BSAVA

ORIGINAL ARTICLE

Bilateral surgery of humeral intracondylar fissures and humeral condylar fractures is associated with increased complication rates

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Objectives: To compare the postoperative complication rates and outcomes of client-owned dogs treated surgically for humeral intracondylar fissures and/or humeral condylar fractures either as unilateral or bilateral simultaneous procedures.

Materials and Methods: Hospital records from a single referral centre in the United Kingdom were reviewed retrospectively. Dogs were categorised into the unilateral and bilateral groups and then further subdivided according to the surgical procedure performed. Clinical follow-up and a client evaluation scheme were used to identify complications and assess functional outcomes.

Results: Medical records of 75 skeletally mature dogs met the inclusion criteria. The overall complication rate was 36.0%. There was a 1.57-fold increase in the complication rate in bilateral humeral intracondylar fissure compared to unilateral humeral intracondylar fissure and a 2.22-fold increase in humeral intracondylar fissure/humeral condylar fracture compared to unilateral humeral condylar fracture. When minor complications were excluded, the complication rate for bilateral surgeries overall was double that of unilateral procedures. Major surgical complications predominated in the bilateral groups, while major medical complications predominated in the unilateral groups. Surgical site infection was 1.68-fold more prevalent in bilateral humeral intracondylar fissure compared to unilateral humeral intracondylar fissure and 4.45-fold more prevalent in bilateral humeral intracondylar fissure/humeral condylar fracture than in unilateral humeral condylar fracture. Unilateral humeral intracondylar fissure and humeral condylar fracture consistently outperformed the bilateral procedures in functional recovery. Across all bilateral groups, no postoperative complications were detected in the prophylactically treated limb.

Clinical Significance: Single-stage bilateral surgery is associated with markedly increased complication rates, particularly in bicondylar fractures. Delaying intervention on the prophylactic limb until the onset of clinical signs might be considered due to higher complication rates in single-stage procedures.

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INTRODUCTION

Fractures of the humeral condyle (HCFs) account for 41% of humeral fractures in dogs and may be classified as lateral condylar (56% to 67%), medial condylar (4% to 16%) or bicondylar (33% to 58%) (Bardet et al., 1983; Cockett & Jones, 1985; Denny, 1983; Gluding et al., 2022; Rørvik, 1993; Vannini et al., 1988). Typical management of HCF comprises placement of a transcondylar screw (TCS) combined with an anti-rotational plate or pin along the fractured supracondylar crest(s). Supracondylar plate placement has been associated with a lower complication rate than pin fixation, estimated at 7% to 15% (Eayrs et al., 2021; García et al., 2020; Martini et al., 2022; Moffatt et al., 2019; Perry et al., 2015). In skeletally mature dogs, HCFs often arise secondary to a humeral intracondylar fissure (HIF). A HIF is a slit-like lesion in a midsagittal plane of the humeral condyle, usually surrounded by dense sclerotic bone (Moores, 2021). The aetiology of this condition remains unclear, although it may be related to incomplete ossification of the humeral condyle, repetitive mechanical overload and/or humero-anconeal incongruity (Danielski & Yeadon, 2022; Farrell et al., 2011; Marcellin-Little et al., 1994; Meyer-Lindenberg et al., 2002; Moores & Moores, 2017; Walton et al., 2020). Irrespective of whether HIF develops as a failure of ossification, fatigue fracture or both, the underlying conformational predisposition might be the same (Moores, 2021).

Based on the published evidence (Martin et al., 2010; Moores & Moores, 2017), some surgeons may elect to screen dogs with a clinically significant HIF or HCF for contralateral HIF and recommend prophylactic stabilisation. However, multiple studies have reported high overall complication rates following TCS placement of 15% to 59.5%, with surgical site infection (SSI) and seroma formation being the most frequently reported complications (prevalences of up to 30% to 42% and 32%, respectively) (Chase et al., 2019; Hattersley et al., 2011; Walton et al., 2020). Moreover, the development of complications has been reported to significantly affect the functional outcome (Chase et al., 2019). Given the high complication rate following TCS placement and its effect on functional outcomes, some surgeons may elect not to proceed with prophylactic stabilisation of a HIF in a limb where no overt clinical signs are present. Instead, they may prefer to await the onset of lameness or fracture before pursuing surgery. As SSI is the most common complication following TCS placement, and as the rate of SSI has previously been shown to be negatively influenced by the duration of anaesthesia (Frey et al., 2010; Fuertes-Recuero et al., 2025), other surgeons may elect to perform staged bilateral surgery. These decisions impact on the duration of the patient's recovery, the number of anaesthetic episodes and client costs; yet, to the authors' knowledge, no investigation has been performed into the complication rates and outcomes following unilateral versus bilateral surgery of HIF and/or HIF/HCF.

This study aimed to compare the postoperative complication rates and overall outcomes of client-owned dogs treated surgically for either unilateral or bilateral concurrent procedures. We hypothesise that dogs treated with single-stage bilateral surgery (*i.e.*, contralateral TCS placement in asymptomatic HIF or concurrent HIF stabilisation at the time of HCF repair) exhibit a greater incidence of postoperative complications compared to those undergoing a single limb procedure.

MATERIALS AND METHODS

Data collection

Hospital records (October 2018 to December 2023) from a single referral centre in the United Kingdom were retrieved retrospectively to identify dogs over 12 months of age presented for surgical treatment of HIF, HCF or both. The analysed data included signalment (age, sex/neuter status, breed and body weight), history, clinical examination findings, imaging findings (radiography and/or computed tomography), diagnosis, surgical technique and results of follow-up examinations.

