Clinical Communication

Lateral Epicondylar Fissure Fractures after Transcondylar Screw Placement for the Treatment of Humeral Intracondylar Fissures and Humeral Condylar Fractures

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ABSTRACT

Objective The aim of this study was to report an intraoperative complication that has been noted during the surgical application of transcondylar screws (TCS). Although a recent study has shown medial epicondylar fissure fractures during medial to lateral TCS application in dogs treated for humeral intracondylar fissures (HIF), our study pertains to lateral epicondylar fissure fractures occurring during surgery for HIF, lateral condylar fractures and intracondylar Y fractures.

Study Design Retrospective, multicentre case series, including seven client-owned dogs. Data collection included signalment, imaging findings, surgical method and implants used for the repair, postoperative complications and outcome at 6 to 8 weeks of follow-up.

Results Two dogs were treated for bilateral HIF, one for unilateral HIF, two for lateral condylar fractures and two for intracondylar Y fractures. Intervention after diagnosing the intraoperative lateral fissure fracture included adding a washer and a transcondylar Kirschner wire or an adjunctive TCS. One dog was euthanized due to financial constraints following implant failure 2 weeks after lateral condylar fracture repair. Six dogs had a good outcome with return to function.

Conclusion Humeral epicondylar fissure fractures can occur in the lateral epicondyle during TCS placement in dogs treated for HIF, lateral condylar fractures and intracondylar Y fractures.

Keywords dogs, elbow, fracture fixation, orthopaedic surgery, intraoperative complications

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Introduction

The placement of a humeral transcondylar screw (TCS) is a technique used for the stabilization of humeral intracondylar fissures (HIF) and as part of the repair of humeral condylar fractures.[1–4] Intraoperative complications reported during placement of TCS for the stabilization of HIF are reported to occur in 2.9 to 5.7% of cases and include intra-articular screw placement, broken drill bits and broken Kirschner wires.[5–8] More recent studies aimed to increase the accuracy of screw placement, whilst lowering complication rates; these included comparing medial and lateral approaches, using specific drill guides, or using fluoroscopy to guide screw placement.[4–7,9] The use of screw sizes between 30 and 50% of the humeral condyle isthmus has been recommended, with larger screw sizes suggested to be more resistant to fatigue from cyclic loading.[1,2,4] However, TCS diameter relative to the isthmus of the humeral condyle (ratio TCS/isthmus) has been linked to joint penetration and to a recently reported intraoperative complication, the medial epicondylar fissure fracture.[5,7,10] The authors have previously identified a similar complication affecting the lateral epicondyle following placement of a TCS in a lateral-to-medial direction. No previous studies have reported the occurrence of this lateral epicondylar fissure fracture (LEFF). Here, we report a case series of seven dogs with this complication where lateral epicondylar fissure or fracture occurred following lateral-to-medial TCS placement during surgical repair of HIF and humeral condylar fractures. The aim was to describe the method of diagnosis, the surgical intervention performed and the clinical outcomes.

Materials and Methods

Clinical records were searched for dogs that had undergone TCS placement for the treatment of HIF or humeral condylar fractures at two referral hospitals between January 2017 and July 2022. Inclusion criteria were dogs that had undergone TCS placement in a lateral-to-medial direction and had developed an LEFF during TCS placement. We separately recorded the total number of dogs that had a TCS placed lateral to medial for the treatment of HIF or humeral condylar fractures during the same study period. For the cases of LEFF, details recorded included signalment, history, physical examination findings, imaging findings at the time of identification of the complication, surgical method and implants used for the repair of both the initial HIF or humeral condylar fracture and the subsequent LEFF. Follow-up data were collected, which included lameness grade, complications and their treatments. Complications were classified following Cook and colleagues into minor, major and catastrophic.[11] For each case identified, the sagittal computed tomography scan images were reviewed, and the minimum humeral condylar diameter, or isthmus, was measured in a cranial to caudal direction, as previously described.[7] This was then used to calculate the screw diameter to isthmus ratio (ratio TCS/isthmus). Intraoperative fluoroscopy images or immediate postoperative orthogonal radiographs were reviewed to assess the location of the fracture. The angle of the fracture in relation to the humeral shaft was calculated and centred on the screw head as described previously for medial epicondylar fissure fractures.[10] Descriptive statistics were performed.

