed across the condyle. Then the second half pin was applied to the lateral surface of the distal part (1-2 cm to the fracture line) of the proximal fragment and secured to the frame. Once acceptable reduction of the fracture was achieved, the construct was completed by placing additional one or two half pins to the craniolateral surface of proximal humerus in closed fashion (figure 2.b). Before closure of the surgery site, half pin fixation bolts were secured to the carbon-fibre arches firmly and all nuts were controlled for being firmly attached to the frame. In all dogs, stability of the immobilized fracture fragments was checked under flexion, extension, and rotation of the elbow joint. Surgery site was closed routinely. In the anatomical reconstruction of the fractures no adjunctive implants were used, except Kirschner wires and intercondylar lag screws used in intracondylar fractures. Postoperative radiographs were obtained and then pin-skin tension adjustments were made, if necessary, while animals were under general anesthesia. At the time of the discharge, owners were instructed to clean the pin tract-skin interface every other day, use daily antibiotic spray. Weekly recheck examinations and radiographic assessments were performed and the fixator was removed following interfragmental bony bridgings were seen. Also goniometric examinations of both operated and contralateral elbow joints were done at final follow up examinations and the discrepancy between maximum flexion ranges were recorded. Radiological and final clinical assessments were performed by a surgeon aware of previous surgery.

Evidence of pathologic changes in the joint (osteoarthritis score) (0-4) were scored as follows: No radiographic evidence of articular pathology (0), joint effusion/soft tissue changes without evidence of osteoarthritis (OA) (1), evidence of early/minimal OA (2), moderate OA changes (3), severe OA changes (4) [14].

At the final follow up examination, a clinical lameness score (0-5) was given as follows: No observable lameness (0), intermittent, mild weight-bearing lameness with little if any change in gait (1), consistent, mild weight-bearing lameness with little change in gait (2), moderate weight-bearing lameness – obvious lameness with noticable “head bob” and change in gait (3), severe weight-bearing lameness – “toe-touching” only (4), non-weight-bearing (5) [14].

**FIGURE 2:** (a) The segment on the lateral aspect of the humerus occupied by the brachialis muscle, from apex of the proximal safe area to the apex of the distal safe area, represents an unsafe corridor due to the presence of the radial nerve (white arrow) (b) In SESFS, the first two pins (1, 2) inserted to the lateral surface of distal humerus. Once acceptable reduction of the fracture was achieved, the construct was completed by placing additional one or two half pins (3) to the craniolateral surface of proximal humerus in closed fashion.
Results

Information regarding each animal’s signalment and history, fracture description, fixator configuration, time elapsed between fracture occurrence and repair, duration of the operation procedure, complications, concurrent injuries, time to limb usage and fixator removal, osteoarthritis score, and the lameness score at the final follow up examination are listed in Table I.

The animals ranged in age from 3 months to 18 months (mean 7.5 months). Body weights ranged from 5 to 13 kg (mean 9.4 kg). Distribution of the fractures according to the fracture type were 6 supracondylar simple (figure 3.a-b), 3 supracondylar comminuted, and 3 intracondylar. The history was motor vehicle accident in 9 dogs, and falling from an elevated height in 3 dogs. Affected limb was right in 8 dogs and left in 4 dogs. There was no evidence of neurological dysfunction in any of the dog.

Three dogs had concurrent orthopedic injuries. Case no. 3 had contralateral supracondylar femur and femoral neck fracture, and ipsilateral mid-diaphyseal oblique tibial fracture. Tibial and supracondylar femoral fractures were both stabilized with SESFS and excision arthroplasty was performed to the femoral neck fracture. Case no. 7 was presented with ipsilateral stable

