Kirschner wire fixation of Salter-Harris type IV fracture of the lateral aspect of the humeral condyle in growing dogs. A retrospective study of 35 fractures

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Clinical Communication

Kirschner wire fixation of Salter-Harris type IV fracture of the lateral aspect of the humeral condyle in growing dogs: a retrospective study of 35 fractures

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Summary

Objectives: To evaluate the use of Kirschner wires for treatment of fractures of the lateral aspect of the humeral condyle in growing dogs.

Methods: Retrospective analysis of 35 fractures/elbows (33 dogs) of the lateral aspect of the humeral condyle treated by insertion of multiple transcondylar and one antirotational Kirschner wires. Radiographic and clinical re-evaluations were carried out immediately after surgery, at four weeks and, when required, at eight weeks postoperatively. Long-term follow-up was planned after a minimum of six months. The relationship between different implant configurations and clinical outcome was analysed statistically.

Results: Complete functional recovery was seen in 31 elbows (30 dogs), 3 elbows (2 dogs) had reduction in the range of motion and 1 elbow (1 dog) had persistent grade 1 lameness two months postoperatively. Major complications occurred in 8 elbows (8 dogs) and all were resolved by implant removal. Implant configuration did not affect outcome. Long term evaluation in 12 cases with a mean follow up of 4 years showed absence of lameness, normal function and no or mild radiographic evidence of osteoarthritis in 11 cases.

Clinical significance: Fracture of the lateral aspect of the humeral condyle in growing dogs can be successfully treated by multiple transcondylar convergent or parallel Kirschner wires, resulting in adequate fracture healing.

Keywords: Immature dogs, fracture of humeral condyle, Kirschner wire.

Introduction

Fractures of the humeral condyle are reported to account for 41% of humeral fractures in dogs (1). The lateral aspect of the humeral condyle (capitulum) is fractured more often than the medial aspect (trochlea) because of anatomical and biomechanical differences. Fractures of the lateral aspect of the humeral condyle are reported for 34 to 67% of humeral condyle fractures (1-3) and for 37% of all distal humeral fractures (4). The peak occurrence of fractures of the lateral aspect of the humeral condyle in dogs is between 3 and 4 months of age (1). In 90% of dogs, the cause is minor trauma (2, 3, 5), chiefly injuries sustained in jumps and falls from heights of less than 1.5 m (6). In immature dogs, condylar fractures are generally Salter-Harris type IV (7, 8) although type III fractures occasionally occur (6, 9). Incomplete ossification of the humeral condyle (IOHC) has been reported to be a predisposing factor for condylar fracture in several breeds (10-13). Conventional treatment of lateral aspect of the humeral condyle fractures involves anatomical reduction, positioning of a transcondylar lag screw and insertion of a supracondylar anti-rotational Kirschner wire or bone screw (4, 6). This technique allows rapid functional recovery and primary bone healing. In immature dogs, particularly miniature and toy breeds, the dimension of the condyle, soft consistency of the bone and presence of the growth plate can make screw insertion difficult with little margin for error (14). Alternative techniques of fracture fixation by insertion of multiple Kirschner wire (14, 15) or self-compressing pins (16, 17) have been reported. The aim of this study was to evaluate the efficacy of surgical treatment of fractures of the lateral aspect of the humeral condyle with multiple Kirschner wires in immature dogs.

Materials and Methods

Medical records from three different veterinary institutions (Centro Veterinario Luni Mare, Clinica Veterinaria Vezzoni and Università di Medicina Veterinaria di Torino - Italia) were retrospectively reviewed to identify dogs with fractures of the lateral aspect of the humeral condyle treated with pins or Kirschner wires between December 2001 and October 2014. Information obtained included date of presentation, date of surgery, sex, breed, age and body weight of the dogs and surgical reports. Dogs were included in the study if they were less than seven months old and had a fracture of the lateral part of the humeral condyle and a minimum follow-up period of four weeks.

Preoperative evaluation

Mediolateral and craniocaudal radiographic views were obtained for both elbows of each dog. Radiographs of the non-affected contralateral elbow were examined for IOHC.