Results

Seven dogs with LEFF met the inclusion criteria. All dogs were initially presented for investigation of thoracic limb lameness, which had developed during normal exercise. In the cases of HIF, lameness was chronic and mild to moderate (grade 1–3/5). For the fracture cases (lateral condylar and intracondylar Y) lameness was acute in onset and severe (grade 5/5).[12] The signalment, clinical signs and final diagnosis of each case are presented in **Supplementary Table S1** (available in the online version only). Concurrent changes related to the elbow joint were found in five cases and included the following: ulnar subchondral sclerosis (cases 1, 3, 4 and 7), osteoarthritis (cases 2, 3 and 7) and medial coronoid process disease (cases 2 and 7). Concurrent contralateral HIF was found in four cases. Two dogs had previous contralateral elbow surgery; one intracondylar Y fracture (repaired) and one TCS applied following diagnosis of HIF. The surgical technique for TCS placement was performed in all HIF cases as previously described.[5] For the lateral humeral condylar fracture cases, the TCS was applied using an inside-out technique through a standard lateral approach to the humeral condyle.[1] For the intracondylar Y fracture cases, a medial and a lateral approach were performed for placement of plates, but the TCS was placed via the inside-out technique through the lateral incision. Countersinking of the TCS head was not performed.

Identification and Treatment of Lateral Epicondylar Fissure Fractures

Table 1 summarizes the methods used for identification of the fracture, the method of repair, additional implants used and the postoperative complications. Lateral epicondylar fissure fractures were recognized during surgery in cases 2, 3, 4, 5 and 6. A "crack" was heard whilst tightening the TCS in cases 4 and 5. Lateral epicondylar fissure fractures were identified from intraoperative fluoroscopy (lateromedial projection) in cases 2 and 3 (**Fig. 1**). This was not grossly visible initially; however, once seen on fluoroscopy, further surgical dissection allowed visualization on the lateral epicondyle. For case 6, the operating surgeon noticed that the TCS continued to advance easily past the point where the screw head contacted the bone. The screw was removed at this point to investigate the cause of this problem, and the fissure was then identified. In cases 1 (**Fig. 2**) and 7, the fissure was noted at the time of the immediate postoperative radiographs on the mediolateral projections. All the LEFF were then identified at the time of revision surgery. Surgical stabilization of the fissure varied between cases: a flat washer was placed beneath the existing TCS and a transcondylar Kirschner wire was added (cases 1 and 7; **Fig. 3A**); a spiked washer was placed beneath the existing TCS (cases 2 and 3; **Fig. 3B**); an adjunctive 2.4-mm TCS was placed (case 4; **Fig. 4**); the previously applied TCS was removed and a new 2.4-mm lag screw was placed across the LEFF and two transcondylar 1.4-mm Kirschner wires were applied (case 5; **Fig. 5**); the previously applied 4.5-mm TCS was replaced with a 3.5-mm TCS while two 2.0-mm lag screws were placed across the LEFF (case 6). Following surgical stabilization, all surgical approaches were closed routinely, and no other intraoperative complications were reported. All the dogs recovered well from surgery, with 5/7 cases weight-bearing on the affected limb within 24 hours and the remaining 2/7 cases weight-bearing within 48 hours. All dogs were discharged between 1 and 4 days after surgery with instructions to the owners to administer either oral meloxicam (Metacam, Boehringer Ingelheim, Berkshire, United Kingdom) or robenacoxib (Onsior, Elanco Animal Health, Hampshire, United Kingdom) for 7 to 14 days. Cases 1, 2 and 5 were discharged with cephalexin (15 mg/kg twice a day; Cephacare, Animal Care Group, York, United Kingdom) for 7 days, whilst case 7 was discharged with amoxicillin clavulanic acid (20 mg/kg twice a day; Clavaseptin, Vetoquinol Towcester, United Kingdom) for 7 days. The LEFF angle was measured in six cases and varied between 185 and 264 degrees (**Table 1**); in one case, the angle could not be measured due to superimposition with the implants. There was one minor postoperative complication of a seroma (case 3) and one major type 1 complication (case 7), which involved back-out of the transcondylar Kirschner wire 2 weeks after surgery, and it was removed percutaneously. In the same dog (case 7), a mild back-out of the TCS was noted at the follow-up appointment, but no intervention was required (**Table 1**). One catastrophic complication was registered for case 6 two weeks after surgery; *en bloc* failure of the distal plate-screws construct was noted on radiographs, where the three screws in the distal segment pulled out of the bone with secondary bone displacement (**Fig. 6**). The dog was euthanatized after the owners declined revision surgery due to financial constraints. The six remaining dogs were represented at 6 to 8 weeks after surgery for follow-up examination, including orthogonal radiographs; these showed stable implants and evidence of healing of the fissure fractures. At that time, after being managed with strict rest following surgery, five had returned to acceptable function with no reported lameness, and one had reduced function (2/5 lame).

