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CASE REPORT

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Multiligament stifle injury, a multicenter retrospective study in 26 dogs

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[Correction added on 18 April 2023, after first online publication: Pilar Lafuente's affiliation was updated in this version].

Abstract

Objectives: To describe multiligament stifle injury in dogs and report complications and long-term outcomes.

Methods: Medical records of dogs surgically treated for multiligament stifle injury were reviewed from six veterinary hospitals. Long-term follow-up was collected from referring veterinarians.

Results: Twenty-six client-owned dogs and 26 stifles were included. Road traffic accidents and limb entrapment were the most common causes of injury. Cranial cruciate and lateral collateral ligament rupture was the most common combination of injury (10 cases). The caudal cruciate ligament was damaged in 12/23 cases but was surgically addressed in only 2 cases. Cranial cruciate ligament rupture was present in all cases and was managed using TPLO (6 cases), extracapsular suture (15 cases) and TTA (2 cases). Postoperative immobilisation with a transarticular external skeletal fixator was used in 4/26 cases. Intraoperative complications were reported in 2/23 cases, short-term complications in 17/25 cases, of which eight were major, and long-term complications in 7/18, of which two were major. Patella luxation was seen in one case and is a previously unreported complication. The overall outcome was excellent in 9/24 cases, good in 5/24 cases, fair in 7/24 cases and poor in 3/24 cases. Follow-up time ranged from 1.5 months to 9 years with the median (IQR) of 9.5 (4.0 to 28.5) months.

Conclusions: Multiligament stifle injury in dogs is associated with a high rate of major complications. The overall outcome was good to excellent in just over half of the dogs.

KEYWORDS
canine, joints, orthopaedic, trauma

1 | INTRODUCTION

Multiligamentous injury to the stifle is a rare orthopaedic condition in dogs which occurs following damage to the primary or secondary joint restraints (Aron, 1988; Bruce, 1998). The primary joint restraints are the four ligaments of the stifle joint (the cranial and caudal cruciate ligaments and the medial and the lateral collateral ligaments); the secondary joint restraints are the joint capsule, menisci, tendons and muscles.

Such injuries can be generated when large extrinsic bending and torsional forces are applied concurrently to the stifle joint (Aron, 1988; Smith, 1995). Such forces can be generated by high-energy trauma like road traffic accidents, falls from heights or catching the limb while jumping a fence (Hulse & Shires, 1986; Robins, 1990). The most common combination of injuries reported involves the cranial and caudal cruciate ligaments as well as the lateral collateral ligament (Bruce, 1998).

Surgical treatment consists of a thorough exploration of the joint. The integrity of the cruciate ligaments and menisci are carefully evaluated. Severe meniscal damage may necessitate total or partial meniscectomy; however, in more mildly affected cases, primary tears can be sutured to the surrounding joint capsule (Bruce, 1999). Collateral ligament injuries can be addressed with primary repair and prosthetic reconstruction. Cranial cruciate ligament injury can be treated using fabello-tibial sutures or osteotomy techniques such as tibial plateau levelling osteotomy (TPLO) or tibial tuberosity advancement (TTA). Recommendations regarding appropriate treatment of caudal cruciate ligament rupture are speculative due to a lack of long-term follow-up. However, a study evaluating experimental transection and partial excision of the caudal cruciate ligament in dogs concluded that isolated transection of the caudal cruciate ligament produces minimal clinical and pathological changes in the stifle joint during a 6-month period (Harari et al., 1987). Reported stabilisation techniques include extracapsular procedures, intraarticular tissue graft and osteotomies (Kowaleski & Pozzi, 2018). A study has also suggested the use of a temporary transarticular pin intraoperatively to aid reduction and appropriate tensioning of sutures (Welches & Scavelli, 1990).

The use of postoperative immobilisation following repair of injured ligaments is controversial. While many authors recommend postoperative immobilisation to prevent mechanical failure of the repair (Aron, 1988; Bruce, 1998; Connery & Rackard, 2000; Hulse & Shires, 1986; Jaeger et al., 2005; Welches & Scavelli, 1990), other studies have demonstrated the deleterious effect of postoperative immobilisation on connective tissue. These include cartilage degeneration, decreased range of motion, joint contracture and muscle atrophy (Akeson et al., 1973; Akeson et al., 1987; Behrens et al., 1989).

Described techniques for postoperative immobilisation include transarticular pinning of the stifle joint (Welches & Scavelli, 1990), hinged transarticular external skeletal fixator (Lauer et al., 2008), transarticular external skeletal fixation (Aron, 1988), extracapsular articulated stifle stabilising implant (Embleton & Barkowski, 2012) or external coaptation (Schoenecker et al., 1997). The duration of postoperative immobilisation is also controversial. When possible, primary reconstruction of the injured ligaments with 4 weeks of immobilisation has been recommended (Schoenecker et al., 1997).

