Long-term outcome following management of canine humeral intracondylar fissure using a medial approach and a cannulated drill system

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Abstract
This study evaluated the feasibility, complications and long-term outcomes of using a cannulated drill system combined with intraoperative imaging to place a transcondylar screw for the management of canine humeral intracondylar fissure. Thirteen dogs were enrolled, with one dog undergoing staged bilateral surgery. No intraoperative complications occurred. Five minor (36%) and three major (21%) postoperative complications occurred, giving an overall complication rate of 57%. None of the screws placed penetrated the articular surface. The mean duration of surgery was 28 min (SD ±3.5) for dogs that developed a major complication versus 46 min (SD ±18.1) for those that did not (p=0.015). The duration of preoperative lameness was significantly shorter for cases which suffered a major complication (2 days; SD ±2.8) than those that did not (34 days; SD ±31.7, p=0.008). None of the variables assessed were significantly associated with minor complications. Median time from surgery to last follow-up was 5.8 years (range 3.5–8.5 years). Median Liverpool Osteoarthritis in Dogs questionnaire score at the final point of follow-up was 16 (range 7–27). A significant number of patients were found to require analgesia at long-term follow-up.

Introduction
Humeral intracondylar fissure (HIF) is a developmental or acquired condition of the canine elbow joint, which results in a mechanical weakness in the axial region of the humeral condyle. Radiographically, it is characterised by a partial or complete radiolucent zone that runs through the humeral condyle in a sagittal plane. The condition was previously referred to as incomplete ossification of the humeral condyle (IOHC), as it was believed to arise from a failure of the two principal centres of ossification that give rise to the humeral condyle to fuse, either partially or fully. More recent findings, however, have revealed that an intracondylar fissure may also develop in mature dogs, where imaging studies have previously documented an apparently normally ossified humeral condyle, thus the term IOHC is no longer deemed an accurate description of the pathology underlying the development of this condition. In the UK, HIF most commonly affects spaniel breeds, and can be detected either incidentally or as a cause of lameness. It frequently occurs bilaterally and can predispose to ‘minimal trauma’ fracture of the humeral condyle. A recent report estimated that 18% of incidentally diagnosed cases of HIF progress to condylar fracture.

Following the diagnosis of HIF, a single transcondylar bone screw is often placed, with the aim of reducing relative motion between the lateral and medial parts of the humeral condyle, so reducing lameness and the risk of a subsequent humeral condylar fracture. Placement of a transcondylar screw, however, has been associated with a surprisingly high complication rate, with the largest study to date reporting an overall complication rate of 60%, the most common of which were seroma and surgical site infection (SSI). SSI is
becoming increasingly challenging to manage due to the rising incidence of infections attributed to bacteria resistant to commonly used antibiotics. Fracture of the transcondylar screw remains a lifelong risk for dogs with HIF because failure of the medial and lateral parts of the condyle to unite following implant placement allows continued cyclic loading of the implant, potentially leading to fatigue failure. To increase the resistance to fatigue failure, a screw with a relatively large core diameter is usually used. However, as the diameter of the screw increases, so does the risk of inadvertent penetration of the articular surface during screw placement due to the complex geometry of the condyle.

Techniques to optimise positioning of the transcondylar screw include the use of intraoperative fluoroscopy and aiming devices. Cannulated drill systems allow the point of entry and direction of a small guidewire (typically between 1.1 and 1.6 mm in diameter), to be assessed fluoroscopically before committing to drilling the condyle over this wire. This has the benefit that the guidewire can be repositioned with less iatrogenic damage to the bone and overlying soft tissues than the drill bit or screw itself might cause. The use of a cannulated drill system has previously been reported for the repair of humeral condylar fractures and for the management of HIF with a shaft screw. To our knowledge, the management of HIF by placing a transcondylar screw from medial to lateral, using a cannulated drill system, has not previously been reported.