Statistics

A total of 281 dogs and 372 elbows were operated on in the time frame selected; 189 were right elbows (50.8%) and 183 were left (49.2%). There were 164 HIF (44.1%), 144 lateral condylar fractures (LCF) (38.7%), 51 intracondylar Y fractures (13.7%) and 13 medial condylar fractures (MCF) (3.5%). The direction of the TCS

Table 1 Transcondylar screw placement, lateral epicondylar fissure fractures identification, additional implants and complications

Case	Transcondylar screw type and diameter (mm)	Ratio transcondylar screw/isthmus	Transcondylar screw placement method	Method of fracture identification	Angle of lateral epicondylar fissure fractures (degrees)	Method of stabilization	Additional implants	Postoperative complications
1	Cortical (4.5 mm)	34.8%	Positional	Radiographs, computed tomography	193	Flat washer + transcondylar Kirschner wire	None	–
2	Cortical (4.5 mm)	37.5%	Positional	Intraoperative fluoroscopy	205	Spiked washer	None	–
3	Cortical (4.5 mm)	39.8%	Positional	Intraoperative fluoroscopy	185	Spiked washer	None	Seroma
4	Cortical (4.5 mm)	37.5%	Lag	Crack heard during surgery, radiographs	199	2.4-mm transcondylar screw screw	2.7-mm LCP[a] medial, 2.7-mm Evolox plate[b] lateral	–
5	Cortical (3.5 mm)	26.3%	Lag	Crack heard during surgery, computed tomography	264	Transcondylar screw removed + 2.4-mm lag screw across the lateral epicondylar fissure fracture + two transcondylar 1.4-mm Kirschner wires	3.5-mm LCP[a] medial, 2.7-mm LEAP plate[c] lateral	–
6	Cortical (4.5 mm)	34.6%	Lag	Unable to tighten transcondylar screw, radiographs	Not applicable	2.0-mm lag screw across the lateral epicondylar fissure fracture + 4.5-mm transcondylar screw replaced with 3.5 mm	2.7-mm LEAP plate[c]	Screws-LEAP plate backout
7	Cortical (4.5 mm)	38.9%	Lag	Radiographs	197	Flat washer + transcondylar Kirschner wire	2.7-mm Evolox plate[b]	Kirschner wire backout, screw backout

[a]Locking Compression Plate; DePuy Synthes, West Chester, PA, United States.
[b]N2 UK Ltd, Unit Q, Fishers Grove, Farlington, Portsmouth, United Kingdom.
[c]Lateral Epicondylar Anatomic Plate; Fusion Implants, Merseyside, United Kingdom.

