AperTO - Archivio Istituzionale Open Access dell'Università di Torino

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

This is the author's manuscript

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1686610> since 2022-01-27T17:02:51Z

Published version:

DOI:10.3415/VCOT-16-05-0071

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

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

F. Cinti*†, G. Pisani*, L.Vezzoni†, B. Peirone°, A. Vezzoni†.

*Centro Veterinario Luni Mare, Via Togliatti 8/10, 19034 Luni Mare-Ortonovo (SP), Italy

†Clinica Veterinaria Vezzoni, Via Massarotti 60/A, 26100 Cremona, Italy

°Department of Veterinary Science, School of Veterinary Medicine Turin, Via Largo P.Braccini 2-5, 10095 Grugliasco (To), Italy

Filippo Cinti DVM, PhD

Guido Pisani, DMV Dipl. ECVS

Luca Vezzoni, DMV

Bruno Peirone, DMV, PhD, Associated Professor

Aldo Vezzoni, DMV, S.C.M.P.A., Dipl. ECVS

Corresponding Author:

Aldo Vezzoni DVM, Dipl. ECVS

Clinica Veterinaria Vezzoni, Via Massarotti 60/A, 26100 Cremona, Italy

Phone: 0372-23451 E-mail: aldo@vezzoni.it

1 **Summary**

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

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

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

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

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

20

21

22

23

24

25 **Introduction**

26 Fractures of the humeral condyle are reported to account for 41% of humeral fractures in dogs (1).
27 The lateral aspect of the humeral condyle (capitulum) is fractured more often than the medial aspect
28 (trochlea) because of anatomical and biomechanical differences. Fractures of the lateral aspect of
29 the humeral condyle are reported for 34 to 67% of humeral condyle fractures (1-3) and for 37% of
30 all distal humeral fractures (4). The peak occurrence of fractures of the lateral aspect of the humeral
31 condyle in dogs is between 3 and 4 months of age (1). In 90% of dogs, the cause is minor trauma
32 (2, 3, 5), chiefly injuries sustained in jumps and falls from heights of less than 1.5 m (6). In
33 immature dogs, condylar fractures are generally Salter-Harris type IV (7, 8) although type III
34 fractures occasionally occur (6, 9). Incomplete ossification of the humeral condyle (IOHC) has been
35 reported to be a predisposing factor for condylar fracture in several breeds (10-13). Conventional
36 treatment of lateral aspect of the humeral condyle fractures involves anatomical reduction,
37 positioning of a transcondylar lag screw and insertion of a supracondylar anti-rotational Kirschner
38 wire or bone screw (4, 6). This technique allows rapid functional recovery and primary bone
39 healing. In immature dogs, particularly miniature and toy breeds, the dimension of the condyle, soft
40 consistency of the bone and presence of the growth plate can make screw insertion difficult with
41 little margin for error (14). Alternative techniques of fracture fixation by insertion of multiple
42 Kirschner wire (14, 15) or self-compressing pins (16, 17) have been reported. The aim of this study
43 was to evaluate the efficacy of surgical treatment of fractures of the lateral aspect of the humeral
44 condyle with multiple Kirschner wires in immature dogs.

45

46

47

48

49

50 **Materials and Methods**

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

58 *Preoperative evaluation*

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

61 *Surgical technique*

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

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

79 *Postoperative evaluation and care*

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

87 *Clinical and radiographic follow-up*

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

101 *Statistical Analysis*

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

106

107

108

109

110

111

112

113

114

115

116

117

118

119

120

121

122

123

124 **Results**

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

146 *Short-term follow-up*

147 Follow-up examinations at four weeks postoperatively showed complete clinical recovery and no
148 lameness in 27 of 33 dogs (Table 2). Grade 1 lameness was present in five dogs and grade 2
149 lameness in one. Radiographic examination at four weeks showed fracture healing in 31 elbows and

