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Medial epicondylar fissure fracture as a complication of transcondylar screw placement for the treatment of humeral intracondylar fissure

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Abstract

Objective: To report the incidence of medial epicondylar fissure fracture (MEFF) after medial-to-lateral transcondylar screw placement in dogs with humeral intracondylar fissure (HIF) and to identify risk factors for MEFF.

Study design: Retrospective study.

Sample population: Seventy-four client-owned dogs (88 elbows).

Methods: Medical records of dogs surgically treated for HIF, and postoperative imaging studies were reviewed for demographics, fracture characteristics, and repair techniques. The width of the transcondylar screw was expressed relative to the height of the condyle. Screw angle and degree of countersinking were recorded. Information from case records and follow-up radiographs were used to identify complications.

Results: Medial epicondylar fissure fracture was identified in 10 elbows (11.4%) following medial-to-lateral transcondylar screw placement: 4 cases were detected intraoperatively, 2 on immediate postoperative radiographs, 1 during routine radiographic follow up, and 3 when radiographs were reviewed for this study. A larger relative screw size was found to increase the risk of MEFF ($P = .004$, OR = 1.5). Fifteen additional complications were identified in 13/80 elbows at a median of 6 weeks postoperatively (range 1–56 weeks). Screw loosening was the most frequent complication ($n = 9$) and was the only complication in dogs with MEFF ($n = 3$); MEFF tended to increase the risk of perioperative screw loosening ($P = .06$).

Conclusion: Medial epicondylar fissure fracture occurred in 10/88 elbows treated for HIF and was more common in elbows treated with a larger screw size relative to the height of the condyle.

Clinical significance: Placing transcondylar screws with a diameter inferior to 41% of the height of the condyle is recommended to avoid MEFF. Medial epicondylar fissure fracture appears to have a low clinical significance in the perioperative period, although its effect on long-term outcome remains unknown.

1 | INTRODUCTION

Humeral intracondylar fissures (HIF) may be diagnosed as incidental findings or as an infrequent cause of thoracic limb lameness and elbow discomfort in dogs, particularly spaniel breeds.[1–3] The pathogenesis of these lesions remains unclear: initially proposed as incomplete fractures of the humeral condyle,[4] they were subsequently attributed to a failure of normal osseous fusion. Humeral intracondylar fissures were termed incomplete ossification of the humeral condyle due to their identical location to the cartilaginous plate that forms between the 2 ossification centers of the humeral condyle in growing dogs.[1] However, some recent evidence has provided support to suggest that these lesions may be stress induced.[5–9]

Conservative treatment of HIF resulted in subsequent fractures in 3/12 dogs that had been identified as having a HIF lesion during treatment of a contralateral fracture.[1] Similarly, HIF diagnosed as an incidental finding in 30 dogs subsequently fractured in 18% of dogs, and 6% became lame and required surgical treatment.[8] Such treatment relies on a transcondylar screw placed from a lateral or medial approach to the humeral condyle.[10] However, screws are prone to fatigue failure at the level of the fissure, with reported rates varying between 0% and 10%.[2,3,11–13] This failure has been attributed to the inconsistent healing of the HIF, maintaining intracondylar instability and associated stress on the screw.[1–3,14] Placement of relatively large diameter screws across the humeral condyle is typically recommended to prevent implant failure.

