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Minimally Invasive Reduction and Stabilization of Fractures of the Humeral Condyle by Skeletal Traction in Dogs: 18 Cases

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Abstract

Closed reduction or limited open reduction in conjunction with internal or external fixation has been recommended as the preferred treatment for many types of fractures, but this technique has rarely been recommended for articular fractures because of the need for anatomic alignment of articular surfaces. However, the proposed benefits of closed reduction should be applicable to articular fractures if appropriate reduction and implant placement can be achieved. The aim of this study was to retrospectively evaluate a surgical technique for minimally invasive reduction and stabilization of fractures of the humeral condyle by means of intraoperative traction applied to the ulna under fluoroscopic guidance. Nineteen fractures of the humeral condyle in eighteen dogs were reduced by intraoperative osteotaxis applied by traction of the ulna, minimally invasive approach to the epicondyle and fracture stabilization under fluoroscopic guidance. Postoperative reduction was considered good or excellent in most fractures. This technique can be considered as a potential option for the treatment of condylar fractures, allowing for minimally invasive reduction and stabilization, thus avoiding the need for surgical exposure of the elbow joint.

Keywords

- fracture of the humeral condyle
- minimally invasive stabilization
- skeletal traction
- dogs

Introduction

Fractures of the humeral condyle represent 5% of bone fractures in dogs and cats, and accounted for 41% of humeral fractures in a survey of 107 fractures.[1,2] The lateral side (capitulum) is fractured more commonly because of anatomic and biomechanical differences with the medial side (trochlea), accounting for 37% of all distal humeral fractures.[2–5] The capitulum, which articulates primarily with the radial head, is located lateral to the longitudinal axis of the diaphysis and is supported by the relatively small lateral epicondylar crest,[6] leading to an increased incidence of lateral fractures. Fractures of the trochlea occur in 6.9 to 11%, and dicondylar (also known as T-Y) fractures represent 25.9 to 35% of fractures affecting the humeral condyle.[2–4] Most fractures occur in puppies during their growth phase; since growth plates close between 5 and 8 months of age, even relatively minor trauma during this phase may lead to fractures.[7–9] In immature dogs, condylar fractures are generally Salter-Harris type IV, although type III fractures occasionally occur.[10,11] Specific diseases may predispose to condylar fracture, as is the case in humeral condylar fissure (HCF) in spaniels.[9] Treatment of humeral condyle fractures involves anatomical reduction, positioning of a transcondylar lag or position screw and insertion of a supracondylar antirotational Kirschner wire (K-wire), bone screw or a neutralization plate.[10,12,13] Alternative techniques of fracture fixation in puppies by the insertion of multiple K-wires or self-compressing pins have been reported.[6,14,15]

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Reduction techniques can be performed using either open or closed approaches. The main difference lies in pursuing a good reduction in the joint surface under visual guidance or in a closed way by fluoroscopy-assisted guidance. The latter is more likely to preserve the vascular supply to the bone and soft tissues,[16,17] thus potentially reducing the later development of osteoarthritis.

One study reported that 43% of patients treated with open surgery developed osteoarthritis and varying degrees of postoperative (PO) lameness.[18] Another study analysed 11 fractures reduced by fluoroscopy-assisted closed procedure and stabilization of the fracture with a compression screw and antirotational K-wire emphasizing the advantages of closed reduction; advantages included minimal disruption of soft tissues and the blood supply, decreased risk of infection and earlier return to function.[17] The aim of this study was to evaluate the feasibility and the short-time efficacy of a reduction technique for condylar fractures using skeletal traction performed by a traction stirrup (Ad Maiora, Cavriago, Italy),[19] with a minimally invasive approach and fracture stabilization.

Materials and Methods

Medical records of the patients operated at Clinica Veterinaria M. E. Miller for the treatment of humeral condylar fractures were reviewed. The information obtained included signalment, body weight, date of surgery and surgical report (►**Table 1**). Being a retrospective study, dogs were considered candidates for inclusion if they were operated on by the closed reduction technique heir in described.

Fracture reduction was achieved through skeletal traction using a traction stirrup (Ad Maiora, Cavriago, Italy) and stabilized employing multiple K-wires placed in the condylar and epicondylar areas in puppies (►**Fig. 1**), or using a transcondylar lag screw in adult dogs (►**Fig. 2**). The PO radiographs were evaluated for assessing the reduction, and the percentage of reduction was normalized against the size of the condyle.