Medical records of 79 skeletally mature dogs in which a HIF or HCF were stabilised were identified. Three dogs were excluded from the study due to the lack of both clinical and questionnaire follow-up data. A single dog with bilateral HCF was also excluded, resulting in 75 dogs meeting the inclusion criteria. Seven of the 75 dogs included in the study were deceased at the time of data collection; four of these dogs were euthanised for reasons unrelated to the surgery. As detailed in Fig 1, the dogs were divided into groups based on the surgical procedure performed. Dogs with HIF were divided into two subgroups: unilaterally treated HIF and bilaterally treated HIF. The dogs presented with HCF were divided into four subgroups: unicondylar HCF with a contralaterally treated HIF (HIF/UCF), bicondylar HCF with a contralaterally treated HIF (HIF/BCF), unilateral unicondylar HCF (UCF) and unilateral bicondylar HCF (BCF). Additionally, the overall complication rate between the unilateral surgery and bilateral concurrent surgery was compared. A client

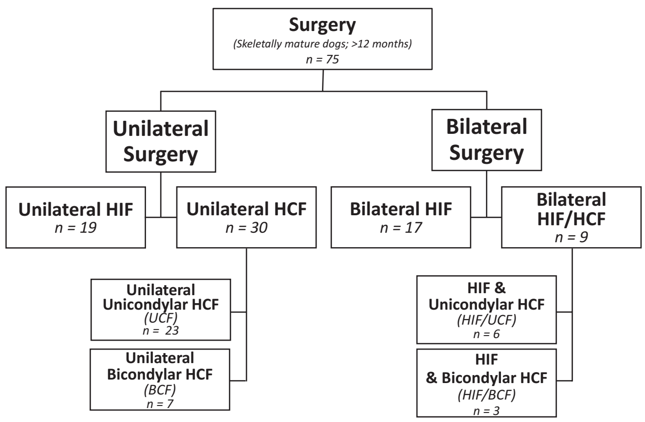

FIG 1. Algorithm for clinical classification of surgical interventions. The algorithm outlines the systematic grouping of procedures into categories based on the surgery performed. Criteria for classification included radiographic findings, surgical approach and implant selection. HCF Humeral condylar fractures; HIF Humeral intracondylar fissure.

evaluation scheme was conducted, and the clients were contacted over the phone using a unitary questionnaire (Table Q1). Questions were designed to identify complications and patient outcomes.

Terminology

For the purpose of this study, follow-up was defined as postoperative (0 to 3 months), short- (3 to 6 months), medium- (6 to 12 months) or long-term (>12 months). Definitions of postoperative complications (minor, major medical or surgical, and catastrophic), SSI, and functional and final outcomes were based on previously published criteria (Carrera et al., 2008; Cook et al., 2010; Weese, 2008; Yin et al., 2023). More specifically, minor complications required no treatment, major complications needed intervention and catastrophic complications resulted in amputation or euthanasia.

Surgical procedure

All surgeries were performed by one of nine board-certified surgeons. The anaesthetic protocol was determined according to individual patient requirements by the attending board-certified anaesthetist. During general anaesthesia, multiparameter monitoring in compliance with the hospital protocols was implemented, and readings were recorded in 5-minute intervals. All dogs were administered intravenous antibiotics (22 mg/kg cefuroxime, Zinacef 750 mg, Glaxo Operations UK Limited) at a minimum of 30 minutes before the surgical incision and repeated every 90 minutes until the skin closure. Limbs were clipped and aseptically prepared for surgery according to hospital protocols.

For HCF, standard surgical approaches were made to the humeral condyle and distal humerus, and the approaches were extended proximally as required (Brinker et al., 2014). Approaches were either lateral, medial or both, depending on fracture configuration. No ulnar osteotomies or triceps tenotomies were performed. Fractures were reduced and stabilised according to AO principles (Turner, 2005). Supracondylar locking compression plates (LCPs) were placed in all dogs with HCF. The implant sizes and modes of placement of TCS were chosen at the surgeons' discretion. All dogs in which unilateral or bilateral HIF was diagnosed were treated surgically. All HIFs were stabilised using a medial to lateral transcondylar screw following a small approach to the medial humeral epicondyle (Brinker et al., 2014). The type, mode (positional vs. lag screw), size and method of screw placement (freehand, intraoperative imaging, aiming device) were dictated by the operating surgeon. For both HCF and HIF, routine layered closure was performed, and an adhesive, absorbent dressing was placed (Primapore; Smith & Nephew, Hertfordshire, UK). Postoperative orthogonal radiographs were obtained for all dogs to ensure acceptable apposition, alignment and apparatus. The dogs were discharged from the hospital when comfortable, usually within 24 to 48 hours. The clients were instructed to administer nonsteroidal anti-inflammatory drugs in all dogs. Exercise restriction for 6 to 8 weeks was prescribed in all dogs. Postoperative antibiotics were dispensed prophylactically at the surgeons' discretion.

Data analysis

Descriptive statistics and tables were created in R version 4.4.2 (R Core Team, 2024). Age, body weight and questionnaire follow-up time were assessed for normality using the Shapiro–Wilk test. Numerical and categorical data describing the cohort were presented as medians, ranges and proportions. Data points were rounded to one decimal place. For one dog with planned, staged bilateral procedures, each limb surgery was considered an independent dog. A *post hoc* power analysis was performed for each of the planned statistical tests using the pwr.chisq.test() function from the pwr package (Champely, 2020); in all cases, the sample size was underpowered to detect a moderate effect size (Cramer's *V*). Effect sizes ranged from 0.098 to 0.298, and power ranged from 7.7% to 35.7%. The significance level was set at 0.05 and degrees of freedom ranged from 1 to 2. Due to small effect sizes and low power from the *post hoc* power calculations, only descriptive statistics are reported here.