Several studies of stifle disruption repair have shown a reduction in range of motion of the stifle joint after surgery, with most of the limitation occurring in flexion (Boudrieau et al., 2003; Hulse & Shires, 1986; Nixon et al., 1997; Schoenecker et al., 1997).

The aim of this study was to describe traumatic stifle injury in dogs and to investigate factors associated with clinical outcome and postoperative complications. We hypothesised that the use of postoperative immobilisation would be related to a higher complication rate and to a poorer outcome.

2 | MATERIALS AND METHODS

Medical records were reviewed from six referral hospitals in the United Kingdom (the institution are not listed in the blinded document) from 1993 to 2019 and included client-owned dogs treated for traumatic stifle injury. Data collected from the medical records included breed, sex, age, affected limb, cause of injury, presence of concurrent injuries, clinical findings, immediate postoperative and follow-up radiographic findings, intraoperative findings, injury configuration, surgical procedures performed, postoperative stifle reduction, use of postoperative immobilisation, type and duration of immobilisation, revision surgery required, survival to discharge, duration of hospitalisation, short- and long-term complications and overall outcome. Animals in which the only ligament injured was the cranial cruciate ligament and animals with simultaneous bilateral stifle luxation were excluded from the study.

A definitive diagnosis was established on the basis of clinical, radiographic and intraoperative findings. Evidence for ligament damage was based on the presence of partial or complete disruption of the substance of the ligament or ligament-bone avulsion.

All dogs were treated surgically. The affected joints were explored to determine the presence of cruciate (cranial and caudal) ligament, meniscal or collateral ligament tears. Cruciate ligament tears were classified as complete or partial. Collateral ligament injuries were graded as: grade I in case of parenchymal haematoma/oedema (only few fibres torn), grade II in case of partial tear of the ligament and grade III in case of complete ligament rupture (Slocum & Slocum, 1997). Injuries were addressed at the discretion of the operating surgeon and performed surgical techniques were recorded. When meniscal damage was encountered, either meniscectomy (partial or total) or primary repair with sutures was performed.

The occurrence and nature of postoperative complications were recorded. Complications were categorised as major (surgical intervention performed) or minor (managed nonsurgically). Details of any revision surgery were recorded. Furthermore, complications were classified as short- (STC) or long-term complications (LTC), if reported before or after 8 weeks from the index surgery, respectively.

Long-term follow-up was obtained from referring veterinarians following owners' consent. The Liverpool Osteoarthritis in Dogs (LOAD) index, a clinical metrology instrument developed by the University of (name of university removed) and exclusively distributed by Elanco Animal Health, which has been shown to have a correlation with force-platform data (Barrack et al., 1995), was used to evaluate the dogs in this study. The Liverpool Osteoarthritis in dogs (LOAD) questionnaire was sent by post to all owners of dogs that were still alive at the time of the study when full owner address was available.

The overall outcome was determined from the latest follow-up and assigned into one of the following categories: excellent (return to full function without lameness); good (occasional/intermittent mild lameness); fair (persistent mild/moderate lameness); poor (moderate/severe lameness, amputation or euthanasia).

2.1 | Statistics

Demographic and clinical variables were summarised using median, interquartile range (IQR) and range for numerical variables and by frequency and percentage for categorical variables. Differences between groups were compared using Mann–Whitney *U* test for numerical variables and a likelihood-ratio G test or Fisher's exact test for categorical variables. The Wilson score method was used to calculate 95% confidence intervals (CI 95%) for proportions. All tests were two sided. A significance level (α) was set at 0.05. Statistical analysis was performed in TIBCO Statistica 13.3.0 (TIBCO Software Inc., Palo Alto, CA, USA).

3 | RESULTS

Twenty-six dogs were included in the study. Thirteen dogs were males (6/13 neutered), and 13 were females (9/13 spayed).

There were 3 crossbreeds and 22 pedigree dogs. The breed of one dog was not reported. Border collies (4), Whippets (3), Labrador retrievers (3) and Golden retrievers (2) were represented by more than one individual. Dogs weighed between 5.5 and 50 kg with the median (IQR) weight of 20.9 (14.3 to 31.5) kg. The median (IQR) age was 5.5 (3.4 to 9.0) years with the range from 3.4 to 9 years. The right side was affected in 73% of dogs (19), while the left side was affected in 27% of dogs (7).

The cause of trauma was unknown in 4/26 of dogs. The most common causes of injury were road traffic accidents in 6/26 dogs. Six (6/26) dogs suffered injury due to getting their limb caught in something, 4/26 were injured from landing after a jump, 2/26 from running, 1/26 dog from running into a pole, 1/26 from collision with another dog, 1/26 dog from unspecified trauma and in 1/26 dog, the injury occurred while walking.