Preoperative Evaluation

Medio-lateral (ML) and cranio-caudal (CC) radiographic views were obtained for both elbows. Radiographic images of the non-affected contralateral elbow were examined for HCF in the dogs older than 4 months. A 15 degrees craniomedial-caudolateral view was taken to identify the HCF radiolucent line.[9]

Surgical Procedure

Dogs were positioned in lateral recumbency with the limb to be operated on in the uppermost position for fractures of the

Table 1 Case details

Dog	Breed	Weight (kg)	Age	Location and side	Type	Surgery duration	Stabilization technique	Gender
1	English Setter	10	116 d	L L + medial fragment	SH IV	4h, 15m	K-wire //	M
2	French Bulldog	7	176 d	L R	SH IV	2h, 20m	K-wire //	M
3	Italian Mastiff	15	167 d	M R	SH IV	2h, 40m	K-wire //	M
4	French Bulldog	5	158 d	Y R	SH IV	4h	K-wire spring effect	F
5	Drahthaar	11	104 d	L L	SH IV	1h, 50m	K-wire //	F
6	Boxer	11	107 d	L L	SH IV	1h, 25m	K-wire //	M
7	French Bulldog	6	129 d	L L	SH IV	2h	K-wire //	M
8	Pinscher	0.8	101 d	Y R	SH IV	3h, 10m	K-wire //	F
9	German Shepherd	10	90 d	M L	SH IV	2h, 45m	Divergent K-wire	F
10	Pinscher	1.7	147 d	L R	SH IV	2h, 20m	K-wire //	M
11	French Bulldog	8	215 d	L L	SH IV	2h, 20m	K-wire //	F
12	Labrador Retriever	15	97 d	L R	SH IV	2h	K-wire //	M
13	Newfoundland	20	124 d	L R	SH IV	3h, 15m	Divergent K-wire + ESF	M
13	Newfoundland	20	124 d	L L	SH IV	2h	K-wire //+ ESF	M
14	Boxer	10	98 d	L L	SH IV	1h, 50m	Divergent K-wire	M
15	Springer Spaniel	24	7 y, 1 mo	L R	FLHC	2h, 30m	K-wire + screw	M
16	Springer Spaniel	24	3 y, 4 mo	L R	FLHC	2h, 20m	K-wire + screw	M
17	French Bulldog	4.7	112 d	L L	SH IV	2h, 55m	K-wire //	F
18	Epagneul Breton	19	8 y, 8 mo	L R	FLHC	4h	K-wire + screw	M

Abbreviations: //, parallel K-wire; d, days; ESF, external skeletal fixator; F, female; FLHC, fracture of the lateral humeral condyle; K-wire, Kirschner wire; LL, lateral left; LR, lateral right; M, male; mo, month; ML, medial left; MR, medial right; SH, Salter Harris; y, year; YR, Y fracture right.

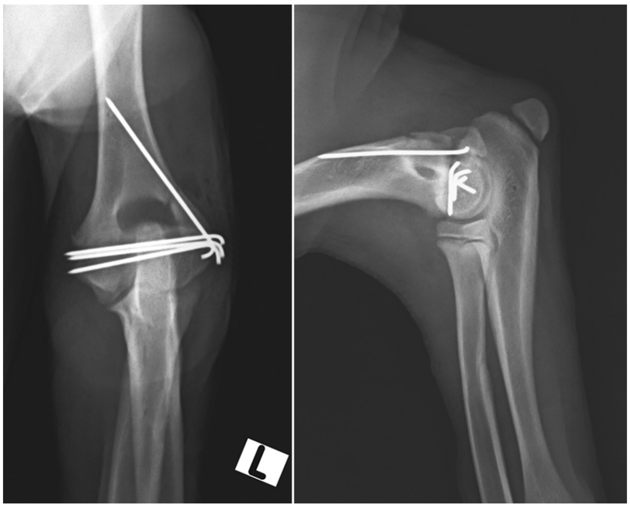

Fig. 1 Postoperative radiographs of a skeletally immature dog (number 5) with fracture of the lateral aspect of the humeral condyle.