RESULTS

Analysed data

Of the 75 dogs, 49 underwent a single limb intervention and 26 underwent bilateral surgery. Unilateral and bilateral HIFs were stabilised in 19 and 17 dogs, respectively. Of nine dogs with HCF and contralateral HIF, six were unicondylar and three were bicondylar fractures. Unilateral HCF was repaired in 30 dogs (23 unicondylar and seven bicondylar). All dogs in the unilateral groups were presented with lameness. In the bilateral groups, 96.2% (25/26) of dogs were presented with unilateral lameness. One dog with bilateral HIF was presented without lameness but demonstrated left-sided and mild right-sided elbow discomfort on orthopaedic examination.

There were 33 male entire, seven female entire, 20 male neutered and 15 female neutered dogs. The age of dogs diagnosed with HIF ranged from 12 to 118 months (median 44), and their body weight ranged from 4.2 to 34.5 kg (median 19.1). Dogs diagnosed with HCF or HIF/HCF ranged in age from 12 to 153 months (median 52.0) and in body weight from 4.78 to 40.5 kg (median 18.0). Among dogs with HIF, the majority of dogs were spaniel breeds or their crosses (27/36). The non-spaniel breeds consisted of Labrador Retrievers ($n=3$), German Shepherd Dogs ($n=2$), Border Collie ($n=1$), Yorkshire Terrier ($n=1$) and two crossbreeds. Among dogs with HCF, the majority of dogs were spaniel breeds or their crosses (30/39). The non-spaniel breeds consisted of French Bulldogs ($n=4$), Pug ($n=1$), Vizsla ($n=1$), Labrador Retriever ($n=1$) and two crossbreeds.

Complications

No complications were encountered in 48/75 dogs (64.0%), giving an overall complication rate of 36.0% (Fig 2). Complication rates were 28.6% (14/49) in unilateral and 50.0% (13/26) in bilateral procedures, irrespective of diagnosis (Table 1). In total, the complication rate was 33.3% (12/36) for dogs operated only for HIF (either unilateral or bilateral) and 38.5% (15/39) for all dogs with HCF (unilateral and those with a surgically treated contralateral HIF). Among dogs treated for HIF, the complication rate was 26.3% (5/19) in unilateral HIF and 41.2% (7/17) in bilateral HIF. Among dogs diagnosed with unilateral HCF, the complication rate was 26.1% (6/23) in UCF and 42.9% (3/7) in BCF (Table 2). In bilateral HIF/UCF dogs, the complication rate was 50.0% (3/6) and 100.0% (3/3) in HIF/BCF. When comparing the unilateral HCF and bilateral HIF/HCF groups, the complication rates were 30.0% (9/30) and 66.7% (6/9), respectively. The stratified comparison of complications is demonstrated in Figs 3 and 4 and Tables 3 and 4.

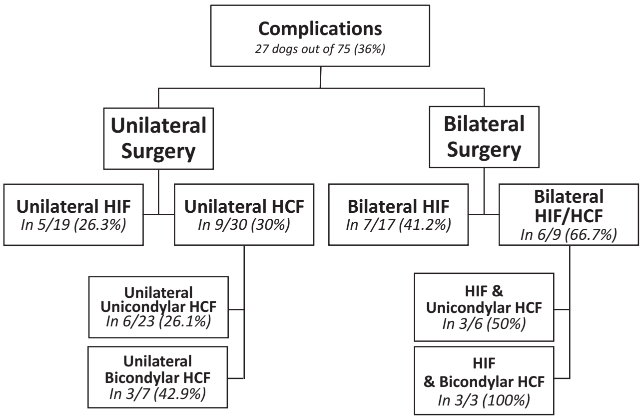

FIG 2. Distribution and prevalence of postoperative complications. The total number of dogs with reported postoperative complications is incorporated into the schematic to illustrate their prevalence (%) and distribution across surgical groups and subgroups. HCF Humeral condylar fractures; HIF Humeral intracondylar fissure.

Interestingly, across all bilateral groups, no postoperative complications were detected in the prophylactically treated limb, as in all but one dog, complications occurred exclusively in the limb affected by lameness. The exception was a dog that developed a minor complication bilaterally and initially presented with bilateral elbow pain without apparent lameness.

Surgical site infection

Surgical site infection was diagnosed in 12/75 dogs (16.0%), comprising 44.5% (12/27) of all complications. Five dogs (10.2%) in unilateral and seven dogs (26.9%) in the bilateral groups developed SSI. The infection rate was 10.5% (2/19) in unilateral HIF and 17.6% (3/17) in bilateral HIF, with SSI accounting for 40% (2/5) and 42.9% (3/7) of complications, respectively. For unilateral HCF, the infection rate was 10% (3/30), compared with 44.5% (4/9) in bilateral HIF/HCF dogs, with SSI forming 33.3% (3/9) and 66.7% (4/6) of complications, respectively. Of the 12 dogs with SSI, nine (75%) were dispensed postoperative antibiotics (Table 3).

Outcomes

Clinical follow-up (0 to 3 months) was available for 69/75 dogs (92.0%) overall. Clinical follow-up was conducted in all unilateral HIF dogs and 94.1% (16/17) of bilateral HIF dogs. In unilateral HIF, nine (47.4%), eight (42.1%) and two dogs (10.5%) achieved full, acceptable and unacceptable functions, respectively (Fig 5). In bilateral HIF, nine (56.3%), four (25%) and three dogs (18.8%) achieved full, acceptable and unacceptable functions, respectively. In dogs with HCF

