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The full details of the published version of the article are as follows:

TITLE: Repair of Y-T Humeral Condyle Fractures with Locking Compression Plate Fixation

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JOURNAL: Veterinary and Comparative Orthopaedics and Traumatology

PUBLISHER: Thieme Publishing

PUBLICATION DATE: 20 June 2019

DOI: 10.1055/s-0039-1691825

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ABSTRACT

Objectives: To describe the use of Locking compression plates (LCP) in Y-T humeral condyle fractures and to evaluate their clinical outcome.

Methods: Retrospective review, including clinical, radiographic, and canine brief pain inventory outcome evaluation.

Results: 18 consecutive dogs met the inclusion criteria, and 15/18 were considered to have humeral intercondylar fissure (HIF). Twelve of 18 dogs had simple fractures, the remaining 6 had comminuted fractures. Postoperative radiographs revealed accurate intra-condylar reconstruction (articular step defect [ASD] less than 1mm) in 17/18 of patients. Short-term outcome was considered fully functional in 9/13 and acceptable in 3/13 patients. Complications were diagnosed in 2/13; infection in one with resolution after antibiotic treatment, and one case of implant failure. Nine of 18 owners provided post-operative questionnaire responses (median 25, range 14–52 months) and 8/9 clients perceived the treatment to have resulted in an excellent overall outcome.

Clinical significance: Repair of Y-T humeral fractures with LCP allowed for hybrid fixation and monocortical screw placement in distal fracture fragments. There was no significant ASD at the intra-condylar fracture line in most cases. ASD using combined medial and lateral approaches depends upon the accuracy of supracondylar reduction, particularly on the side that is reduced and stabilised first, and the use of locking screws may have been influential in minimising primary loss of reduction, potentially maintaining the initial fragment reduction.

Repair of Y-T humeral condyle fractures with locking compression plate (LCP) fixation

INTRODUCTION

Distal humeral condylar fractures, often described as Y-T fractures, are common in dogs and involve an intra-articular fracture of the humeral condyle with concurrent separation from the diaphysis (1–4). Rigid fracture fragment fixation and precise reconstruction of the articular surface are paramount to optimise functional outcome and limit development of osteoarthritis (1, 5). Typically, the fragments are reduced via olecranon osteotomy or combined medial and lateral approaches, followed by rigid internal fixation (1, 2). To date, their functional outcome has been assessed subjectively and results have been variable (1, 3, 6).

There has been considerable interest in locking plate technology for fracture repair, with results demonstrating advantages under certain circumstances (7–9). Cortical plating produces compression between the implant and the bone, relying on the generation of friction between plate and bone and between screw head and plate (10, 11), whereas in locking plates, the screw is mechanically coupled to the plate (10). This minimises the compressive forces exerted by the plate, thereby protecting periosteal vasculature and avoiding loss of reduction from imperfect plate contouring (10). The string of pearls[R] locking implant has been previously used to stabilise Y-T fractures in 13 dogs, and this repair yielded good results, although additional surgery was required in 4/13 (2). The Locking Compression Plate (LCP) has the advantage of allowing either cortical or locking screw placement at each hole (7, 10), facilitating the use of this implant as a compression plate, a locked internal fixator, or a hybrid style fixation (10). The aim of this study was to report the outcomes of Y-T humeral condyle fractures in dogs repaired using LCP with a transcondylar screw.

MATERIALS & METHODS

Medical records of dogs presented to the Royal Veterinary College during the period January 1st 2010 – September 1st 2016 with a distal Y-T humeral condylar fracture that was stabilised with a transcondylar screw and at least one LCP plate were reviewed. The following information was gathered for each patient: signalment, body weight, pertinent medical history/findings including suspected presence of humeral intracondylar fissure (HIF) (12) from intraoperative subjective assessment (sclerotic, relatively avascular intra-articular fracture surface, which was hard to drill), pre-operative radiographs, implants placed, time to radiographic union (defined by cortical bridging and lack of visible fracture line), complications encountered, post-operative lameness and range of motion (Appendix Table 1). Ethical approval was granted by the institutional ethics committee (URN: M20160089).