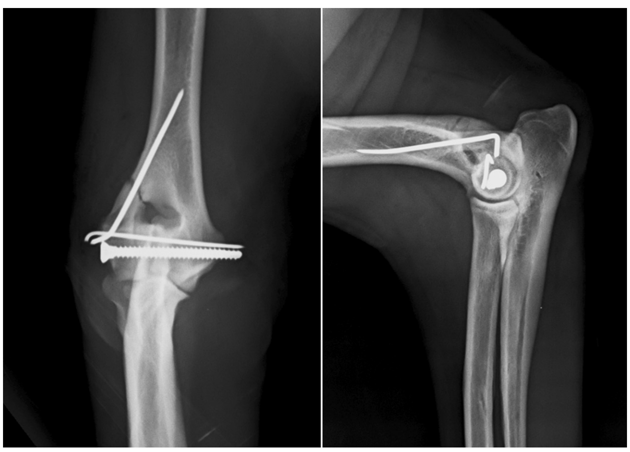

Fig. 2 Postoperative radiographs of an adult dog (number 18) with fracture of the lateral aspect of the humeral condyle.

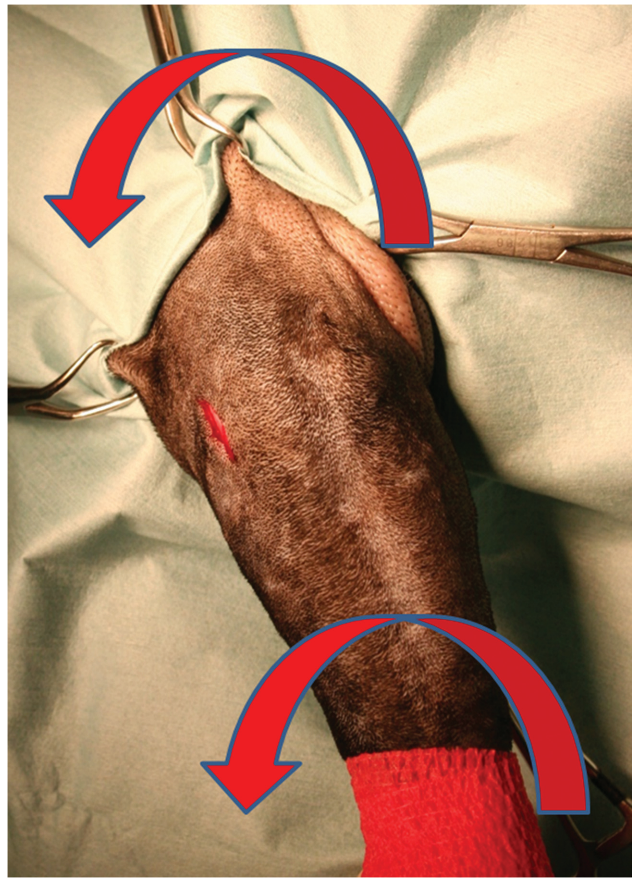

Fig. 3 Intraoperative position of the limb to perform the sagittal projection of the condyle with the C-arm in the vertical position. Extreme pronation of the humerus was induced together with the antebrachium (proximal = top – lateral = left). The minimally invasive surgical approach to the lateral epicondyle is visible.

capitulum and in lowermost position for fractures of the trochlea, while they were positioned in dorsal recumbency for bicondylar fractures, allowing access to both the lateral and the medial side by adducting and abducting the limb. The dog's body was stabilized by means of padded traction bands (Ad Maiora, Cavriago, Italy), as previously described.[19] Two orthogonal fluoroscopic images were taken before any reduction attempt, so as to define the exact magnitude of fracture displacement. The lateral projection was straightforward, with the C-arm in the vertical position. For the sagittal projection, the rotation of the C-arm in the horizontal plane proved to be very time-consuming, and a specifically designed technique was developed to perform the sagittal projection of the condyle with the C-arm in the vertical position as for the lateral projection, in this way dramatically reducing the time needed for visualization. Extreme pronation of the humerus was induced together with the antebrachium (►**Fig. 3**). In this way, a CC projection was performed, speeding up the fluoroscopic evaluation. A 1.0- to 1.5-mm K-wire was placed orthogonally through the proximal ulna, just distally to the elbow on the axis of the humerus and connected to a traction stirrup (Ad Maiora, Cavriago, Italy).[19] The stirrup is made of two mobile arms (A) with a joint (J) and a threaded bar (T) with a nut (N) (►**Fig. 4**). Tightening the nut, the arms are spread apart in a progressive way. Their extremities hold bolts with a perforated screw

Fig. 4 Intraoperative picture of the stirrup applied for skeletal traction. The stirrup is made of two mobile arms (A) with a joint (J) and a threaded bar (T) with a nut (N). Tightening the nut, the arms are spread apart in a progressive way, thus tensioning the Kirschner wire (K) that is inserted through the ulna .