<table>
<thead>
<tr>
<th>Case no</th>
<th>History</th>
<th>Description of the fracture</th>
<th>Fixator configuration</th>
<th>Duration from injury to surgery (days)</th>
<th>Duration of the procedure (minute)</th>
<th>Postoperative complications</th>
<th>Concurrent injuries</th>
<th>Time to limb usage/fixator removal (days following surgery)</th>
<th>OA following surgery</th>
<th>LS following surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4-m-old, 5 kg, F, Cocker Spaniel</td>
<td>Supracondylar, simple, R</td>
<td>40°, 3 arched, 2P: 3mm Ø 2 ETHP 1D: 3mm Ø 1 ETHP</td>
<td>2</td>
<td>46</td>
<td>None</td>
<td>None</td>
<td>♣/40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4-m-old, 9 kg, M, Labrador Retriever</td>
<td>Intracondylar, L</td>
<td>40°, 3 arched</td>
<td>2</td>
<td>72</td>
<td>Mild pin tract discharge</td>
<td>None</td>
<td>2/32</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>5-m-old, 8 kg, M, English Pointer</td>
<td>Supracondylar, simple, R</td>
<td>40°, 3 arched</td>
<td>1</td>
<td>45</td>
<td>None</td>
<td>Left supracondylar femur and collum femoris fracture, right mid-diaphyseal tibia fracture</td>
<td>4/32</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>6-m-old, 11 kg, M, Mix breed</td>
<td>Supracondylar, comminuted, L</td>
<td>45°, 3 arched, 2P: 3mm Ø 3 ETHP 1D: 4mm Ø 1 ETHP</td>
<td>14</td>
<td>51</td>
<td>Malunion deformity</td>
<td>None</td>
<td>2/30</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>11-m-old, 12kg, F, Mix breed</td>
<td>Supracondylar, simple, R</td>
<td>45°, 3 arched, 2P: 3mm Ø 3 ETHP 1D: 4mm Ø 1 ETHP</td>
<td>1</td>
<td>50</td>
<td>Mild pin tract discharge</td>
<td>None</td>
<td>4/35</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>3-m-old, 5kg, M, Turkish Kangal</td>
<td>Supracondylar, simple, R</td>
<td>40°, 3 arched, 2P: 3mm Ø 3 ETHP 1D: 3mm Ø 1 ETHP</td>
<td>2</td>
<td>41</td>
<td>None</td>
<td>None</td>
<td>♣/30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>6.5-m-old, 13kg, F, German Shep.</td>
<td>Supracondylar, comminuted, R</td>
<td>45°, 4 arched, 3P: 4mm Ø 3 ETHP 1D: 4mm Ø 1 ETHP</td>
<td>1</td>
<td>48</td>
<td>None</td>
<td>R, Mc-III-IV fracture</td>
<td>7/42</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>5-m-old, 7 kg, M, Mix breed</td>
<td>Supracondylar, comminuted, L</td>
<td>40°, 3 arched, 2P: 3mm Ø 2 ETHP 1D: 4mm Ø 1 ETHP</td>
<td>2</td>
<td>56</td>
<td>None</td>
<td>None</td>
<td>♣/36</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>18-m-old, 8kg, F, Terrier</td>
<td>Supracondylar, simple, L</td>
<td>40°, 3 arched, 2P: 3mm Ø 2 ETHP 1D: 4mm Ø 1 ETHP</td>
<td>3</td>
<td>62</td>
<td>None</td>
<td>None</td>
<td>3/42</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>9-m-old, 12 kg, M, Mix breed</td>
<td>Supracondylar, simple, R</td>
<td>45°, 4 arched, 3P: 3mm Ø 3 ETHP 1D: 4mm Ø 1 ETHP</td>
<td>4</td>
<td>88</td>
<td>None</td>
<td>R, 6-7th rib fracture, pneumothorax</td>
<td>4/40</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>6-m-old, 10 kg, F, Turkish Kangal</td>
<td>Supracondylar, simple, R</td>
<td>45°, 3 arched</td>
<td>1</td>
<td>53</td>
<td>None</td>
<td>None</td>
<td>3/35</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>14-m-old, 13 kg, F, English Setter</td>
<td>Intracondylar, R</td>
<td>45°, 3 arched, 3P: 4mm Ø 3 ETHP 1D: 4mm Ø 1 ETHP</td>
<td>4</td>
<td>96</td>
<td>Mild pin tract discharge</td>
<td>None</td>
<td>5/48</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

F: female, M: male, m:month, FEH: falling from an elevated height, MVA: motor vehicle accident, R: right, L: left, P: proximal, D: distal, Ø: diameter, ETHP: end threaded half pin, Mc: metacarpus, ■: adjunctive fixation with Kirschner wires or lag screw application, ♣: immediately after waking up from anesthesia, OA: osteoarthritis score at final follow up examination, LS: Lameness score at final follow up examination.

