ORIGINAL ARTICLE

Computed tomographic re-evaluation of skeletally immature French bulldogs previously diagnosed with humeral intracondylar fissure: 12 cases (2018-2022)

V. C. Hutchings and S. Rutherford

frank. Pet Surgeons, Leeds, UK

[1]Corresponding author email: vhutchings@frankpetsurgeons.com

Objectives: The objective of this study was to present the follow-up findings obtained through computed tomography in skeletally immature French bulldogs previously diagnosed with humeral intracondylar fissures.

Materials and Methods: Medical records from a surgical referral centre between January 2018 and September 2022 were evaluated for all dogs with a humeral condylar fracture where preoperative CT of both humeri was performed. French bulldogs between the age of 12 weeks and 12 months were identified and evaluated for the presence of contralateral humeral intracondylar fissure. The dogs with follow-up CT were evaluated for humeral intracondylar fissure resolution.

Results: A total of 137 humeral condylar fractures were operated on within the study period, 58 of which were in French bulldogs. Twenty-seven French bulldogs had a contralateral humeral intracondylar fissure with 12 dogs matching the inclusion criteria. Follow-up CT demonstrated resolution of the humeral intracondylar fissure in 11 (91.7%) of 12 cases.

Clinical Significance: Contralateral humeral intracondylar fissures are common in skeletally immature French bulldogs sustaining humeral condylar fractures and the majority of these fissures tend to fuse within the follow-up period. Due to the potential for breed variation in ossification of the humeral condyle, follow-up CT may be warranted in skeletally immature French bulldogs before considering prophylactic transcondylar screw placement.

Journal of Small Animal Practice (2024); **65**, 817–821
DOI: 10.1111/jsap.13768

Accepted: 26 June 2024; Published online: 14 August 2024

INTRODUCTION

Humeral intracondylar fissures (HIFs) are recognised to predispose to complete humeral condylar fracture (HCF). The pathogenesis of this condition remains controversial, but there are two hypotheses: when clinical signs are first recognised in adults, HIF is likely to be a form of stress fracture (Danielski et al., 2024; Danielski & Yeadon, 2022; Farrell et al., 2011; Witte et al., 2010) while in younger dogs, a developmental HIF, or incomplete ossification of the humeral condyle (IOHC), is more likely (Marcellin-Little et al., 1994).

While recent literature has discussed the possibility of HIF in brachycephalic breeds, with a particular focus on French bulldogs (FBDs) (Anderson et al., 2022; Smith et al., 2020; Strohmeier

This study was presented at the Resident Forum at the ECVS Annual Scientific Meeting 2023, Karków and at the ACVS Surgery Summit, Louisville, Kentucky, 2023.

JOURNAL OF SMALL ANIMAL PRACTICE
JSAP
BSAVA

& Harris, 2021), information remains scarce when compared to that available in Spaniels (Butterworth & Innes, 2001; Denny, 1983; Marcellin-Little et al., 1994; Meyer-Lindenberg et al., 2002; Moores, 2021; Moores & Moores, 2017). Several scientific studies report that fusion of the centres of ossification of the humeral condyle occurs at 8 to 12 weeks of age (Anderson et al., 2022; Carrera et al., 2008; Farrell et al., 2011; Kvale et al., 2022; Marcellin-Little et al., 1994; Sanchez Villamil et al., 2020; Schettler et al., 2022); however, it is not clear which breeds this relates to and where the data has originated from.