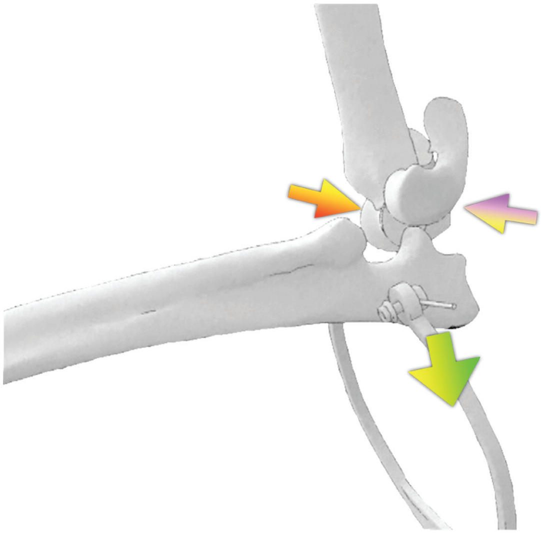

Fig. 5 Diagram showing the principle of ligamentotaxis. The Kirschner wire is placed orthogonally through the proximal ulna, just distal to the elbow on the axis of the humerus and connected to a traction stirrup. When traction is applied by the stirrup, the ulna is displaced caudally (*green arrow*), thus avoiding the interference with the intercondylar fracture area and potentially preventing the reduction in the condylar fragments, which can move back to their original location (*red* and *purple arrows*).

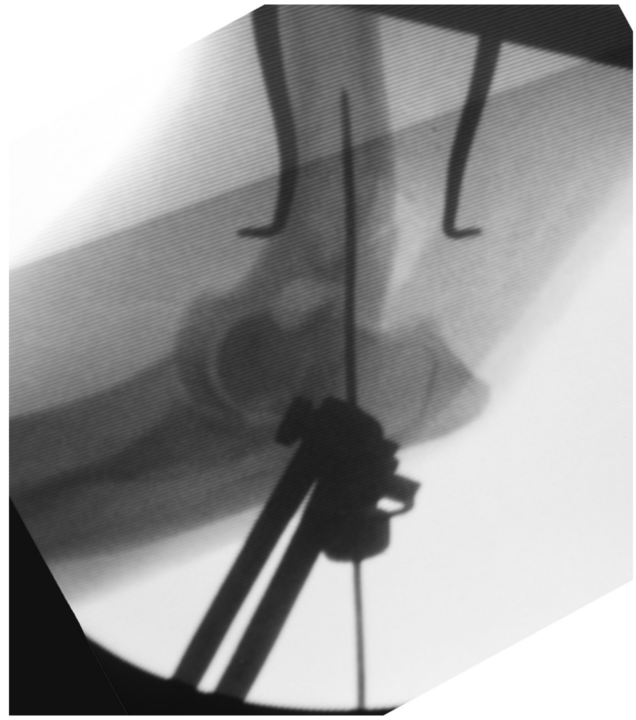

Fig. 6 Medio-lateral fluoroscopic view of the elbow joint of an immature dog with a fracture of the lateral portion of the humeral condyle after reduction and stabilization of the epicondylar fracture by means of a Kirschner wire.

that can lock a K-wire (K) up to 1.5 mm in diameter. Once the K-wire is locked at both extremities, the opening of the arms will tension the wire. The tensioned wire will not bend during traction, and this will prevent it from cutting through the surrounding soft tissues, as shown by the clinical use of circular fixators.[20] A 3/4-cm-long surgical approach to the lateral or medial epicondyle was performed, and the proximal part of the fractured epicondyle was observed. Traction was then manually applied by the stirrup to displace the ulna caudally, thus avoiding any interference of the ulna with the intercondylar fracture area, potentially interfering with the reduction in the condylar fragments (►**Fig. 5**).[21] Furthermore, the muscle and tendon attachments between the ulna and the humeral condyle bring the fractured fragment back close to its original location for the principle of ligamentotaxis.[22] Specific attention was paid to achieve anatomical reduction in the epicondylar fracture, without opening the elbow joint to visually check for proper reduction in the joint surface. The assumption was that when the epicondylar area is perfectly reduced, the articular surface of the condyle should be reduced as well. Then, a pointed reduction forcep (Synthes, Milan, Italy) was applied on both sides of the humeral condyle to stabilize the fracture and two orthogonal fluoroscopic views were taken to confirm that fracture reduction was adequate. If the fluoroscopic views showed unsatisfactory reduction, the clamp was released, the reduction in the epicondyle was revised and the clamp was applied again. A 1.0- to 1.5-mm K-wire, depending on the dog's size, was used to stabilize the epicondylar fracture first. The condylar fracture was then stabilized by means of K-wires in immature dogs or by a transcondylar positional screw in mature dogs (►**Fig. 6**), while maintaining the reduction forcep in place (►**Fig. 7**). Once the K-wires were inserted, the forcep was removed and the small incision (►**Fig. 8**) closed routinely. The size and the number of K-wires were related to the size of the dog.