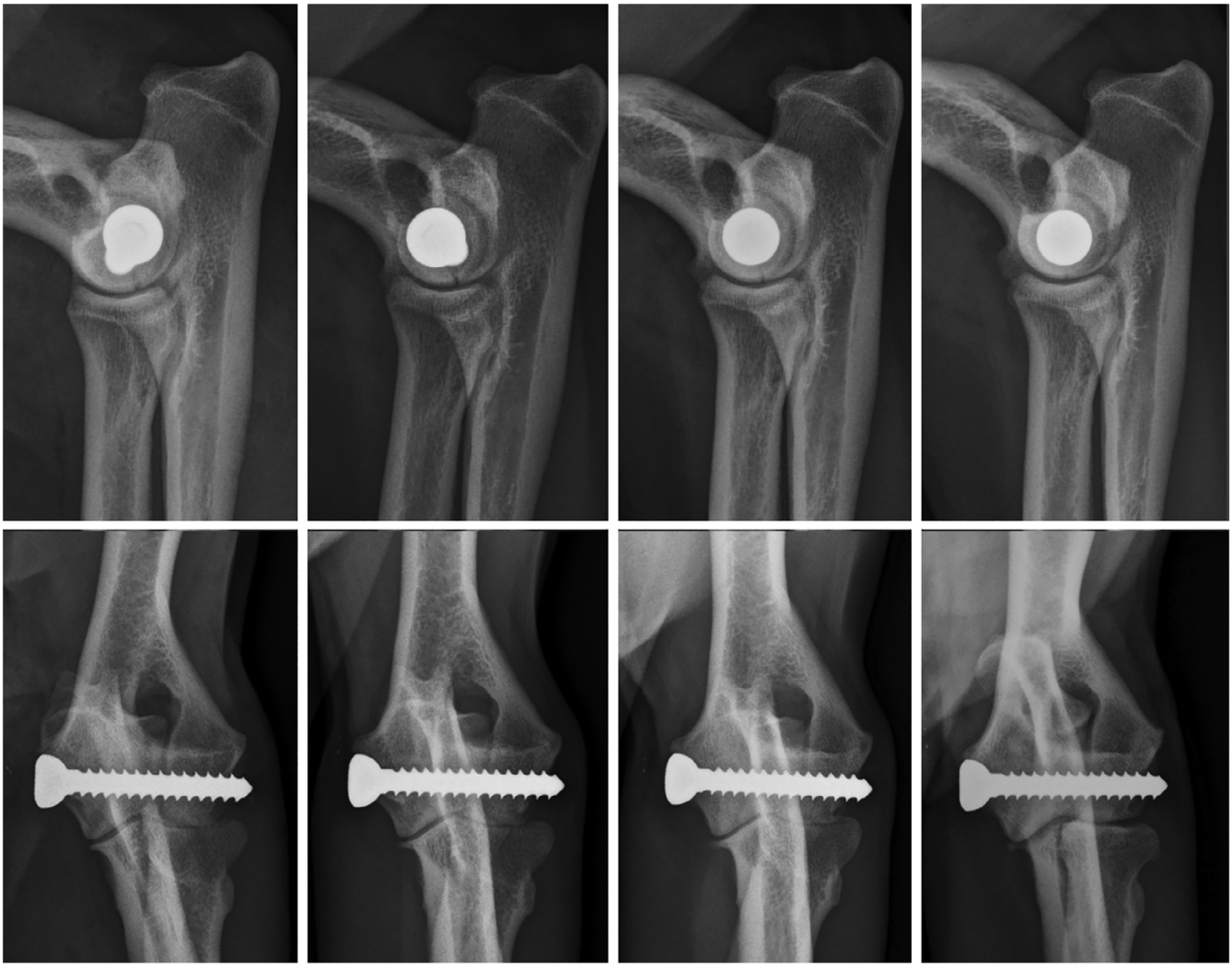

FIGURE 1 Top row – mediolateral radiographs; bottom row – craniocaudal radiographs of the elbow of a 3 year old, female, neutered, springer spaniel with medial epicondylar fissure fracture (MEFF) at 0, 6, 11, 17 weeks (left – right). At 17 weeks the fissure fracture is healed but still faintly visible on the lateral view, with some new bone formation visible on the cranio-caudal view

The authors have recently identified a novel intraoperative complication following placement of transcondylar screws, visible as a radiolucent line (fissure fracture) on the medial epicondyle or nonarticular portion of the medial humeral condyle (Figure 1). As far as the authors are aware, no previous studies have reported the occurrence of this lesion, which we have termed medial epicondylar fissure fracture (MEFF). As such, there is no current information on potential risk factors for this complication, which, if known, may reduce the risk of MEFF developing in future cases. Similarly, it is currently unknown whether MEFF has an impact on perioperative outcome.

The primary aim of this study was to report the incidence of MEFF. Secondary objectives were to identify risk factors associated with the development of MEFF and to determine if there was any association between MEFF and subsequent complications.

2 | MATERIALS AND METHODS

Hospital records were searched to identify dogs that had undergone surgical treatment of HIF between 2010 and 2019. Cases were included if hospital records were complete, and preoperative computed tomography (CT) and immediate postoperative radiography were available for review. Cases re-examined a minimum of 6 weeks postoperatively were included in an analysis of complications.

Data collected from the clinical records included breed, age, weight, HIF type (complete/partial, as assessed by CT), implant type, and surgical approach. Postoperative lateral and cranio-caudal projections of the distal humerus were evaluated by both authors to assess for the presence or absence of MEFF, including their location on the condyle if present (described as an angle relative to the humeral shaft, centered on the screw head – Figure 2). The minimum diameter of the humeral condyle (on CT and radiography) was measured to calculate the width of the screw relative to that of the condyle (screw size to condylar height ratio). Screw angle was measured and compared to a reference line drawn between the medial and lateral epicondyles as described previously,[15] and degree of countersinking (less than or greater than 50% of the screw head) was documented.

Information from case records, including clinical findings during orthopedic re-examination and follow-up radiographs, was used to identify additional complications. Complications were defined as major (requiring additional medical or surgical treatment to resolve) or minor (no additional treatment required to resolve) according to previously published guidelines.[16] If both a major and minor complication occurred in an elbow, the elbow was classed as having suffered a major complication for the purposes of calculating total complication rate.

