Received: 2 February 2023 | Revised: 7 June 2023 | Accepted: 13 June 2023
DOI: 10.1002/vetr.3172

VetRecord

ORIGINAL RESEARCH

Long-term outcome in dogs with cranial cruciate ligament disease evaluated using the canine orthopaedic index

Karolina Engdahl[1] | **Annika Bergström**[1] | **Odd Höglund**[1] | **Elena R. Moldal**[2] | **Ulf Emanuelson**[1] | **Gudrun S. Boge**[2,3]

[1]Department of Clinical Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden

[2]Department of Companion Animal Clinical Sciences, Norwegian University of Life Sciences, Oslo, Norway

[3]Norwegian Medicines Agency, Oslo, Norway

Correspondence
Karolina Engdahl, Department of Clinical Sciences, Swedish University of Agricultural Sciences, P.O. Box 7054, Uppsala 750 07, Sweden.
Email: Karolina.Engdahl@slu.se

Present address
Gudrun S. Boge,Norwegian Medicines Agency, Oslo, Norway

Funding information
Agria Pet Insurance Research Foundation

Abstract

Background: Cranial cruciate ligament disease (CCLD) is common in dogs, but studies on the long-term treatment outcome are scarce.

Methods: The long-term outcome in a cohort of 71 dogs with CCLD treated with tibial plateau levelling osteotomy (TPLO, $n = 18$), tibial tuberosity advancement (TTA, $n = 23$) or lateral fabellotibial suture (LFS, $n = 30$) was evaluated using the canine orthopaedic index.

Results: The risk of stiffness and lameness was increased in dogs treated with TPLO (stiffness: incidence rate ratio [IRR] 1.33, $p = 0.015$; lameness: IRR 1.34, $p = 0.020$) or TTA (stiffness: IRR 1.26, $p = 0.035$; lameness: IRR 1.31, $p = 0.026$) when compared to LFS at a median follow-up time of 4.6 years.

Limitations: No follow-up veterinary examination was performed. Data were collected from only two university animal hospitals, and thus, a referral bias towards more complicated cases is possible, which may limit the generalisability of the results.

Conclusion: Clinicians can use the results to inform dog owners about the expected long-term outcome in dogs with CCLD.

KEYWORDS
canine, epidemiology, orthopaedics, outcome of surgery, risk factor, stifle

INTRODUCTION

Cranial cruciate ligament disease (CCLD) is one of the most common orthopaedic conditions in dogs and the most common stifle joint disease requiring veterinary care.[1,2] The disease generally affects middle-aged to older dogs and large-sized breeds, although dogs of all ages and sizes may develop the condition.[3–5] There are over 60 variations of surgical procedures described for the treatment of CCLD, which are divided into osteotomy procedures such as tibial plateau levelling osteotomy (TPLO) and tibial tuberosity advancement (TTA), extracapsular stabilisation procedures such as lateral fabellotibial suture (LFS) and intra-articular stabilisation procedures.[6–9]

The outcome after surgical treatment of CCLD is generally reported as successful,[10–16] although high-quality studies comparing the intermediate- to long-term outcome in dogs treated with different surgical techniques are sparse.[8,17] According to a recent review of TPLO and TTA, there is not enough evidence to support one method over the other.[17] However, a couple of earlier reviews concluded that TPLO is the method most likely to return dogs to normal function[8] and is associated with lower complication rates, improved clinical–functional outcomes and less osteoarthritis (OA) progression than TTA.[18] However, OA progresses in the affected joint regardless of the treatment method, and chronic pain is frequently reported in dogs with CCLD despite surgical treatment.[11,12,19–21]

Treatment outcome in dogs with CCLD has been evaluated in several ways, for example, by using force plate gait analysis, visual gait observation, orthopaedic and physiotherapeutic examination, radiography for evaluation of OA progression and owner questionnaires.[8,17,22–29] Owner questionnaires based on behaviour are considered one of the most reliable tools for assessment of chronic pain in dogs.[30–32] There are several questionnaires available, such as the canine orthopaedic index (COI), the Helsinki chronic pain index (HCPI), the Liverpool osteoarthritis in dogs, the canine brief pain inventory (CBPI) and the Bologna healing stifle injury index (BHSII).[33–37] The COI is available in a validated Swedish version and has previously been used to evaluate the long-term prognosis in dogs with elbow dysplasia.[38,39]

The aims of this study were to use the COI to evaluate the owner-assessed long-term outcome in dogs with CCLD and to compare the results for dogs treated with TPLO, TTA or LFS, controlling for potential confounding variables.

MATERIALS AND METHODS

Study design

A historical cohort study was performed by distributing the COI to owners of dogs treated for CCLD at two university veterinary hospitals in Oslo, Norway (hospital 1), and Uppsala, Sweden (hospital 2), between 1 January 2011 and 31 December 2016.

Data

The medical records of eligible dogs were reviewed, and data including treatment details and demographic information were collected. Inclusion criteria were a diagnosis of CCLD confirmed either by a positive cranial drawer test, a positive tibial compression test, or by observation of a ruptured ligament during arthroscopy or arthrotomy, treatment with either TPLO, TTA or LFS, and a completed COI at follow-up. Exclusion criteria were dogs with concurrent collateral ligament rupture, dogs diagnosed at the two veterinary hospitals but surgically treated at other clinics and dogs with prior treatment of contralateral CCLD. Dogs that had already been euthanased by the time the COI was distributed were also excluded. The reference population for this study is dogs with CCLD treated with TPLO, TTA or LFS at veterinary hospitals in Northern Europe.

The canine orthopaedic index

The dog owners were contacted by telephone between 1 August and 15 October 2018, and email addresses were collected. A questionnaire including the COI, as well as additional questions regarding the current use of analgesic medication, was emailed to the dog owner if the dog was still alive. The validated Swedish version of the COI includes 16 questions separated into five parts (Table 1): stiffness, function, lameness/gait, quality of life and the owner's perception. Each question is scored from 1 (least severe alternative) to 5 (most severe alternative), which means that a lower score indicates less stiffness/lameness and vice versa.