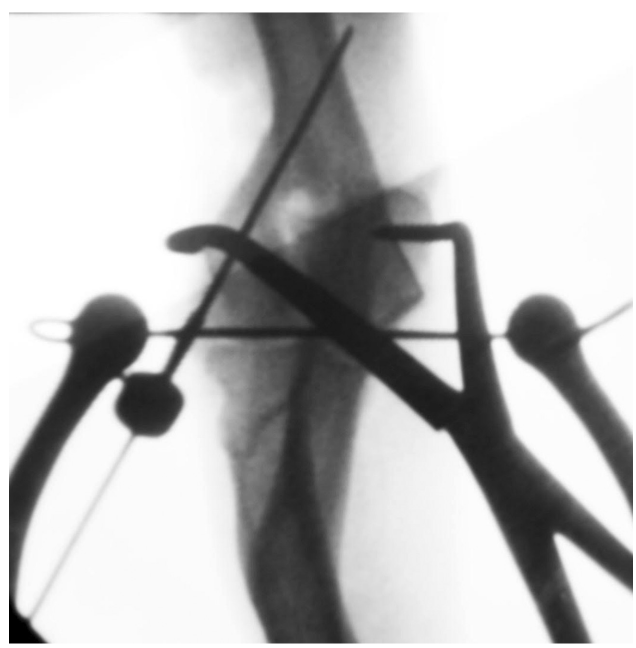

Fig. 7 Cranio-caudal fluoroscopic view of the elbow joint of an immature dog with fracture of the capitulum after reduction and epicondylar stabilization by means of a Kirschner wire. The forcep holds the reduction fracture until the fracture will be stabilized. Note the presence of the traction stirrup at the level of the proximal ulna.

Fig. 8 Intraoperative picture of the minimally invasive approach to the lateral epicondyle. Once the fracture is stabilized, the traction stirrup can be easily removed to allow for easier bending and cutting of the Kirschner wires.

Postoperative Radiographic Assessment

Immediate PO measurements were taken in both ML and CC projections (►**Table 2**).

For the comparison of the reduction achieved, the measurements were normalized to the diameter of the humeral condyle in both ML and CC projections. To determine the diameter of the humeral condyle (HCD) in ML projection, a circle including the articular area of the condyle (►**Fig. 9**) was drawn. To determine the diameter of the humeral condyle in CC projection, a circle including the medial and lateral epicondyles (►**Fig. 10**) was drawn. The normalization of the fracture gap against the condyle size was necessary to avoid incorrect evaluation of the same gap in condyles with different sizes. The reduction in the epicondyle in the ML projection was evaluated by drawing a point on the edge of the fracture line on each fragment of the medial or lateral epicondylar fracture. Afterwards, the points were connected to each other by a line orthogonal to the cortex, and its length was measured. When the spots were superimposed, the measure was zero, indicating the absence of fragment diastasis and therefore anatomic reduction (►**Fig. 9**). The reduction in the epicondyle and of the articular surface of the condyle in the CC projection was evaluated by drawing a point on the edge of the fracture line on each fragment of the medial or lateral supracondylar fracture or on each fragment of the articular profile of the condyle. Afterwards, the points were connected to each other by a line orthogonal to the cortex, and its length was measured (►**Fig. 10**). The actual measure was calibrated against a radiographic marker of known size on the picture. The percentage of reduction was then calculated normalizing the measure with the condyle diameter using the formula:

% of reduction = HCD in CC or ML projection – gap at the fracture lines / HCD in CC or ML projection

where 0 means 100% displacement of the fracture and 1 means 100% reduction in the fracture.