Concurrent traumatic injuries were present in six dogs and these included pneumomediastinum, pneumothorax, abdominal hernia, subcutaneous emphysema, pelvic fractures, malleolar fracture, rib fracture, iliac fracture, shoulder luxation, head trauma and skin wounds.

Surgical findings were not available for all the dogs. All dogs with available surgical finding data (24/24) reported rupture of the cranial cruciate ligament. Rupture was complete in 23 dogs; the extent of rupture was not reported in the remaining dog.

The caudal cruciate ligament was ruptured in 12/23 dogs of which eight were completely ruptured.

Medial collateral ligament injury was reported in 6 of 24 dogs, of which 5 were partial tears (grade II), and 1 case was completely ruptured (grade III).

Lateral collateral ligament rupture was reported in 16/24 dogs, of which 12 were grade II sprain and 3 were completely ruptured (grade III), while in 1 dog, the type of lesion was not specified.

The different combinations of ligament injuries are illustrated in Table 1. Five different combinations were reported. The most common combination encountered was damage to the lateral collateral ligament and cranial cruciate ligament reported in 10/23 dogs. Injuries of two ligaments were reported in 12/23 dogs, while the remaining 11/23 dogs injured three ligaments.

Meniscal injuries were observed in 17/23 dogs, of which 16 were medial meniscal injuries and 4 were lateral meniscal injuries. In three of those dogs, both menisci were injured. The lateral meniscus was the only meniscus injured in one dog.

Twenty-two procedures were performed by a diplomate as a primary surgeon, and the remaining 2/24 procedures were performed by a nondiplomate veterinary surgeon. Surgical time ranged from 90 to 220 min with the median (IQR) of 120 (105–158) min.

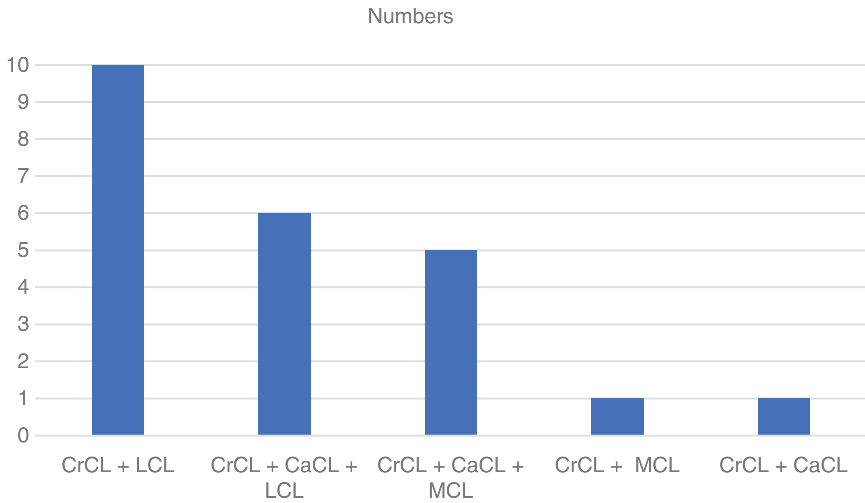
Cranial cruciate ligament injuries were treated using an extracapsular technique in 15/23 dogs and with osteotomy in 8/23 of dogs, of which 6 had a TPLO and two had a TTA.

Caudal cruciate ligament injuries were treated in 2/12 of cases with primary repair; in both cases, the technique performed to achieve primary repair was not reported. In seven cases, the techniques to address medial collateral ligament injury were reported; these included primary repair augmented with prosthetic orthopaedic wire in two cases, primary repair augmented with prosthetic nylon suture in two cases, prosthetic orthopaedic wire alone in two cases and prosthetic nylon suture alone in one case.

In 16 dogs, the techniques to address lateral collateral ligament injury were reported. The most common technique performed was primary repair augmented with a prosthetic fibrewire suture in seven dogs (7/16), primary repair augmented with a nonspecified prosthetic suture in 3/16 dogs, prosthetic fibrewire alone in 3/16 dogs, primary repair augmented with prosthetic nylon suture in 2/16 dogs and prosthetic polypropylene suture alone in 1/16 dog.

Surgical techniques to address medial meniscal injury were reported in 16 dogs. A partial meniscectomy was performed in 4/16 dogs, a caudal pole hemimeniscectomy was performed in 6/16 dogs, a total meniscectomy was performed in 4/16 dogs, the meniscal tear was primarily repaired in 1/16 dog and the meniscal tear was not surgically addressed in 1/16 dog. Surgical techniques to address lateral meniscal injury were reported in four dogs. A caudal pole hemimeniscectomy was performed in half of the cases (2/4), a total meniscectomy was performed in one dog (1/4) and the meniscal tear was not addressed in one

TABLE 1 Combination of ligament injuries.