150 persistence of a radiolucent fracture line in four elbows. Of the eight dogs that were re-examined at
151 eight weeks because of lameness, radiolucent fracture lines or both combined at four weeks, one
152 dog had mild lameness (grade 1), two had reduced range of motion of the elbow while all had
153 radiographic evidence of fracture healing. Eight dogs suffered major complications that required
154 surgical correction. Kirschner wire migration accompanied by seroma formation occurred in six
155 dogs four to six weeks postoperatively and resolved after implant removal through a stab incision in
156 the skin. One broken Kirschner wire was removed in one dog (no.3). Soft tissue irritation occurred
157 in another dog (no. 32) three months postoperatively and resolved within three weeks after implant
158 removal (Fig. 4). Grade 1 lameness persisted in one dog (no.12) and reduced the range of motion of
159 the elbow in two others (nos. 17 and 28). There was no significant difference between the number,
160 diameter and direction (convergent or parallel) of Kirschner wires and time required for bone
161 healing or incidence of complications.

162 *Long-term follow-up*

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

173

174

175 **Discussion**

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

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

201 In our study approximately 23% (8/35) of fractures required an additional minimally-invasive
202 surgery for implant removal because of migration or breakage of implants and soft tissue irritation.
203 However, those complications resolved following implant removal and did not seem to have a long-
204 term impact on bone healing or on functional recovery with the exception of three cases: no. 12, no.
205 17 and no. 28 (Tab. 1-2). This type of fracture repair provided good results; however, it is important
206 to point out that all the dogs in our study were skeletally immature and the majority were small
207 breed dogs (mean 3.5 months and 3.7 kg). In larger or in more skeletally mature dogs, different
208 methods of treatment including screw fixation and a neutralization plate might be more appropriate,
209 being the gold standard for the treatment of such fractures (4, 6, 27). The number and diameter of
210 the Kirschner wires were related to the size of the dog. Our results show a decreased tendency to
211 implant migration in cases where the Kirschner wires have been bent against the bone before
212 cutting, with an incidence of 5.3% against 31.2% of un-bent Kirschner wires. Thus Kirschner wires
213 bending should be recommended, nevertheless it may be considered that the soft bones of young dogs
214 are predisposed to damage during bending of large Kirschner wires, and for this reason, in our
215 study only Kirschner wires smaller than 1.4 mm have been bent. The insertion of one transcondylar
216 positive-profile threaded Kirschner wires that does not cross the physis may be an alternative
217 technique to maintain the compression at the fracture site produced by the reduction forceps, and
218 prevent Kirschner wire migration, working as a positional screw (19). This technique was used in
219 four cases of our study with good results. The use of crossed Kirschner wires has been advocated
220 for maintaining the compression achieved by reduction forceps (15). However, this technique
221 increases the risk of crossing the growth plates thus potentially affecting bone length at skeletal
222 maturity. Avoiding the growth plate is easier with parallel Kirschner wires. A study of femoral neck
223 fractures showed that mechanical forces applied to Kirschner wires inserted in a parallel fashion are
224 distributed equally between the Kirschner wires (28). In contrast, divergent pins are associated with
225 uneven distribution of the load between the implants and render the fixation significantly weaker
226 and thus predispose the repair to failure (28). We found no significant difference in outcomes

227 between the parallel or convergent crossed Kirschner wire configurations, probably because of the
228 limited number of cases included in the study. Further biomechanical studies should be made to
229 evaluate which is the best Kirschner wires configuration in humeral condyle fractures. A previous
230 study of dogs with fracture of the lateral aspect of the humeral condyle evaluated the impact of
231 growth plate damage after Salter-Harris type IV fracture (29). Humeral length, evaluated
232 radiographically, was not decreased in that study regardless of whether or not the implants crossed
233 the growth plate. The distal growth plate of the humerus, which is responsible for only 20% of the
234 longitudinal growth, closes at about five to eight months of age (30, 31). Thus, even if premature
235 closure of the distal humeral growth plate should occur, the effects are likely to be minimal with the
236 exception of very young puppies (29). Long-term follow-up after a median period of four years
237 postoperatively showed a favourable outcome, normal function of the affected limb and no or only
238 mild radiographic signs of OA in the majority of cases (Table 3), which is in contrast to what has
239 been reported by Gordon. It is difficult to postulate the reason of the lower incidence of post-
240 traumatic osteoarthritis reported in our study, also because of the different populations of the two
241 studies, with a predominance of small breed dogs in our study compared to Gordon study in which
242 Labrador Retrievers were most commonly affected (32).