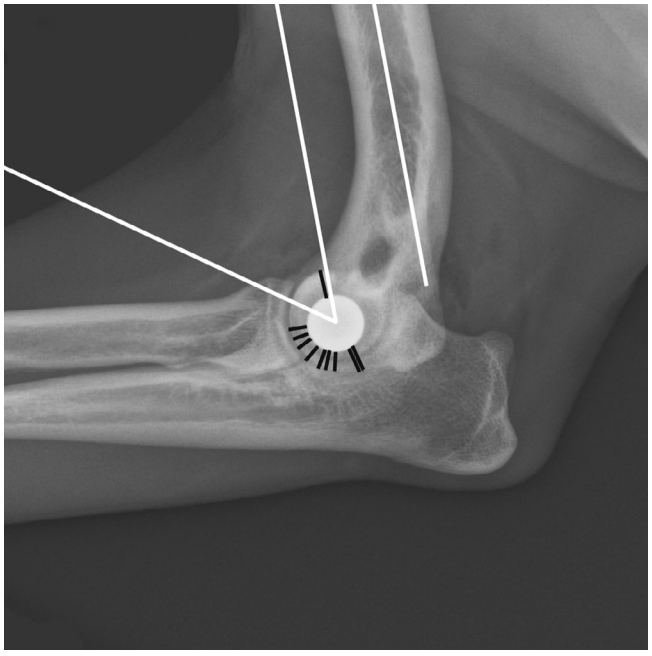

FIGURE 2 Representation of medial epicondylar fissure fracture locations (lateral radiograph), including an example of angle calculation relative to the long axis of the humerus (white lines)

2.1 | Surgery

Anesthetic protocols were chosen on an individual basis according to the preference of the attending anesthetist. Antibiotic prophylaxis with intravenous cefuroxime (20 mg/kg) was administered 30 minutes prior to surgery and repeated if required every 90-120 min. Antibiotic treatment was continued at the discretion of the surgeon for 7 days postoperatively.

All surgical procedures were performed at the authors' institution, either by a board-certified surgical specialist or a surgical resident under the direct supervision of a board-certified surgical specialist. Stainless steel (316 LVM; low-carbon vacuum melt surgical stainless steel) transcondylar screws (4.5 mm shaft screw, 2.7 mm / 3.5 mm / 4.5 mm cortical screws: Veterinary Instrumentation, Sheffield, United Kingdom) were placed using fluoroscopic guidance via a limited medial or lateral approach to the humeral condyle, according to surgeon preference. Surgical technique for transcondylar screw placement was as previously described.[3,12] Countersinking was performed manually following drilling. Where

screws were placed in lag fashion, drill stops (Veterinary Instrumentation) were applied to the drill bit to enable accurate drilling of the glide hole. Postoperatively, patients were hospitalized for analgesia and discharged the following day with a 7-day course of nonsteroidal anti-inflammatory medication. Discharge instructions included strict cage or room rest with slow lead walks for a maximum of 5 min., 3 to 4 times daily for 6-8 weeks.

2.2 | Statistics

Statistical analysis was performed with commercially available software (IBM SPSS Statistics: IBM Corp., Armonk, NY, USA). Categorical data were reported as numbers and percentages. Continuous data were assessed for normality using the Shapiro-Wilk test; normally distributed data were reported as means and standard deviations, and non-normally distributed data were reported as medians and ranges.

To assess potential risk factors for MEFF development, the binary outcome variables of "MEFF/No MEFF" were compared with a number of explanatory variables. The categorical explanatory variables of complete/partial HIF, shaft/cortical screw, medial/lateral approach, and degree of countersinking (<50%, >50%) were compared using Fisher's exact test. Continuous explanatory variables of weight, age, screw size to condylar height ratio, and screw angle were compared with an unpaired *t*-test (normally distributed variables), or the Mann-Whitney *U*-test (non-normally distributed variables). All explanatory variables with a *P*-value less than .2[17] were assessed with a binary logistic regression model to determine their relative significance. To assess relationship between MEFF development and subsequent complications (all categorical variables) Fisher's exact test was used. Statistical significance was set at $P < .05$.

3 | RESULTS

During the study period, 74 dogs (88 elbows) were treated for HIF with a transcondylar screw. No cases were excluded from the assessment of MEFF incidence or from the evaluation of risk factors. The most common breed was the English springer spaniel ($n = 48$, 65%), followed by cocker spaniels ($n = 15$, 20.3%), Labrador retrievers ($n = 5$, 6.7%), spaniel cross breeds ($n = 3$, 4.1%) and 1 each of clumber spaniel, German shepherd dog and Cavalier King Charles spaniel (1.3% each). Dogs weighed 7-33 kg (mean ± SD, 18.9 ± 4.37 kg); the median age was 36 months (range 5-120 months).