Table 1. Postoperative complication rates by diagnosis and surgery

	Surgical group	Number of dogs (*n*)	Dogs with complications (*n*)	Dogs with major surgical complications (*n*)	Dogs with major medical complications (*n*)	Major complication rate (%)	Complication rate (%)
	Total	**75**	**27**	**9**	**6**	**20**	**36.0**
Surgical approach	Unilateral	49	14	1	5	12.2	28.6
	Bilateral	26	13	8	1	34.6	50.0
Diagnosis	HIF	36	12	6	3	25.0	33.3
	HCF or HIF/HCF	39	15	3	3	15.4	38.5
Procedure	Unilateral HIF	19	5	1	3	21.1	26.3
	Bilateral HIF	17	7	5	0	29.4	41.2
	Unilateral HCF	30	9	0	2	6.7	30.0
	Bilateral HIF/HCF	9	6	3	1	44.4	66.7

Postoperative complication rates in dogs treated surgically for HIF and/or HCF, performed as either unilateral or single-stage bilateral concurrent procedures, stratified by surgical approach, diagnosis and procedure type. Values are reported as number of dogs (*n*) and percentages (%)
HCF Humeral condylar fractures, HIF Humeral intracondylar fissure, HIF/HCF Unilateral humeral condylar fractures with contralateral humeral intracondylar fissure

Table 2. Postoperative complications rates by surgery subgroup

Group (*n*)	Subgroup	Number of dogs (*n*)	Dogs with complications (*n*)	Major complication rate (%)	Complication rate (%)
Unilateral (49)	HIF	19	5	21.1	26.3
	UCF	23	6	4.3	26.1
	BCF	7	3	14.3	42.9
Bilateral (26)	HIF	17	7	29.4	41.2
	HIF/UCF	6	3	33.3	50.0
	HIF/BCF	3	3	66.7	100.0

Postoperative complication rates in dogs treated surgically for HIF and/or HCF, stratified by surgical subgroup. Values are reported as number of dogs (*n*) and percentages (%)
BCF Bicondylar humeral condylar fracture, HIF Humeral intracondylar fissure, HIF/BCF Unilateral humeral intracondylar fissure with contralateral bicondylar humeral condylar fracture, HIF/UCF Unilateral humeral intracondylar fissure with contralateral unicondylar humeral condylar fracture, UCF Unicondylar humeral condylar fracture

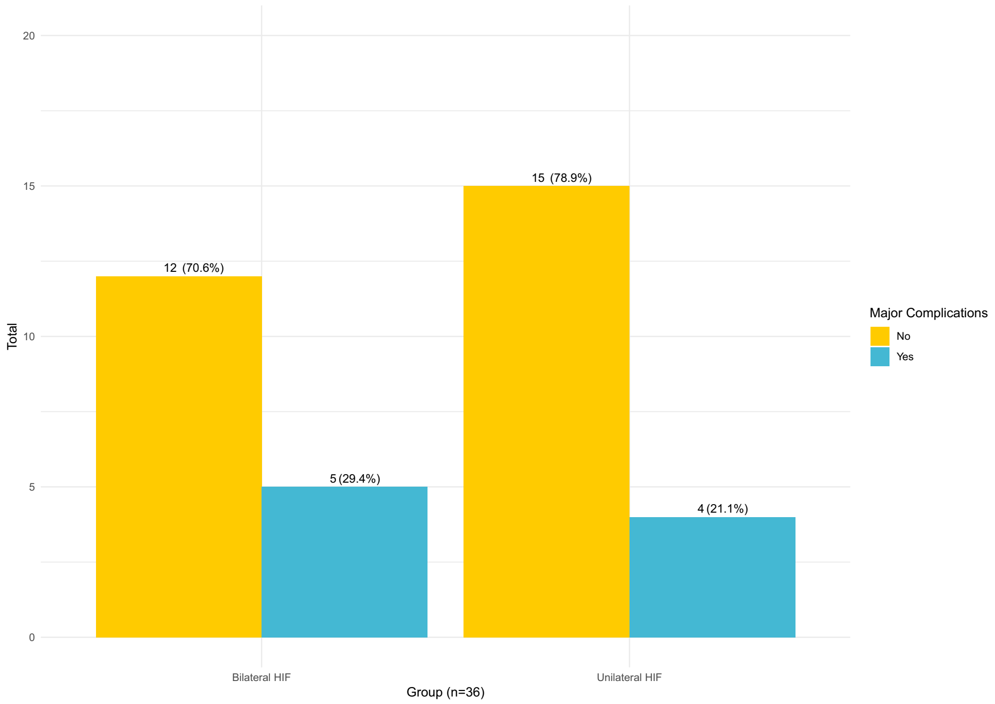

FIG 3. Distribution of major postoperative complications in dogs treated surgically for humeral intracondylar fissures (HIFs), stratified by procedure side. Bars represent the number of dogs with and without major complications and are expressed as percentages.