In contrast to Spaniel breeds, the majority of HCFs in FBDs occur in skeletally immature patients (Anderson et al., 2022; Sanchez Villamil et al., 2020; Smith et al., 2020). This may suggest that delayed ossification of the humeral condyle is one of the inciting causes of this pathology; however, whether this represents a failure of ossification or breed variation in physeal closure times remains unknown. A recent study rejected the hypothesis that the humeral condyle of FBDs ossifies later than 8 to 12 weeks (Anderson et al., 2022) however, no sequential computed tomography (CT) studies were performed, and the conclusion of the study was simply drawn on the fact that presence of a fissure did not appear to significantly decrease with age. In contrast, a recent case report demonstrated spontaneous resolution of a HIF in a 4-month-old FBD (Garland et al., 2023). Prophylactic screw placement represents the traditionally accepted treatment for HIF, particularly in Spaniels (Butterworth & Innes, 2001; Marcellin-Little et al., 1994; Moores, 2021; Moores & Moores, 2017). However, prophylactic transcondylar screw placement is by no means a benign procedure and reported post-operative complication rates range from 17.5% to 69.2% (Carwardine et al., 2021; Chase et al., 2019; Jenkins & Moores, 2022; Low et al., 2024; McCarthy et al., 2020; Meyer-Lindenberg et al., 2002). Hence, avoiding the necessity for transcondylar screw placement may result in reduced morbidity in dogs.

The aim of this study was to retrospectively assess whether HIFs in FBDs fuse with time, indicating that humeral condylar ossification occurs later in the FBD.

MATERIALS AND METHODS

Clinical data collection

The medical database (January 2018 to September 2022) from a single surgical referral centre in the United Kingdom was searched for all fractures treated; all HCFs were then specifically identified. All FBDs with a HCF were evaluated further. CT images of the contralateral limb, which were obtained at the time of HCF diagnosis, were assessed for the presence of HIF. Inclusion criteria for this study were dogs between 12 weeks and 12 months of age which had a contralateral HIF and had follow-up CT scans performed at a later date. Dogs without follow-up CT or those sustaining bilateral fractures were excluded.

Retrieved data included patient breed, sex, age, presence of a contralateral HIF and whether the HIF was complete or partial. Additionally, the presence of contralateral HIF and the degree of fusion were also recorded for those FBDs undergoing follow-up CT examination.

All dogs were anaesthetised for both the initial and the follow-up CT studies. Dogs were positioned in sternal recumbency with the elbow extended and the neck flexed laterally. Each limb was scanned individually. Images were collimated from the proximal antebrachium to the distal humerus, ensuring to include the medial coronoid process and the proximal aspect of the lateral epicondylar crest. The same CT scan parameters were used for all patients (GE Revolution ACTs double-helical CT 16 slice; 120vKp, 30mAs at 0.625 mm slice thickness).

All CT studies were reviewed with a DICOM viewer (EasyImage VetZ GmbH Sattlerstrabe 40 30916 Isernhagen, Germany) using multiplanar reconstruction to obtain images in three planes: sagittal, transverse and dorsal planes in bone and soft tissue algorithms. Images were reviewed by a board-certified orthopaedic surgeon experienced in interpreting elbow CT images and an ECVS resident in small animal surgery. Transverse images and dorsal plane reconstructions were used to assess the contralateral humeral condyle to the fracture. The presence or absence of HIF was recorded and, if present, it was further classified as partial or complete. In accordance with previous work (Carrera et al., 2008), fissures were described as complete if the hypoattenuating line extended from the articular surface to the supratrochlear foramen, and partial fissures were diagnosed if the hypoattenuating line extended only part-way across the humeral condyle. The height of the fissure was measured in the dorsal plane and divided by the height of the condyle to calculate the percentage of fissure length (Anderson et al., 2022).

Follow-up data collected

Routine follow-up was performed 4 to 8 weeks following HCF surgical stabilisation, when clinical union of the fracture was anticipated to have occurred. Dogs presenting with a contralateral fissure present at the time of the initial fracture had a follow-up CT scan performed under the same anaesthetic episode as the follow-up radiographs. All images were reviewed by a board-certified surgeon who had knowledge of the patient's history and had reviewed the initial CT. If the fissure was still evident the percentage of fissure length was calculated and compared to the initial measurements to calculate the degree of fusion. In dogs where a fissure was still present on the follow-up CT images, placement of a transcondylar screw was recommended and performed under the same general anaesthetic. If no HIF was evident, the patient was recovered from anaesthesia with no treatment performed.

Study design

This study does not reach the threshold for specific ethical approval. The data obtained was restricted to routine procedures only and signed consent for patients to be included in the study was obtained from all clients.