Before distribution, the validated Swedish version of the COI[38] was translated into Norwegian by one of the authors (G. S. B.). Due to the close similarity of the two languages, no formal validation was performed. The questionnaire was distributed via Questback (www.questback.com) on 30 April 2019, and two reminders were sent. It was distributed in Swedish to dog owners in Sweden and in Norwegian to dog owners in Norway.

Risk factors

Surgical technique was defined as the main exposure variable, which was separated into three categories: TPLO, TTA and LFS. The first stifle was included in the analysis in dogs that suffered subsequent contralateral CCLD during the study period. Potential confounders for the association between the main exposure (surgical technique) and the outcome of the COI were hospital, sex, bodyweight*, overweight* (body condition score [BCS] >5/9, >3/5 or subjectively assessed as overweight by the examining veterinarian), age*, acute lameness*, orthopaedic* and non-orthopaedic comorbidities*, insurance status* and the surgeon's experience level (experienced non-board-certified surgeon, resident, board-certified surgeon). In addition, a variable for the time from surgery to questionnaire reply was included in the analysis to control for differences in the duration of the follow-up period between the treatment groups. The variables for acute lameness and orthopaedic and non-orthopaedic comorbidities were classified as yes/no. Information about subsequent contralateral CCLD was also collected but not included in the analysis, as it was an intervening variable (located on the causal path between the main exposure and the outcome).

Statistical analysis

The statistical analyses were performed in R (version 4.0.0).[40] Categorical variables are presented as number and percentage cases per category, and continuous variables are presented as median (interquartile range [IQR], range) since graphical assessment and the Shapiro–Wilk test showed deviance from normality. From a clinical perspective, age and bodyweight were considered the most important potential confounders, and the Kruskal–Wallis one-way ANOVA was used to explore differences in these variables between the treatment groups. Differences in the duration of the follow-up period between treatment groups were also compared with the Kruskal–Wallis one-way ANOVA. Subsequent contralateral CCLD and analgesic/anti-inflammatory treatment at the time of the questionnaire reply could potentially affect the COI scores. Therefore, the COI scores of dogs with unilateral and subsequent contralateral CCLD were compared

* At the time of diagnosis.

TABLE 1 The validated Swedish version of the canine orthopaedic index, here back-translated to English, that was distributed to 71 owners of dogs with cranial cruciate ligament disease

Part/question	Range of scores
Stiffness	5–25
(1) How severe is your dog's stiffness after first wakening in the morning?	1–5
(2) Later in the day, how severe is your dog's stiffness after lying down for at least 15 minutes?	1–5
(3) How much of a problem does your dog have rising to standing after lying down for at least 15 minutes?	1–5
(4) In general, over the past month, how much difficulty has your dog had with his or her joints?	1–5
(5) How often did your dog 'pay' for over-activity with increased pain or stiffness the following day?	1–5
Function	4–20
(6) Jumping up (as in getting into the car or onto the bed)?	1–5
(7) Jumping down (as in getting out of the car or off of the bed)?	1–5
(8) Climbing up (as in stairs, ramps or curbs)?	1–5
(9) Climbing down (as in stairs, ramps or curbs)?	1–5
Lameness/gait	4–20
(10) On average, how severe was your dog's limp during mild activities (such as short walks)?	1–5
(11) On average, how severe was your dog's limp during moderate activities (such as long walks, playing or running)?	1–5
(12) How often did your dog limp the day after moderate activities (such as long walks, playing or running)?	1–5
(13) How often have you been aware of your dog's joint problems?	1–5
Quality of life	2–10
(14) In the past 4 weeks, what has been your level of concern that your dog's joint problems will shorten his or her life?	1–5
(15) In the past 4 weeks, what has been your level of concern that your dog is generally slowing down?	1–5
Perception	1–5
(16) Overall, how would you rate your dog's quality of life over the past 4 weeks?	1–5

Note: The scores are presented as minimum–maximum, where 1 is the least severe alternative and 5 is the most severe alternative.

with the Kruskal–Wallis one-way ANOVA, and the chi-squared test was used to assess the association between bilateral disease, the use of analgesic/anti-inflammatory treatment and surgical treatment.

A score for each part of the COI was calculated and used in the statistical analysis by summing the individual scores on the questions within each part. If missing answers were identified, the score for each part was calculated by summing the individual scores on the questions with answers. Poisson regression models were applied to evaluate the association between the main exposure variable (surgical technique) and the outcome (the COI) by using the glm() function with family = 'poisson' from the stats package. Separate models were built for each of the five parts of the COI. The function check_overdispersion() from the performance package was used to test for overdispersion.[41] If the models showed signs of overdispersion, negative binomial regression models were applied instead, with the glm.nb() function from the MASS package.[42] The models were fitted by iteratively reweighted least squares.

Univariable analyses were performed with the variables listed in the risk factors section and treatment as the main exposure variable. Variables with p-values less than 0.2 were included in the initial multivariable models. Manual stepwise backward elimination was performed for variable selection in the multivariable models, and p-values less than 0.05 were considered statistically significant. Incidence rate ratios (IRRs) with 95% confidence intervals (CIs) were calculated by exponentiation of the coefficients from the final models. Excluded variables were reintroduced in the final models to evaluate potential confounding, with a more than 20% change in the coefficient in the statistical model considered to indicate confounding. The Wald test was used to evaluate the significance of multilevel categorical variables, and the Akaike information criterion was used to compare the models. Interactions were not considered due to the relatively few dogs included in the study population. The variance inflation factor was used to test for multicollinearity in the final regression models.

RESULTS

The questionnaire was distributed to 101 dog owners, of whom 84 replied, resulting in a response rate of 83.2%. Of the 84 owners, 71 (84.5%) indicated that their dogs were still alive at the time of the questionnaire reply. Thus, the final study population included 71 dogs, of which 18 (25.4%) were treated with TPLO, 23 (32.4%) with TTA and 30 (42.3%) with LFS (Table 2). Age and bodyweight differed significantly between the treatment groups (5.34, 3.67 and 6.86 years; 37.3, 25.7 and 10.2 kg for TPLO, TTA and LFS, respectively, $p < 0.001$ for both comparisons).