Surgical technique

All dogs had a combined medial and lateral surgical approaches and internal fixation (1,13) Typically, the medial supracondylar fracture was reduced first using a Kirschner wire(s) or lag screw(s), aiming for anatomic reduction. A suitable LCP plate was positioned medially, at the most distal aspect of the medial epicondyle, aiming for at least three screws distal to the fracture and three screws proximal to it. Minimal contouring was needed and consideration of screw placement was made to ensure that screws requiring angulation were placed first with cortical screws. Locking screws were placed thereafter, either bi or mono-cortically. The medial side was then packed with saline moistened cotton gauze sponges to allow for the lateral approach to the humerus (1). An 'inside-out technique' transcondylar screw was placed (lag or positional by surgeon preference) aiming for screw diameter of 30-50% of the narrowest portion of the condyle. In the majority, a second LCP plate was contoured and applied, aiming for at least two bicortical screws distal and three proximal to the fracture line. The plate was variably placed between caudo-lateral and caudal sides of the humeral condyle, with the caudal aspect of the condyle reducing the requirement for plate contouring by twisting. Cortical screws were placed prior to locking.

Radiographic Assessment

Fracture configuration was assessed from the preoperative radiographs. The implants and repair were assessed on post-operative radiographs[a]. The accuracy of articular surface reduction, and the resulting articular surface defect (ASD), was measured from digitally scaled caudocranial radiographs and graded as 0 (<1mm), 1 (1-2mm) or 2 (>2mm). Plate size and length, screw type (cortical or locking) and number in each fragment, and any additional implants were recorded. Radiographs were assessed for fracture configuration, healing, and implant stability by a board certified veterinary radiologist. Two authors, FM and RM (a board certified small animal surgeon), assessed all radiographic parameters.

Short-term follow-up

Radiographic follow-up was scheduled at 6-8 weeks and thereafter as required. Clinical records were evaluated for the short-term follow-up assessment, including range-of-motion, visual gait scored out of 10 (14), and for any instability, swelling, crepitus or any signs of discomfort. All clinical assessment were made by one of four board certified small animal surgeons, or experienced surgical residents under their supervision. Overall clinical outcome defined using standardised definitions (15). For the purpose of this study, *full function* described those dogs with very mild or no reduction of elbow flexion and a lameness score of 0-2/10. Dogs with moderate reduction in elbow flexion and a lameness score of 3-6/10 were deemed to have *acceptable function,* and those with severe reduction in elbow flexion coupled with a lameness score of 7-10/10 were defined as having *unacceptable function*. Post-operative infection associated with the surgery included those within 12 months of surgery (16, 17. Complications were defined as per current recommendations (15). Long-term follow-up from 12 months onwards was based on the canine brief pain inventory (CBPI) and an additional owner questionnaire (15, 18).

[a] Horos version 2.2.0 for Macintosh.