TABLE I: Preoperative and postoperative details of 12 dogs with distal humeral fracture managed with SESFS.
metacarpus III-IV fracture, which were splinted. Case no. 10 was presented with ipsilateral 6-7th rib fracture which were complicated with pneumothorax. A chest tube was placed and stayed in place until pneumothorax was resolved. External fixation of humeral fracture was carried out after this process.

Four dogs experienced complications after fixator application. The most common complication was pin tract discharge during the convalescence period. This local inflammation did not complicate with lameness in any of the dog. The dogs developed minor pin tract discharge were responded to improved cleaning of pin-skin interfaces and oral antibiotic§§ administration based on cultures and sensitivities. Case no. 4 was diagnosed with failed fracture repair due to collapse of the attempted coaptation. In this dog the elapsed time from fracture to repair was 14 days. At the initial examination decreased fracture mobility was observed. In the surgical treatment process, bone fragments were fixed to the frame without any reduction attempt in order not to harm the regenerated fibrocartilaginous callus formation. At the final follow up examination, despite radiographically significant malunion deformity, the dog revealed intermittent, mild weight-bearing lameness.

Duration from injury to surgery was ranged 1 to 14 days. All of the fractures obtained union. Three of the dogs started use the limb immediately after waking up from anesthesia (figure 4.a). In the other dogs the time ranged from 2 to 7 days (figure 4.b). Time to fixator removal ranged from 30 to 48 days (mean 37 days).

In present study, two of the 40° and three of the 45° three arched frames were reused after vapour sterilization (15 minutes at 130°C). There was no visible damage associated with reusing any of the arches, and no structural failures occurred.

Final clinical and radiological evaluation was performed between 34 to 56 weeks after removal of the fixator. In all dogs, 5 to 15 degrees of decrease in flexion range in the elbow

![Figure 3](image-url)

**Figure 3:** Preoperative medio-lateral (a) and cranio-caudal (b) x-rays of case no.1. Immediate postoperative cranio-caudal x-rays after fixation with three, 3 mm Ø ETHP and 40°, 3 arched SESFS (c). At the final follow-up radiographic examination on postoperative 44th week, there was no evidence of articular pathology observed in both cranio-caudal (d) and medio-lateral (e, f) x-rays.
joint of the operated limb was observed according to the go-
niometric examination of the operated limb at final follow up
examinations. At the final follow up examination, there was
no evidence of articular pathology in 6 dogs (figure 3) but soft
tissue changes or early minimal osteoarthritis was observed
in the other 6 dogs. According to the final clinical examination,
there was no observable lameness in 9 dogs while intermittent,
mild weight-bearing lameness was observed in 3 dogs.

**Discussion**

The canine humerus is a concentric bone and concentric
bones were defined as those completely, or almost completely,
covered by muscle masses and not offering safe corridors
for pin insertion. The muscle bulk around the humerus and
the proximity of the chest wall preclude the use of the stronger
type II or III fixators [15]. A safe area exists in the craniola-
teral aspect of the proximal humerus which is palpable sub-
cutaneously and not covered by muscle masses. The next
distal palpable point is represented by the lateral epicondylar
crest on the lateral aspect of the distal fourth of the humerus,
which ends in the lateral epicondyle [11]. The division of the
humeral diaphysis into lateral and medial condyles and the
presence of the supracondylar foramen limit the bone availa-
ble implant placement in the distal fragment during internal
fixation [16]. Special care has to be exercised in the distal hu-
erus to avoid intra-articular pin placement and impaired
elbow movement as pin insertion in the distal half of the ole-
cranon fossa would interfere with the anconeal process during
full extension of the elbow. The segment on the lateral aspect
of the humerus occupied by the brachialis muscle, from apex
of the proximal safe area to the apex of the distal safe area,
represents an unsafe corridor due to the presence of the radial
nerve. In order to reduce the incidence of premature pin loo-
sening, maximal pin to bone contact and bone purchase can
be achieved by inserting the pins at a proper angulation; pins
used in the proximal safe area are ideally inserted with a slight
craniolateral to caudomedial while the condylar pins inserted
lateral to medial direction [11]. Semicircular external skeletal
fixation system enables multi-plane half pin application from
the same frame and this explains why SESFS is preferred and
used in present study.