TABLE 2 Descriptive features at the time of diagnosis in 71 dogs with cranial cruciate ligament disease (CCLD)

Variable	TPLO ($n = 18$)	TTA ($n = 23$)	LFS ($n = 30$)	Total ($n = 71$)
Number of dogs				
Hospital 1	0 (0%)	23 (100%)	8 (26.7%)	31 (43.7%)
Hospital 2	18 (100%)	0 (0%)	22 (73.3%)	40 (56.3%)
Age (years)	5.34 (2.60–7.38, 0.84–9.15)	3.67 (2.21–4.65, 0.54–5.66)	6.86 (4.85–8.21, 0.96–10.4)	4.88 (2.87–7.52, 0.54–10.4)
Bodyweight (kg)	37.3 (31.6–42.7, 19.7–75.0)	25.7 (22.0–31.9, 11.0–48.0)	10.2 (7.65–13.9, 3.50–34.3)	22.0 (10.8–33.5, 3.50–75.0)
Overweight	11 (61.1%)	4 (17.3%)	12 (40.0%)	27 (35.2%)
Sex				
Female	9 (50.0%)	14 (60.9%)	18 (60.0%)	41 (57.7%)
Male	9 (50.0%)	9 (39.1%)	12 (40.0%)	30 (42.3%)
Insurance	18 (100%)	15 (65.2%)	25 (83.3%)	58 (81.7%)
Stifle affected				
Right	8 (44.4%)	10 (43.5%)	16 (53.3%)	34 (47.9%)
Left	10 (55.6%)	13 (56.5%)	14 (46.7%)	37 (52.1%)
Acute lameness	9 (50.0%)	4 (17.3%)	4 (13.3%)	17 (23.9%)
Orthopaedic disease	4 (22.2%)	4 (17.4%)	8 (26.7%)	16 (22.5%)
Non-orthopaedic disease	4 (22.2%)	4 (17.4%)	2 (6.67%)	10 (14.1%)
Joint inspection (at treatment)	18 (100%)	13 (56.5%)	28 (93.3%)	59 (83.1%)
Arthrotomy	4 (22.2%)	11 (47.8%)	25 (83.3%)	40 (56.3%)
Arthroscopy	18 (100%)	2 (8.7%)	3 (10%)	23 (32.4%)
Concurrent meniscal injury[a]	2 (11.1%)	6 (46.2%)	9 (32.1%)	17 (28.8%)
Surgeon's experience level				
Experienced surgeon	7 (38.9%)	21 (91.3%)	21 (70.0%)	49 (69.0%)
Resident	3 (16.7%)	2 (8.70%)	4 (13.3%)	9 (12.7%)
Board-certified surgeon	8 (44.4%)	0 (0%)	5 (16.7%)	13 (18.3%)
Subsequent contralateral CCLD	7 (38.9%)	7 (30.4%)	15 (50%)	29 (40.8%)
Follow-up (years, treatment to COI)	3.30 (3.15–4.49, 2.51–6.19)	5.96 (4.86–6.58, 3.18–8.28)	3.69 (3.12–5.79, 2.49–8.23)	4.61 (3.24–6.17, 2.49–8.28)

Note: Categorical variables are presented as number of dogs (percentage) and continuous variables as median (interquartile range, range).
Abbreviations: COI, canine orthopaedic index; LFS, lateral fabellotibial suture; TPLO, tibial plateau levelling osteotomy; TTA, tibial tuberosity advancement.
[a]Of the dogs with joint inspection.

The median time from surgery to questionnaire reply was 4.61 years (IQR 3.24–6.17, range 2.49–8.28) and varied with treatment ($p < 0.001$, see Table 2). The surgeries were performed by 13 surgeons, of which two (15.4%) were board-certified, four (30.8%) were residents and seven (53.8%) were experienced but not board certified. Sixteen (22.5%) dogs were affected by orthopaedic comorbidities at diagnosis, of which the most common diagnoses were patellar luxation (eight dogs, 11.3%), osteochondrosis of the stifle (three dogs, 4.23%) and hip dysplasia (two dogs, 2.82%). Neuter status and orthopaedic examination findings were not consistently described in the medical records and thus are not reported here.

Six dogs in each treatment group (33.3%, 26.1% and 20.0% of the dogs treated with TPLO, TTA and LFS, respectively) were on analgesic/anti-inflammatory treatment at the time of the questionnaire reply. Sixteen dogs (22.5%) received non-steroidal anti-inflammatory drugs and one dog (1.41%) received pentosan polysulphate sodium injections. Information about the type of analgesic/anti-inflammatory drug was missing for one dog (1.41%). Eight (11.3%) dogs received medication on a daily basis and 10 (14.1%) only if the owner considered it necessary, based on clinical signs. There was no significant difference in the use of analgesic/anti-inflammatory treatment between the treatment groups ($p = 0.587$).

The scores for all parts of the COI were right-skewed (i.e., towards lower values, see Table 3). Three dogs had missing values on one or two of the COI questions: one dog had a missing answer on question 4, one on questions 6 and 7, and one on questions 12 and 13.

Overdispersion was present in the final Poisson models for the stiffness, function and lameness/gait parts of the COI. Thus, these were replaced with negative binomial models, and the output from the final models is presented in Table 4. The variance inflation factor revealed no multicollinearity in the final models. None of the variables was significantly associated with the quality of life and the dog owner's perception parts of the COI ($p > 0.05$).

TABLE 3 The scores for the five parts of the canine orthopaedic index (COI) in 71 dogs with cranial cruciate ligament disease

Part of COI	TPLO ($n = 18$)	TTA ($n = 23$)	LFS ($n = 30$)	Total ($n = 71$)
Stiffness (maximum 25)	8 (7.25–13, 5–20)	9 (7–11, 4–20)	7 (5–9, 5–16)	8 (5.50–11, 4–20)
Function (maximum 20)	6 (4–9.75, 2–13)	6 (4–8, 4–14)	6 (4–8, 4–13)	6 (4–8, 2–14)
Lameness/gait (maximum 20)	8.5 (5.25–12, 4–15)	8 (5.5–11.5, 4–19)	5 (4.25–8.75, 2–13)	7 (5–10.5, 2–19)
Quality of life (maximum 10)	3.5 (2.25–4.75, 2–7)	3 (2–4, 2–9)	3 (2–4, 2–8)	3 (2–4, 2–9)
Perception (maximum 5)	2 (1–2.75, 1–4)	2 (1–2.50, 1–4)	2 (1–2.75, 1–4)	2 (1–3, 1–4)

Note: The scores are the sum of the scores on the questions within each part of the COI and are shown as median (interquartile range, range).
Abbreviations: LFS, lateral fabellotibial suture; TPLO, tibial plateau levelling osteotomy; TTA, tibial tuberosity advancement.