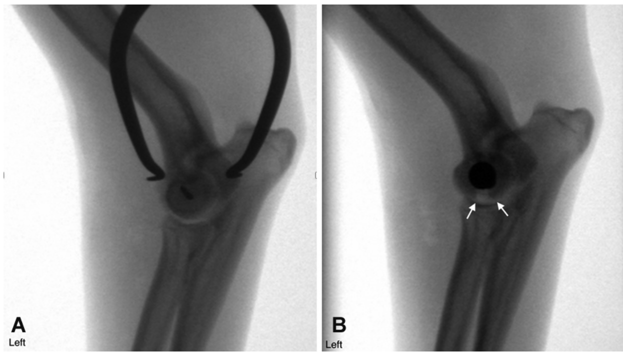

Fig. 1 Mediolateral intraoperative fluoroscopy of case 2. (**A**) shows the Kirschner wire in place before the placement of the transcondylar screw. (**B**) shows transcondylar screw in place with lateral epicondylar fissure fracture (arrows) before addition of spiked washer.

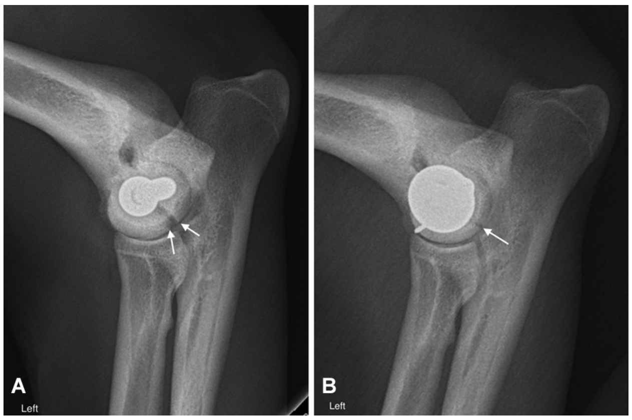

Fig. 2 Mediolateral postoperative radiographs of case 1. (**A**) is the immediate postoperative radiograph with a lateral epicondylar fracture (arrows). (**B**) is the postoperative radiograph following revision surgery and placement of a flat washer and transcondylar Kirschner wire.

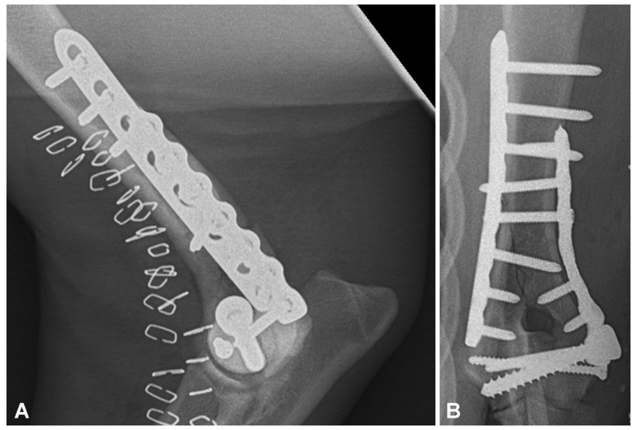

Fig. 4 Mediolateral and craniocaudal postoperative radiographs of case 4. (**A, B**) show the addition of a 2.4-mm transcondylar screw placed distocranially to the primary transcondylar screw.

was lateral to medial in 250 (67.2%) and medial to lateral in 122 cases (32.8%). In the HIF cases only, the direction was medial to lateral in 100 (61%) and lateral to medial in 64 (39%). Lateral epicondylar fissure fractures occurred in 4.7% of TCS placed for HIF in a lateral-to-medial direction, 3.9% of cases of intracondylar Y fractures and 1.4% of cases of LCF.

Discussion

This case series is the first report of LEFF as an intraoperative complication during the surgical treatment of HIF and humeral condylar fractures, where TCS were placed from a lateral-to-medial direction. Overall, they occurred in 1.9% of the elbows of dogs operated at our two institutions. The same complication affecting the medial epicondyle has been recently reported by Jenkins and Moores, with medial epicondylar fissure fractures occurring in 10/88 elbows (11.4%) when the TCS was applied from medial to lateral in cases with HIF.[10] The decision on how to