RESULTS

Clinical data

The database revealed a total of 409 fractures, 132 of which were HCFs in 128 dogs who also had CT of the contralateral

elbow. Three populations were identified: 58 fractures in 56 FBDs (43.8%, two bilateral HCFs); 53 fractures in 51 Spaniels (39.8%, two bilateral HCFs); and 21 fractures in other breeds (16.4%).

The age range of FBDs sustaining HCF was 2 months to 3 years. The median age of the dogs included in this study was 4 months (range: 3 to 5 months). There was no evidence of gender predilection with 29 females and 27 males.

Fifty-four dogs sustained unilateral HCF with 27 dogs (50%) documented to have a contralateral HIF. Three dogs were excluded as they were over 12 months of age, and two dogs were excluded as they were 12 weeks of age or under. Twenty-two dogs within the study age range had contralateral HIF; eight dogs had complete fissures while 14 presented with partial ones.

Follow-up results

Of the 22 dogs with contralateral HIF 12 had follow-up CT (Table 1). The remaining 10 dogs were not included in the study because 6 did not have a follow-up CT examination, 2 were lost to follow-up and 2 had prophylactic transcondylar screws placed without follow-up CT being performed.

In the 12 dogs meeting the inclusion criteria, the HIF was no longer evident in 11 humeral condyles (91.7%) (Fig 1). At the time of follow-up, one HIF remained evident (case #8). This dog was 4 months old at the time of HCF. Follow-up CT was performed 4 and 8 weeks later, when the patient was 5 and 6 months of age, respectively. Retrospective analysis of the CT images revealed that this fissure was in fact reducing in size: the degree of fusion progressed from a complete fissure at 4 months of age, to 21% fusion at 5 months, to 52% fusion at 6 months (Fig 2). Despite progression of fusion, a prophylactic transcondylar screw was placed at the final follow-up 2 months after fracture repair.

DISCUSSION

Our results concur with previous studies in that most FBDs that suffer HCFs are skeletally immature (Anderson et al., 2022; Sanchez Villamil et al., 2020; Smith et al., 2020). Almost half of these skeletally immature dogs have a contralateral HIF at the time of fracture, with partial fissures appearing to be more common than complete. However, follow-up CT images revealed

Table 1. French bull dogs under 12 months of age with a contralateral HIF

Patient	Age at initial CT (months)	Partial or complete HIF	Percentage fissure length	Age at follow-up CT	Presence of HIF at follow-up	Degree of fusion (%)
#1	3	Partial	42.48	4	No	100
#2	3	Complete	100	4	No	100
#3	3	Partial	69.22	4	No	100
#4	3	Partial	58.51	4	No	100
#5	4	Partial	34.51	5	No	100
#6	4	Partial	62.89	6	No	100
#7	4	Complete	100	5	No	100
#8	4	Complete	100	5+6	Yes, TCS placed	21.23+51.79
#9	4	Partial	80.28	6	No	100
#10	5	Partial	66.58	6	No	100
#11	5	Partial	66.13	7	No	100
#12	5	Partial	67.73	6	No	100