Complete HIF was present in 69 (78%) of elbows, equally distributed between left (51%) and right (49%) elbows. The most frequent transcondylar screws that were placed were 4.5 mm shaft screws ($n = 74$, 84.1%), followed by 4.5 mm cortical screws ($n = 10$, 11.4%) (9 lag, 1 positional), 3.5 mm cortical screws ($n = 3$, 3.4%) (1 lag, 2 positional), and 1 × 2.7 mm cortical screw (1.1%) (positional). Eighty-five screws were placed via a medial approach (96.6%) and 3 were placed via a lateral approach (3.4%). Degree of countersinking was <50% of the screw head in 61.4% elbows ($n = 54$), and >50% in 38.6% ($n = 34$). The median screw angle was −3.5 degrees (range: −20 to 2.5). The median screw size to condylar height ratio was 40.2% (range: 30.6-47.9). Arthroscopic treatment of medial coronoid process disease was performed prior to transcondylar screw placement in 25% of elbows ($n = 22$). Postoperative antibiotics were administered in 92% of cases ($n = 81$).

3.1 | Medial epicondylar fissure fractures

Medial epicondylar fissure fractures were documented in 10 elbows (10 dogs, 11.4%) during placement of a 4.5 mm shaft screw via a medial approach (Table 1). Four cases were recognized intraoperatively. One 4.5 mm shaft screw was replaced with a 4.5 mm cortical screw in one of these cases. An audible crack was heard when the screw was tightened in 2 cases; in these cases, and 2 others the fissure fracture was also visible on intraoperative fluoroscopy as a line emanating from the screw hole. Arthroscopy was performed in one of these cases to confirm the absence of articular involvement. No evidence of fissure fractures propagating to the articular surface was detected on postoperative cranio-caudal radiographs.

Medial epicondylar fissure fracture was not recognized during surgery but was identified on immediate postoperative radiography in 2 cases. It was only identified on follow-up radiographs 6-weeks after surgery in one elbow. It was only identified during radiographic review for the present study in 3 elbows. The fissure fractures were predominantly located between 169 and 270 degrees, although one was located at 5 degrees (Figure 2).

None of the dogs with MEFF was treated differently in the recovery period. Nine cases with MEFF returned for re-examination at 6-weeks postoperatively, and at this time point the lesions were still visible radiographically. Two cases were re-evaluated until radiographic healing of the fissures, at 14 and 17 weeks postoperatively (Figure 1).

TABLE 1 Case, complication and treatment data for all elbows that developed complications following treatment of HIF

Case	Breed	Age, months	Weight, kg	SS: CH, %	Treatment	Approach	Postoperative antibiotics	Complication	MEFF recognized at time?	Time of complication	Treatment of complication	Classification	Time of last re-check
1	Cocker spaniel	60	12.6	43.7	4.5 mm SS	Medial	Yes	MEFF	Yes – intraoperative fluoroscopy, radiography	Intraoperative	No specific treatment	Minor	12w
2	Springer spaniel	102	24.5	46.4	4.5 mm SS	Medial	Yes	MEFF	No	Intraoperative	No specific treatment	Minor	6w
3	Springer spaniel	36	14.3	42.1	4.5 mm SS	Medial	Yes	MEFF	Yes – radiography, acknowledged in surgery report	Intraoperative	No specific treatment	Minor	6w
4	Springer spaniel	7	15.9	44.5	4.5 mm SS	Medial	Yes	MEFF	Yes – intraoperative fluoroscopy, radiography	Intraoperative	No specific treatment	Minor	6w
5	Springer spaniel	7	15.6	42.8	4.5 mm SS	Medial	Yes	MEFF / screw loosening	No – recognized at 6w when screw loosened	Intraoperative / 6w	No specific treatment / Surgical – replaced with longer screw & medial nut	Major surgical	12w
6	Springer spaniel	36	15.8	40.5	4.5 mm SS	Medial	Yes	MEFF	Yes – audible crack, fluoroscopy, arthroscopy, radiography	Intraoperative	4.5 mm SS changed for 4.5 mm CS intraoperative	Minor	17w
7	Springer spaniel	12	14	47.9	4.5 mm SS	Medial	Yes	MEFF / screw loosening	No	Intraoperative / 56w	No specific treatment / surgical – replaced with longer screw & medial nut	Major surgical	64w
8	Springer spaniel	40	16.9	41.5	4.5 mm SS	Medial	Yes	MEFF	No	Intraoperative	No specific treatment – reexamination not performed	Minor	0w
9	Cocker spaniel	108	12.3	46.4	4.5 mm SS	Medial	Yes	MEFF / screw loosening	Yes – audible crack, fluoroscopy, radiography	Intraoperative / 6w	No specific treatment / surgical – screw tightened	Major surgical	12w
10	Springer spaniel	22	21	38.4	4.5 mm SS	Medial	No	MEFF	Yes – radiography, acknowledged in surgery report	Intraoperative	No specific treatment	Minor	6w