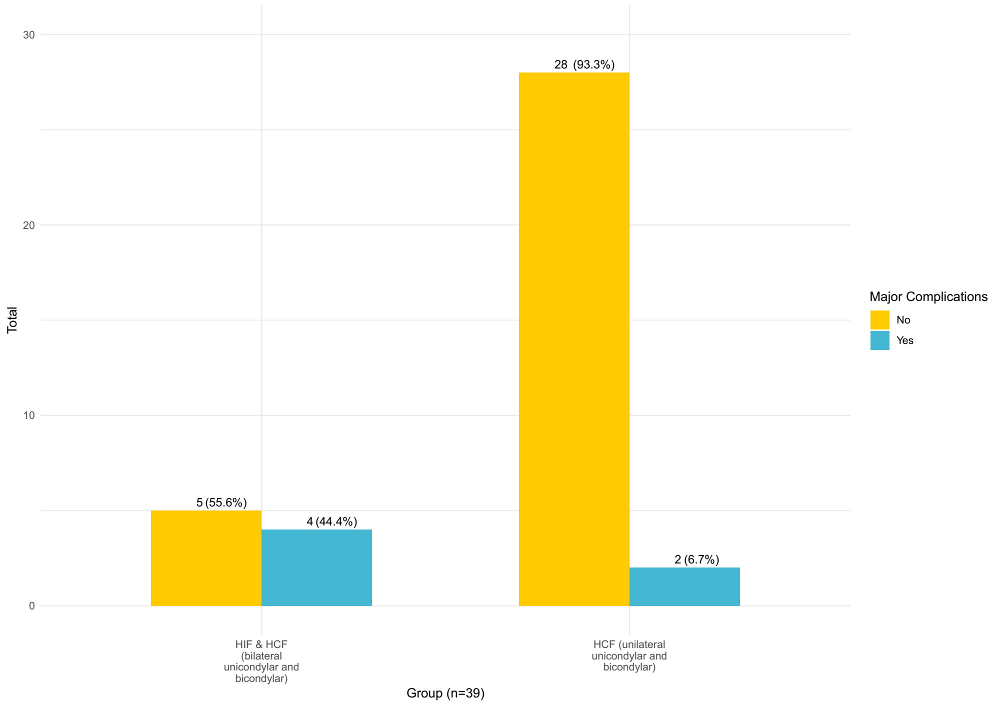

FIG 4. Distribution of major postoperative complications in dogs treated surgically for humeral condylar fractures (HCFs), stratified by procedure side. Bars represent the number of dogs with and without major complications and are expressed as percentages. HIF Humeral intracondylar fissure.

and HIF/HCF, it was conducted in 86.7% (26/30) of unilateral and 88.9% (8/9) bilateral dogs. In unilateral HCF, full function was achieved in 12 (46.2%) dogs, while acceptable and unacceptable functions were recorded in 11 (42.3%) and three (11.5%) dogs, respectively (Fig 6). In bilateral dogs, full function was achieved in two (25%) dogs, while acceptable and unacceptable functions were experienced in three (37.5%) and three (37.5%) dogs, respectively.

The client questionnaire was obtained in 47/75 dogs (62.7%) overall. The short-, medium- and long-term follow-ups were

Table 3. Postoperative complications: subgroup analysis by complication type

Group (*n*)	Subgroup	Total complications (*n*)	Complication rate (%)	Minor	Major medical	Major surgical	Catastrophic	SSI	ABs
Unilateral (49)	HIF (19)	5	26.3	0	3 (60.0%)	1 (20.0%)	1 (20.0%)	2 (10.5%)	10 (52.6%)
	UCF (23)	6	26.1	3 (50.0%)	1 (16.7%)	0	2 (33.3%)	2 (8.7%)	13 (56.5%)
	BCF (7)	3	42.9	1 (33.3%)	1 (33.3%)	0	1 (33.3%)	1 (14.3%)	6 (85.7%)
Bilateral (26)	HIF (17)	7	41.2	2 (28.6%)	0	5 (71.4%)	0	3 (17.6%)	14 (82.4%)
	HIF/UCF (6)	3	50.0	1 (33.3%)	1 (33.3%)	1 (33.3%)	0	1 (16.7%)	5 (83.3%)
	HIF/BCF (3)	3	100.0	0	0	2 (66.7%)	1 (33.3%)	3 (100.0%)	3 (100.0%)

Prevalence of postoperative complications in dogs treated surgically for HIF and/or HCF, stratified by surgical subgroup and complication type, based on previously described criteria (Cook et al., 2010). Values are reported as number of dogs (*n*) and percentages (%). Surgical site infection (SSI) is presented as a distinct complication, with postoperative antibiotic use reported for contextual interpretation

ABs Dogs discharged with postoperative oral antibiotics, BCF Bicondylar humeral condylar fracture, HCF Humeral condylar fracture, HIF Humeral intracondylar fissure, HIF/BCF Unilateral humeral intracondylar fissure with contralateral bicondylar humeral condylar fracture, HIF/UCF Unilateral humeral intracondylar fissure with contralateral unicondylar humeral condylar fracture, SSI Surgical site infection, UCF Unicondylar humeral condylar fracture

Table 4. Type postoperative complications by groups

Group	Complication	Number of dogs (*n*)
Unilateral HIF	Euthanasia due to septic arthritis	1
	Intra-articular long-acting glucocorticoid injection	2
	Requirement for systemic antibiotics	1
	Surgically treated seroma	1
Bilateral HIF	Aseptic loosening	2
	Self-limiting low-grade lameness	1
	Septic loosening	2
	Seroma	1
	Wound dehiscence	1
Unilateral HCF	Delayed wound healing	1
	Implant failure	1
	Low-grade lameness	1
	Low-grade lameness and delayed wound healing	1
	Septic implant loosening	1
	Seroma	1
	Surgical site infection requiring systemic antibiotic treatment	2
	Wound dehiscence	1
Bilateral HIF/HCF	Low-grade lameness (treated with intra-articular long-lasting glucocorticoid injection)	1
	Septic implant loosening	4
	Seroma	1

Types of postoperative complications observed in dogs treated surgically for HIF and/or HCF, stratified by surgical group. Values are reported as the number of dogs (*n*) experiencing each complication

HCF Humeral condylar fractures, HIF Humeral intracondylar fissure, HIF/HCF Unilateral humeral condylar fractures with contralateral humeral intracondylar fissure

collected in three, nine and 35 dogs, respectively (range: 3 to 62 months; median 24). In the unilateral HIF group, one (10%), six (60%) and three dogs (30%) attained full, acceptable and unacceptable functions, respectively. In bilateral HIF, full and acceptable functions were achieved in six (60%) and four (40%) dogs, respectively. In unilateral HCF, full function was observed in 14 (66.7%) dogs, while acceptable and unacceptable functions were experienced in six (28.6%) and one (4.8%) dogs, respectively. In bilateral HIF/HCF dogs, full function was not achieved in any dog, and acceptable and unacceptable functions were noted in five (83.3%) and one sole dog (16.6%), respectively.