RESULTS

Eighteen fractures met the inclusion criteria, with a short-term follow-up from 2.5 weeks to seven months. The ages of the dogs ranged from six months to eight years (median: 3 years 6 months), and bodyweight ranged from 8.5kg to 35kg (mean: 19.6kg). Breeds are reported in Appendix Table 1. Humeral intracondylar fissure pathology was identified in 15/18 fractures. Twelve of 18 dogs had 'simple' fractures, and six had comminuted fractures; four condylar, one supracondylar and condylar, and one had severe supracondylar comminution with a mid-diaphyseal fracture of the humerus that had propagated through previous screw holes bilaterally (failed repair referred for revision). All dogs had open combined medial and lateral approaches, although one required additional olecranon osteotomy due to intra-articular comminution. The supracondylar region was stabilised with bilateral LCP in 16/18 dogs, a LCP (medially) with veterinary cuttable plate (VCP) (laterally) in one dog and a single LCP (medially) with supracondylar stabilization on the lateral side using a Kirschner-wire in one. By weight, dogs <10kg had 2.4 LCP bilaterally. 10-20kg dogs had 2.7 LCP medially in 9/11 cases, two had 2.4 LCP, and the lateral component was stabilized with a 2.4 LCP (n=6) or 2.7LCP (n=4). Dogs weighing 20-30kg had 2.7 LCP medially (n=4), and ¾ had 2.7 LCP laterally, one had a 2.4 LCP. Dogs >30kg had a 2.7 LCP applied medially in all cases (N=2), and a 2.7 LCP (n=1) or a 3.5 LCP (n=1) applied laterally (Appendix Table 1).

Medial implants and lateral implants

See Appendix Table 2.

Additional implants

The diameter of the single transcondylar screw inserted in each case was 4.5mm (n=14), 3.5mm (n=3) or 2.7mm (n=1). Additional implants were placed in 9/18 cases, including a lag screw (cases 3, 4, 7, 8, 9) or Kirschner wire (2, 17, 19), or both (case 18). Kirschner wires and tension band were placed for the olecranon osteotomy (case 17). (Full details Appendix Table 1).

Accuracy of fracture reduction and fracture healing

Post-operative radiographs taken immediately after surgery demonstrated ASD of 2 in one dog, ASD 1 in 4 dogs, and ASD 0 in 13/18 dogs (Figure 1, Appendix Table 3). Sub-optimal implant position and reduction of fragments (malalignment of the humeral metaphysis/diaphysis) was documented in one patient (case 15). This dog was a revision of a referred previously failed Y fracture repair, and had a non-reconstructable supracondylar fracture region. Thirteen cases had short-term radiographic follow-up (range 2.5-13 weeks), of which, osseous union was evident in 7/13 dogs by 6-8 weeks post surgery. In a further four, evidence of fracture healing was apparent with stable implants. Three of these cases (4, 7 and 11) had full function on clinical assessment and did not require further appointments. One of these four (case 18) developed a major complication and was euthanised. In 2/13 dogs (case 8 and 17), no evidence of healing was seen at the first post-operative appointment, however subsequent radiographic assessment demonstrated complete osseous union at five and seven months respectively.

Clinical Assessment

Short-term outcome was considered fully functional in 9/13 patients. This included case 8, which has a grade 7/10 lameness on the repaired limb at 2.5 weeks post-operatively with septic arthritis (with cytological confirmation) and made a full recovery (0/10 lame) after a 6-week course of antibiotic medication. A further 3/13 had acceptable function. One dog had unacceptable function with significant reduction in elbow range of movement, marked muscle atrophy and was persistently grade 5/10 lame despite radiographic union at 7 months (case 17). This dog had intracondylar comminution and an additional olecranon osteotomy had been performed at surgery to facilitate surgical reduction.

Complications

Major complications were reported in 2/13 patients. Of the major complications, case 8 developed a post-operative infection 2.5 weeks post surgery, however, no implant instability was noted and a full recovery was made following a six week course of antibiotic medication. The second dog (case 18) had a supracondylar comminuted Y fracture, and suffered delayed screw breakage and subsequently plate fracture and infection. Notably this dog had been treated with chronic steroid therapy for skin disease prior, and after fracture repair, exercise restriction was not enforced by the owner. This dog weighed 17.9kg, and was approximately 40% overweight based on breed average (Figure 2). Follow-up radiographs showed some transcondylar but little supracondylar remodelling. Short-term recovery was good, with a lameness score of 2/10, only mild reduction in elbow flexion, stable implants and evidence of some intra-condylar, but minimal supracondylar remodelling was observed at seven weeks post-operative check. At sixteen weeks, multiple fractured screws were noted, all in the distal medial fracture fragment. By eight months, further screw and subsequent plate failure had occurred, and sampling revealed active infection. He was concurrently diagnosed with bilateral tarsocrural synovial osteochrondromatosis and euthanised.