Surgical technique

Dogs were premedicated and general anaesthesia was induced. Before surgery cefazoline[a] (20 mg/kg intravenously [IV]) was administered prophylactically. Dogs were placed in dorsal recumbency with the fractured limb in a hanging position and aseptically prepared for surgery. The fracture was treated with open reduction via craniolateral approach to the elbow and supracondylar region or by closed reduction (18, 19). First, the fracture was reduced and compressed by applying single[b] or twin[c] pointed reduction forceps. Reduction was confirmed by anatomical realignment of the lateral epicondylar crest and, when required, by checking the congruity of the articular surface. Closed reduction was confirmed using fluoroscopy. Fixation was then carried out with two or three transcondylar Kirschner wires or Steinmann pins inserted from the lateral epicondyle using an entry point midway along an imaginary line between the epicondyle and the articular surface of the humeral condyle and at an angle of 45° to the long axis of the humeral shaft (4). Implants were placed in either a convergent direction so that Kirschner wires intersected medial to the fracture line or parallel to one another (Fig. 1-2). The procedure was completed by insertion of a supracondylar

Kirschner wire or Steinmann pin into the lateral epicondylar crest or lateral epicondyle in a proximomedial direction to engage the medial humeral cortex. Intraoperative fluoroscopy was used in all fractures undergoing closed reduction and in some of the other fractures to evaluate correct positioning of the Kirschner wires (19). The incisions were closed routinely.

Postoperative evaluation and care

Craniocaudal and mediolateral radiographic views of the elbow were obtained postoperatively to evaluate fracture reduction and implant positioning. According to the surgeon's preference, a modified Robert Jones or a carpal flexion bandage was applied for five days, or the limb was left unbandaged. All dogs were discharged and the owner received amoxicillin with clavulanic acid[d] (20 mg/kg orally for five days) or cefazoline[a] (20 mg/kg orally for five days) and meloxicam[e] (0.05 mg/kg orally for one week). Furthermore, restriction of physical activity was recommended for four weeks.

Clinical and radiographic follow-up

Clinical examination and mediolateral-craniocaudal radiographic views were performed at four weeks and at eight weeks postoperatively. Long-term follow-up was performed in available cases at a minimum of 6 months postoperatively, either by performing a clinical and radiographic examination when possible or by telephone interview of the owner. Lameness was graded using a scale of 0 to 4 (20). Range of motion of affected limb was compared with the opposite limb; in cases of bilateral fracture it was compared to a reference range. The normal range of motion of the elbow joint is approximately 130 degrees, with normal limits being approximately 36 degrees (range, 34 to 38 degrees) in flexion and 165 degrees (range, 164 to 167 degrees) in extension, as measured via goniometry in awake Labrador Retrievers (21). Radiographs and clinical findings were used to assess fracture healing, time required for bone healing and incidence of complications. Owner satisfaction relating to postsurgical complications, lameness and changes in activity and behaviour of the dogs and pain upon manipulation of the repaired elbow was investigated in the dogs in which long-term follow-up was available.

Statistical Analysis

The correlations between the number, diameter and placement direction (convergent or parallel) of Kirschner wires and time required for bone healing or incidence of complications were analysed using Fisher's Exact Test. Differences were considered significant at $P < 0.05$. The long-term outcome was not analysed because of the small number of cases.