This study was performed to evaluate the benefit of a cannulated drill system in the accurate placement of a transcondylar screw under fluoroscopic guidance. Our primary hypothesis was that the use of a cannulated drill system combined with intraoperative fluoroscopic guidance would allow accurate positioning of the transcondylar screw within the humeral condyle, preventing inadvertent penetration of the articular surface. In addition, we aimed to document the perioperative and postoperative complications and long-term outcome associated with this technique.

**Materials and methods**

Case records from The University of Edinburgh’s Hospital for Small Animals were searched to identify dogs where a cannulated drill bit had been used in the placement of a transcondylar screw for management of a HIF. Cases were included if they had undergone surgery between 2010 and 2015, if the surgery was performed by the same primary surgeon (JRM) and if the cases had returned for follow-up examination.

Data recorded included signalment, severity of preoperative lameness, size of cannulated drill bit used, size of transcondylar screw placed, time to return to weight-bearing postoperatively and documented complications. Based on standardised reporting definitions, complications were categorised as catastrophic, major or minor. Preoperative lameness was assigned a score of 0 to 5 based on the clinical description (table 1).

Preoperative imaging was assessed for the presence of additional elbow joint pathology, a contralateral HIF, and whether the fissure(s) were complete or incomplete. Postoperative imaging was used to assess the position of the transcondylar screw. The mediolateral radiographic view or a computed tomography (CT) scan was used to define screw eccentricity within the condyle by recording the distance between the centre of the screw head and the centre of the humeral condyle as described by Grand. Where a postoperative cranio-caudal radiographic projection or CT scan, was available the transcondylar screw angulation was calculated by comparing the angle made between the central axis of the screw and a line connecting the medial and lateral humeral epicondyles.

Long-term outcomes were evaluated by owner questionnaire, using the validated Liverpool Osteoarthritis in Dogs (LOAD) questionnaire alongside a series of owner questions previously used to evaluate outcomes in a report on the use of shaft screws in the management of HIF.

**Surgical procedure**

Anaesthetic protocols were tailored to each individual case. All but one dog received postoperative non-steroidal anti-inflammatory drugs (NSAIDs), the specific drug, dose and duration varying between cases. The dog which did not receive NSAIDs was discharged with a short course of oral codeine (1 mg/kg PO, q 12 hours).

All patients received perioperative intravenous antibiotics, either cefuroxime or co-amoxiclav (20 mg/kg) commencing 30 min before the first surgical incision and repeated every 90–120 min depending on the hospital protocol at the time.

Patients were positioned in lateral recumbency with the affected limb lowermost. A limited approach to the medial epicondyle of the humerus was made and fluoroscopic imaging was used to ensure the elbow was positioned in the true mediolateral plane. Under fluoroscopic guidance, the tip of a 1.6-mm guidewire was positioned centrally over the body of the humeral condyle, at a point typically just distal and cranial to the medial epicondyle. The guidewire was inserted a short distance into the condyle, at a point typically just distal and cranial to the medial epicondyle. The guidewire was inserted a short distance into the condyle, at a point typically just distal and cranial to the medial epicondyle.

**Table 1 Lameness grading system**

| Clinical description                                      | Lameness score |
|----------------------------------------------------------|----------------|
| No lameness                                              | 0              |
| Mild, weight-bearing lameness                            | 1              |
| Mild to moderate, weight-bearing lameness                 | 2              |
| Moderate, weight-bearing lameness                         | 3              |
| Severe, weight-bearing lameness                           | 4              |
| Non-weight-bearing lameness                               | 5              |

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distance into the humeral condyle and the position and direction of drilling verified by fluoroscopy. If the position of the wire was deemed satisfactory, it was advanced approximately 75% of the distance across the humeral condyle, otherwise it was removed and repositioned. A 3.2-mm cannulated drill bit was advanced over the guidewire to create a pilot hole for screw placement. The drill bit was irrigated with saline during drilling, and repeatedly removed and cleaned prior to the conclusion of drilling to remove the dense sclerotic bone which became impacted in the flutes reducing cutting efficiency. A 4.5-mm stainless steel cortical screw was then placed as a position screw, aiming to leave at least two threads protruding from the lateral condyle. Screw position was documented by intraoperative fluoroscopy prior to lavage and wound closure.