HIF Humeral intracondylar fissure

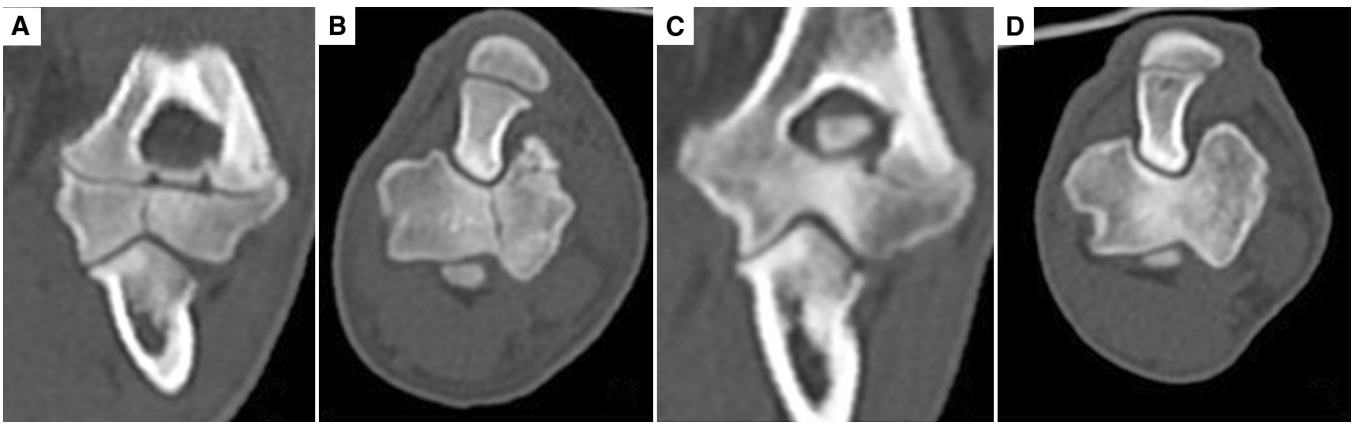

FIG 1. Dorsal (A) and transverse (B) computed tomography reconstructions of an elbow in a 4-month-old French bulldog. There is a hypoattenuating line extending across the entire length of the humeral condyle, surrounded by hyperattenuating, sclerotic bone. Computed tomography reconstructions 5 weeks later, revealed fusion of the fissure in dorsal (C) and transverse (D) planes. The hypoattenuating line has been replaced with hyperattenuating, sclerotic bone.