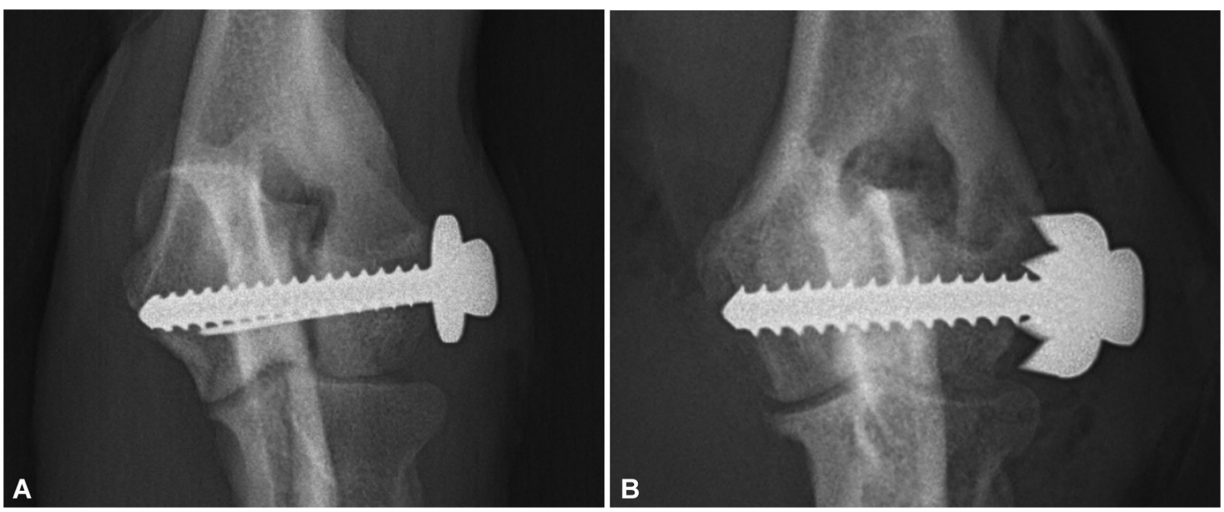

Fig. 3 Craniocaudal postoperative radiographs of cases 1 and 2. (**A**) is the postoperative radiograph of case 1 shows a flat washer and transcondylar Kirschner wire added to the transcondylar screw. (**B**) is the postoperative radiograph of case 2 shows a spiked washer added to the transcondylar screw.

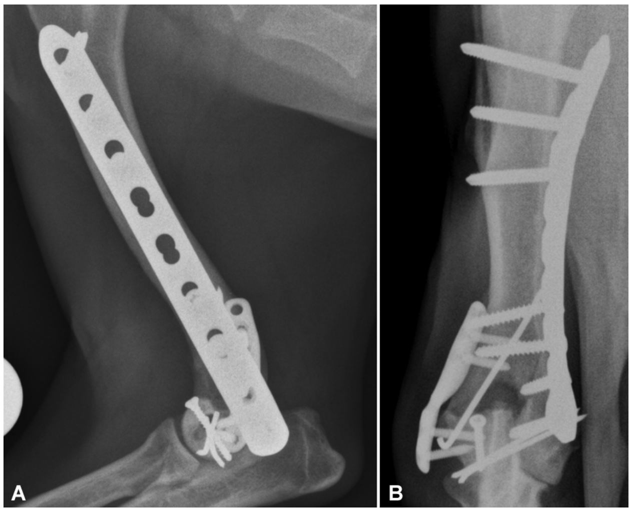

Fig. 5 Mediolateral and craniocaudal postoperative radiographs of case 5. (**A, B**) show the addition of a 2.4-mm lag screw across lateral epicondylar fissure fracture and two transcondylar 1.4-mm Kirschner wires. Note that the primary transcondylar screw was removed.