Data analysis was performed using a commercial statistical software package (SPSS V.22). Descriptive statistics were derived from all 14 elbows, but for further analysis, only data from the first surgery were included. Continuous data were assessed graphically for normality and normally distributed data were assessed with an independent t-test. Data that were not normally distributed were analysed with Mann-Whitney U test. Categorical data were assessed with Fisher’s exact test. Statistical significance was set at \( P \) value <0.05.

A subset of 10 elbows had postoperative imaging available, and of these, one elbow was excluded from statistical analysis to avoid inclusion of the same animal twice in Mann-Whitney U testing.

**Results**

Thirteen dogs met the inclusion criteria, with one dog undergoing two surgeries (one on each elbow under separate anaesthetic episodes), totalling 14 elbows. There were six males (four entire, two neutered) and seven females (three entire, four neutered), of which nine were Springer Spaniels, two were Cocker Spaniels and two were Labrador Retrievers. Median age was 4 years (range 0.4–8.3 years) (figure 1A). The median body mass was 17 kg (range 14.4–22.1 kg).

Three cases had no history of lameness prior to surgery. For the remaining 11 cases, the duration of lameness prior to surgery ranged between 1 and 90 days with a median of 28 days. Four cases had no evidence of contralateral HIF, and 10 cases had confirmed (based on imaging) or presumptive (based on history of a previous contralateral humeral condylar fracture) contralateral HIF. Three cases were diagnosed with concurrent medial coronoid process disease (MCPD) affecting the ipsilateral elbow. Individual case details are summarised in table 2. Eleven cases had a complete HIF in the operated limb and three were classified as incomplete based on CT findings. No additional procedures were performed under the same anaesthetic episode as transcondylar screw placement. Ten right elbows and four left elbows underwent surgery. The median duration of surgery (data available for 13/14 cases) was 35 min (range 20 to 70 min). No intraoperative complications occurred. In the 12 cases for which it was recorded, all dogs were weight-bearing on the operated limb on the first postoperative day.

There were 5/14 minor complications and 3/14 major complications, giving an overall complication rate of 8/14 (table 3). The dog in which both affected elbows were treated by placement of a transcondylar screw (in separate surgeries, 6 weeks apart) suffered a major and a minor complication, both affecting the second side. The median time to development of a postoperative complication was 10 days (range 6–587 days).

Eight questionnaires were returned (figures 2 and 3). The median LOAD score was 16 (range 7–27), with six of the cases classified as having a mild or moderate score.\(^1\) Cases with returned questionnaires were a median of 5.8 years post-surgery (range 3.5–8.5 years).
TABLE 2
Summary of diagnostic findings for the surgical (ipsilateral) and contralateral elbow, listed by case

| Case | Ipsilateral elbow condition | Contralateral elbow condition |
|------|-----------------------------|-------------------------------|
| 1    | None                        | HIF, managed conservatively   |
| 2    | None                        | MCPD, managed conservatively  |
| 3    | None                        | HIF with previously treated LHC fracture |
| 4    | None                        | HIF with previously treated LHC fracture |
| 5    | None                        | None                          |
| 6    | None                        | HIF with previously treated LHC fracture |
| 7    | MCPD, managed conservatively | MCPD, managed conservatively |
|      |                             | HIF, managed by placement of a transcondylar screw at a separate surgery (not using a cannulated drilling system) |
| 8    | MCPD, managed conservatively | MCPD, managed conservatively |
|      |                             | Partial HIF, managed conservatively |
| 9    | None                        | None                          |
| 10   | None                        | HIF, managed by placement of a transcondylar screw at a separate surgery (not using a cannulated drilling system) |
| 11   | None                        | HIF, managed by placement of a transcondylar screw at a separate surgery (not using a cannulated drilling system) |
| 12   | None                        | HIF with previously treated LHC fracture |
| 13   | None                        | None                          |

HIF, humeral intracondylar fissure; LHC, lateral part of the humeral condyle; MCPD, medial coronoid process disease.