The overall final outcome was concluded as excellent in 42/75 dogs (56.0%), good in 23/75 dogs (30.7%), fair in 4/75 dogs (5.3%) and poor in 6/75 dogs (8.0%) (Table 5). This study found an excellent or good outcome in 65/75 (86.7%) of dogs overall. In dogs where the client questionnaire was not conducted, the clinical follow-up was used to establish the final outcome. No dogs in the unilaterally operated groups had surgery for either HIF or HCF on the contralateral limb during the study period.

DISCUSSION

Despite evidence of fissure propagation (Witte et al., 2010) and reports of a 14% prevalence of HIF in non-clinical dogs and an 18% risk of subsequent HCF within 2 years (Moores, 2021; Moores et al., 2012), there is no definitive consensus that asymptomatic HIFs should be treated surgically. This study represents the first comparative evaluation of postoperative complication rates and overall outcomes following unilateral versus bilateral surgery for HIF, HCF or HIF/HCF. The main finding of this study was an increased complication rate associated with single-stage bilateral procedures, confirming our hypothesis. Overall, complications were 1.75 times more frequent following bilateral surgery, increasing to approximately twofold when minor complications were excluded. Considering diagnosis, complication rates increased 1.57-fold for bilateral HIF and 2.22-fold for HIF/HCF.

The presented data indicate that HCF had a slightly higher complication rate (38.5%) than HIF (33.3%). However, and more importantly, dogs undergoing bilateral HIF/HCF surgery displayed an elevated complication rate (66.7%), exceeding that of bilateral HIF repairs (41.2%). This was most evident in dogs with bicondylar HCF across both subgroups (43% in unilateral BCF and 100% in HIF/BCF). Such a disparity likely reflects fundamental differences in surgical complexity between the two conditions. HIF stabilisation represents a prophylactic intervention before condylar failure, where bone architecture remains intact, allowing optimal screw purchase and mechanical stability with minimal iatrogenic trauma. In contrast, BCFs often involve substantial articular incongruity necessitating more complex fixation, which may be inherently

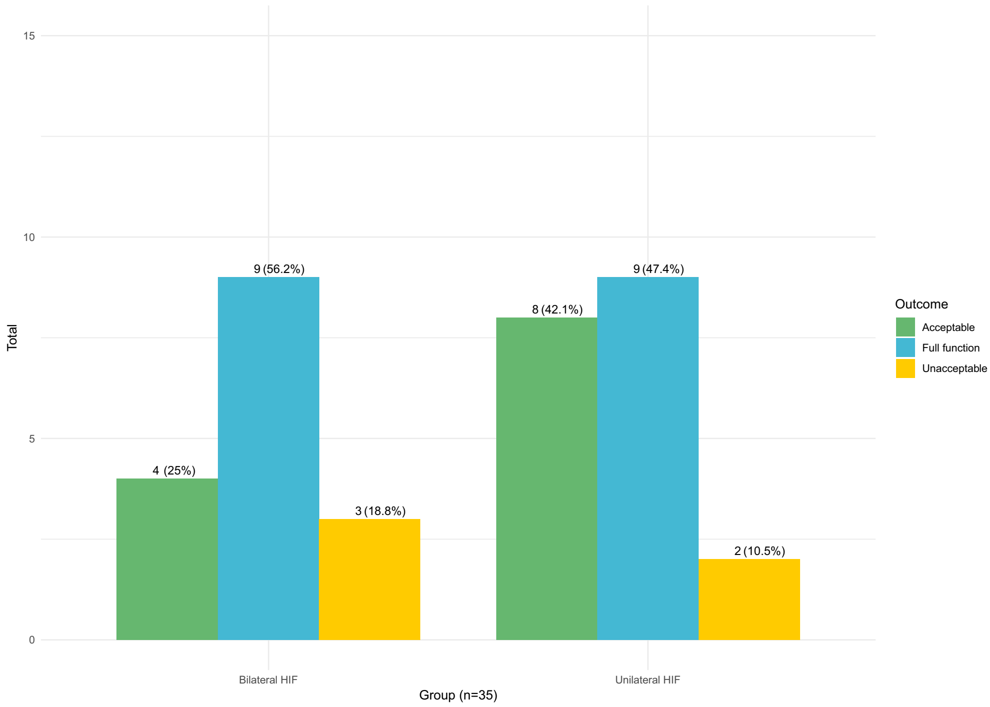

FIG 5. Clinical outcome (0 to 3 months) of humeral intracondylar fissures (HIFs) by procedure side. Clinical outcome encompassing in-person assessment up to 3 months postoperatively in dogs treated surgically for HIF, stratified by procedure side. Bars represent the number of dogs in each outcome category and are expressed as percentages.

less stable and more susceptible to implant failure. Moreover, chronic bone remodelling and sclerosis associated with pre-existing HIF may compound implant loading and instability, contributing to the higher complication rates observed in HIF/HCF dogs. Similarly, a clinically significant HIF is expected to demonstrate greater instability than a clinically silent HIF. This concern may be further amplified when a clinically significant HIF coexists with a contralateral HCF, as simultaneous bilateral intervention may increase postoperative mechanical demands. This speculation may be supported by the fact that all complications recorded in this study occurred in the clinically affected limb, suggesting that increased postoperative load during single-stage bilateral surgery may exert excessive mechanical stress on the repair, promoting micromotion and screw loosening. Screw loosening may occur independently or in association with SSI. Other contributing factors, including implant size, design (*e.g.*, cortical, locking and other designs), mode (*i.e.*, positional versus lag) or side of placement, were not assessed and fall beyond the scope of this study. Additionally, general anaesthetic and surgical durations are typically longer for HCF repairs. Prolonged anaesthetic and operative times have been associated with increased complication rates, particularly SSI (Frey et al., 2010; Fuertes-Recuero et al., 2025), further underscoring the challenges inherent in managing concurrent HIFs and HCFs.