TABLE 4 The final multivariable negative binomial regression models for the stiffness, function and lameness/gait parts of the canine orthopaedic index in a cohort of 71 dogs with cranial cruciate ligament disease

Variable	Coefficient	Std. error	IRR	95% CI	*p*-Value
Stiffness					
Intercept	2.02	0.08	–	–	–
Treatment[a]					0.026
LFS	–	–	1	–	–
TTA	0.23	0.11	1.26	1.02–1.55	0.035
TPLO	0.29	0.12	1.33	1.06–1.68	0.015
Surgeon's experience level[b]					0.018
Exp. surg.	–	–	1	–	–
Resident	0.29	0.13	1.33	1.03–1.71	0.026
Board-cert.	–0.17	0.14	0.84	0.64–1.10	0.211
Function					
Intercept	1.60	0.16	–	–	–
Follow-up	0.06	0.03	1.06	1.00–1.13	0.047
Lameness/gait					
Intercept	1.83	0.09	–	–	–
Treatment[c]					0.033
LFS	–	–	1	–	–
TTA	0.27	0.12	1.31	1.03–1.65	0.026
TPLO	0.29	0.13	1.34	1.05–1.72	0.020
Orth. disease	0.21	0.12	1.23	0.98–1.55	0.076[d]

Abbreviations: board-cert., board-certified surgeon; CI, confidence interval; exp. surg., experienced but not board-certified surgeon; follow-up, duration of follow-up period in years; IRR, incidence rate ratio; LFS, lateral fabellotibial suture; orth. disease, concurrent orthopaedic disease at the time of diagnosis; Std. error, standard error; TPLO, tibial plateau levelling osteotomy; TTA, tibial tuberosity advancement.
[a]No significant difference between TPLO and TTA was found (IRR 1.06, 95% CI: 0.83–1.37, $p = 0.640$).
[b]No significant difference was found between board-certified surgeons and experienced non-board-certified surgeons (IRR 0.84, 95% CI: 0.64–1.10, $p = 0.211$).
[c]No significant difference between TPLO and TTA was found (IRR 1.028, 95% CI: 0.80–1.32, $p = 0.831$).
[d]The Akaike information criterion (AIC) suggested that the model fit was better when the variable for concurrent orthopaedic diseases was included, albeit not statistically significant (AIC 373.2 for the full model and 374.3 for the model without the variable for orthopaedic disease).

Reintroduction of excluded variables in the final models revealed that bodyweight had a confounding effect on the association between surgical technique and lameness/gait (greater than 20% change in the coefficients for TPLO and TTA) and a borderline confounding effect on the association between surgical technique and stiffness (20.2% change in the coefficient for TPLO, Table 5). The associations between surgical technique and stiffness and lameness/gait were no longer significant when bodyweight was included in the model ($p > 0.05$). There was no significant association between bodyweight and stiffness and lameness/gait.

Twenty-nine (40.8%) dogs suffered subsequent contralateral CCLD during the study period, and there was no significant difference in the number of affected dogs within each treatment group ($p = 0.350$). Dogs with subsequent contralateral CCLD had significantly lower scores than dogs with unilateral CCLD on the stiffness part (median scores 7 [IQR 5–8, range 5–18] and 9 [IQR 6.25–11, range 4–20], $p = 0.037$) and the owner's perception part (median scores 1 [IQR 1–2, range 1–4] and 2 [IQR 1.25–3, range 1–4], $p = 0.023$). There was no significant difference in the scores of dogs with subsequent contralateral CCLD and unilateral CCLD on the function part (median scores 5 [IQR

TABLE 5 The multivariable negative binomial regression models for the stiffness and lameness/gait parts of the canine orthopaedic index in a cohort of 71 dogs with cranial cruciate ligament disease with bodyweight added to the final model

Variable	Coefficient	Std. error	IRR	95% CI	*p*-Value
Stiffness					
Intercept	1.99	0.10	–	–	–
Treatment					0.267
LFS	–	–	1	–	–
TTA	0.20	0.13	1.22	0.95–1.56	0.119
TPLO	0.23	0.17	1.26	0.90–1.77	0.185
Surgeon's experience level[a]					0.020
Exp. surg.	–	–	1	–	–
Resident	0.29	0.13	1.33	1.04–1.71	0.025
Board-cert.	–0.16	0.14	0.85	0.64–1.12	0.250
Bodyweight	0.002	0.004	1.00	0.99–1.01	0.640
Lameness/gait					
Treatment					0.411
LFS	–	–	1	–	–
TTA	0.19	0.14	1.21	0.92–1.59	0.179
TPLO	0.16	0.18	1.17	0.82–1.68	0.379
Orth. disease	0.22	0.11	1.25	0.99–1.57	0.059
Bodyweight	0.01	0.01	1.01	1.00–1.01	0.297

Abbreviations: board-cert., board-certified surgeon; CI, confidence interval; exp. surg., experienced but not board-certified surgeon; IRR, incidence rate ratio; LFS, lateral fabellotibial suture; orth. disease, concurrent orthopaedic disease at the time of diagnosis; Std. error, standard error; TPLO, tibial plateau levelling osteotomy; TTA, tibial tuberosity advancement.

[a]No significant difference was found between board-certified surgeons and experienced non-board-certified surgeons (IRR 1.18, 95% CI: 0.89–1.16, $p = 0.250$).

2–8, range 2–12] and 6 [IQR 4.25–8, range 4–14], $p = 0.056$), the lameness/gait part (median scores 6 [IQR 4–9, range 2–15] and 7 [IQR 5–11.8, range 4–19], $p = 0.258$) and the quality of life part (median scores 3 [IQR 3–4, range 2–7] and 3 [IQR 2–4, range 2–9], $p = 0.689$).