Table 3
Specific postoperative complications observed with allocation to major or minor grouping

| Case | Minor complication                           | Major complication                        |
|------|---------------------------------------------|--------------------------------------------|
| 1    | Lateral seroma                              |                                            |
| 3    | Surgical site infection (SSI), resolved with antibiotic treatment |
| 4    | SSI, resolved with antibiotic treatment     |                                            |
| 6    | Mediastinal seroma                          |                                            |
| 8    | Acute lameness, 10 days postoperatively, resolved with exercise restriction and analgesia |
| 10   | Acute lameness, 92 days postoperatively, resolved with conservative management | Screw breakage, 1.5 years postoperatively, resolved with screw replacement |
| 14   | Mild lameness, 9 days postoperatively, resolved with conservative management |                                            |

**Figure 1B.** Five out of the eight dogs had a contralateral HIF. The median LOAD score for dogs without a contralateral HIF was 7 (range 7–20) versus 18 for dogs with a contralateral HIF (range 7–27), but this difference was not significant (p=0.27). Seven of the eight dogs returned to full limb use within 3 months of surgery. One dog never regained full function on the operated limb, continuing to demonstrate periods of stiffness. This patient had previously had a transcondylar screw placed to treat HIF on the contralateral limb with fracture of that screw and subsequent screw replacement. Six patients were not receiving any analgesic medication at the point of last follow-up, with three patients receiving sporadic analgesic medication and four receiving daily medication.

There was no significant association between the presence of a complete or incomplete HIF, breed

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**Figure 2**
Scatter plot illustrating load scores (median±IQR) for those cases that returned the questionnaire (n=8), separated by the presence of absence of major complications in the postoperative period. LOAD, Liverpool Osteoarthritis in Dogs questionnaire.

**Figure 3**
Long-term owner follow-up as determined from the questionnaire adapted from Moores et al.15 (A) Time taken to return to full limb use. (B) Limb use at follow-up: excellent (never lame or stiff); good (occasional lameness or stiffness); fair (reasonable limb use but frequent lameness); poor (permanently very lame). (C) Use of analgesics for the elbow: sporadic (not every month); frequently (every month); very frequently (every week).
developed minor complications had a longer mean follow-up. Contrary to the findings for major complications, dogs that suffered a complication (major or minor) did not affect the score between dogs which suffered a complication. For the single case that returned a LOAD questionnaire after having developed a major complication, the score was 22 versus a mean score of 15 (SD ±8) for the other seven cases (figure 2); however, this difference was not statistically significant (p=0.41). The duration of preoperative lameness was significantly shorter for the cases which suffered a major complication (2 days, SD ±2.8) than for those that did not (34 days, SD ±31.7) (p=0.008).

There was no significant association between dogs that were receiving analgesia at the time of follow-up and whether they had developed a major postoperative complication. For the single case that returned a LOAD questionnaire after having developed a major complication, the score was 22 versus a mean score of 15 (SD ±8) for the other seven cases (figure 2); however, this difference was not statistically significant (p=0.41). When both major and minor complications were combined for analysis, there was no difference in LOAD score between dogs which suffered a complication (n=3) and those that did not (n=5) (p=0.312). Suffering a complication (major or minor) did not affect the likelihood of requiring analgesia at the time of last follow-up.

None of the variables evaluated were significantly associated with minor complications (table 5). Contrary to the findings for major complications, dogs that developed minor complications had a longer mean surgical time (56 min, SD ±11.1) than those that did not (36 min SD ±17.3), but this difference was not statistically significant (p=0.06).