Long-term Outcome

Nine of 18 owners provided questionnaire responses at a median postoperative time of 25 months (range 14–52), (Appendix Table 4). Owners rated the success of surgery as excellent in 8/9 dogs and good in 1/ 9. Impression of their dogs overall quality of life was excellent in 7/9, very good in 1/9 and good 1/9. All owners were very satisfied with the treatment outcome, except for one who was ‘satisfied’. On-going lameness or stiffness was reported in 3/9 dogs; two requiring long-term administration of non-steroidal anti-inflammatory drug medication and intermittent therapy with tramadol. Activity levels post-surgery were reported as very active in 4/9 dogs, active in 3/9, average in 1/9, and inactive in 1/9. The canine brief pain inventory scores are reported in Appendix Table 4.

DISCUSSION

The outcome following repair of Y-T fractures using LCP was favourable; short-term outcome considered ‘fully functional or acceptable’ in 12/13 patients, and only 1/13 had unacceptable function. This is not dissimilar to other strategies of repair for Y-T fractures (1,2), although some studies have had a subjectively assessed outcome that was worse, with only 52-64% of dogs achieving satisfactory results (3, 6). When considering these types of clinical case series, it is important to acknowledge that subjective clinical assessment, which is known to be variable and susceptible to caregiver placebo can makes direct comparison difficult (20). However this LCP study was aligned to current recommendations for outcome determination in clinical studies (15).

The bilateral approach (1) was used in all cases and evaluation of postoperative radiographs revealed accurate intra-condylar similar to the anatomic reduction from the string of pearls fixation with a bilateral approach (2). In contrast, 50% of dogs had poor reduction associated with this approach and cortical plating (1). Non-locking implants require highly accurate contouring to ensure sufficient friction between the plate and the underlying bone and to avoid primary reduction loss (11, 21). Plating the distal humerus is particularly challenging due to the required twist and bend on the plate. If accurate plate conformation is not achieved, cortical plates could lead to a primary loss of reduction as the bone is pulled out of alignment towards the plate (2, 21). In this LCP series, the majority of screws in the medial and lateral distal fracture fragments were placed as locking screws, potentially reducing disturbance of the reduction, and hence maintaining a good articular reduction (22) from their fixed angle stability (23). This may have had particular benefit when first reducing the medial portion of the condyle, maintaining the supracondylar reduction, which if not correct will inhibit subsequent accurate intracondylar alignment when the lateral part is reduced. The LCP allowed for hybrid fixation that was employed in all cases in this series, however, it is important to ensue the plate is accurately contoured and in contact with the bone in regions where non-locking screws are placed, and placing non-locking screws prior to locking screws (22). The string of pearls also had improved articular reconstruction, but differs from the LCP, as it uses cortical screws (23), which are at higher risk of breaking due to their smaller core diameter when compared with the locking screws (23). However, no such implant failures were reported by Ness and colleagues (2).

Notably, the majority of screws were placed in the distal fragments were monocortical without any clear negative impact. There remains debate as to the number of screws required proximal and distal to the fracture line in locking plate systems. It is thought that the increased stability of locking screws may allow for fewer cortices to be engaged in each bone segment whilst maintaining rigid fixation (21) and recommendations vary from two to four cortices (22, 24, 25). Based on this study, the use of hybrid fixation including monocortical locking screws gave good clinical results.

Major implant related complications were only diagnosed in a comminuted fracture in a small, overweight, chondrodystrophic breed dog that was suspected of having underlying HIF and was receiving chronic steroid therapy for skin disease. The comminution of the fracture coupled with the co-morbidities were probably significant factors for the delayed fracture healing, and implant breakage as post-operative reconstruction was deemed suitable. The other major complication was septic arthritis diagnosed at two-and-a-half weeks post surgery and a six week course of antibiotics lead to full recovery. Complete fracture union was achieved by five months post surgery and the dog was reported to have excellent limb function with only mild reduction in elbow flexion.