Multiple additional factors might have contributed to the elevated complication rates in the bilateral groups; however, as all complications occurred in the clinically affected limb, the conceivable influence of surgical fatigue, prolonged anaesthesia or two surgical approaches appears less likely. This contradiction would be particularly evident in dogs with HCF, in which the fractured limb is typically addressed before contralateral TCS placement. Collectively, our findings suggest that prophylactic HIF stabilisation with concurrent HCF repair warrants careful reconsideration, as this approach may impose an increased surgical burden without clear immediate benefit. A more conservative strategy, potentially involving staged intervention prioritising the fractured limb, particularly in cases of bicondylar HCF, may mitigate these risks, although careful case selection and individualised treatment planning remain essential. Further prospective studies are required to evaluate these speculations.

The overall complication rate of this cohort was high (36.0%) but comparable to reported rates of 15% to 59.5% (Carwardine et al., 2021, 2024; Chase et al., 2019; Hattersley et al., 2011; Jenkins & Moores, 2022; McCarthy et al., 2020; Moores et al., 2014). Yet notably, the incidence and distribution of major complications differed between the groups. Regardless of diagnosis, major complications were 1.75 times more frequent in bilateral dogs, with 88.9% being surgical, resulting in an approximately 5.3-fold increase in the need for further surgical intervention. Conversely, most major complications in unilateral dogs were medical (83.0%), with seroma representing the only surgical complication. As seromas are typically managed conservatively and may resolve without surgery, this group may otherwise have had no major surgical complications. Similar trends were observed when considering the diagnosis. Bilateral HIF was associated with a 3.57-fold higher incidence of major surgical complications, and dogs undergoing bilateral HIF/HCF carried a 50.0% risk of major

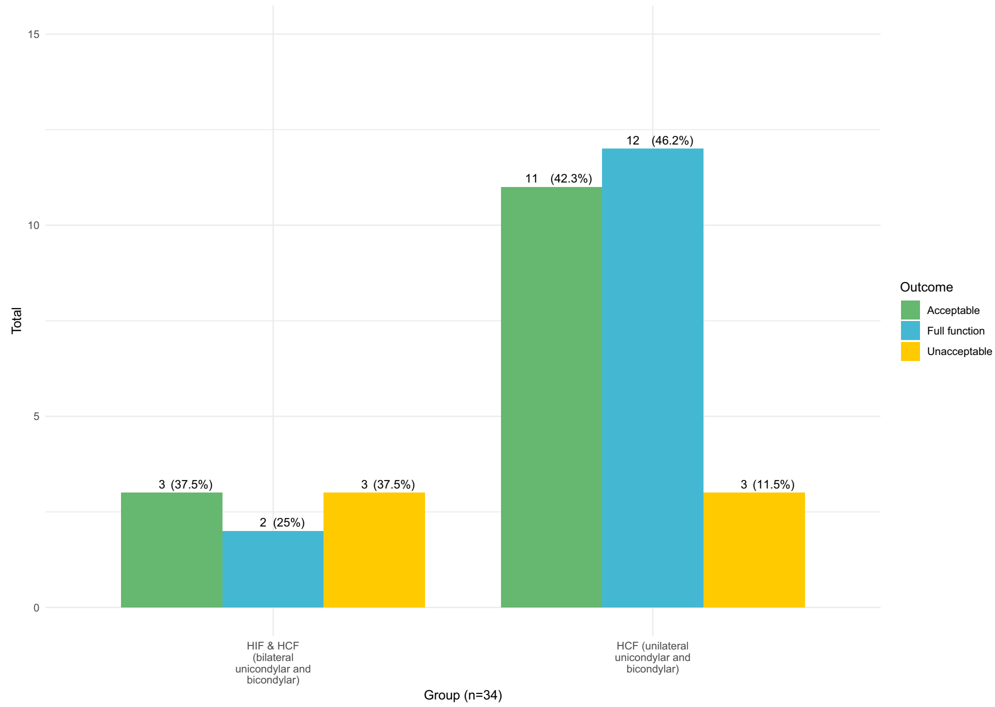

FIG 6. Clinical outcome (0 to 3 months) of humeral condylar fractures (HCFs) by procedure side. Clinical outcome encompassing in-person assessment up to 3 months postoperatively in dogs treated surgically for HCF, stratified by procedure side. Bars represent the number of dogs in each outcome category and are expressed as percentages. HIF Humeral intracondylar fissure.

Table 5. Summary of final procedure outcomes by surgery type

Procedure type	Subgroup	Total (*n*)	Excellent (%)	Good (%)	Fair (%)	Poor (%)
Unilateral procedures		49	55.1	28.6	8.2	8.2
Bilateral procedures		26	57.7	34.6	0	7.7
Unilateral HIF		19	52.6	21.1	21.1	5.3
Bilateral HIF		17	64.7	29.4	0	5.9
Unilateral HCF		30	56.7	33.3	0	10
	UCF	23	52.2	34.8	0	13.0
	BCF	7	71.4	28.6	0	0
Bilateral HIF/HCF		9	44.4	44.4	0	11.1
	UCF	6	50.0	33.3	0	16.7
	BCF	3	33.3	66.6	0	0
Total		75	56.0	30.7	5.3	8.0

Final procedure outcomes in dogs treated surgically for HIF and/or HCF, stratified by comparison of unilateral versus single-stage bilateral surgery. Outcomes are reported as percentages within each group and subgroup
BCF Bicondylar humeral condylar fracture, HCF Humeral condylar fractures, HIF Humeral intracondylar fissure, UCF Unicondylar humeral condylar fracture

surgical complications. Five dogs experienced catastrophic complications, and grouping major and catastrophic events continued to favour unilateral procedures. The most common minor complications were seroma formation and low-grade, self-limiting lameness, the latter being infrequently reported in previous studies compared with seroma and SSI (Carwardine et al., 2021, 2024; Chase et al., 2019; Hattersley et al., 2011; McCarthy et al., 2020; Moores et al., 2014).