TABLE 1 (Continued)

Case	Breed	Age, months	Weight, kg	SS:CH, %	Treatment	Approach	Postoperative antibiotics	Complication	MEFF recognized at time?	Time of complication	Treatment of complication	Classification	Time of last re-check
11	Spaniel cross	5	11.8	40.9	4.5 mm SS	Medial	No	Seroma / screw loosening	N/A	1w / 6w	Surgical – replaced with greater degree of countersinking & medial nut applied	Major surgical	12w
12	Springer spaniel	21	20	39.1	4.5 mm SS	Medial	Yes	Seroma	N/A	1w	None – resolved by 6w	Minor	12w
13	Springer spaniel	36	21.8	41.3	4.5 mm SS	Lateral	Yes	Deep SSI (*Staph. intermedius*)	N/A	8w	Surgical – implant removal, antibiotic treatment with amoxycillin/clavulanate	Major surgical	14w
14	Springer spaniel	16	18.4	39.8	4.5 mm SS, lateral epicondylar 5-hole 2.7 mm SOP plate	Lateral	Yes	Deep SSI (*Pseud. aeruginosa*)	N/A	4w	Surgical – implant removal (transcondylar screw only), antibiotic treatment with marbofloxacin	Major surgical	10w
15	Springer spaniel	48	24.2	35.4	4.5 mm SS	Medial	Yes	Superficial/deep SSI (*Pseud. aeruginosa)*	N/A	2w superficial SSI, 6w deep SSI	Medical – antibiotic treatment with marbofloxacin	Major medical	14w
16	Springer spaniel	48	19.9	40.5	4.5 mm SS, lateral epicondylar k-wire	Medial	Yes	Deep SSI (*Staphylococcus* spp. / screw loosening	N/A	3w / 6w	Antibiotic treatment with amoxycillin/clavulanate / surgical – implant removal	Major surgical	10w
17	Springer spaniel	60	20.6	38.4	4.5 mm SS	Medial	Yes	Screw loosening	N/A	10w	Surgical – screw retightened	Major surgical	16w
18	Springer spaniel	48	28	40.5	4.5 mm SS	Medial	Yes	Screw loosening	N/A	16w	Surgical – screw retightened	Major surgical	25w
19	Cocker spaniel	96	18.8	39.1	4.5 mm SS	Medial	Yes	Screw loosening	N/A	6w	Surgical – screw retightened	Major surgical	14w
20	Springer spaniel	60	19.9	39.1	4.5 mm SS	Medial	Yes	Screw loosening and fracture	N/A	9w	Surgical – fracture repair	Major surgical	15w

Abbreviations: CS, cortical screw; MEFF, medial epicondylar fissure fracture; SOP, string of pearls; SS, shaft screw; SS:CH, screw size to condylar height ratio; SSI, surgical site infection.

TABLE 2 Results of the Mann-Whitney *U*-test assessing the non-normally distributed continuous variables of age, screw size to condylar height ratio, and screw angle

Variable	Median (range)	*U* value	*P* value
MEFF age (months)	36 (7–108)	373.5	0.828
No MEFF age (months)	36 (5–108)		
MEFF screw size to condylar height ratio (%)	43.3 (38.4–47.9)	144.5	0.001
No MEFF screw size to condylar height ratio (%)	39.8 (30.6–47.9)		
MEFF screw angle (degrees)	−5.9 (−20–2.5)	280.0	0.148
No MEFF screw angle (degrees)	−3.1 (−23–11.5)		

Abbreviations: MEFF, medial epicondylar fissure fracture.