Postoperative imaging was available for 9 of the 13 elbows, with two sets of imaging from the elbows which suffered a major postoperative complication. None of the screws penetrated the articular surface based on assessment of the available images which included three postoperative CTs. The median screw angulation was 8° (range 3°–28°), the median screw eccentricity:condylar radius ratio (EC:CR) was 0.4 (range 0.1–1.0). There were no significant associations between screw angulation, eccentricity or EC:CR and major or minor complications.

**Discussion**

Based on postoperative imaging, none of the transcondylar screws placed in this study penetrated the articular surface. CT would have been the optimal imaging modality for this assessment because multiplanar reconstruction allows for more accurate assessment of screw position than plain radiographs. In these clinical cases, postoperative CT was only performed to evaluate the contralateral elbow for the presence of HIF, rather than as a routine imaging modality. This resulted in only three out of the nine cases having a postoperative CT scan available for review; therefore, there was a reliance on the quality (specifically positioning of the limb) of postoperative radiography or fluoroscopy for assessment of screw angulation. It has previously been suggested that penetration of the articular surface by the screw may be under-reported because a surgeon might identify and

### Table 4  Risk factors assessed against major complications (significant P values (<0.05) highlighted in bold)

| Risk factor                          | Major complications | Count | Mean | SD  | P value |
|--------------------------------------|---------------------|-------|------|-----|---------|
| Age at time of surgery (years)       | No                  | 11    | 3.0  | ±2.4| 0.47    |
| Weight at time of surgery (kg)       | No                  | 11    | 17.4 | ±2.2| 0.23    |
| Duration of preoperative lameness (days) | No              | 11    | 15.4 | ±0.5| 0.008   |
| Duration of surgery (min)            | No                  | 10    | 26   | ±18.1| 0.015   |
| LOAD score                           | No                  | 7     | 15   | ±7.9| 0.41    |
| Time to follow-up (years)            | No                  | 11    | 4.4  | ±2.8| 0.54    |
| Time to LOAD (years)                 | No                  | 7     | 5.8  | ±2  | 0.98    |
| Screw angulation (degrees)           | No                  | 7     | 12   | ±10 | 0.5     |
| Screw eccentricity:condylar radius ratio | No                | 7     | 0.4  | ±0.3| 0.84    |
| LOAD, Liverpool Osteoarthritis in Dogs questionnaire |

### Table 5  Risk factors assessed against minor complications (significant P values (<0.05) highlighted in bold)

| Risk factor                          | Minor complications | Count | Mean | SD  | P value |
|--------------------------------------|---------------------|-------|------|-----|---------|
| Age at time of surgery (years)       | No                  | 9     | 3.9  | ±2.8| 0.06    |
| Weight at time of surgery (kg)       | No                  | 9     | 16.7 | ±2.4| 0.31    |
| Duration of preoperative lameness (days) | No              | 9     | 18.1 | ±1.3| 0.27    |
| Duration of surgery (min)            | No                  | 8     | 36   | ±17.3| 0.06    |
| LOAD score                           | No                  | 6     | 15   | ±8.9| 0.45    |
| Time to follow-up (years)            | No                  | 9     | 4.5  | ±1.9| 0.9     |
| Time to LOAD (years)                 | No                  | 6     | 5    | ±1.2| 0.11    |
| Screw angulation (degrees)           | No                  | 7     | 12   | ±10 | 0.44    |
| Screw eccentricity (mm)              | No                  | 7     | 4    | ±2  | 0.86    |
| Screw eccentricity:condylar radius ratio | No                | 7     | 0.4  | ±0.2| 0.83    |

(Springer Spaniel, yes or no), sex, age, body mass, presence of preoperative lameness, ipsilateral MCPD, whether the left or right limb was operated, screw angulation, screw eccentricity:condylar radius ratio and the development of a major complication (table 4).

The mean duration of surgery was 28 min (SD ±3.5) for dogs that developed a major complication versus 46 min (SD ±18.1) for those that did not (p=0.0015). The two cases that developed a major complication had both undergone surgeries to stabilise a contralateral, lateral humeral condylar fracture (presumed secondary to HIF); however, this association was not statistically significant (p=0.46). The duration of preoperative lameness was significantly shorter for the cases which suffered a major complication (2 days, SD ±2.8) than for those that did not (34 days, SD ±31.7) (p=0.008).