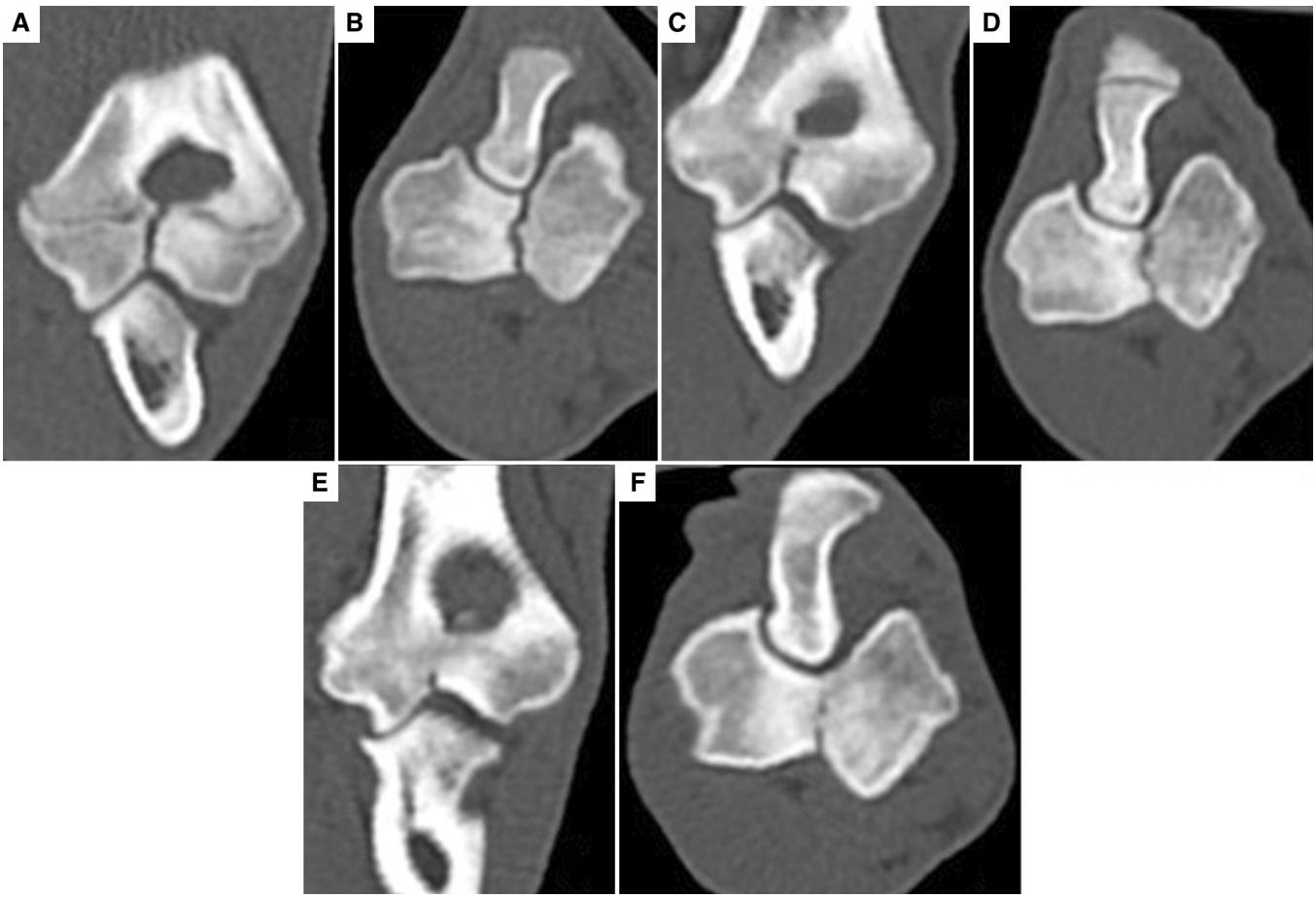

FIG 2. Dorsal (A) and transverse (B) computed tomography reconstructions of the elbow with a complete HIF of patient #8, whose HIF had not completely fused at follow-up. Dorsal (C) and transverse (D) computed tomography reconstructions at follow-up 4 weeks later revealing 21% fusion and at follow-up 8 weeks later, demonstrating 52% fusion (dorsal E and transverse F).

that 91.7% of these HIFs fuse within 4 to 8 weeks from the initial diagnosis. This is further corroborated by a recently published case report, describing CT diagnosis of a HIF in a 4-month-old FBD, which resolved within 3 months of diagnosis (Garland et al., 2023).

Several references have stated that the medial and lateral portions of the humeral condyle fuse at 8 to 12 weeks of age (Anderson et al., 2022; Carrera et al., 2008; Farrell et al., 2011; Kvale et al., 2022; Marcellin-Little et al., 1994; Sanchez Villamil et al., 2020; Schettler et al., 2022). The age at which humeral condylar fusion should be complete is frequently attributed to work performed by Hare (Hare, 1959, 1961; Lesbre, 1897; Schaeffer, 1934; Seoudi, 1948) or Chapman (1965). Hare describes the variance in appearance of ossification centres rather than fusion thereof. Chapman (1965) reports that epiphyseal closure occurred between 19 and 33 weeks of age in three Beagles. As such the origin of the frequently quoted 8 to 12 weeks remains unclear. While small case numbers and breed variation limit direct comparisons, the age range reported by Chapman (1965) more closely aligns with the results of this case series than the commonly reported fusion time of 8 to 12 weeks.

In cases where follow-up CT was available, 91.7% of HIFs identified in skeletally immature dogs fused, albeit later than the frequently referenced 8 to 12 weeks of age. Further research is required to establish the normal age range for humeral condylar ossification in different breeds. HCFs are commonly encountered in skeletally immature FBDs (Anderson et al., 2022; Sanchez Villamil et al., 2020; Smith et al., 2020). It is unclear whether this is the result of an underlying aetiology (such as delayed ossification of the humeral condyle or anatomic variance) which places them at an increased risk, or whether it is related to the increased popularity of the breed. Studies evaluating the age at which the centres of ossification appear in different breeds suggest that chondrodystrophic breeds complete ossification later than non-chondrodystrophic breeds (Chapman, 1965; Hare, 1959). However, these studies were conducted in the 1950s and 1960s and were limited by small sample sizes. The follow-up data in this study shows that the majority of HIFs diagnosed in FBDs under 12 months of age had fused at 4- to 8-week follow-up. The one FBD where the HIF did not fuse was only 6 months old at the time of final follow-up. It is possible that this HIF may have gone on to fuse if it had been given more time, and certainly the measurements performed reveal that this fissure was reducing in size, indicating progressive fusion. The potential for breed differences in ossification times is interesting and warrants further investigation as this may result in better understanding of the pathogenesis of HCFs, and therefore more definitive

guidelines on when to place prophylactic transcondylar screws. Although not the focus of this study, three of the FBDs diagnosed with contralateral HIF in this study were skeletally mature and, interestingly, the fissures were complete and were associated with intense sclerosis of the humeral condyle. Therefore, the potential remains in this breed for other pathogeneses (such as stress fracture), some of which may merit screw placement.