Results

Signalment, type of fracture, site, surgical description and the radiographic evaluation of 19 fractures in 18 dogs were shown in ►**Table 1**. Sixteen fractures were Salter-Harris type IV and three were suspected to be associated with HCF, based on the breed. Fifteen involved the capitulum (78%), two affected the trochlea (11%) and two were dicondylar fractures (11%). Nine fractures affected the left limb (47%) and ten affected the right limb (53%). One patient presented with bilateral fractures of the capitulum. Mean weight at surgery was 11.2 kg (median: 10 kg, range: 0.8–24 kg). The population was made up of two different groups of patients. The main group ($n = 15$) were puppies with a history of trauma; mean age was 129 days (median: 116 days, range: 90–215). The second group ($n = 3$) were mature patients where the potential inciting cause of fracture was HCF; mean age was 6 years and 4 months (median: 7 years, 1 month, range: 3 years, 4 months–8 years, 8 months). Twelve patients were male and six were female. Surgery duration was on average 157 minutes (median: 140 minutes, range: 85–255 minutes). Sixteen condylar fractures (84.2%) in puppies were stabilized using multiple K-wires. Stabilization of unicondylar (lateral or medial) humeral fracture in mature dogs (three, 15.8%) was achieved with a transcondylar position screw and antirotational wire. Immediate PO assessments are shown in ►**Table 2**. Mean reduction in the articular profile of the condyle in CC view was 98.3% (median: 98.3%, range: 93.1–100%). Mean reduction in the lateral epicondyle in CC view was 98.6% (median: 99.2%, range: 96.3–100%). Mean reduction in the medial epicondyle in CC view was 95.6% (median: 96%, range: 90.2–100%). Mean reduction in the lateral epicondyle in ML view was 97% (median: 100%, range: 79–100%). Mean reduction in the medial epicondyle in ML view was 85.7% (median: 87.2%, range: 68.3–100%). Case number 4 presented a dicondylar fracture of the right humerus. Fracture stabilization was maintained using divergent transcutaneous K-wires with a spring effect.[23] Case number 13 presented a bilateral fracture of the capitulum. At the end of the surgical procedure an articulated, monoplanar, transarticular external fixator centred over the centre of rotation of the elbow was applied bilaterally. The rationale for the transarticular fixator was to protect the elbows from excessive loads in the immediate PO period because the dog was forced to bear weight on them being the fracture bilateral.

Discussion

The results of our study are comparable with previously published papers on the treatment of condylar fractures.[17,24] The majority of the cases in our study were immature dogs therefore had a Salter-Harris type IV fracture, which is reported as the most common humeral fracture in immature dogs.[11] The anatomical conformation of the distal humerus and HCF are considered predisposing factors for the occurrence of condylar fractures.[9,25] In nine cases in this study, the extent of the incongruence of the fracture at the epicondyle

Table 2 Immediate PO assessments

Dog	Humeral condyle diameter CC (mm)	Humeral condyle diameter ML (mm)	PO radiographic assessment joint line CC (mm)	Percentage reduction joint line CC (mm)	PO radiographic assessment lateral epicondyle CC (mm)	Percentage reduction lateral epycondyle CC (mm)	PO radiographic assessment medial epicondyle CC (mm)	Percentage reduction medial epicondyle CC (mm)	PO radiographic assessment lateral epicondyle ML (mm)	Percentage reduction lateral epicondyle ML (mm)	PO radiographic assessment medial epicondyle ML (mm)	Percentage reduction medial epicondyle ML (mm)
1	47	15.4	0.0	100.00%	0.0	100.00%	NA		0.0	100.00%	–	–
2	32.6	10.8	0.9	97.24%	0.7	97.82%	–		0.7	93.24%	–	–
3	49.5	18.8	3.4	93.13%	–	–	2.1	95.76%	–	–	0.0	100.00%
4	32.6	10.4	0.9	97.18%	1.2	96.38%	1.2	96.29%	2.2	79.04%	3.3	68.27%
5	39.5	15.5	0.0	100.00%	0.0	100.00%	–	–	0.0	100.00%	–	–
6	45.6	16.9	0.0	100.00%	0.0	100.00%	–	–	0.0	100.00%	–	–
7	31.6	10.5	1.8	94.46%	1.8	94.30%	–	–	0.3	97.14%	–	–
8	15.1	5.5	0.6	96.29%	0.0	100.00%	1.5	90.26%	0.0	100.00%	1.4	74.55%
9	44.5	16.8	0.0	100.00%	–	–	0.0	100.00%	–	–	0.0	100.00%
10	21.2	6.9	0.0	100.00%	0.0	100.00%	–	–	0.0	100.00%	–	–
11	33.2	10.4	0.0	100.00%	0.0	100.00%	–	–	0.0	100.00%	–	–
12	45	19.6	0.0	100.00%	1.0	97.78%	–	–	1.0	94.90%	–	–
13 R	56.2	17.3	1.1	98.04%	1.1	98.04%	–	–	1.0	94.22%	–	–
13L	57.5	18.4	1.1	98.09%	0.9	98.42%	–	–	1.2	93.48%	–	–
14	50.8	13	1.2	97.64%	1.1	97.83%	–	–	0.0	100.00%	–	–
15	46.4	14.7	0.8	98.30%	0.0	100.00%	–	–	0.0	100.00%	–	–
16	47.1	16.5	1.1	97.66%	1.7	96.31%	–	–	0,0	100,00%	–	–
17	28.6	11.2	0.0	100.00%	NA		–	–	NA		–	–
18	45.7	15.1	0.0	100.00%	0.0	100.00%	–	–	0.0	100.00%	–	–
Average	46.35	15.25	0.7	98.32%	0.6	98.56%	1.2	95.58%	0.4	97.00%	1.2	85.70%
SD	0.92	0.21	0.87	2.06%	0.67	1.76%	0.88	4.01%	0.65	5.49%	1.56	16.71%
Median	46.35	15.25	0.6	98.31%	0.4	99.21%	1.3	96.02%	0.0	100.00%	0.7	87.27%