![Fixator tolerance was good to excellent in all dogs. Clinical view of case no.1 immediately after the operation (a) and case no.11 on postoperative 3rd day (b).](image)

![Cranio-caudal x-rays of case no. 2 preoperatively (a) and immediately after the operation (b). Medio-lateral x-ray immediately after removal of the fixator on postoperative 32nd day (c). Medio-lateral x-ray (d) and clinical view of the dog on postoperative 25th week (e).](image)
There are advantages and disadvantages to use of low-stiffness ESF constructs. Low-stiffness ESF configurations allow for axial micromotion and bone loading at the fracture site, which are beneficial to healing; however, they can contribute to high shear stress at the bone-pin interface during weight-bearing resulting in high strain and premature pin loosening [17]. It may be prudent to avoid low-stiffness frames in heavier dogs because forces acting at the bone-pin interface are increased and as frame stiffness increases, time to bone union increases [17]. Increasing the number of fixation pins from the minimum of two pins per major fragment increases the area of pin-bone interface, thus decreasing the incidence of bone resorption and subsequent pin loosening. The larger pins are stiffer than smaller pins by a direct relationship to the fourth power of the radius; thus a small increase in diameter produces a large increase in stiffness [18]. Single pin fixation of a fragment contravenes conventional recommendations for external fixation [8,9]. But fixation of a juxta-articular fragment as in distal humeral and femoral fractures complicates with restricted pin insertion area. Because of such limitations, hybrid external fixation systems were designed and started to use [19]. In the study performed by KIRBY et al. [10], fixation of femoral and humeral fractures were made with linear-circular hybrid external skeletal fixator in 21 dogs and 8 cats. In 5 of the dogs, the fracture type was supracondylar and/or intracondylar. The fixation of the condyles were made with single threaded pin in 4 dogs and with multiple half pins (2.4 mm Φ) in one dog. In the present study, a single negative profile ETHP -in the largest diameter that was thought could be - was placed bicortically across the condyle. This biomechanical factor resulted in additional load sharing by the external skeletal fixator during weightbearing, specifically placing substantial stress on the distal condylar ETHP. In order to avoid pin loosening due to excessive strain on the condylar ETHP, the weights of the dogs were limited to 13 kg. Although any exercise or training restriction, except jumping from an elevated height was instructed to any of the owner the use of a single pin in distal fragment did not complicated with reduction failure in any of the dogs.

An adequate blood supply is necessary for bone to carry out its normal physiological function. It has been suggested that the porosity observed under plates could be attributed to a response to cortical flow alteration induced following placement of the plate [20]. The altered flow may alter the microenvironment in cortical bone beneath plates inducing vascular ingrowth and bone resorption [8]. In locking plate systems (LCP) it is not necessary to press a locking plate against the bone as conventional plating systems, a feature which protects periosteal vascularity and removes the need for accurate contouring of the implant. In a study repair of humeral Y-T fractures were done with a new “String of Pearls” locking plate system [21]. Two plate fixation was performed in all 13 dogs with a mean weight of 22.8 kg and results were good to excellent except one poor dog. Requirement of a more extensive exposure and necessity of a new surgical procedure for removal of the plates are two disadvantages of bone plates when compared with ESF.