DISCUSSION

In this study, we have compared the owner-assessed long-term outcomes of three surgical treatment methods for CCLD in dogs using the COI. We found that dogs treated with TPLO or TTA had a higher risk of stiffness and lameness at follow-up than dogs treated with LFS. Furthermore, we found that function decreased with increasing follow-up time, that dogs with orthopaedic comorbidities at diagnosis of CCLD had an increased risk of long-term lameness and that dogs surgically treated by residents had a higher risk of long-term stiffness than dogs treated by experienced but not board-certified surgeons. The causality of these findings needs to be verified in future prospective studies.

Several previous studies have evaluated the outcome after TPLO, TTA and LFS by using dog owner questionnaires. Moore et al.[43] evaluated long-term outcomes after TPLO and TTA by using the COI and found significantly lower COI scores for dogs treated with TPLO than with TTA. These results differ from the results of the current study, as no significant difference in COI scores was found for dogs treated with TPLO and TTA. Mölsä et al.[20] used the HCPI and reported no difference in questionnaire scores for dogs treated with osteotomy procedures (TPLO and TTA), LFS or an intra-articular stabilisation technique when controlling for age, which differed between the treatment groups. Bodyweight also differed significantly between the treatment groups, but no association with the scores of the HCPI and bodyweight was found.[20] Gordon-Evans et al.[44] evaluated the outcome in dogs treated with TPLO or LFS with the CBPI in a randomised, blinded and controlled clinical trial and reported no significant difference in the improvement of the questionnaire scores compared to preoperative scores between the treatment groups at the 12-month follow-up. However, dogs treated with TPLO had a significantly better outcome on gait analysis at the 12-month follow-up. There was no difference in bodyweight between the treatment groups.[44] Thus, the results of the current study differ from previous reports, as dogs treated with TPLO and TTA had a higher risk of lameness and stiffness than dogs treated with LFS. One likely explanation for the different results is that the HCPI and the CBPI focus on pain evaluation, while the COI is designed to assess the overall outcome in dogs with orthopaedic disease, similar to the BHSII.[33,37,45,46] Neither the HCPI nor the CBPI includes direct questions regarding lameness, which was one of the two COI parts that differed between the treatment groups in the current study. Furthermore, the CBPI does not include specific questions regarding stiffness, which also differed between the treatment groups in our study. Another important difference is the follow-up time, which was longer in the current study (median 4.6 years) than in the studies by Mölsä et al. (mean 2.7 ± 0.8 years) and Gordon-Evans et al. (12 months). This may affect the results, as a longer follow-up time also means a longer time for OA progression in the affected joints, which affects clinical signs such as lameness and stiffness.

Having a concurrent orthopaedic comorbidity at diagnosis was associated with an increased risk of lameness at follow-up. The effect of orthopaedic comorbidities on the outcome in dogs with CCLD is not thoroughly evaluated in the literature, but it seems reasonable that comorbidities such as patellar luxation and stifle joint osteochondrosis could affect the prognosis and clinical signs, such as lameness, in dogs with CCLD, for example, by accelerating the progression of OA.

An association between the surgeon's experience level and stiffness was detected, with dogs surgically treated by residents having an increased risk of stiffness compared to dogs surgically treated by experienced non-board-certified surgeons. Previous studies have reported an increased risk of surgical site infections and major complications after surgeries performed by less experienced surgeons or residents.[11,47] This could be related to a longer duration of surgery and anaesthesia, less experience with orthopaedic surgery, unintended intraoperative tissue trauma, or suboptimal optimisation of the osteotomy or the LFS affecting the biomechanical stabilisation of the joint.[11,47] However, it was not evaluated if the association between the surgeon's experience level and stiffness was mediated through the occurrence of postoperative complications in the current study.

The scores on the functional items of the questionnaire (i.e., the dog's ability to jump/climb up and down) decreased with increasing follow-up time, but there was no significant association between age at diagnosis and long-term function. Thus, it seems that function decreases with time regardless of age at CCLD surgery. This could potentially be explained by OA progression after surgery, which could affect the dog's ability or willingness to perform activities such as jumping or climbing.

Neither treatment nor any of the risk factors were significantly associated with the quality of life and the owner's perception parts of the COI. These parts focus on the dog owner's level of concern regarding the impact of the joint problem on longevity and activity and the dog's overall quality of life. Owners of dogs with OA are often worried about their dogs for reasons such as veterinary visits, medications and not being able to interact with the dog as desired.[48] However, it is not certain that the owners' level of worry regarding their dogs' joint problems correlates with the level of clinical signs such as stiffness or lameness, which could explain the results.

Subsequent contralateral CCLD was an intervening variable and thus not included as a potential confounder in the statistical models. Dogs with subsequent contralateral CCLD had a significantly lower degree of stiffness and lower owner's perception scores than dogs with unilateral CCLD. It could be that the bilaterally affected dogs showed fewer signs of chronic stiffness, but a more likely explanation is that it was more challenging for the owners to notice bilateral compared with unilateral hindlimb stiffness.

There was a significant variation in bodyweight between the treatment groups, and when bodyweight was included in the models the associations between surgical technique and stiffness and lameness/gait were no longer significant. Thus, the associations were influenced by bodyweight, although neither the magnitude of this influence nor the causality could be evaluated in this retrospective setting. Increasing bodyweight has been reported as a risk factor for complications after CCLD surgery, for OA development and for CCLD-related euthanasia, but the effect of bodyweight on the outcome in dogs with CCLD is not commonly evaluated in the literature.[17,49–55] Based on the results of the current study, bodyweight could possibly affect long-term stiffness and lameness in dogs with CCLD, with an increased risk in heavier dogs. Future prospective randomised clinical trials that evaluate the effect of treatment and bodyweight on the long-term outcome in dogs with CCLD are warranted.

Two potential confounders for the association between surgical technique and stiffness/lameness are the activity level and type of activities that the dog performs. A trend of treatment with osteotomy procedures in dogs being used for sports, hunting, etc., and/or with high activity levels, is possible, while dogs held for company and/or with lower activity levels were possibly treated with LFS to a higher extent. These factors could also affect the outcome of the stiffness and lameness parts of the COI, as mild lameness or stiffness could be perceived as a large problem for an active dog used in dog sports but not for a companion dog. The association between the activity level and surgical technique and its impact on the long-term outcome in dogs with CCLD could not be evaluated in this retrospective setting and should be explored in future prospective studies.