None of the variables evaluated were significantly associated with minor complications (table 5). Contrary to the findings for major complications, dogs that developed minor complications had a longer mean surgical time (56 min, SD ±11.1) than those that did not (36 min SD ±17.3), but this difference was not statistically significant (p=0.06).

Postoperative imaging was available for 9 of the 13 elbows, with two sets of imaging from the elbows which suffered a major postoperative complication. None of the screws penetrated the articular surface based on assessment of the available images which included three postoperative CTs. The median screw angulation was 8° (range 3°–28°), the median screw eccentricity:condylar radius ratio (EC:CR) was 0.4 (range 0.1–1.0). There were no significant associations between screw angulation, eccentricity or EC:CR and major or minor complications.
correct this error as it occurs, such that reporting of this intraoperative complication may not be as consistent as reporting of postoperative complications.\textsuperscript{11} In the largest study of complications related to humeral transcondylar screw placement, one screw was repositioned intraoperatively although further details on this were not provided.\textsuperscript{9} Complete surgery reports were available for all of the cases in this study and one of the authors was the primary surgeon for all of the procedures; therefore, we can confidently report that no incidences of suspected intraoperative joint penetration occurred in this cohort. Clarke et al\textsuperscript{12} have previously reported an intra-articular screw placement rate of 3/32 (9.4%), which may be due to the narrower safe corridor when drilling from medial to lateral.\textsuperscript{11} Despite this, a medial to lateral approach is preferred by some surgeons because it has been suggested to have a lower rate of seroma formation and infection\textsuperscript{12,19} while also allowing concurrent arthroscopy to be readily performed.\textsuperscript{20,21} Our findings support the use of a cannulated drill system combined with fluoroscopy to reduce the incidence of inadvertent penetration of the articular surface. No screws had to be repositioned intraoperatively, and this is most likely due to the benefit of being able to check the position of the smaller diameter guidewire and adjust it as necessary prior to placement of the screw.

The largest study on stabilisation of HIF with a transcondylar cortical screw reported overall complication rates up to 59.5%, with 44% developing a seroma and 42% developing SSI.\textsuperscript{9} A more recent report\textsuperscript{19} documented a higher complication rate of 18/26 elbows but a similar rate of SSI (11/26). The present study reports an overall complication rate of 8/14, similar to that of Hattersley et al, but with a much lower rate of seroma formation (2/14) and SSI (2/14). The high overall number of complications in our study may be due to the availability of long-term follow-up and to varying definitions of complications between studies. The lower rate of seroma formation and SSI seen here supports previous suggestions that the medial to lateral approach may lower the risk of these complications, but further evidence is required to strengthen this claim.\textsuperscript{12,15,19}

Few risk factors for the development of postoperative complications have been consistently identified, but those suggested include breed (Labrador Retrievers predisposed), increasing body mass and placement of a position rather than a lag screw.\textsuperscript{9} In this study, we found that a shorter surgical time and a shorter duration of preoperative lameness were associated with a higher rate of major complications. Five of the six dogs that suffered a complication also had a contralateral HIF, although no statistical association between these traits was found, possibly due to the relatively high overall rate of dogs with contralateral HIF in our study population. The relationship between major postoperative complications (which were both SSIs) and a shorter duration of preoperative lameness has not, to our knowledge, been previously reported for this condition. One potential explanation for this finding might be that dogs that either showed no lameness or had a very recent onset of lameness may have returned to full weight-bearing through the operated limb earlier than those with a more chronic history of lameness. Although all dogs were weight-bearing through the operated limb on the first postoperative day, no force plate data were collected, so the degree of weight-bearing was not quantified objectively. Full weight-bearing through the limb in the early postoperative period may lead to increased movement at the HIF, which in turn might facilitate the development of a SSI by a mechanism similar to that which contributes to the establishment of bacterial infection in unstable fractures.\textsuperscript{22–24}