CrCL: cranial cruciate ligament; LCL: lateral collateral ligament; CaCL: caudal cruciate ligament; MCL: medial collateral ligament.

dog (1/4). A temporary transarticular pin for intraoperative stabilisation was used in one dog. Postoperative joint immobilisation was used in 4/26 dogs. In all four dogs, a transarticular external fixator was used. Median duration of postoperative immobilisation was 4 weeks and 5 days (range from 4 to 8 weeks).

All patients survived to discharge, with a median (IQR) duration of hospitalisation of 3 (2–4) days and range from 1 to 7 days. Intraoperative complications were reported in 2/23 dogs. One dog developed a fibular head fracture, which was not stabilised. Medial patellar luxation was noted intraoperatively in one dog following repair of the ligament injuries. This was addressed with an antirotational fabellotibial fibrewire suture; in this dog, patellar luxation was not reported preoperatively.

Short-term complications were reported in 16/25 dogs; revision surgery was required in seven of these dogs. Persistence of stifle luxation was reported as a short-term complication in six cases; persistence of moderate to severe lameness in four cases; and lateral patellar luxation, seroma, digital flexor tendon contracture and extracapsular suture failure occurred in one case each. Three cases developed short-term complications associated to the external skeletal fixator including pin breakage (2), pin tract infection (1) and pin loosening (1). One case developed two short-term complications (pin breakage and pin tract infection).

Revision surgery was performed in 7/25 of dogs. In two dogs with persistence of luxation, additional medial support to the stifle joint was provided with screws and prosthetic sutures. In one dog, a TPLO procedure was performed to address persistent instability as a result of failure of the extracapsular suture. One dog underwent revision surgery to address a lateral patellar luxation. In one dog with a loose screw, a broken femoral pin and joint infection, the screw and the transarticular external skeletal fixator were removed. In one dog the proximal tibial pin was replaced ten days postoperatively due to persistent bleeding from pin tract; in the same dog, the proximal femoral pin was found loose and therefore it was replaced 3 weeks postoperatively. In one dog with persistence of stifle luxation 1 week after surgery, revision surgery was recommended; however, the owner declined further treatment and the dog was euthanised. In the other two dogs with persistence of stifle luxation, revision surgery was not performed; the reason for lack of surgical correction was unknown. Long-term complications occurred in 7/18 dogs. Complications reported were persistence of mild lameness in three dogs, persistence of mild stifle instability in two dogs, severe lameness in one dog and lateral patellar luxation in one dog despite revision surgery to address it. Of 24 dogs with available outcome, outcome was excellent in 9 dogs, good in 5 dogs, fair in 7 dogs and poor in 3 dogs. Follow-up time ranged from 1.5 months to 9 years with the median (IQR) of 9.5 (4.0–28.5) months. Statistical analysis looking at factors associated with poorer outcome showed that dogs with a fair or poor outcome were significantly older ($p = 0.015$) (Table 2); no other factors was found to be associated with a poorer outcome (Table 3). The LOAD questionnaire was available for six dogs. Median LOAD score was 6/52 (range 5–16) (0 = normal, 52 = severely disabled). These results indicated that the owners that answered to the questionnaires reported that five dogs were only mildly (LOAD score 0–10) and one dog was moderately (LOAD score 11–20) affected. Based on the questionnaire scores, no owners considered their dog being severely or extremely affected following surgical management of stifle luxation. Due to the low number of dogs with available LOAD questionnaires, the LOAD scores were not considered in the statistical analysis.

Injury of the medial and lateral collateral ligament was correlated with a significantly higher risk of short-term complications ($p = 0.046$), while dogs that developed long-term complications had a significantly lower body weight ($p = 0.010$) (Table 4). No other factors were found to be significantly associated with short- or long-term complications (Tables 3 and 5) nor with poorer outcome (Table 6).

TABLE 2 The relationship between demographic and medical categorical characteristics of dogs with stifle joint injury and the poor/fair outcome.

Variable	Category	Dogs with poor or fair outcome/all dogs in the category (%)	*p* Value
Sex	Male	4/10 (40)	0.999
	Female	5/12 (42)	
Castration	Yes	7/14 (50)	0.380
	No	2/8 (25)	
Side affected	Right	6/16 (33)	0.655
	Left	3/6 (50)	
Vehicular trauma	Yes	1/6 (17)	0.178
	No	8/15 (53)	
Concurrent traumatic injuries	Yes	0/5 (0)	0.054
	No	9/17 (53)	
CdCL rupture	Yes	5/11 (45)	0.670
	No	3/9 (33)	
CdCL complete rupture	Yes	3/8 (38)	0.999
	No	5/12 (42)	
MCL rupture	Yes	1/6 (17)	0.325
	No	7/14 (50)	
LCL rupture	Yes	6/13 (46)	0.642
	No	2/7 (29)	
No. of ligaments ruptured	Two	4/10 (40)	0.999
	Three	4/10 (40)	
Combination of ligament injuries besides CrCL	MCL+CdCL	1/5 (20)	0.331[a]
	LCL+CdCL	3/5 (60)	
	LCL	3/8 (38)	
	MCL	0/1 (0)	
	CdCL	1/1 (100)	
Medial meniscus injury	Yes	7/15 (47)	0.603
	No	1/5 (20)	
Lateral meniscus injury	Yes	1/4 (25)	0.619
	No	7/16 (44)	
Any meniscus injury	Yes	8/16 (50)	0.117
	No	0/4 (0)	
CrCL rupture Osteotomy	Yes	3/8 (38)	0.999
	No	5/12 (42)	
TPLO	Yes	2/6 (33)	0.999
	No	6/15 (40)	
Total meniscectomy in either meniscus	Yes	1/4 (25)	0.569
	No	7/12 (58)	
Use of temporal transarticular pin	Yes	1/1 (100)	0.400
	No	7/19 (37)	
Post op joint immobilisation	Yes	3/6 (50)	0.655
	No	6/16 (38)	