The limitations of this study include its retrospective nature. Additionally, there was a lack of blinding of the radiographic reviewers. Although this is the largest study to date evaluating HIFs in FBDs (Anderson et al., 2022; Sanchez Villamil et al., 2020; Smith et al., 2020; Strohmeier & Harris, 2021) the numbers are still relatively small. Finally, CT scans were exclusively accessible during routine clinical follow-up appointments and were conducted at non-standardised intervals.

Ideally, to document the typical timeline of ossification in this particular breed, a prospective study evaluating serial CT scans at regular intervals until the dogs reach skeletal maturity would be necessary.

In conclusion, this study documented that the majority of HIFs diagnosed in skeletally immature FBDs had healed by the time of the follow-up CT examination. Therefore, the placement of a prophylactic transcondylar screw may not be recommended in skeletally immature FBDs.

Author contributions

V. C. Hutchings: Collection of data, data analysis and interpretation, manuscript composition, final revision and approval of final manuscript. **S. Rutherford:** Study design, provision of data, analysis and interpretation of data, critical revision and approval of final manuscript.

[1]Conflict of interest

None of the authors of this article has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

Data availability statement

No data available. All the relevant data is inlcuded in the publication. Existing datasets are not publicly available due to privacy concerns.

References

Anderson, O.J., Langley-Hobbs, S.J. & Parsons, K.J. (2022) Humeral condylar fractures and fissures in the French bulldog. *Veterinary Surgery*, **52**, 134–145.

Butterworth, S.J. & Innes, J.F. (2001) Incomplete humeral condylar fractures in the dog. *Journal of Small Animal Practice*, **42**, 394–398.

Carrera, I., Hammond, G.J.C. & Sullivan, M. (2008) Computed tomographic features of incomplete ossification of the canine humeral condyle. *Veterinary Surgery*, **37**, 226–231.

Carwardine, D., Burton, N.J., Knowles, T.G., Barthelemy, N. & Parsons, K.J. (2021) Outcomes, complications and risk factors following fluoroscopically guided transcondylar screw placement for humeral intracondylar fissure. *Journal of Small Animal Practice*, **62**, 895–902.

Chapman, W.L. (1965) Appearance of ossification centres and epiphyseal closures as determined by radiographic techniques. *Journal of the American Veterinary Medical Association*, **147**, 138–141.

Chase, D., Sul, R., Solano, M.A., Calvo, I., Joslyn, S. & Farrell, M. (2019) Short- and long-term outcome after transcondylar screw placement to treat humeral intracondylar fissure in dogs. *Veterinary Surgery*, **48**, 299–308.

Danielski, A. & Yeadon, R. (2022) Humero-anconeal elbow incongruity in spaniel breed dogs with humeral intracondylar fissure: arthroscopic findings. *Veterinary Surgery*, **51**, 117–124.

Danielski, A., Quinonero Reinaldos, I., Solano, M.A. & Fatone, G. (2024) Influence of oblique proximal ulnar osteotomy on humeral intracondylar fissure in 35 spaniel breed dogs. *Veterinary Surgery*, **53**, 287–301.

Denny, H.R. (1983) Condylar fractures of the humerus in the dog; a review of 133 cases. *Journal of Small Animal Practice*, **24**, 185–197.

Farrell, M., Trevail, T., Marshall, W., Yeadon, R. & Carmichael, S. (2011) Computed tomographic documentation of the natural progression of humeral intracondylar fissure in a cocker spaniel. *Veterinary Surgery*, **40**, 966–971.