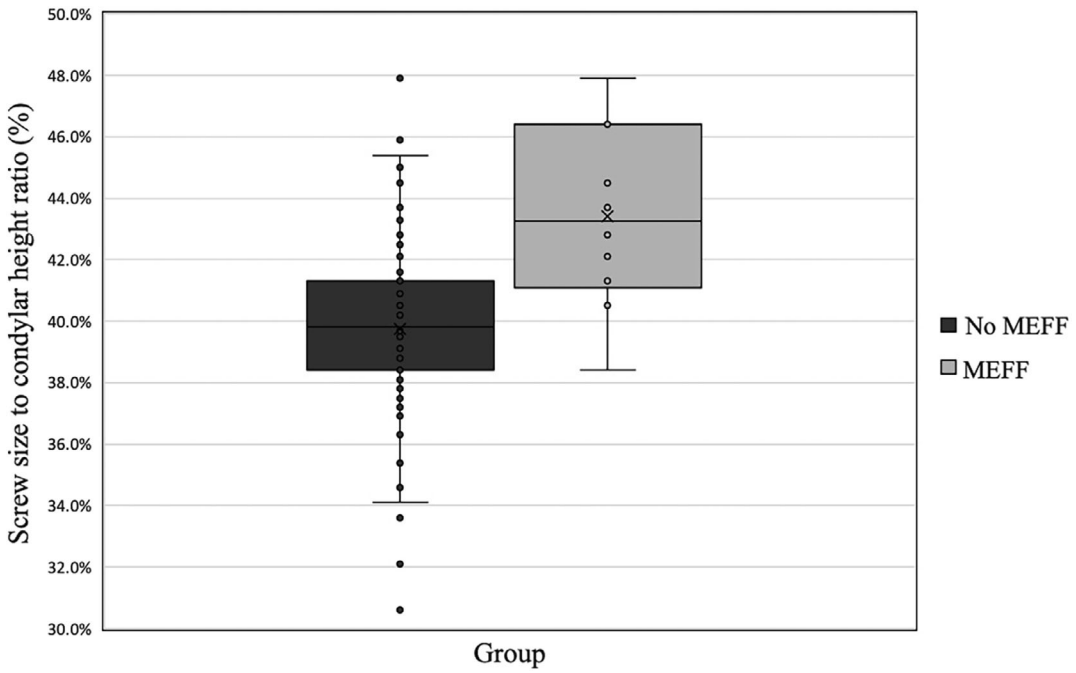

FIGURE 3 Box (25%-75% range) and whisker (0-100% range) plot of screw size to condylar height ratio (%). MEFF, medial epicondylar fissure fracture

3.2 | Risk factors

No relationship was identified between MEFF and placement of a shaft screw ($P = .353$), partial/complete fissure ($P = .683$), medial/lateral approach ($P = 1.0$), or degree of countersinking ($P = 1.0$). There was also no association between screw angle and age (Table 2). Lower bodyweight was associated with an increased risk of MEFF ($P = 0.042$); MEFF mean weight 16.3 kg (range 12.3-24.5 kg), non-MEFF mean weight 19.2 kg (range 7-34 kg). Screw-size to condylar height ratio was also associated with an increased risk of MEFF ($P = .001$, Table 2 and Figure 3).

The relative significance of weight, screw size to condylar height ratio, and screw angle was evaluated with binary logistic regression (Table 3). Screw size to condylar height ratio was the most significant of these explanatory variables associated with an increased risk of MEFF development ($P = .004$, OR: 1.521, CI: 1.145-2.021).

3.3 | Complications

Routine re-examination was documented in 80 elbows (66 dogs, 90.9% of all elbows), including 9 cases with MEFF, at a mean of 6.5 weeks postoperative (SD ± 1.23, range 6-12 weeks). One case with MEFF, and 7 cases without MEFF (treated with 4.5 mm shaft screws ($n = 5$), 4.5 mm cortical screw ($n = 1$), 3.5 mm cortical screw ($n = 1$)) did not present for re-examination and were

TABLE 3 Results of binary logistic regression determining relative significance of weight, screw size to condylar height ratio, and screw angle

Variable	*P* Value	Odds ratio	95% Confidence interval
Weight (kg)	0.318	0.907	0.750–1.098
Screw size to condylar height ratio (%)	0.004	1.521	1.145–2.021
Screw angle (degrees)	0.790	0.081	0.790–1.014

excluded for assessment of additional complications. Fifteen additional complications were identified in 13 elbows, at a median of 6 weeks postoperative (range 1-56 weeks) (Table 1). Most complications were perioperative (0-3 months),[16] although 2 cases underwent additional re-examination when they suffered a short-term complication (3-6 months), and long-term complication (>12 months) at 16 and 56 weeks respectively. Repeat radiographs were not performed for 14 elbows (none of which had MEFF). No concerns were raised during orthopedic examination (no lameness, good range of motion, no discomfort on examination, and the screw head was not palpably prominent).

The most frequent complication was screw loosening ($n = 9$, 11.2%), which typically occurred in the absence of infection ($n = 8$), at a median of 6-weeks postoperative (range 6-56 weeks). Infection was consistently excluded by cytological assessment of synovial fluid, in conjunction with clinical and radiographic evaluations. Screw loosening was the only complication seen in dogs with MEFF ($n = 3$). The presence of MEFF was not found to increase the risk of subsequent perioperative screw loosening (Fisher's exact test, $P = .06$). A lateral humeral condylar fracture occurred secondary to screw loosening in 1 case (without MEFF) at 9-weeks following surgery. All dogs with screw loosening were identified on orthopedic re-examination as having a palpably prominent screw head, prior to repeat radiography being performed; 6 cases were noted at 6 weeks postoperatively; 3 other cases were identified at 9 weeks (as above), 16, and 56 weeks respectively. Four of the 9 dogs with screw loosening were not lame at the time of re-examination, these cases were all identified at the 6-week re-examination.