Some limitations should be mentioned. Causal inference for the associations found in the study cannot be drawn due to the retrospective setting. Thus, prospective studies are needed to confirm the causality of the reported associations. The study includes the COI for outcome evaluation, which is a validated questionnaire that was recommended for use in dogs with OA in a recent review of owner-reported outcomes for canine orthopaedic care.[35,38,45,56,57] Despite this, we acknowledge that outcome assessment with force plate gait analysis would have strengthened the results. The COI has been validated in Swedish but not in Norwegian and was translated into Norwegian by one of the co-authors. Although validation of the Norwegian version would have been desirable, it was not considered necessary due to the great similarities across the languages. The study included dogs treated at two referral hospitals, and thus, a referral bias towards more complicated cases is possible, which may limit the generalisability of the results to dogs treated with the same procedures at smaller veterinary clinics. The reference population for this study was dogs treated with TPLO, TTA or LFS at veterinary hospitals in Northern Europe, but data were only collected from two University Animal Hospitals, and it is not known to what extent these hospitals represent general veterinary hospitals in Northern Europe, which is highlighted as a limitation.

Many of the dogs diagnosed and treated from 2011 to 2016 had died or been euthanased before the distribution of the questionnaire due to the long follow-up time. It is possible that the outcome of the dogs that were still alive at follow-up was different from the dogs that had been euthanased during the follow-up period (i.e., that the dogs with worse outcomes were euthanased at an earlier stage and thus not included in this study). As the treatment was not randomised, uncontrolled factors (such as the owners' economic circumstances) could potentially act as confounders for the association between the treatment and the outcome. In addition, there is a risk that other orthopaedic conditions acquired after diagnosis of CCLD affected the outcome. However, such conditions were likely evenly distributed between the treatment groups. The occurrence of postoperative complications might also have affected the outcome, but as an intervening variable it was not included in the statistical analysis. A mediation analysis could have been conducted to evaluate the direct effect of postoperative complications and surgical technique on the outcome of the COI, but due to the relatively small study population and the diversity of potential complications, such analysis was not performed. Some medical records only included subjective assessments of overweight and no comment on the BCS. A complete assessment of BCS on all included dogs would have been preferred in order to evaluate the potential association between overweight and treatment outcome. Information about neuter status at the time of surgery was unavailable in the medical records. Although a question about neutering status at the time of surgery could have been included in the questionnaire, it was omitted due to the high risk of recall bias regarding the date of neutering in relation to the date of CCLD surgery. Preoperative scoring of radiographic signs of OA was not possible, as some dogs lacked preoperative radiographs. It should also be mentioned that each treatment group included relatively few individuals, which could have affected the power of the statistical calculations.

Finally, some dogs were on continuous or intermittent analgesic treatment at the time of the questionnaire reply, which may have biased the results towards a more favourable outcome compared to dogs not given treatment. However, it is unlikely that it biased the association between the surgical treatment and the outcome, as the use of analgesic treatment did not differ significantly between the treatment groups.

CONCLUSIONS

Stiffness, lameness and decreased function were relatively common in dogs surgically treated for CCLD at a median follow-up of 4.6 years. Dogs treated with TPLO and TTA procedures had a significantly higher risk of stiffness and lameness at long-term follow-up than dogs treated with LFS, although bodyweight varied between the treatment groups, with heavier dogs in the osteotomy groups, which influenced the results. Dogs surgically treated by residents had a higher risk of stiffness at follow-up, and function decreased with an increasing follow-up period. In addition, dogs with orthopaedic comorbidities at diagnosis had a tendency towards an increased risk of lameness.

AUTHOR CONTRIBUTIONS

All authors contributed to the study design. Karolina Engdahl and Gudrun S. Boge collected the data under supervision from Odd Höglund, Annika Bergström, Ulf Emanuelson and Elena R. Moldal. Karolina Engdahl carried out the data analysis and was the major contributor to the manuscript, with substantial input from the other authors. All authors participated in the discussions and revisions of the entire text. All authors read and approved the final manuscript.

ACKNOWLEDGEMENTS

The authors wish to thank the dog owners for returning the questionnaires and Agria Pet Insurance Research Foundation for funding this research. The PhD project of one of the authors (Karolina Engdahl) was financed by the Agria Pet Insurance Research Foundation.

CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

All methods were carried out in accordance with relevant guidelines and regulations. Informed oral consent to participate in the study and collect data was obtained from all dog owners. The study was granted an exemption from requiring ethics approval by the Council for Animals in Research and Education at the Swedish University of Agricultural Sciences, as ethics approval is not necessary for performing such a questionnaire study according to the law.

ORCID

Karolina Engdahl https://orcid.org/0000-0003-2800-9990
Annika Bergström https://orcid.org/0000-0003-1133-8747
Odd Höglund https://orcid.org/0000-0003-0978-836X

Ulf Emanuelson https://orcid.org/0000-0001-7889-417X
Gudrun S. Boge https://orcid.org/0000-0001-6889-4002