Analysis of SSI demonstrated higher infection rates in bilateral dogs, despite most being discharged with postoperative antimicrobials, with rates 67% higher in bilateral HIF and 345% higher in bilateral HIF/HCF. The use of postoperative antimicrobials in veterinary orthopaedic surgery remains contentious, with inconsistent evidence of benefit (Aiken et al., 2015; Spencer & Daye, 2018), and intraoperative prophylaxis alone is generally considered sufficient for clean procedures involving implants (Välkki et al., 2020). In the light of rising antimicrobial resistance and the absence of an apparent protective effect in this cohort, discontinuation of postoperative antimicrobials may be appropriate, and omission in selected cases, such as minimally invasive TCS placement, warrants further investigation (Schmökel et al., 2021). The SSI rate in this study was 16.0%, accounting for 44.5% of all complications, representing a lower incidence than recently reported rates, which remain as high as 42.3% (Potamopoulou et al., 2023). SSI in dogs with HIF remains challenging to manage due to persistent fissures following TCS placement. Consequently, if implant replacement is required, the risk of infection persists. Alternative techniques, such as proximal ulnar osteotomy, avoid transcondylar implants but remain controversial (Danielski et al., 2024). Given the approximately

2.64-fold higher SSI rate in bilateral dogs in this study and its association with poorer outcomes (Chase et al., 2019), a single-stage bilateral approach appears less appealing.

The presented findings challenge commonly adopted recommendations for prophylactic intervention in non-clinical limbs based on reported HIF progression and fracture risk (Moores, 2021; Moores et al., 2012; Witte et al., 2010). Overall, prophylactic contralateral surgery in this study was associated with increased complication rates without a clear reduction in the subsequent need for contralateral surgical intervention. Prospective clinical research involving regular contralateral limb surveillance is warranted to better define the long-term benefits and indications for surgery in asymptomatic limbs.

Two key limitations should be acknowledged. First, the retrospective design relied on clinical records with limited standardisation, no randomisation and surgical decision-making influenced by clinical and imaging findings, including contralateral HIF appearance. Additional bias may have arisen from surgeon-specific preference and experience, predefined treatment plans, and intra- and interobserver variability among assessors, clinicians or clients. Moreover, inconsistent imaging protocols (not all unilateral HCF dogs underwent CT), variable radiographic follow-up and intervals (6 to 269 weeks) and absence of objective lameness scoring may have resulted in unrecognised or misinterpreted complications. The second key limitation represents the lack of a staged bilateral intervention group, necessitating further comparative research. Additionally, prophylactic screening of the contralateral limb following unilateral HIF diagnosis was not performed, rendering it speculative whether de novo lesions might have been detected. Moreover, bacteriological confirmation was not available for all SSI cases. In addition, concurrent procedures, such as elbow arthroscopy, were performed in some dogs, but their impact is beyond the scope of this study. Furthermore, data derived from the non-validated questionnaire used in this study should be interpreted with caution. Finally, the small sample size restricted the analysis to descriptive statistics, precluding inference of causality or population-level associations and potentially oversimplifying the data, while introducing assumptions regarding data distribution and collection. However, given the underpowered design, more comprehensive statistical analyses would likely yield unreliable conclusions.

In summary, simultaneous bilateral surgery of HIF and HCF is associated with increased complication rates compared to unilaterally operated cases. Delaying surgical intervention of the prophylactic limbs or awaiting the clinical onset is an alternate and appropriate strategy that may reduce the risk of complications and, potentially, avoid surgery on the contralateral limb entirely. Such an approach may be especially prudent in bicondylar HCF. Interestingly, all complications in bilateral dogs occurred in the initially affected limb rather than the prophylactically treated one, and no unilateral dogs required surgical intervention of the contralateral limb during the study period. Further prospective research comparing single-stage versus staged surgery is required to draw specific conclusions and provide definitive guidelines. Irrespective of the higher complication rate in the bilateral groups, the final overall outcomes were comparable, with good to excellent outcomes achieved in 86.7% of dogs.

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Author contributions

B. Mala: Conceptualisation, Data curation, Formal analysis, Investigation, Visualisation, Writing – original draft. **L. Marrone:** Data curation. **M. Basinska:** Data curation, Visualisation. **R. Malkani:** Conceptualization (statistical design), Formal analysis, Investigation, and Visualisation. **M. Erwood:** Conceptualization (statistical design), Formal analysis, Investigation, and Visualisation. **T. Easter:** Conceptualisation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing – review and editing. All authors approved the manuscript and are publicly accountable for relevant content. All authors have been personally and actively involved in substantive work leading to the manuscript, approved the content, and are publicly accountable for all relevant aspects.

Disclosure

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Conflict of interest

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table Q1. Questionnaire on client-perceived complications and treatment outcomes. A structured client evaluation scheme was implemented to assess postoperative complications and long-term outcomes following surgery. The questionnaire was specifically designed to identify postoperative complications, including wound healing concerns, the need for additional intervention and changes in limb function, and to evaluate longer-term outcomes, including the degree of exercise restriction, ongoing medical management and overall quality of life. Responses were obtained telephonically, and the follow-up interval ranged from 3 to 62 months (median 24 months)