Optimal fixation of articular fractures involves restoration of joint congruity and through precise anatomical reduction and stable fixation of articular component of the fracture while minimising soft tissue trauma and allowing for early mobilisation of the joint [22]. The complex conformation of the distal humerus and small size of the juxtaarticular condylar fracture segments complicate implant placement [4, 5, 23]. Fracture stability is dependent on interfragmentary friction and on the integrity of the supracondylar components of the fracture repair [24]. Fixation by screws inserted in lag fashion is generally used to stabilize humeral condylar fractures to provide interfragmentary compression and promote primary bone healing [4, 6, 25]. A condylar ETHP does not achieve the adequate compression between the fractured condyles. So, in present study, the treatment procedure of 3 intracondylar fractures was achieved in two steps: fixation of intercondylar fracture with Kirschner wires or a lag screw and stabilization of the supracondylar fracture with SESFS. Because of the restricted area in lateral condylar surface, the intercondylar lag screw was applied from slightly proximal of the lateral epicondyle in order not to interfere with the condylar half pin. In a recent study, humeral condylar fractures were repaired with self-compressing Orthofix pins in 23 dogs [26]. As a future project, by using the self-compressing Orthofix pin in distal arch, intracondylar fractures can be treated by SESFS with no adjunctive fixation.

Condylar humeral fractures carry guarded prognosis and have a high incidence of complications including fixation failure, refracture and development of post-traumatic osteoarthritis however, prognosis for leg function after repair of distal diaphyseal and or supracondylar fractures is good to excellent [4]. Reduced elbow flexion and post-traumatic osteoarthritis are consistent findings in dogs that have had surgical stabilization of articular fractures of the distal humerus, but do not appear to correlate with a poor clinical outcome [2, 27]. Nine dogs in present study had an excellent functional outcome without lameness. Although there was no pain in range of motion, clinical examination revealed 5 to 15 degrees reduced flexion in comparison to the contralateral elbow in all dogs. In a study evaluating the long-term results of humeral condylar fracture repair 13 dogs, it was found that all of the elbows developed post-traumatic osteoarthritis, however, there was no correlation between the presence of radiographic osteoarthritis and limb function [27]. In present study, although 6 of the dogs showed evidence of osteoarthritis, only 3 of them revealed intermittent mild lameness. According to present authors, it may be possible that young dogs are more capable of recovering from articular fractures without developing degenerative joint disease.

Ideally, patients with distal humeral fracture should be operated on as soon as possible after they have been thoroughly evaluated and appropriately stabilized. Surgical repair with either open or closed reduction is recommended within 24 to 72 hours [14]. Decreased range of joint motion is a major complication associated with distal humeral fractures, so early return of limb use is important. Early ambulation not only induce fracture healing by promoting axial micromotion also prevent disuse atrophy and muscle contractures in fracture patients [28, 29]. The primary goal of using SESFS in these case series was achieving early ambulation and use of the fractured limb.

Carbon-fibre materials are lightweight, x-ray transparent and sufficiently stable under vapour sterilization conditions.
The x-ray transparency enables traditional view radiographs without interference from overlapping arches which is more important in medio-lateral projections [30]. In present study, presence of carbon arches enhanced our ability to assess fracture healing on the lateral radiographic projections. A 6 holed, 45°carbon-fiber arch weighs 12.5 g. An aluminum and a 316L stainless steel arch the same size as carbon-fiber arches approximately 20 g and 50 g respectively. So a standard 4 arched frame weighs 120 g, 150 g, and 270 g if the arches are made of carbon-fiber, aluminum and 316L stainless steel respectively. Although carbon-fiber is an expensive orthopedic material, durability and reusability of the system reduce the cost. These superiorities augment the worth of carbon-fiber in veterinary orthopedics.

As a result it was concluded that unilateral SESFS found to be practical and efficient in the treatment of the distal humeral fractures of young or small breed dogs weighing less than or equal to 13 kg. This is the preliminary report about the treatment of distal humeral fractures in dogs with a single distal pin frame designed SESFS in which early postoperative and long term results seem to be favorable.

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References