(Continues)

TABLE 2 (Continued)

Variable	Category	Dogs with poor or fair outcome/all dogs in the category (%)	*p* Value
Revision surgery	Yes	2/5 (40)	0.999
	No	7/16 (44)	
STC	Yes	6/13 (46)	0.999
	No	3/8 (38)	
LTC	Yes	3/7 (43)	0.608
	No	2/8 (25)	

[a]Likelihood-ratio *G* test.

4 | DISCUSSION

Traumatic stifle injury is a rare condition in dogs. Injury of some or all the stabilising structures of the stifle joint leads to significant stifle instability.

In this study, the most frequent combination of injuries was the cranial cruciate ligament and the lateral collateral ligament. This differs from previous studies where the most common combination of injuries involved both cruciate ligaments and the lateral collateral ligament (Bruce, 1998; Hulse & Shires, 1986). It has been hypothesised in a previous study that structures on the medial aspect of the stifle joint are more commonly injured because the point of impact (especially road traffic accident) frequently occurs on the lateral aspect of the limb (Hulse & Shires, 1986). Of the 10 dogs with concurrent cranial cruciate and lateral collateral ligament injury, 3 had their limb caught in a fence. It has been speculated that when this occurs, the dog begins to fall down on the other side exerting rotational and compressive forces medially, generating large tensile and shear forces on the lateral aspect of the stifle joint causing injuries of the primary and secondary lateral restraints (Bruce, 1998). In our study, the lateral collateral ligament was found injured in 16 dogs, while the medial collateral ligament was injured in 6 dogs. An in vivo study aiming to characterise the dynamic interaction of the four major ligaments in the canine stifle found that the internal and external rotation that accompanies valgus and varus loading, respectively, appear to be important in dispersing forces throughout the ligament restraint system in the stifle. Overall, valgus loads appear to be more shared by the ligaments than are varus loads (Roush et al., 2007). With varus loading, significant strains were found in the lateral collateral, which suggests that during the traumatic events in most of our cases, a large varus force may be a significant component causing this type of injury.

Interpretation of the findings at surgery can be challenging, Noyes and others demonstrated that a ligament can appear grossly intact while having lost load-carrying ability (James & de Lorimier, 1998). Aron in his study recommended that all ligaments should be inspected directly while undergoing stress palpation (Aron, 1988). All the affected joints should be carefully assessed with a thorough inspection of the menisci and joint capsule injuries. It has been suggested that the menisci should be preserved when possible and peripheral

TABLE 3 The relationship between demographic numerical characteristics of dogs with stifle joint injury and the poor/fair outcome.

	Outcome				
	Fair/poor outcome		Excellent/good outcome		*p* Value
Characteristic	*n*	Median, IQR (range)	*n*	Median, IQR (range)	
Age (years)	9	7.3, 5.5–9.0 (4.8–9.4)	13	3.3, 1.2–6.0 (0.8–10)	0.015
Body weight (kg)	9	21.5, 20.0–30.0 (11.5–50.0)	11	20.3, 14.2–33.0 (5.5–40.0)	0.648

The results in red indicate a statistically significant value.

meniscal injuries meticulously reconstructed (Hulse & Shires, 1986; Smith, 1995).

In the present series, primary repair of meniscal injuries was only performed in two cases, one meniscal injury was left untreated and meniscectomies (six partial meniscectomies, seven hemimeniscectomies and five total meniscectomy) were performed in the other cases. Contrary with what expected, none of the dogs undergoing a total medial meniscectomy reported a poor outcome.

The outcomes in the four dogs where a total meniscectomy was performed were fair in one dog, good in two dogs and excellent in one dog. The three dogs in this series with a poor outcome all reported injuries of both the medial and lateral menisci; from this information, the authors can speculate that lack of lateral and medial meniscal support may lead to poor limb function and poorer outcomes.