Results

Signalment, cause of fracture, results of orthopaedic examination, surgical description, radiographic evaluation and results of follow-up examination of the 35 fractures in 33 dogs that met the inclusion criteria are shown in appendix tables 1 and 2. All dogs had grade 4 lameness at the time of initial examination. All fractures were classified as Salter-Harris type IV of the lateral aspect of the humeral condyle and there were no pre-existing radiographic signs of osteoarthritis. Radiographic signs of IOHC of the contralateral humerus were evident in one elbow. An open surgical approach was used in 29 fractures and six fractures were reduced in a closed fashion. Stabilisation was achieved using two transcondylar Kirschner wires and one supracondylar (antirotational) Kirschner wire in 16 fractures and three transcondylar Kirschner wires and one supracondylar Kirschner wire in 19 fractures. Implant diameter varied from 0.8 to 2.0 mm (Table 1). Smooth Kirschner wires were used in all but four fractures, in which a single transcondylar threaded positive-profile Kirschner wire ranging in size from 1.2 to 1.5 mm was used. Transcondylar Kirschner wires were convergent and crossed medial to the fracture line in 26 fractures. In the remaining nine fractures, Kirschner wires were inserted in a parallel direction or in a convergent direction but without crossing one another (Fig. 1) and without interfering with the growth plate. In 19 elbows, the extremity of the Kirschner wire was bent toward the bone before cutting, while in the remaining 16 elbows it was cut at the level of the bone. Postoperative radiographs showed anatomical reduction of 28 fractures. An epicondylar gap of 1 mm was present in 4 fractures and a gap of 2 mm in 3 fractures. In one of the three latter fractures, a 1-mm articular cartilage off-set step was also visible at the joint surface (Fig. 3). In 17 elbows, a Robert Jones (n=14) or carpal flexion bandage (n=3) was applied for 5 days postoperatively and no bandage was used in the remaining 18 elbows.

Short-term follow-up

Follow-up examinations at four weeks postoperatively showed complete clinical recovery and no lameness in 27 of 33 dogs (Table 2). Grade 1 lameness was present in five dogs and grade 2 lameness in one. Radiographic examination at four weeks showed fracture healing in 31 elbows and persistence of a radiolucent fracture line in four elbows. Of the eight dogs that were re-examined at eight weeks because of lameness, radiolucent fracture lines or both combined at four weeks, one dog had mild lameness (grade 1), two had reduced range of motion of the elbow while all had radiographic evidence of fracture healing. Eight dogs suffered major complications that required surgical correction. Kirschner wire migration accompanied by seroma formation occurred in six dogs four to six weeks postoperatively and resolved after implant removal through a stab incision in the skin. One broken Kirschner wire was removed in one dog (no.3). Soft tissue irritation occurred in another dog (no. 32) three months postoperatively and resolved within three weeks after implant removal (Fig. 4). Grade 1 lameness persisted in one dog (no.12) and reduced the range of motion of the elbow in two others (nos. 17 and 28). There was no significant difference between the number, diameter and direction (convergent or parallel) of Kirschner wires and time required for bone healing or incidence of complications.

Long-term follow-up

Long-term follow up was available in 20 dogs from 6 months to 9 years (mean 4 years). Clinical and radiographic long-term follow up examination in 12 dogs showed absence of lameness and normal function in 11 dogs and grade I lameness in one dog at 6 months (no. 12). Two dogs had reduced range of motion of the elbow (no. 12, no. 28). Radiographic evaluation showed grade one osteoarthritis in one elbow (no. 19) and grade 2 osteoarthritis in six elbows, using a 0-3 scoring system (22). One dog (no. 15) had a major complication (migration of two Kirschner wires) eight years postoperatively (no. 15) (Fig. 5, Table 3). All dog owners were satisfied with the long-term outcome of the fracture treatment. Telephone interview of the owner was performed in the remaining 8 cases. Owners reported satisfaction relating to surgical outcome, level of activity and absence of lameness.