Several of the cases were lost to follow, however 13/18 had equivalent follow-up as the 13 cases with string of pearls plates (2). This LCP study has the longest follow-up to date for Y-T fractures and further used a clinical metrology instrument. Other published work has had maximum 11 weeks and 14 weeks (1, 2), whereas all cases here had short-term median of 6 weeks follow-up and 50% (9 cases) had long-term of 25 months (median), up to 52 months. Overwhelming, clients perceived the treatment to give an excellent overall outcome (88%). Quality of life was perceived to be excellent in 7/9 cases. and otherwise either very good or good. Ongoing lameness was seen in 3/9 of the dogs and was effectively managed using medical treatment and controlled exercise, allowing a good level of activity. This surgical technique gave a rapid return to activity post procedure (4/9 dogs very active, 4/9 active and one dog inactive post operatively) and achieved mostly excellent results long-term, with 8/9 of owners very satisfied with the outcome for their pet (one owner was ‘satisfied’).

In the present study, short-term outcome was excellent or adequate in most cases as was the long-term outcome. No dogs required additional surgery, however the implant failure dog could have been a potential candidate for revision, although the pre-existing circumstances would remain a concern. The short-term outcome compared favourably with previously reports (1 – 3, 6). Overall, the use of LCP, taking advantage of hybrid fixation and monocortical locking screws distally, gave good clinical outcomes and accurate articular alignment.

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FIGURE CAPTIONS

Figure 1: Case 4 (Labrador Retriever) preoperative caudocranial (a) and mediolateral projections (b) showing simple condylar humeral fracture with a short lateral and long medial component. Immediate postoperative caudocranial (c) and mediolateral (d) views showing a medial 2.7mm and lateral 2.4mm LCP, using hybrid fixation with a 4.5mm transcondylar positional cortical screw. A small intra-articular gap persists consistent with HIF pathology and the ASD is 0.7mm. (e) Caudocranial and (f) mediolateral views at the 8 week post-operative stage showing ongoing intra-condylar gap, with remodelling supra-condylar fracture lines.