Garland, B.W., Dumitru, E.A., Ororbia, A. & Oxley, B. (2023) Spontaneous resolution of a humeral intracondylar fissure in a skeletally immature French bulldog. *Veterinary and Comparative Orthopaedics and Traumatology*, **06**, e37–e40. Available from: https://doi.org/10.1055/s-0043-1762901

Hare, W.C.D. (1959) Radiographic anatomy of the canine pectoral limb. Part II. Developing limb. *Journal of the American Veterinary Medical Association.*, **135**, 303–310.

Hare, W.C.D. (1961) The ages at which the centres of ossification appear roentgenographically in the limb bones of the dog. *American Journal of Veterinary Research*, **22**, 825–835.

Jenkins, G. & Moores, A.P (2022) Medial epicondylar fissure fracture as a complication of transcondylar screw placement for the treatment of humeral intracondylar fissure. *Veterinary Surgery*, **51**, 600–610.

Kvale, E., Kalmukov, I., Grassato, L., Kalff, S. & Solano, M. (2022) Epicondylar plate fixation of humeral condylar fracture in immature French bulldogs: 45 cases (2014-2020). *Journal of Small Animal Practice*, **63**, 532–541.

Lesbre, F.X. (1897) Contribution à l'étude de l'ossification du squelette des mammifères domestiques. *Annales de la Société Agriculture Lyon*, **5**, 1–106.

Low, D., Hutchings, V. & Rutherford, S. (2024) Long-term outcome and complications after transcondylar screw placement for canine humeral intracondylar fissure. *Veterinary and Comparative Orthopaedics and Traumatology*. Advance online publications. https://doi.org/10.1055/s-0043-1777808

Marcellin-Little, D.J., DeYoung, D.J., Ferris, K.K. & Berry, C.M. (1994) Incomplete ossification of the humeral condylar in spaniels. *Veterinary Surgery*, **23**, 475–487.

McCarthy, J., Woods, S. & Mosley, J.R. (2020) Long-term outcome following management of canine humeral intracondylar fissure using a medial approach and a cannulated drill system. *Veterinary Record*, **186**, 490–497.

Meyer-Lindenberg, A., Heinen, V., Fehr, M. & Notle, I. (2002) Incomplete ossification of the humeral condyle as a cause of lameness in dogs. *Veterinary and Comparative Orthopaedics and Traumatology*, **15**, 187–194.

Moores, A.P (2021) Humeral intracondylar fissure in dogs. *Veterinary Clinics of North America: Small Animal Practice*, **51**, 421–437.

Moores, A.P & Moores, A.L. (2017) The natural history of humeral intracondylar fissure: an observational study of 30 dogs. *Journal of Small Animal Practice*, **58**, 337–341.

Sanchez Villamil, C., Phillips, A.S.J., Pegram, C.L., O'Neill, D.G. & Meeson, R.L. (2020) Impact of breed on canine humeral condylar fracture configuration, surgical management, and outcome. *Veterinary Surgery*, **49**, 639–647.

Schaeffer, H. (1934) Die ossifikationsvorgönge im gleidmassenskelett des hundes. *Gengenbaurs Jb*, **74**, 472–514.

Schettler, M., Cassel, N., Elliot, R.C., Fosgate, G.T., Schettler, K. & Biller, D. (2022) A prevalence study of canine humeral condylar fracture over a ten-year period at an academic teaching hospital. *Veterinary and Comparative Orthopaedics and Traumatology*, **35**, 191–197.

Seoudi, R. (1948) X-ray examination of epiphyseal union as an aid to the estimation of the age in dogs. *The British Veterinary Journal*, **103**, 150–155.

Smith, M.A.J., Jenkins, G., Dean, B.L., O'Neill, T.M. & Macdonald, N.J. (2020) Effect of breeds as a risk factor for humeral condylar fracture in skeletally immature dogs. *Journal of Small Animal Practice*, **61**, 374–380.

Strohmeier, U.W. & Harris, K.P (2021) Humeral intracondylar fissures in French bulldogs. *Veterinary Record*, **189**, e504.

Witte, P.G., Bush, M.A. & Scott, H.W. (2010) Propagation of a partial incomplete ossification of the humeral condyle in an American cocker spaniel. *Journal of Small Animal Practice*, **51**, 591–593.