Discussion

The anatomical conformation of the distal humerus (17) and the presence of growth plates predispose immature dogs to fracture of the lateral aspect of humeral condyle. All of the cases in our study had a Salter-Harris type IV fracture, which is considered the most common humeral fracture in immature dogs (8). Incomplete ossification of the humeral condyle is considered a predisposing factor for the development of condylar fracture (10). In our cases there were three breeds considered to be a risk of IOHC, however only one dog had radiographic signs of IOHC of the contralateral non-fractured humerus. However, radiography showed complete healing of the fracture in those dogs. Computed tomography of the contralateral humerus may be a better method for detection of IOHC when there are no radiographic signs (23). In our study, Miniature Pinschers were most frequently affected (14/33); however, further studies are required to evaluate whether this breed is predisposed to humeral condyle fracture. The goal of articular fracture repair is anatomic reduction and rigid fixation to obtain primary bone healing that allows early complete functional recovery of the joint while minimising subsequent development of osteoarthritis (24). Bone healing is more rapid in immature than mature dogs (25), which shortens the time required for support of the healing bone by the implants. Tomlinson (1997) argued that because the bones of immature dogs are small and soft, repair with a lag screw may be contraindicated (15). The technique used in our study provided adequate stabilisation of the fracture and was relatively easy to carry out. Kirschner wire fixation also can be done using closed reduction under fluoroscopic guidance, provided that muscular contracture has not occurred (19). Intraoperative fluoroscopy also is advantageous in open reduction techniques to confirm correct positioning of the implants and anatomical reduction.

The results of our study indicate that the described technique is effective for treating fractures involving the lateral part of the humeral condyle in immature dogs. This method had been previously rejected as a suitable repair for young and hyperactive animals based on the observation of an increased incidence of early Kirschner wire migration and hence fracture displacement (26).

In our study approximately 23% (8/35) of fractures required an additional minimally-invasive surgery for implant removal because of migration or breakage of implants and soft tissue irritation. However, those complications resolved following implant removal and did not seem to have a long-term impact on bone healing or on functional recovery with the exception of three cases: no. 12, no. 17 and no. 28 (Tab. 1-2). This type of fracture repair provided good results; however, it is important to point out that all the dogs in our study were skeletally immature and the majority were small breed dogs (mean 3.5 months and 3.7 kg). In larger or in more skeletally mature dogs, different methods of treatment including screw fixation and a neutralization plate might be more appropriate, being the gold standard for the treatment of such fractures (4, 6, 27). The number and diameter of the Kirschner wires were related to the size of the dog. Our results show a decreased tendency to implant migration in cases where the Kirschner wires have been bent against the bone before cutting, with an incidence of 5.3% against 31.2% of un-bent Kirshner wires. Thus Kirshner wires bending should be recommend, nevertheless it may be considered that the soft bones of young dogs are predisposed to damage during bending of large Kirschner wires, and for this reason, in our study only Kirschner wires smaller than 1.4 mm have been bent. The insertion of one transcondylar positive-profile threaded Kirschner wires that does not cross the physis may be an alternative technique to maintain the compression at the fracture site produced by the reduction forceps, and prevent Kirschner wire migration, working as a positional screw (19). This technique was used in four cases of our study with good results. The use of crossed Kirschner wires has been advocated for maintaining the compression achieved by reduction forceps (15). However, this technique increases the risk of crossing the growth plates thus potentially affecting bone length at skeletal maturity. Avoiding the growth plate is easier with parallel Kirschner wires. A study of femoral neck fractures showed that mechanical forces applied to Kirschner wires inserted in a parallel fashion are distributed equally between the Kirschner wires (28). In contrast, divergent pins are associated with uneven distribution of the load between the implants and render the fixation significantly weaker and thus predispose the repair to failure (28). We found no significant difference in outcomes between the parallel or convergent crossed Kirschner wire configurations, probably because of the limited number of cases included in the study. Further biomechanical studies should be made to evaluate which is the best Kirschner wires configuration in humeral condyle fractures. A previous study of dogs with fracture of the lateral aspect of the humeral condyle evaluated the impact of growth plate damage after Salter-Harris type IV fracture (29). Humeral length, evaluated radiographically, was not decreased in that study regardless of whether or not the implants crossed the growth plate. The distal growth plate of the humerus, which is responsible for only 20% of the longitudinal growth, closes at about five to eight months of age (30, 31). Thus, even if premature closure of the distal humeral growth plate should occur, the effects are likely to be minimal with the exception of very young puppies (29). Long-term follow-up after a median period of four years postoperatively showed a favourable outcome, normal function of the affected limb and no or only mild radiographic signs of OA in the majority of cases (Table 3), which is in contrast to what has been reported by Gordon. It is difficult to postulate the reason of the lower incidence of post-traumatic osteoarthritis reported in our study, also because of the different populations of the two studies, with a predominance of small breed dogs in our study compared to Gordon study in which Labrador Retrievers were most commonly affected (32).