Deep surgical site infection (SSI) occurred in 4 elbows (5%), all without MEFF. Surgical site infection was initially suspected based on clinical signs of septic arthritis (lameness, inflammation, joint effusion, discharge was present in 2 cases [Cases 13 and 16; Table 1]). Osteolysis around the transcondylar screw and a marked neutrophilic arthritis respectively were subsequently detected, along with a positive culture of synovial fluid/implants/discharge fluid. All dogs had been treated with oral postoperative antibiotics. Two of the dogs that developed a deep SSI had had additional implants placed to treat nondisplaced partial lateral epicondylar crest stress fractures; a single laterally applied epicondylar Kirschner wire with a medially applied transcondylar screw was placed in 1 case, and a laterally applied epicondylar 2.7 mm SOP locking plate (Orthomed UK Ltd., Huddersfield, United Kingdom) with a laterally applied transcondylar screw was placed in another. Only these 2 cases had additional implants placed. Two dogs without MEFF developed seromas (2.5%), both resolving spontaneously, although 1 dog subsequently developed a major complication (screw loosening).

Six dogs with MEFF had no further perioperative (0-3 months) complications; 1 case was not re-examined, although the owner reported no complications during telephone follow up. These cases were all classified as having minor perioperative complications based on the occurrence of MEFF. Three cases with MEFF went on to develop screw loosening and were treated surgically; 2 of these cases were identified at 6 weeks postoperative and classified as having a major surgical perioperative (0-3 months) complication. Additional perioperative complications per elbow were defined as minor (1/80, 1.25%), major surgical (7/80, 8.75%), and major medical (1/80, 1.25%). One case with screw loosening identified at 16 weeks postoperative was classified as a major surgical short-term (3-6 months) complication. One case with MEFF had screw loosening identified at 56 weeks postoperatively, classified as a major surgical long-term (>12 months) complication.

The rate of perioperative complications was 22.4%, of which 12.5% were major (11.25% surgical, 1.25% medical) and 9.9% were minor. One case developed a major surgical short-term complication and 1 a major surgical long-term complication (both contributing 1.25% to total complication rate). Overall, complications were documented in 24.9% of elbows (15% major and 9.9% minor).

4 | DISCUSSION

This study is the first to report MEFF as an intraoperative complication during the surgical treatment of HIF, documented in 10/88 (11.4%) elbows. Increasing the size of

the transcondylar screw relative to the dimensions of the humeral condyle increased the risk of MEFF. The lower value of the interquartile range of screw size to condylar height ratio (Figure 3) prompts us to recommend the placement of screws that do not exceed 41% of the minimum humeral condyle diameter.

Increasing screw size reduces the rim of bone around the screw head and may predispose to fissure fracture as the screw is tightened. A screw size of 30%-50% of the isthmus of the humeral condyle has previously been recommended to treat HIF, although this range was based on clinical experience rather than an analysis of outcomes.[18] Further, Barnes et al.[10] suggested that a humeral condylar diameter of greater or equal to 10 mm can safely accommodate a 4.5 mm transcondylar screw; equivalent to a 45% relative screw size. The magnitude of difference in median screw size to condylar height ratio between groups (MEFF / no MEFF) was small in our study, and both groups had a similar data range (Table 3). However, most MEFF fractures in our study were associated with a screw size exceeding 41% of the condylar height. When choosing a screw size for a specific case, surgeons should consider the risk and consequence of fatigue failure of a smaller implant versus the risk and consequence of MEFF with a larger implant. Further studies are required to better quantify these risks. The second factor likely to influence the occurrence of MEFF consists of the amount of torque applied while tightening the screw. Although this force cannot be assessed retrospectively, the authors believe, based on their clinical experience, that higher torque may be placed on transcondylar screws than when placing similar screws as plate screws. The use of torque limiters may be worthy of consideration when placing transcondylar screws in the future. The consistent development of MEFFs during placement of shaft screws in this study may reflect their predominant use in our practice, as this implant was not detected as a predisposing factor in our statistical analyses ($P = .353$). Medial epicondylar fissure fracture originates at the screw head, prompting the authors to speculate that any lagged screw with a domed head (i.e., including standard cortical screws) may be at risk of causing MEFF when the screw head is tightened against the medial epicondyle.