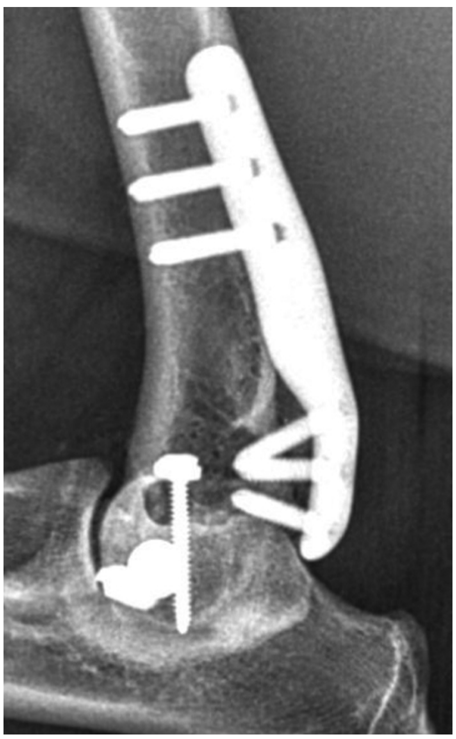

Fig. 6 Mediolateral follow-up radiographs of case 6. The three distal screws had loosened, and subsequently, the distal portion of the plate pulled out from the humeral condyle.

address this complication at the time of diagnosis varied between cases and was at the discretion of the operating surgeon. Interestingly, the medial epicondylar fissure fracture reported by Jenkins and Moores did not undergo any further surgical stabilization in part because many of the complications were identified retrospectively.[10] In our case series, all the LEFF had adjunctive fixation. Due to the retrospective nature of the study, it is not possible to establish if the clinical outcomes would have been the same without intervention. However, the only catastrophic complications occurred in a case where, at the time of revision surgery, the TCS was replaced with one of a smaller diameter. This may have predisposed to instability and secondary implant failure. Nonetheless, another case had the TCS completely removed and replaced with two transcondylar Kirschner wires while a lag screw was placed across the LEFF, and no complications were recorded for this dog. These different scenarios illustrate the complexity of this complication and the difficult decision-making process a surgeon must face if this occurs. On one hand, there is the concern to stabilize the iatrogenic lateral epicondylar fissure and to prevent any means that caused it, or that may worsen it. In this matter, the attention is focused on the TCS. On the other hand, the surgeon must not forget the planning previously performed to address and stabilize the primary injury. Transcondylar screw diameter relative to humeral condyle diameter has been linked to medial epicondylar fissure fracture formation, and a recommendation of not using screw sizes that exceed 41% of the humeral condyle isthmus has been suggested.[10] In this series, the ratio TCS/isthmus was all less than 41%. A potential contributory factor for the development of LEFF could be related to overtightening of the TCS. Overtightening can generate excessive stress where the screw head contacts the bone surface, leading to microfractures or fissures and failure of the cortex. The TCS is placed in a metaphyseal region where cortical bone is relatively thin, making it more susceptible to damage from the screw head. Additionally, the lateral humeral epicondyle is smaller than the medial epicondyle, potentially increasing vulnerability. In the cases operated on at our institutions, there was indeed no record of medial epicondylar fissure fracture. This is in contrast to what was reported by Jenkins and Moores, suggesting that anatomy alone is not sufficient to fully explain the pathogenesis of this intraoperative complication.[10] Humeral condylar bone in animals with HIF or condylar fractures secondary to HIF is subject to bone remodelling, resulting in bone sclerosis. This affects the mechanical properties of bone and may predispose to increased risk of fissure development and propagation. Countersinking would result in the distribution of stress under the screw head and may reduce the risk of LEFF development. However, if excessive cortical bone is removed, the screw head may sink into the medullary canal, potentially leading to fissuring. To avoid LEFF, we would advise the judicious use of countersinking and avoiding excessive tightening of the TCS. The use of a torque limiter may help prevent overtightening; however, critical torque values for screw insertion in the canine humeral condyle are not currently known. Further work would be required to determine the optimal torque limiter settings necessary to prevent humeral bone fissuring during the placement of the TCS. In our cases, countersinking was not performed, and a torque limiter was not used. Other possible causes of LEFF may include the TCS entry point and the TCS angle; these factors would influence the contact area between the screw head and the lateral epicondyle, creating different stress patterns. The application method of the TCS could also be a factor. In our cases, interfragmentary compression was either achieved using pointed bone reduction forceps followed by application of the TCS as a positional screw or by applying a standard lag screw. Lateral epicondylar fissure fractures were encountered following both methods. It has been shown that significantly greater compression is generated across condylar fractures by lag screws in comparison to positional screws; however, biomechanical studies analysing the forces exerted by contact of the screw head on the epicondyle with these techniques are lacking and may be critical in the development of LEFF.[13]