Boudrieau et al. (2003) suggest that severe stifle instability secondary to multiligamentous stifle injury leads to severe meniscal damage that often requires meniscectomy. Our study supports this suggestion as of the ten cases that injured three ligaments, seven reported a medial meniscal injury, three reported a lateral meniscal injury, two of these dogs injured both the medial and the lateral meniscus.

In our study, all the cases where a transarticular external skeletal fixator was used for postoperative immobilisation reported short-term complications, but none of them reported persistent instability as a short- or long-term complication. However, the low number of cases in this study does not allow the authors to provide recommendations on the use of postoperative immobilisation.

Proper management of traumatic joint luxation in small animals requires complete assessment and treatment of life-threatening injuries, early joint reduction and stabilisation, and early return of joint function (Conzemius et al., 2002). Early mobilisation after surgical repair of stifle ligaments does not seem to compromise ligament healing or result in undue ligamentous laxity. Results from Piper and Whiteside's study support the concept that early mobilisation after surgical repair of injured stifle ligaments may be beneficial in dogs (Baker et al., 2003). In fact, the mobilised stifles in their study were more stable, and the medial collateral ligaments were stronger (Baker et al., 2003). In an experimental study conducted by Denny et al. (2005), the intraarticular changes in dog stifles were studied following repair of the cranial cruciate and medial collateral ligaments under various postoperative managements: early mobilisation, immobilisation for 6 weeks in a plaster cast and limited mobilisation for 4 weeks in a cast brace. Based on their results, they concluded that postoperative immobilisation for more than 6 weeks causes considerable damage to the articular cartilage.

In the two cases of this study where postoperative immobilisation lasted longer than 5 weeks (5.5 and 8 weeks), the outcome was fair in one case and good in one case. All the cases where postoperative immobilisation was used reported short-term complications, two cases reported reduced stifle range of movement. In these two cases, postoperative immobilisation lasted, respectively, 4 and 8 weeks. Although immobilisation was not related to short- or long-term complications, persistent instability was recorded as a short-term complication in six dogs and as a long-term complication in two dogs where postoperative immobilisation was not applied.

In another experimental study comparing two hinged transarticular external skeletal fixator for multiple ligamentous injuries of the canine stifle, objective measures suggested that hinged external skeletal fixator is not indicated for adjuvant treatment after repair of experimentally induced ligament injuries (Lauer et al., 2008). Other studies showed that prolonged immobilisation has deleterious effect of ligament healing, while physiologically loaded ligaments have fibres that are oriented along lines of force, leading to a stronger and more functional ligament (Conzemius et al., 2002; Nunamaker et al., 2006). In the only case in our study where postoperative immobilisation lasted longer than 6 weeks (8 weeks) reduced range of motion was reported; however, this dog reported a good outcome at last follow-up (45 months following the injury).

Despite what is reported in the literature, postoperative immobilisation was not found to be significantly related to short- or long-term complications, or to a poorer outcome. Therefore, our hypothesis was not validated. This may well be due to low case numbers however as only four cases had postoperative immobilisation. All four dogs in our study where postoperative immobilisation was used reported injury of three ligaments, all these dogs injured both cranial and caudal cruciate ligaments and one of the collateral ligaments. The authors speculated that the decision for postoperative immobilisation may have been biased as surgeons may be more inclined to use postoperative immobilisation in dogs with severe joint instability compared with dog with a lesser degree of stifle joint instability. Therefore, the results of our study must be interpreted with caution. Looking at these cases individually, it was noted that two cases required revision surgery for

TABLE 4 The relationship between demographic and medical categorical characteristics of dogs with stifle joint injury and short-term complications (STC).

Variable	Category	Dogs with STC/all dogs in the category (%)	*p* Value
Sex	Male	7/11 (64)	0.999
	Female	8/12 (67)	
Castration	Yes	10/13 (77)	0.221
	No	5/10 (50)	
Side affected	Right	12/17 (71)	0.621
	Left	3/6 (50)	
Vehicular trauma	Yes	6/7 (86)	0.193
	No	8/15 (53)	
Concurrent traumatic injuries	Yes	5/6 (83)	0.369
	No	10/17 (59)	
CdCL rupture	Yes	7/10 (70)	0.650
	No	5/10 (50)	
CdCL complete rupture	Yes	6/7 (86)	0.158
	No	6/13 (46)	
MCL rupture	Yes	6/6 (100)	0.046*
	No	7/15 (47)	
LCL rupture	Yes	7/15 (47)	0.046*
	No	6/6 (100)	
No. of ligaments ruptured	Two	6/11 (55)	0.670
	Three	6/9 (67)	
Combination of ligament injuries besides CrCL	MCL+CdCL	4/4 (100)	0.098[a]
	LCL+CdCL	2/5 (40)	
	LCL	4/9 (44)	
	MCL	1 /1 (100)	
	CdCL	1/1 (100)	
Medial meniscus injury	Yes	9/15 (60)	0.999
	No	3/5 (60)	
Lateral meniscus injury	Yes	3/3 (100)	0.242
	No	9/17 (53)	
Any meniscus injury	Yes	10/16 (63)	0.999
	No	2/4 (50)	
CrCL rupture osteotomy	Yes	5/8 (63)	0.999
	No	7/12 (58)	
TPLO	Yes	4/6 (67)	0.999
	No	10/16 (63)	
Total meniscectomy in either meniscus	Yes	4/4 (100)	0.234
	No	6/12 (50)	
Use of temporal transarticular pin	Yes	0/1 (0)	0.400
	No	12/19 (63)	
Post op joint immobilisation	Yes	5/6 (83)	0.369
	No	10/17 (59)	