Abbreviations: CC, cranio-caudal; ML, medio-lateral; NA, not applicable for the presence of fragments; SD, standard deviation.

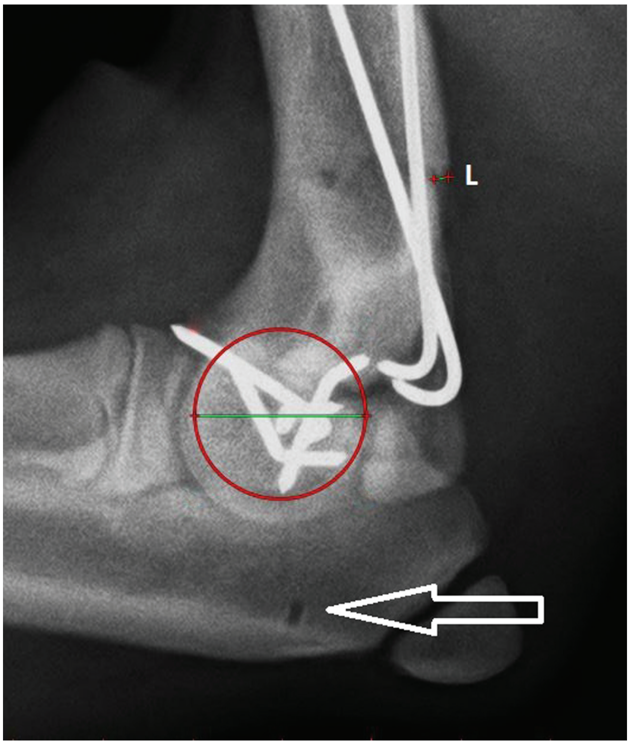

Fig. 9 Medio-lateral radiograph showing the circle including the articular part of the condyle (*red circle*), whose diameter is used for the normalization of the measure of the reduction in the fracture (*green line*). The fracture displacement (line L) at the epicondlar level is then measured and normalized against the circle diameter. The case shown in the picture (n. 12) was on purpose selected with a gap at the fracture level to show how the displacement was measured. Note the small hole (*arrow*) at the level of the proximal ulna that represents the point where the Kirschner wire for the traction stirrup was inserted.