Failure to identify the LEFF intraoperatively with fluoroscopy could have been due to the reduced resolution of fluoroscopy compared to digital radiography, due to limb position during the use of intraoperative fluoroscopy not being as standardized and precise as with postoperative radiographs, or because fluoroscopy is used as a dynamic surgical aid rather than as a diagnostic tool. To optimize the chance of visualizing the lateral or medial epicondylar fissure fractures, it is important to have a well-positioned lateral radiographic projection with the beam parallel to the TCS (**Fig. 1**). Without this projection, there is a risk of superimposition of the implant over the fissure fracture, as suggested by Jenkins and Moores.[10] The orientation of the fissure in relation to the radiographic beam could also make it not evident on the fluoroscopic or radiographic lateral images: the fissure would only be visible when it is parallel to the radiographic beam. Similarly, the LEFF was not visible on review of any cranial caudal radiographic projections. Three of the fracture cases had the LEFF suspected clinically intraoperatively and then identified on postoperative imaging (**Table 1**), suggesting that meticulous attention should be paid by the surgeon at the time of tightening the TCS. Repeating intraoperative imaging with high-definition fluoroscopy may also be indicated when LEFF is clinically suspected, such as when a "crack" is heard while tightening the TCS or if the TCS fails to tighten. Prior to the recent publication by Jenkins and Moores reporting medial epicondylar fissure fractures, along with this case series reporting LEFF, the development of an epicondylar fissure fracture has been unreported.[10] This is surprising as it occurred with an incidence of 11.4% and 1.9% in the two studies, respectively. This suggests that careful evaluation of postoperative radiographs is indicated in these cases. Radiographic identification of the iatrogenic fractures is even more challenging when other implants are placed during condylar fracture repair, as they may superimpose with the epicondylar fracture line; a computed tomographic scan may be more sensitive in these cases. Postoperative computed tomography scans were required in two cases in this series to confidently identify the LEFF, and may be necessary when there is clinical suspicion of a fracture which cannot be identified on postoperative radiographs. Jenkins and Moores reported that the majority of medial epicondylar fissure fractures were located between 169 and 270 degrees; similarly, all LEFF reported here were between these angles (from 185 to 264 degrees), so it appears these fissure fractures occur in similar places.[10] Although the location of medial epicondylar fissure fractures on lateral radiographs was found to have a greater variation than the ones presented here, this could be due to a higher number of cases or again due to the different anatomy of the medial and lateral epicondyles.

There are several limitations to this study that are inherent to the retrospective nature. In this study, all cases were identified at the time of or immediately postoperatively. A retrospective review of all postoperative radiographs of dogs treated with TCS placement has not been performed; this may have resulted in some cases not being included in the study, and therefore, the incidence of this complication may be higher. Ultimately, the duration of the follow-up was limited to the 6- to 8-week examination; therefore, it is not possible to draw significant conclusions regarding the different fixation methods used to address this complication.

Conclusion

Lateral epicondylar fissure fractures are an intraoperative complication which can occur during surgical stabilization of HIF and humeral condylar fractures. Although the limited number of cases prevents postulating reliable guidelines, iatrogenic LEFF occurring during fracture fixation appears to be associated with more postoperative complications and may therefore require additional stabilization and closer follow-up compared to LEFF arising during TCS placement for HIF.

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Statements and Additional Information

Conflict of Interest The authors declare that they have no conflict of interest.

Contributors' Statement F.P. and K.P. contributed to the design of the study. F.P. and S.W. performed data collection and analysis, identified the suitable diagnostic imaging and performed radiographic measurements, drafted and revised the manuscript. A.B., N.B., D.C., D.O. and K.P. were primary clinicians and operating surgeons of the cases included in the study, provided clinical data, supervision of the work and editing of the manuscript. All authors provided review of the manuscript and approved the final version.

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