[a]Likelihood-ratio *G* test.
The results in red indicate a statistically significant value.

TABLE 5 The relationship between demographic and medical categorical characteristics of dogs with stifle joint injury and long-term complications (LTC).

Variable	Category	Dogs with LTC/all dogs in the category (%)	*p* Value
Sex	Male	3/7 (43)	0.999
	Female	4/9 (44)	
Castration	Yes	5/9 (56)	0.358
	No	2/7 (29)	
Side affected	Right	5/12 (42)	0.999
	Left	2/4 (50)	
Vehicular trauma	Yes	3/5 (60)	0.593
	No	4/10 (40)	
Concurrent traumatic injuries	Yes	3/4 (75)	0.261
	No	4/12 (33)	
CdCL rupture	Yes	2/6 (33)	0.592
	No	4/7 (57)	
CdCL complete rupture	Yes	2/5 (40)	0.999
	No	4/8 (50)	
MCL rupture	Yes	3/5 (60)	0.580
	No	3/9 (33)	
LCL rupture	Yes	3/10 (33)	0.245
	No	3/4 (75)	
No. of ligaments ruptured	Two	4/7 (57)	0.592
	Three	2/6 (33)	
Combination of ligament injuries besides CrCL	MCL+CdCL	2/3 (67)	0.214[a]
	LCL+CdCL	0/3 (0)	
	LCL	3/6 (50)	
	MCL	1/1 (100)	
	CdCL	-	
Medial meniscus injury	Yes	5/9 (56)	0.559
	No	1/4 (25)	
Lateral meniscus injury	Yes	1/1 (100)	0.462
	No	5/12 (42)	
Any meniscus injury	Yes	5/9 (56)	0.559
	No	1/4 (25)	
CrCL rupture Osteotomy	Yes	3/6 (50)	0.999
	No	3/7 (43)	
TPLO	Yes	2/4 (50)	0.999
	No	4/11 (36)	
Total meniscectomy in either meniscus	Yes	2/3 (67)	0.999
	No	3/6 (50)	
Use of temporal transarticular pin	Yes	-	-
	No	6/13 (40)	
Post op joint immobilisation	Yes	1/4 (25)	0.585
	No	6/12 (50)	

(Continues)

TABLE 5 (Continued)

Variable	Category	Dogs with LTC/all dogs in the category (%)	*p* Value
STC	Yes	6/11 (55)	0.308
	No	1/5 (20)	
Revision surgery	Yes	1/4 (25)	0.585
	No	6/12 (50)	

[a]Likelihood-ratio *G* test.

complications related to the external skeletal fixator. In one dog, one of the pins had to be replaced due to persistent bleeding from the pin tract and in another dog external skeletal fixator was removed at 5.5 weeks due to loosening of one of the pins. However, the overall outcome in dogs where postoperative immobilisation was used was excellent in two dogs, good in one dog and fair in another dog. The author suggests that the potential positive and negative effect of postoperative immobilisation should be carefully evaluated on a case-by-case basis, as well as duration of external skeletal fixation.

In our series dogs with a fair or poor outcome were significantly older and the presence of medial collateral ligament injury were linked to higher risks of short-term complications, while postoperative immobilisation, presence of concurrent injuries and other factors were not significantly associated to/with a higher risk of complications.

Many studies discussed aging as a potential risk factor for the development of osteoarthritis, suggesting joint deterioration occurs increasingly with age (Baker et al., 2003).

These suggestions could explain our results and that elderly dogs are more likely to develop joint osteoarthritis following stifle trauma leading to a poorer outcome. The study did not aim to investigate the potential correlation between the development of osteoarthritis and the outcome, but it would have been interesting to examine this relationship further.

In our study, medial collateral ligament injury was recorded in six dogs, five of which reported a complete tear. Furthermore, five dogs with medial collateral ligament damage sustained injury of both cruciate ligaments; two of these dogs reported a persistent stifle instability. In addition, 83% (5/6) of dogs with medial collateral ligament injury also reported injury of the caudal cruciate ligament, while 38% (6/16) of dogs with lateral collateral ligament injury reported injury of the caudal cruciate ligament. We speculate that the high incidence of complete medial collateral ligament injury with concomitant disease of the cruciate ligaments may indicate that these dogs suffered from a more severe trauma that led to a poorer outcome. However, as previously stated due to the low number of cases, statistical analysis results should be carefully interpreted.