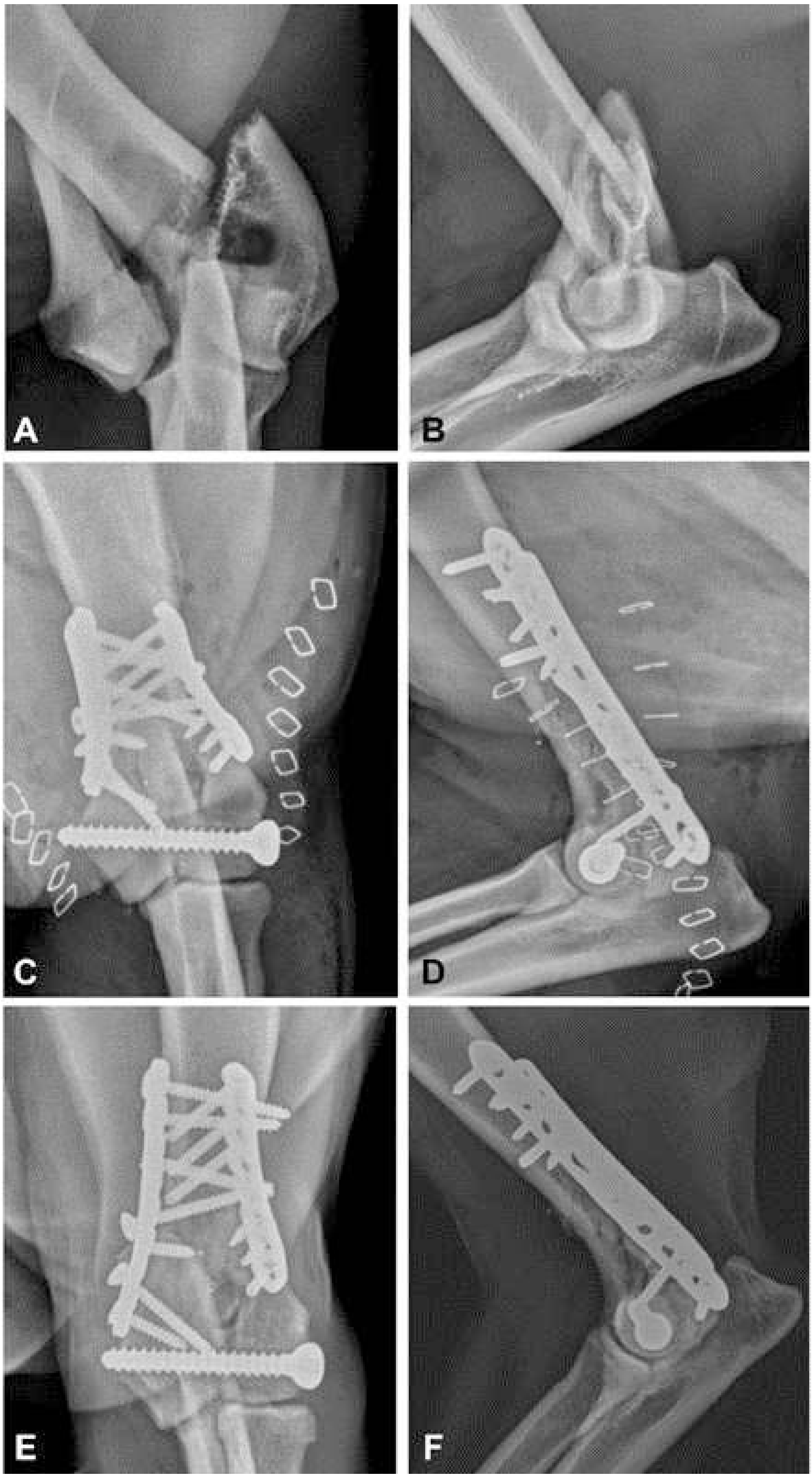
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Figure 2: Case 18 (French Bulldog), weighing 18kg (breed standard 12.5kg), with a comminuted fracture, caudocranial (a) and mediolateral views (b). Post fracture repair with a medial 2.7mm and lateral 2.4mm LCP, with additional lag screw and K wire stabilising the supracondylar comminuted fragment, caudocranial (c) and mediolateral views (d) 8 months later showing multiple screw failures, and bilateral plate fracture centred on the supracondylar region, caudocranial (e) and mediolateral views (f).