A shorter surgical duration is not typically associated with a higher rate of postoperative infection; indeed, the reverse is usually expected.\textsuperscript{25–29} One possible explanation for this finding would be that the short incision length, facilitated in this study by fluoroscopic imaging of the humeral condyle, may have reduced the surgical time associated with approaching and closing the surgical site. In theory, a shorter incision might increase implant contact with the skin and thus increase the risk of implant contamination and subsequent SSI. When placing any implant, contact with the patient’s skin should be avoided to minimise the chance of postoperative infection. Due to the relatively low numbers in this study, these risk factors may have been incorrectly identified. The study was designed to include only the first elbow from each individual dog in statistical analysis to prevent the potential confounding influence an individual dog may have had. This led to the exclusion of one elbow which was affected by both a major and a minor complication. To investigate the potential effect of inclusion of the second elbow from this individual, statistical analysis with this elbow included was also performed but did not identify any additional risk factors for major or minor complications.

The presence of a contralateral HIF, including dogs previously treated for condylar fracture, was not significantly associated with a higher rate of complication. However, it is interesting to note that five out of the six dogs that suffered a complication (minor and major combined) had previously been diagnosed with a contralateral HIF. Higher case numbers are required to further investigate this relationship which may help guide future decision-making and prognosis.

This is the first report of transcondylar cortical screw placement to treat HIF through a medial approach that contains long-term evaluation of outcome. Fifty-three per cent of cases required sporadic or daily analgesia at the time of last follow-up, which was between 3.5 and 8.5 years postoperatively. The four patients receiving analgesia daily had LOAD scores >15, correlating to
a moderate (two cases) or severe (two cases) score.18 Suffering a postoperative complication did not appear to change the requirement for analgesia long term or lead to a higher LOAD score for dogs in this cohort. A recent study looking at the long-term outcome following placement of a transcondylar lag screw via a lateral approach reported that dogs which suffered SSI had a higher likelihood of an unsatisfactory outcome as assessed by owner questionnaire.19 This difference in outcome may be related to the higher number of dogs with SSI (11/26) compared with our report (2/14), to the differing surgical techniques, or to both factors.

In conjunction with the LOAD questionnaire, a questionnaire previously developed for owner follow-up after transcondylar shaft screw placement to treat HIF was used in this study.15 The present cohort showed a faster return to full limb function, but a greater number required analgesia either sporadically or permanently at the time of follow-up compared with those dogs in the study on shaft screw placement.15 This increased requirement for analgesia may be due to the longer duration of follow-up in the present study, which increases the time for further development of osteoarthritis. Similarly, a previous study found progression of radiographic osteoarthritis in 5/9 elbows with HIF at long-term follow-up.19 The development of osteoarthritis may be influenced by concurrent joint disease, most commonly MCPD. It has previously been reported that patients with concurrent MCPD showed a deterioration in limb use over time following transcondylar screw placement.15 We did not find a similar association in our cohort, with only one out of the three patients with concurrent MCPD requiring analgesia (intermittently) at the time of follow-up.

One of the limitations of longer-term follow-up is that many patients may develop other orthopaedic disease, especially in these cases, contralateral HIF or humeral condylar fracture. The LOAD score is unable to distinguish between orthopaedic disease relating specifically to the operated joint and orthopaedic disease originating from other causes. Force plate analysis may have helped to evaluate differences in load-bearing between limbs, but it was not routinely available at our clinic during the time period of the study and few clients are willing or able to return to a referral clinic 2–10 years postoperatively. Force plate data have recently been reported for dogs with HIF treated with a transcondylar lag screw placed via a lateral approach, and this report found reduced peak vertical force in treated limbs, with similarly reduced values in the limbs treated for humeral condylar fracture.19