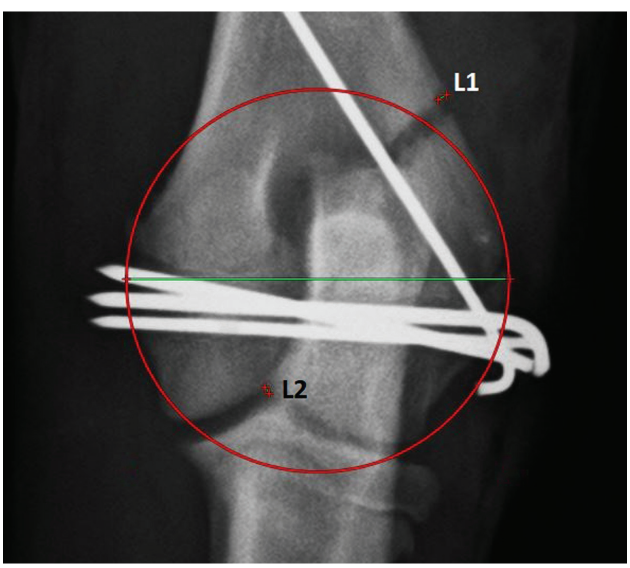

Fig. 10 Cranio-caudal radiograph showing the circle including the lateral and medial epicondyles (*red circle*), whose diameter is used for the normalization of the measure of the reduction in the fracture (*green lines*) at both the epicondylar (L1) and joint surface (L2) level. The case shown in the picture (n. 12) was on purpose selected with a gap at the fracture level to show how the displacement was measured.

level was equal to that present on the articular surface of the humeral condyle in the CC projection, indicating a lack of alignment in the frontal plane. In other three cases, the incongruity was present only at the epicondyle level and not at the articular surface of the humeral condyle. This incongruity is likely to have been caused by insufficient reduction or compression across the supracondylar fracture line during stabilization. Incongruity at the articular surface of the condyle with congruity at the epicondyle level was present in five cases. This incongruity was likely caused by insufficient compression on the humeral condyle during stabilization, or by the presence of fibrin, clots and small bone fragments within the fracture line. Chronicity of the fracture limits treatment options and results in a poorer prognosis. Closed reduction in articular fractures with subsequent internal fixation is recommended for treatment within 24 to 48 hours from trauma and with reduced swelling. Open reduction is recommended in patients more than 48 hours from trauma or for fractures that are difficult to reduce because of swelling, early fibrous callus formation or severe muscle contraction.[26] The prognosis should reflect both these technical issues and the increased risk for development of clinically relevant osteoarthritis.[27]

Our findings suggest that the greatest amount of fracture displacement is in the ML projection. This may be caused by the difficulty of maintaining proper reduction in the epicondyle during the insertion of the first K-wire, while the overall stability is still low. This may cause a rotation relative to the centre of the condyle. The reduction in the fracture using a traction stirrup (Ad Maiora, Cavriago, Italy) and one single reduction forceps was feasible without the need for an open approach of the joint surface, though it had quite a difficult learning curve. Fluoroscopy is mandatory for intraoperative assessment of the reduction in the fracture and to confirm correct positioning of the implants.

Further studies are required to evaluate the impact of minimally invasive fracture reduction on later development of osteoarthritis. The choice to treat fractures in patients in their growth phase exclusively with K-wires was due to the fact that they usually have a very soft bone, and in those patients bone healing is more rapid, which shortens the time required for the implants transfix the fracture.[28]

Tomlinson argued that because the bones of immature dogs are small and soft, repair with a lag screw may be contraindicated.[15,29,30] In 12 cases of this study, the K-wires were inserted in a parallel way, which can be better for avoiding the growth plate.[15] The number and diameter of the K-wires were related to the size of the dog. However, not all the dogs in this study were skeletally immature. In skeletally mature dogs, different methods of treatment including screw fixation plus antirotational K-wire[10,12,13] or a neutralization plate might be more appropriate, being the gold standard for the treatment of such fractures.[4,7,13] The technique was found to be consistently repeatable, and with good fracture reduction outcomes based on PO radiographic examination. It can be considered as a potential alternative to standard open reduction and fixation techniques. Anatomical reduction is not always easy to achieve even with more extensive open approaches for the treatment of bicondylar fractures.[2]

Although the technique described is mini-invasive and technically feasible, there are some disadvantages. Radio-exposure due to the use of fluoroscopy is a concern, for both the surgeons and the operating room personnel. Then, the equipment cost should be considered and the steep learning curve for the appropriate use of the instruments and patient positioning for intra-operative evaluation of fracture reduction. On the average, it required a longer surgery time compared with the standard open approach, as also described by Perry and colleagues.[13] As for most techniques, the length of surgery may decrease once the surgeon masters the procedure.

In conclusion, the procedure is technically feasible, but long-term clinical follow-up is necessary to further evaluate the impact of minimally invasive approach compared with standard open access techniques.

Conflict of Interest

Dr. Gian Luca Rovesti owns shares of the Ad Maiora Company.

Dr. Fabio Barbieri owns shares of the Ad Maiora Company.

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