REFERENCES

1. Johnson J, Austin C, Breur G. Incidence of canine appendicular musculoskeletal disorders in 16 veterinary teaching hospitals from 1980 through 1989. Vet Comp Orthop Traumatol. 1994;7:56–69.
2. Engdahl K, Hanson J, Bergström A, Bonnett B, Höglund O, Emanuelson U. The epidemiology of stifle joint disease in an insured Swedish dog population. Vet Rec. 2021;189:e197.
3. Taylor-Brown FE, Meeson RL, Brodbelt DC, Church DB, Mcgreevy PD, Thomson PC, et al. Epidemiology of cranial cruciate ligament disease diagnosis in dogs attending primary-care veterinary practices in England. Vet Surg. 2015;44:777–83.
4. Witsberger TH, Villamil JA, Schultz LG, Hahn AW, Cook JL. Prevalence of and risk factors for hip dysplasia and cranial cruciate ligament deficiency in dogs. J Am Vet Med Assoc. 2008;232:1818–24.
5. Whitehair JG, Vasseur PB, Willits NH. Epidemiology of cranial cruciate ligament rupture in dogs. J Am Vet Med Assoc. 1993;203:1016–9.
6. Slocum B, Slocum TD. Tibial plateau leveling osteotomy for repair of cranial cruciate ligament rupture in the canine. Vet Clin North Am Small Anim Pract. 1993;23:777–95.
7. Montavon P, Damur D, Tepic S. Advancement of the tibial tuberosity for treatment of cranial cruciate deficient canine stifle. Proceedings of the 1st World Orthopaedic Veterinary Congress, Munich, Germany. 2002.
8. Bergh MS, Sullivan C, Ferrell CL, Troy J, Budsberg SC. Systematic review of surgical treatments for cranial cruciate ligament disease in dogs. J Am Anim Hosp Assoc. 2014;50:315–21.
9. DeAngelis M, Lau RE. A lateral retinacular imbrication technique for the surgical correction of anterior cruciate ligament rupture in the dog. J Am Vet Med Assoc. 1970;157:79–84.
10. Livet V, Baldinger A, Viguier É, Taroni M, Harel M, Carozzo C, et al. Comparison of outcomes associated with tibial plateau levelling osteotomy and a modified technique for tibial tuberosity advancement for the treatment of cranial cruciate ligament disease in dogs: a randomized clinical study. Vet Comp Orthop Traumatol. 2019;32:314–23.
11. Christopher SA, Beetem J, Cook JL. Comparison of long-term outcomes associated with three surgical techniques for treatment of cranial cruciate ligament disease in dogs. Vet Surg. 2013;42:329–34.
12. Au KK, Gordon-Evans WJ, Dunning D, O'Dell-Anderson KJ, Knap KE, Griffon D, et al. Comparison of short- and long-term function and radiographic osteoarthrosis in dogs after postoperative physical rehabilitation and tibial plateau leveling osteotomy or lateral fabellar suture stabilization. Vet Surg. 2010;39:173–80.
13. Dymond N, Goldsmid S, Simpson D. Tibial tuberosity advancement in 92 canine stifles: initial results, clinical outcome and owner evaluation. Aust Vet J. 2010;88:381–5.
14. Nanda A, Hans EC. Tibial plateau leveling osteotomy for cranial cruciate ligament rupture in canines: patient selection and reported outcomes. Vet Med. 2019;10:249–55.
15. Marin K, Unis MD, Horgan JE, Roush JK. Risk factors for short-term postoperative complications in the 8 weeks after tibial plateau leveling osteotomy in dogs weighing less than 15 kilograms: a retrospective study. PLoS One. 2021;16:e0247555.
16. Knebel J, Eberle D, Steigmeier-Raith S, Reese S, Meyer-Lindenberg A. Outcome after tibial plateau levelling osteotomy and modified Maquet procedure in dogs with cranial cruciate ligament rupture. Vet Comp Orthop Traumatol. 2020;33:189–97.
17. Wemmers AC, Charalambous M, Harms O, Volk HA. Surgical treatment of cranial cruciate ligament disease in dogs using tibial plateau leveling osteotomy or tibial tuberosity advancement—a systematic review with a meta-analytic approach. Front Vet Sci. 2022;9:1004637.
18. Beer P, Bockstahler B, Schnabl-Feichter E. Tibial plateau leveling osteotomy and tibial tuberosity advancement—a systematic review. Tierarztl Prax Ausg K Kleintiere Heimtiere. 2018;46:223–35.
19. Lazar TP, Berry CR, Dehaan JJ, Peck JN, Correa M. Long-term radiographic comparison of tibial plateau leveling osteotomy versus extracapsular stabilization for cranial cruciate ligament rupture in the dog. Vet Surg. 2005;34:133–41.
20. Mölsä SH, Hielm-Björkman AK, Laitinen-Vapaavuori OM. Use of an owner questionnaire to evaluate long-term surgical outcome and chronic pain after cranial cruciate ligament repair in dogs: 253 cases (2004–2006). J Am Vet Med Assoc. 2013;243:689–95.
21. Pinna S, Lanzi F, Cordella A, Diana A. Relationship between the stage of osteoarthritis before and six months after tibial tuberosity advancement procedure in dogs. PLoS One. 2019;14:e0219849.
22. Macrì F, Cicero L, Angileri V, Biondi V, Miele P, Scaletta L, et al. Locking compression plates versus locking plates for tibial plateau levelling osteotomy in dogs: progression of osteoarthritis, bone healing score and lameness degree. BMC Vet Res. 2021;17:193.
23. Pownall W, Rytz U, Schuepbach G, Spadavecchia C, Rohrbach H. The influence of the choice of preemptive analgesia on long-term postsurgical pain after tibial plateau leveling osteotomy in dogs. Vet Surg. 2020;50:71–80.
24. Ferreira AJA, Bom RM, Tavares SO. Tibial tuberosity advancement technique in small breed dogs: study of 30 consecutive dogs (35 stifles). J Small Anim Pract. 2019;60:305–12.
25. Bureau S. Owner assessment of the outcome of tibial plateau levelling osteotomy without meniscal evaluation for treatment of naturally occurring cranial cruciate ligament rupture: 130 cases (2009 to 2013). J Small Anim Pract. 2017;58:468–75.
26. Mölsä SH, Hyytiäinen HK, Hielm-Björkman AK, Laitinen-Vapaavuori OM. Long-term functional outcome after surgical repair of cranial cruciate ligament disease in dogs. BMC Vet Res. 2014;10:266.
27. Voss K, Damur DM, Guerrero T, Haessig M, Montavon P. Force plate gait analysis to assess limb function after tibial tuberosity advancement in dogs with cranial cruciate ligament disease. Vet Comp Orthop Traumatol. 2008;21;243–9.
28. Aragosa F, Caterino C, Della Valle G, Fatone G. Tibial tuberosity advancement techniques (TTAT): a systematic review. Animals. 2022;12:2114.
29. Alvarez LX, Repac JA, Kirkby Shaw K, Compton N. Systematic review of postoperative rehabilitation interventions after cranial cruciate ligament surgery in dogs. Vet Surg. 2022;51:233–43.
30. Goldberg ME. A look at chronic pain in dogs. Vet Nurs J. 2017;32:37–44.
31. Belshaw Z, Yeates J. Assessment of quality of life and chronic pain in dogs. Vet J. 2018;239:59–64.
32. Reid J, Nolan AM, Scott EM. Measuring pain in dogs and cats using structured behavioural observation. Vet J. 2018;236:72–9.
33. Hielm-Björkman AK, Rita H, Tulamo R-M. Psychometric testing of the Helsinki chronic pain index by completion of a questionnaire in Finnish by owners of dogs with chronic signs of pain caused by osteoarthritis. Am J Vet Res. 2009;70:727.
34. Brown DC, Boston RC, Coyne JC, Farrar JT. Ability of the canine brief pain inventory to detect response to treatment in dogs with osteoarthritis. J Am Vet Med Assoc. 2008;233:1278–83.
35. Brown DC. The Canine Orthopedic Index. Step 3: responsiveness testing. Vet Surg. 2014;43:247–54.
36. Walton MB, Cowderoy E, Lascelles D, Innes JF. Evaluation of construct and criterion validity for the 'Liverpool Osteoarthritis in Dogs' (LOAD) clinical metrology instrument and comparison to two other instruments. PLoS One. 2013;8:e58125.
37. Pinna S, Lambertini C, Grassato L, Romagnoli N. Evidence-based veterinary medicine: a tool for evaluating the healing process after surgical treatment for cranial cruciate ligament rupture in dogs. Front Vet Sci. 2019;6:65.