We found no relationship between outcome and screw angulation or eccentricity. Our range of screw angulation was similar to previous reports on lateral humeral condylar fractures and HIF.15 29 Although a recent small case series reported a narrower range of screw angulation (1.2° to 7.3°)13 than in the present study, the mechanical effect of angulation of the transcondylar screw is unknown and in this cohort the only patient to suffer from screw breakage had an angulation of 10°, close to the mean angulation of 9°. Similarly, our values for screw eccentricity varied more widely than previously reported values.13 This may be due to the surface topology of the medial epicondyle, which tends to be more prominent and steep shouldered than the lateral epicondyle. The optimal entry point when drilling from medial to lateral can therefore be harder to maintain because the tip of the guidewire has a tendency to slide down the slope of the epicondyle into a more eccentric position. Positioning the patient with the affected limb down facilitates medial to lateral drilling through the condyle, but it may make positioning of the pilot drill hole along the theoretically ideal central line of the humeral condyle more challenging. The single case of screw breakage seen in the current cohort had the lowest measured screw eccentricity of 2 mm. The range of screw angulation was higher than expected based on the use of intraoperative fluoroscopy. This may be due to the upper-limb musculature elevating the proximal humerus when the animal is placed in lateral recumbency. Although the limb is relatively easily rotated around its long axis during surgery to facilitate optimal drill angulation in a craniocaudal direction, correction of the alignment of the humeral condyle in a proximodistal direction while ensuring that the condyle remains stable during drilling is more difficult. There was, however, no association between an increased angulation or eccentricity and the development of complications, and we do not therefore suggest altering the technique on this basis.

We chose to use a cannulated drill system in combination with cortical screws. Alternatively, self-drilling, self-tapping screws could have been inserted directly over the guidewire rather than choosing to use the wire to guide pilot hole placement. Placement of a cannulated, headless, tapered, variable-pitch screw to treat HIF in combination with bone grafting has previously been reported in seven elbows. No cases of implant fracture were reported in that study, although median follow-up was limited, being 14 months.21 We chose to use a standard, 4.5-mm cortical screw over a 4.5-mm cannulated screw, as the solid core of this implant is likely to provide greater resistance to bending and to fatigue failure when compared with a hollow core implant, and the sclerotic nature of the bone typically encountered in cases of HIF may have compromised the cutting efficiency of self-drilling, self-tapping cannulated screws.30

This is the first published description of the surgical technique for placement of a humeral transcondylar cortical screw via a medial approach using a cannulated drill system under fluoroscopic guidance. Intra-articular implant placement was avoided in all 14 elbows, supporting our hypothesis that the use of
a cannulated drill system combined with fluoroscopic placement aids accurate positioning of the screw and minimises the risk of penetration of the articular surface. No intraoperative complications occurred, and although we describe cases performed by a single surgeon, the technique proved simple to perform with no additional training required. Using a cannulated drill bit under fluoroscopic guidance did not prevent the inexplicably high complication rate noted with transcondylar screw placement. We hypothesise that the development of complications, other than intra-articular screw placement, is more likely to be related to the condition and ongoing instability between the medial and lateral parts of the condyle, independent of the technique used for implant placement. Avoiding complications is important for patient health and welfare, but in this cohort, the development of complications did not appear to affect the long-term outcome. There was an unexpectedly high number of patients receiving sporadic or continuous analgesic medication at long-term follow-up in this cohort. Where an ongoing lameness develops following placement of a transcondylar screw to treat HIF, we would encourage rigorous investigation to rule out implant failure which can easily be missed on plain radiographs and suggest that owners should be educated about the likely development and progression of osteoarthritis at the time of diagnosis.

Based on our clinical experience and the findings from this cohort study, we recommend a medial to lateral approach, using a cannulated drilling system in combination with fluoroscopy to optimise placement of a transcondylar screw for the treatment of humeral intracondylar fissure.

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Competing interests. None declared.

Ethics approval. The study design was reviewed and approved by The University of Edinburgh Veterinary Ethical Review Committee (VERC approval no. 53 16).

Data availability statement. All data relevant to the study are included in the article. Data are available on request.

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