243 **Conclusions**

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

253 cases and the retrospective nature of the study, prospective clinical and biomechanical studies are
254 needed to corroborate our findings.

255

256

257 **Nomenclature and Abbreviations**

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

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

260 c. Reduction forceps: Veterinary Instrumentation, UK

261 d. Synulox: Pfizer, Rome, Italy

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

263

264

265

266

267

268

269

270

271

272

273

274

275

276 **References**

2771. Bardet, JF, Hohn RB, Rudy RL, et al. Fractures of the humerus in dogs and cats: A retrospective
278 study of 130 cases. *Vet Surg* 1983; 12: 73-77.
2792. Denny HR. Condylar fractures of the humerus in the dog: A review of 133 cases. *J Small Anim*
280 *Pract* 1983; 24, 185-197.
2813. Rorvik A. Risk factors for humeral condylar fractures in the dog: a retrospective study. *J Small*
282 *Anim Pract* 1993; 34:277-281.
2834. Piermattei DL, Flo GL. Fractures of the humerus. In: *Handbook of [L]small animal orthopedics and*
284 *fracture repair*. Brinker, Piermattei, and Flo (ed 3). Philadelphia, PA, Saunders, 1997; 261–287.
2855. Vannini R, Olmstead ML, Smeak DD. An epidemiological study of 151 distal humeral fractures in
286 dogs and cats. *J Am Anim Hosp Assoc* 1988; 24, 531-536
2876. Tomlinson JL. Fractures of the Humerus. In: *Textbook of Small Animal Surgery* 3th ed. Slatter D
288 (eds). WB Saunders, Philadelphia 2002; 1905-1918.
2897. Brinker WO, Braden TD. Fractures in immature animals. In: *Manual of Internal Fixation in Small*
290 *Animal*. 1st Edn. Brinker WO, Hohn RB and Prieur WD (eds). Springer-Verlag, New York 1984;
291 225-238.
2928. Carmichael S. Fractures in Skeletally Immature Animals. In: *Manual of small animal fracture repair*
293 *and management*. 1st ed. Coughlan AR and Miller A (eds). British Small Animal Veterinary
294 Association, Cheltenham 1998; 103-111.
2959. Hayes GM, Radke H, Langley-Hobbs SJ. Salter-Harris type III fractures of the distal humerus in
296 two dogs. *Vet Comp Orthop Traumatol* 2011; 24: 478–482.
29710. Marcellin-Little DJ, DeYoung DJ, Ferris KK, et al. Incomplete Ossification of the Humeral
298 Condyle in Spaniels. *Vet Surg* 1994; 23; 475-487.
29911. Moores AP, Agthe P, Schaafsma IA. Prevalence of incomplete ossification of the humeral condyle
300 and other abnormalities of the elbow in English Springer Spaniels. *Vet Comp Orthop Traumatol*
301 2012; 25: 211–216