The caudal cruciate ligament injuries were addressed surgically in 9 of the 11 dogs. The two dogs where the injury was not surgically addressed did not report stifle instability as a short- or long-term complication and the outcome was classified as fair in one dog and good in the other dog.

Although this is the largest study of this injury to date, only 26 cases were identified. Due to the limited number of cases, the results need to be interpreted carefully and it is difficult to draw conclusions that help guide clinical practice. However, these cases have been described with the aim of providing some general information on treatment options and their associated outcome, and to better establish the prognosis of dogs suffering from multiligament stifle injury. Limitations of this study are related to its retrospective, multicentric design, with incomplete records and variability introduced by multiple authors collecting data and differences in case management or execution of the surgical procedure between institutions. The study population consisted of a diverse range of breeds and body weights, which may have influenced the evaluation of the outcome due to potential size-related differences. Additionally, the outcome lacks objective patient outcome measures as well as association between the degree of osteoarthritis and outcome. This study represents the largest study of this injury in dogs to date and it highlights the rarity of stifle luxation in dogs. However, the cohort size does not allow the author to draw conclusions regarding comparative efficacy of therapies for treatment of stifle luxation in dogs. The data presented in this study highlights the need for a prospective study with objective assessment of the long-term outcome on joint health and mobility to give further indication on treatments and postoperative immobilisation.

Our results indicate that dogs with long-term complications had a significant lower body weight. The authors speculate that dogs with lower body weight may be more prone to complications due to their smaller size, which makes surgical management of the injured ligaments more challenging. However, other factors may also play a role and further research would be needed to fully understand the relationship between body weight and stifle luxation complications in dogs. The impact of body condition score on the incidence of complications and overall outcome in the context of this injury remains unassessed to a shortage of available data. Further investigation into this relationship would prove valuable.

In conclusion, results from this study suggest that surgical treatment of traumatic stifle injury in dogs is associated with a high complication rate, with the presence of medial collateral ligament injury associated with a higher risk of short-term complications and older age found to be associated with a poorer outcome. Being the largest study of this injury in dogs to date, it highlights the uncommon nature of multiligamentous stifle injury in dogs.

The overall outcome was good to excellent in 14 dogs (58%; CI 95%: 39%; 76%), indicating that only roughly half of dogs maintained a good limb function and good quality of life in the long term.

AUTHOR CONTRIBUTIONS

Mario Coppola: conceptualisation, data curation, formal analysis, investigation, methodology, project administration, resources, software, validation, visualisation, writing – original draft, writing – review & editing. Smita Das: conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, resources, supervision, visualisation, writing – review & editing. George

TABLE 6 The relationship between demographic numerical characteristics of dogs with stifle joint injury and long-term complications (LTC).

	Long-term complications (LTC)				
	Yes		No		*p* Value
Characteristic	*n*	Median, IQR (range)	*n*	Median, IQR (range)	
Age (years)	7	4.6, 1.2–5.5 (1.0–7.0)	9	6.0, 5.0–9.1 (1.0–10.0)	0.100
Body weight (kg)	7	18.6, 9.3–20.3 (5.5–21.5)	8	31.5, 26.0–34.5 (14.2–50.0)	0.007

The results in red indicate a statistically significant value.

Matthews: conceptualisation, data curation, formal analysis, investigation, methodology, resources, writing – review & editing. Matteo Cantatore: conceptualisation, data curation, formal analysis, investigation, methodology, resources, writing – review & editing. M Czopowicz: data curation, formal analysis, methodology, writing – original draft. Luis Silva: conceptualisation, data curation, formal analysis, investigation, writing – review & editing. Jessica McCarthy: conceptualisation, data curation, formal analysis, methodology, project administration, writing – review & editing. Nuria Fernandez-Salesa: conceptualisation, data curation, investigation, resources, visualisation, writing – review & editing. Pilar Lafuente: conceptualisation, data curation, formal analysis, funding acquisition, writing – review & editing. Ross Allan: conceptualisation, data curation, investigation, methodology, resources, visualisation, writing – review & editing. Richard Meeson: data curation, funding acquisition, investigation, writing – review & editing. Elena Addison: conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, supervision, validation, visualisation, writing – original draft, writing – review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest related to this report.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author (MC). The data are not publicly available due to restrictions such as GDPR (General Data Protection Regulation). Access to the data will be granted following a reasonable request to the corresponding author, and subject to any necessary permissions and approvals that may be required by law.

ETHICS STATEMENT

Ethical approval for this study was granted by the institutional animal research ethics committee of the University of Glasgow, School of Veterinary Medicine, Glasgow, United Kingdom (Ref03a/18).

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