Nearly half of MEFFs were not identified at the time of the initial treatment in our study. Cases identified perioperatively included those detected as an audible crack as the screw was tightened, and/or on fluoroscopy during surgery, and/or on immediate postoperative radiography. The radiolucent line is particularly prominent on well positioned medio-lateral radiographic projections of the elbow; rotation in positioning may cause the screw to obscure the fissure line. Indeed, one such case, which had not been visible on the immediate postoperative radiographs, was noted at the 6-week re-examination appointment, when screw loosening was also identified.

Complications were documented in 24.9% of elbows in this study (15% major, 9.9% minor), and these were predominantly perioperative complications (22.4%). Complications may be underreported as most cases reported in our study were not followed beyond the perioperative period (0-3 months). The primary focus of this study is to report MEFF and associated risk factors for its development, rather than to compare different complications between studies. Such comparison is inherently difficult due to differences in treatment (implant type, approach) and follow ups. However, studies assessing complications after lateral placement of transcondylar screws using criteria defined by Cook et al.[16] report rates of 59.5% (n = 79 elbows; unspecified follow-up timeframe),[11] and 69% (n = 26 elbows; perioperative, 0-3 months).[13] Similarly, McCarthy et al. reported a 46.2% perioperative complication rate with a medial approach and cannulated drill system in 14 elbows.[19] Other authors describing medially placed transcondylar screws report slightly lower complication rates; Moores et al. reported complications in 16.7% of elbows, combining perioperative (0-3 months) and short-term (>3-6 months) complications in 14 elbows with HIF treated with shaft screws.[12] Clarke et al. documented complications in 19.4% of 32 elbows treated with medial-lateral screw placement.[20] Our results may reflect the higher number of shaft screws and other lagged cortical screws used in our setting, as the use of lag screws has been associated with a lower number of infections.[11] However, other aspects of case management may impact complication rates, such as the relatively high doses of antimicrobial prophylaxis administered in this study. Placement of a transcondylar screw is a clean, elective procedure with a short duration but development of a surgical site infection in this particular instance could ultimately lead to implant removal and catastrophic outcome (fracture). Controversy remains in both human and veterinary medicine as to appropriate antibiotic stewardship.[21] Further studies are needed to provide objective data on the use of antibiotics in clean orthopedic surgeries where implants are placed, particularly when lifelong (eg, joint replacement, transcondylar HIF screws) rather than short-term (eg, fracture repair) function of those implants is required.

Screw loosening was a frequent complication ($n = 9$), most instances ($n = 8$) occurring without infection. Most cases were re-evaluated at 6 weeks; while screw loosening was identified in 5 elbows at this time point, 4 cases were detected at 9, 10, 16, and 56 weeks postoperatively, when clinical deterioration prompted re-examination.

Screw loosening may increase in frequency with time and may have not been identified in some cases due to the relatively short follow up. However, elbows that developed longer term loosening were re-examined when they suffered a deterioration in limb use, thus the authors consider it unlikely that clinically relevant screw loosening would have gone undetected. All cases of screw loosening involved shaft screws, which have a reduced surface area when compared with cortical screws; reduced friction between the screw and the bone may explain the higher frequency of loosening. Further investigation into the possible causes of loosening was beyond the scope of this paper.

The presence of MEFF tended to increase the risk of further perioperative complications in our population. No dogs had evidence of osseous infilling at the fissure fracture site at 6 weeks postoperatively, although radiographic evidence of healing was seen at 14 and 17 weeks in dogs monitored for a longer period (Figure 1). Three dogs developed subsequent perioperative screw loosening after MEFF ($P = .06$); a relationship between these complications may have been identified with a larger study population, and/or a longer follow-up period. Theoretically, screws could potentially become looser within the cis-cortex in the presence of MEFF. The authors suggest replacing the replacing the shaft screw with a cortical screw when MEFF is identified intraoperatively.

Several limitations to this study are inherent to its retrospective nature. The duration of follow up (6 weeks in most cases), inconsistent radiographic monitoring, and re-examination by multiple assessors limited the evaluation of postoperative complications. However, all cases of screw loosening were identified during clinical examination, thereby limiting the risk of undiagnosed, yet clinically relevant, implant failure. Shaft screws were overrepresented relative to cortical screws, affecting our ability to test the influence of screw design on MEFF. To further investigate risk factors and mitigate bias, the study could be repeated on a larger population, potentially by recruiting cases from other referral hospitals.

In conclusion, MEFF occurred in 10/88 elbows treated with HIF and was more common in elbows treated with a larger screw size relative to the height of the condyle. Surgeons should be aware of the risk of MEFF, particularly in elbows where the screw size to condylar height ratio is greater than 41%. The clinical significance of MEFF in the perioperative period appears to be low and most cases of MEFF heal uneventfully. However, the long-term effect of this complication remains unknown.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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