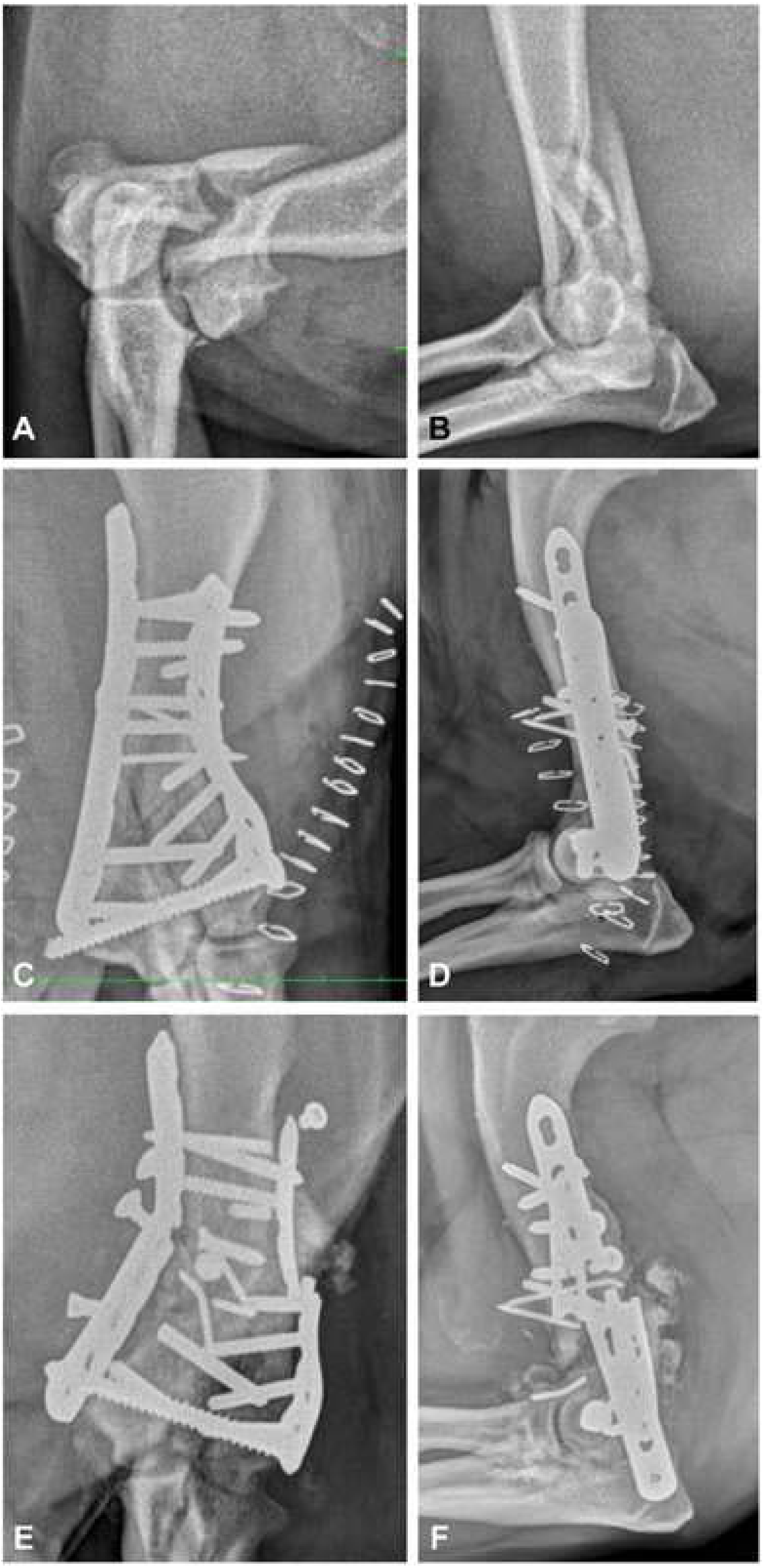
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Table 1: Medial and lateral implants showing range and median values in brackets

	Screws						Plate
	Distal to fracture			Proximal to fracture			
	Locking screws	Monocortical screws	Overall	Locking screws	Monocortical screws	Overall	Size
Medial implant	1–4 (3)	1–5 (3)	2–5 (4)	1–5 (3)	0–4 (0)	3–5 (4)	7–14 (9)
Lateral implant	0–4 (2)	1–4 (3)	2–4 (3)	1–5 (3)	0–4 (1)	2–5 (3)	6–14 (7.5)