38. Andersson A, Bergström A. Adaptation of the Canine Orthopaedic Index to evaluate chronic elbow osteoarthritis in Swedish dogs. Acta Vet Scand. 2019;61:29.
39. Bergström A, Johard S, Lee MH, Comin A. Long-term prognosis of quality of life in dogs diagnosed with mild to moderate elbow dysplasia in Sweden. Front Vet Sci. 2020;7:572691.
40. R Core Team. RStudio: integrated development environment for R. Boston: RStudio, PBC; 2022.
41. Lüdecke D, Ben-Shachar MS, Patil I, Waggoner P, Makowski D. An R package for assessment, comparison and testing of statistical models. J Open Source Softw. 2021;6:3139.
42. Venables WN, Ripley BD. Modern applied statistics with S. New York: Springer; 2002.
43. Moore EV, Weeren R, Paek M. Extended long-term radiographic and functional comparison of tibial plateau leveling osteotomy vs tibial tuberosity advancement for cranial cruciate ligament rupture in the dog. Vet Surg. 2020;49:146–54.
44. Gordon-Evans WJ, Griffon DJ, Bubb C, Knap KM, Sullivan M, Evans RB. Comparison of lateral fabellar suture and tibial plateau leveling osteotomy techniques for treatment of dogs with cranial cruciate ligament disease. J Am Vet Med Assoc. 2013;243:675–80.
45. Brown DC. The Canine Orthopedic Index. Step 2: psychometric testing. Vet Surg. 2014;43:241–6.
46. Brown DC, Boston RC, Coyne JC, Farrar JT. Development and psychometric testing of an instrument designed to measure chronic pain in dogs with osteoarthritis. Am J Vet Res. 2007;68:631–7.
47. Lopez DJ, Vandeventer GM, Krotscheck U, Aryazand Y, Mcconkey MJ, Hayashi K, et al. Retrospective study of factors associated with surgical site infection in dogs following tibial plateau leveling osteotomy. J Am Vet Med Assoc. 2018;253:315–21.
48. Belshaw Z, Dean R, Asher L. “You can be blind because of loving them so much”: the impact on owners in the United Kingdom of living with a dog with osteoarthritis. BMC Vet Res. 2020;16:190.
49. Anderson KL, O’Neill DG, Brodbelt DC, Church DB, Meeson RL, Sargan D, et al. Prevalence, duration and risk factors for appendicular osteoarthritis in a UK dog population under primary veterinary care. Sci Rep. 2018;8:5641.
50. Fitzpatrick N, Solano MA. Predictive variables for complications after TPLO with stifle inspection by arthrotomy in 1000 consecutive dogs. Vet Surg. 2010;39:460–74.
51. Casale SA, McCarthy RJ. Complications associated with lateral fabellotibial suture surgery for cranial cruciate ligament injury in dogs: 363 cases (1997–2005). J Am Vet Med Assoc. 2009;234:229–35.
52. Steinberg EJ, Prata RG, Palazzini K, Brown DC. Tibial tuberosity advancement for treatment of CrCL injury: complications and owner satisfaction. J Am Anim Hosp Assoc. 2011;47:250–7.
53. Ramírez-Flores GI, Del Angel-Caraza J, Quijano-Hernández IA, Hulse DA, Beale BS, Victoria-Mora JM. Correlation between osteoarthritic changes in the stifle joint in dogs and the results of orthopedic, radiographic, ultrasonographic and arthroscopic examinations. Vet Res Commun. 2017;41:129–37.
54. Coletti TJ, Anderson M, Gorse MJ, Madsen R. Complications associated with tibial plateau leveling osteotomy: a retrospective of 1519 procedures. Can Vet J. 2014;55:249–54.
55. Boge GS, Engdahl K, Bergström A, Emanuelson U, Hanson J, Höglund O, et al. Disease-related and overall survival in dogs with cranial cruciate ligament disease, a historical cohort study. Prev Vet Med. 2020;181:105057.
56. Radke H, Joeris A, Chen M. Evidence-based evaluation of owner-reported outcome measures for canine orthopedic care—a COSMIN evaluation of 6 instruments. Vet Surg. 2021;51:244–53.
57. Brown DC. The Canine Orthopedic Index. Step 1: devising the Items. Vet Surg. 2014;43:232–40.

How to cite this article: Engdahl K, Bergström A, Höglund O, Moldal ER, Emanuelson U, Boge GS. Long-term outcome in dogs with cranial cruciate ligament disease evaluated using the canine orthopaedic index. Vet Rec. 2023;e3172. https://doi.org/10.1002/vetr.3172