30212. Robin D, Marcellin-Little DJ. Incomplete ossification of the humeral condyle in two Labrador
303 Retrievers. *J Small Anim Pract* 2001; 42: 231-234.
30413. Rovesti, GL, Fluckiger M, Margini A, et al. Fragmented coronoid process and incomplete
305 ossification of the humeral condyle in a rottweiler. *Vet Surg* 1998; 27: 354-357
30614. Morshead D, Stambaugh JE. Kirschner wire fixation of lateral humeral condylar fractures in small
307 dogs. *Vet Surg* 1984; 13: 1-5.
30815. Tomlinson, JL, Constantinescu GM. Fixation of Lateral Humeral Condylar Fractures with Multiple
309 Kirschner Wires. In: *Current Techniques in Small Animal Surgery* 4th edn. Bojarab MJ (eds).
310 Williams & Wilkins, Baltimore 1997; 1019-1021.
31116. Lanz OI, Lewis DD, Newell SM. Stabilization of a physeal fracture using an orthofix partially-
312 threaded Kirschner wire. *Vet Comp Orthop Traumatol* 1999; 12: 88-91.
31317. Guille AE, Daniel DL, Anderson TP, et al. Evaluation of Surgical Repair of Humeral Condylar
314 Fractures Using Self-Compressing Orthofix Pins in 23 Dogs. *Vet Surg* 2004; 33: 314-322.
31518. Turner TM, Hohn RB. Craniolateral approach for repair of condylar fracture or joint exploration. *J*
316 *Am Vet Med Assoc* 1980; 176: 1264-1266
31719. Cook JL, Tomlinson JL, Reed AL. Fluoroscopically guided closed reduction and internal fixation
318 of fractures of the lateral portion of the humeral condyle: prospective clinical study of the technique
319 and results in ten dogs. *Vet Surg* 1999; 28: 315-321.
32020. Lewis DD, Redasch RM, Beale BS. Result of screw/wire/polymethyl-methacrylate composite
321 fixation for acetabular fracture repair in 14 dogs. *Vet Surg* 1997; 26: 223-234.
32221. Jaegger G, Marcellin-Little DJ, Levine D. Reliability of goniometry in Labradors Retrievers. *Am J*
323 *Vet Res* 2002; 63:979-984.
32422. Lang J, Busato A, Baumgartner D, et al. Comparison of two classification protocols in the
325 evaluation of elbow dysplasia in the dog. *J Small Anim Pract* 1998; 39:169-174.
32623. Carrera I, Hammond GJ, Sullivan M. Computed tomo- graphic features of incomplete ossification
327 of the canine humeral condyle. *Vet Surg* 2008; 37:226 -231.

32824. Morgan ODE, Reetz JA, Brown DC, et al. Complication rate, outcome, and risk factors associated
329 with surgical repair of fractures of the lateral aspect of the humeral condyle in dogs. Vet Comp
330 Orthop Traumatol 2008; 21: 400-405.

33125. Langley-Hobbs SJ. Fractures of the humerus. In: Veterinary Surgery Small Animal, vol 1. Tobias
332 KM, Jhonston SA (eds). Elsevier 2012; 709-720.

33326. Johnson AL, Hulse DA. Management of Specific Fractures. In: Small Animal Surgery. 2nd edn.
334 Fossum TW et al (eds). Mosby, St. Louis 2002; 931-938.

33527. Perry KL, Bruce M, Woods S, et al. Effect of fixation method on postoperative complication rates
336 after surgical stabilization of lateral humeral condylar fractures in dogs. Vet Surg 2015; 44: 246-
337 255.

33828. Lembrechts NE, Verstraete FJM, Sumnerssmith G, et al. Internal fixation of femoral neck fracture
339 in the dog-an in vitro study. Vet Comp Orthop Traumatol 1993; 6: 188-191.

34029. Lefebvre JB, Robertson TR, Baines SJ, et al. Assessment of humeral length in dogs after repair of
341 Salter-Harris type IV fracture of the lateral part of the humeral condyle. Vet Surg 2008; 37:545-549

34230. Sumner-Smith G. Observations on epiphyseal fusion in the canine appendicular skeleton. J Small
343 Anim Pract 1966; 303-306.

34431. Manley P, Henry W, Wilson J. Disease of the epiphyses. In: Canine orthopaedics. 2nd edn.
345 Whittick WG (eds). Philadelphia, Lea and Febiger 1990; 597-600.

34632. Gordon WJ, Besancon MF, Conzemius MG, et al. Frequency of post-traumatic osteoarthritis in
347 dogs after repair of a humeral condylar fracture. Vet Comp Orthop Traumatol 2003; 16: 1–5.

348

349

350

351

352 **Figure Legends**

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

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

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

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

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

372

373

374

375

376

377 **Table Legends**

378 **Table 1.** Signalment, history, number and diameter of Kirschner wires and postoperative
379 radiographic evaluation in 33 dogs with fracture of the lateral aspect of the humeral condyle.

380 Legends: right (R), left (L), male (M), female (F), threaded positive profile Kirschner wire (th).

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

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

389

390