Table 2: Articular reduction, fracture healing and short-term clinical outcome

Case	Intracondylar fracture reduction	Range of motion post-surgery	6–8 weeks check up	12–14 weeks check up	Time to fracture healing (weeks)	Complications (within a year of surgery)	Limb function at follow-up (6–8 weeks)	Limb function (~12–14 weeks)	Reduced range of flexion at follow-up (6–8 weeks)	Reduced range of flexion at follow-up (12–14 weeks)
1	ASD 0	Not documented	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up
2	ASD 0	Excellent	Union, healed	Not documented	6–8	None	0/10	Not documented	Mild	Not documented
3	ASD 1	Not documented	Healed	Not documented	6–8	None	04-Oct	Not documented	Mild	Not documented
4	ASD 0	Good	Delayed union of fracture lines, some callous present, stable implants	Not documented	8+	None	02-Oct	Not documented	Mild	Not documented
5	ASD 0	Good	Progressive healing, stable implants	Not documented	8+	None	0/10	Not documented	None	Not documented
6	ASD 0	Good	Progressive healing, stable implants	Not documented	8+	None	02-Oct	Not documented	Mild	Not documented
7	ASD 1	Not documented	Progressive healing, stable implants, but Incomplete	Not documented	8+	None	0/10	Not documented	Mild	Not documented
8	ASD 0	Not documented	Septic arthritis present 2.5 weeks post op, implants stable.	Progressive healing, union of lateral epicondyle observed at 18 weeks post-op	18+	Major: postoperative infection—septic arthritis Resolved with antibiotic treatment	7/10 at 2.5 weeks post-op due to infection	0/10	Mild	None
9	ASD 0	Good	Advanced continuous healing of fracture	Not documented	8+	None	04-Oct	Not documented	None	Not documented

10	ASD 2	Not documented	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up
11	ASD 0	Good	Progressive healing, implants stable	Not documented	8+	None	03-Oct	Not documented	Mild	Not documented
12	ASD 0	Good	Not documented	Healed	13	None	Not documented	0/10	None	Not documented
13	ASD 0	Not documented	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up
14	ASD 1	Good	Advanced healing, radiographic union	Not documented	8	None	02-May	Not documented	Mod	Not documented
15	ASD 0	**Revision—implant position and reduction of fragments sub-optimal	Lost to follow-up	Lost to follow-up	Lost to follow-up	None Due to revision surgery—implant position and reduction of fragments was suboptimal	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up
16	ASD 0	Not documented	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up	Lost to follow-up
17	ASD 0	Not documented	Progressive healing, implants stable	(next seen at 7 months—healed)	Unknown, radiographs show healed at 7 months	None	7/10 at 3 weeks post-op	5/10 at 7 months post-surgery	Moderate-significant, marked muscle atrophy over spine of scapula	Moderate
18	ASD 1	Good	Evidence of healing, stable implants	Not healed, implant failure documented at 18 weeks	Not healed by 18 weeks	Major: delayed screw breakage and subsequently plate fracture and infection	02-Oct	03-Oct	Mild	Moderate

Table 3: Canine brief pain inventory mean postoperative pain severity scores and pain interference scores

	Success of surgery	**Owner impression quality of life**	**Satisfied with treatment?**	**Ongoing lameness/ stiffness**	**Ongoing medical therapy**	**Activity levels post-surgery**	**Mean post-op pain severity scores**	**Mean interferences scores**
Case 4	Excellent	Very good	Very	Yes, permanently lame, osteoarthritis	Yes: Loxicom Tramadol Gabapentin	Inactive	6.75	6.67
Case 6	Excellent	Excellent	Very	Yes, occasionally (osteoarthritis), but continues to be very active	No	Very active	0	0.33
Case 8	Excellent	Excellent	Very	None	No	Active	0	0
Case 9	Excellent	Excellent	Very	None	No	Very active	0	0
Case 10	Excellent	Excellent	Very	None	No	Very active	0	0
Case 13	Excellent	Excellent	Very	None	No	Active	0	0
Case 14	Excellent	Excellent	Very	None	No	Active	0.5	0
Case 15	Good	Good	Satisfied	Yes, at times non-weight bearing	Yes: Loxicom Tramadol	Average	5	7.5
Case 17	Excellent	Excellent	Very	None	No	Very active	0	0