Conclusions

The results of our study showed that fractures of the lateral aspect of the humeral condyle can be successfully treated with Kirschner wires placed in a convergent or parallel direction in dogs less than seven months of age. Both techniques were straightforward, provided adequate fracture stability for healing and decreased or eliminated the eventuality iatrogenic condylar fracture in the soft bone of puppies. Despite a major complication rate of 23% (8 elbows) attributable to Kirschner wires migration, which was resolved by means of minimally-invasive surgery return to normal elbow function without lameness was recorded in 32 of 35 fractures. Satisfactory results also were obtained at the long-term follow-ups (median 4 years in 12 elbows/11 dogs), at which time the majority of dogs had a good clinical and radiographic outcome. Because of the limited number of cases and the retrospective nature of the study, prospective clinical and biomechanical studies are needed to corroborate our findings.

Nomenclature and Abbreviations

a. Cefazolina Dorom: Teva Pharma Italia, Milano, Italy

b. Reduction Forceps with points: Synthes, Opera Milan, Italy

c. Reduction forceps: Veterinary Instrumentation, UK

d. Synulox: Pfizer, Rome, Italy

e. Metacam: Boehringer Ingelheim Vetmedica GmbH, Ingelheim, Germany

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Figure Legends

Figure 1. Plastic bone model of fracture of the lateral aspect of the humeral condyle showing the possible order and placement of multiple parallel or convergent transcondylar Kirschner wires. Position of 3 or 2 convergent and crossed Kirschner wires (a, b); Position of 2 convergent Kirschner wires (not-crossed) (c) or parallel Kirschner wires (d).

Figure 2. Radiographs showing convergent and crossed Kirschner wires in a dog (no. 20), immediately postoperatively (a, b), and 3 months postoperatively, one Kirschner wire had migrated and was removed (c, d). Radiographs showing parallel Kirschner wires in a dog (no. 27) immediately postoperatively (e, f) and bone healing 1 month postoperatively (g, h).

Figure 3. Radiographs taken preoperatively (a, b) and immediately postoperatively (c, d) in a dog (no. 28). Note the presence of a 2-mm gap and step at the level of the epicondylar crest fracture line (asterisk) and a 1-mm step at the level of the articular surface (arrow). Radiographic views taken 2 months postoperatively showing bone healing with mild joint incongruity and osteoarthrosis(e, f).

Figure 4. Radiographs taken preoperatively (A, B) and immediately postoperatively (C, D) in a dog (no. 14) with fracture of the lateral aspect of the humeral condyle. Radiographs showing bone healing and Kirschner wire migration 1 month postoperatively (E, F).

Figure 5. Radiographs taken immediately postoperatively (a,b,e,f,i,l), 2 years postoperatively (g,h) and 4 years postoperatively (c,d,m,n). Note the absence of OA 4 years postoperatively in case 24 (a-d) and in case 11 (i-n) and mild OA at the last re-evaluation 2 years postoperatively in case 27 (e-h).

Table Legends

Table 1. Signalment, history, number and diameter of Kirschner wires and postoperative radiographic evaluation in 33 dogs with fracture of the lateral aspect of the humeral condyle. Legends: right (R), left (L), male (M), female (F), threaded positive profile Kirschner wire (th).

Table 2. Clinical and radiographic re-evaluation 4 and 8 weeks postoperatively in 33 dogs with fracture of the lateral aspect of the humeral condyle. Legends: range of motion (ROM), Kirschner wire (K).

Table 3. Clinical and radiographic long-term re-evaluation (minimum 6 months - maximum 9 years postoperatively) in 12 dogs with fracture of the lateral aspect of the humeral condyle. The long-term outcome was determined via telephone interview of the owners in eight cases, and long-term re-evaluation was not possible in the remaining cases. Legends: range of motion (ROM), Kirschner wire (K), osteoarthritis (OA).