Retrospective study of 476 tibial plateau levelling osteotomy procedures

Rate of subsequent 'pivot shift', meniscal tear and other complications

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Keywords
Pivot shift, complication, meniscal tear, tibial plateau levelling osteotomy, stifle, canine

Summary
Objective: To determine the rate of subsequent 'pivot shift', meniscal tear and risk factors associated with complications of tibial plateau levelling osteotomy (TPLO) and to assess clinical and owner perception outcome.
Study design: Retrospective study.
Sample population: Three hundred and forty-eight dogs that had undergone TPLO surgical procedures (n = 476 stifles).
Methods: Medical records were reviewed for the retrieval of information on breed, sex, age, body weight, clinical history, radiograph findings, pre- and postoperative tibial plateau angle, limb alignment, unilateral versus bilateral disease, condition of cranial cruciate ligament (CCL) and menisci, implant material, healing time and complications. Clinical and owner-assessed questionnaire outcomes were also recorded.
Results: Forty-six (9.7%) postoperative complications were reported. Twenty (4.2%) were classified as major complications requiring an additional surgical intervention, and 26 (5.5%) as minor complications. No risk factors associated with postoperative complications were identified. Ten (2.1%) subsequent meniscal injuries in the stifles with normal unaltered menisci at time of TPLO were reported with a median postoperative time of 9.5 months. Signs of postoperative 'pivot shift' were reported in 15 (3.1%) stifles. All stifles with a 'pivot shift' had a complete CCL rupture or a debrided partial CCL rupture; a medial menisectomy was identified as a risk factor for a 'pivot shift' ($p = 0.02$). Dogs with intact medial meniscus had a significantly higher activity level ($p < 0.0001$) and a shorter time to peak function ($p = 0.02$) than dogs that underwent menisectomy according to an owner questionnaire.
Conclusions: Dogs with TPLO and intact meniscus seemed to have a better and faster recovery than dogs with TPLO and menisectomy based on owner questionnaires. 'Pivot shift' was infrequent after TPLO surgery. All dogs with a 'pivot shift' had a complete CCL rupture or a debrided partial CCL rupture and menisectomy was identified as a risk factor for its occurrence.
Clinical relevance: Considering the relatively low rate of subsequent meniscal injury after TPLO, systematic medial meniscal release with TPLO may be unnecessary. The 'pivot shift' deserved further investigation to completely understand its mechanism, to identify its anatomic components and potential consequences on the stifle joint.

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Introduction

Cranial cruciate ligament (CCL) rupture is a common orthopaedic condition in dogs and tibial plateau levelling osteotomy (TPLO) procedure which was developed by Slocum in 1993 is frequently performed to treat this condition (1, 2). Retrospective studies reported complication rates of 18.8% to 28% for standard TPLO procedures with a second surgical intervention required in 1.6% to 8.4% of the cases (3–6).

The rate of subsequent meniscal tear after TPLO was reported in previous studies as being 1% to 6.3% (4, 7). Controversy still exists regarding the best way to treat dogs with CCL rupture and intact medial meniscus. Medial meniscal release (MMR) is performed by some surgeons to limit subsequent meniscal tear after TPLO surgery but deleterious effects have been reported with this procedure; the identification of the incidence and risk factors for subsequent meniscal tear as well as the consequences of MMR could be helpful to decide whether or not to perform this procedure (8–11).

Slocum introduced the concept of limb malalignment; the opportunity for correction of limb malalignment is one of the advantages of the TPLO surgery (1, 2). Failure to control the tibial internal rotation resulting in cranial subluxation of the tibial plateau in association with a sudden lateral change in direction of the stifle joint during weight-bearing was referred to as 'pivot shift' (12, 13). This phenomenon, as mentioned in a textbook and a review, has never been reported in previous TPLO retrospective studies and the significance of this motion to functional outcome following TPLO surgery is to date uncertain (12,13).

The purpose of this retrospective study was therefore to report the rate of postoperative complications and potential risk factors associated with standard TPLO surgery, the rate of subsequent meniscal tears with or without MMR, the incidence of the 'pivot shift' phenomenon, and to report clinical and owner-assessed outcome for dogs with CCL rupture treated with a standard TPLO procedure.

Materials and methods

Inclusion criteria

Medical records of all dogs that underwent a standard TPLO for CCL rupture at our hospital, Centre Vétérinaire DVM, between February 2004 and February 2008 were reviewed. A dog was eligible for inclusion when the diagnosis of CCL rupture was confirmed at surgery, the dog was returned for physical examination and radiographic evaluation at least six weeks after surgery, and when information available from the medical record included signalment, details of surgical procedure, history of complications and the findings of follow-up examination.

Signalment

Data obtained from medical records included breed, sex, age, body weight, affected limb, duration and severity of the lameness, stifle and hip radiograph findings, pre- and postoperative tibial plateau angle (TPA), subjective assessment of limb alignment and unilateral versus bilateral CCL rupture. Lameness evaluation was subjectively assessed and reported at a walk and trot by one of the two surgeons (JD or JP) and retrospectively categorically graded for the purpose of this study using the following scale: 0 = no observable lameness; 1 = mild weight-bearing lameness with minimal change in gait; 2 = moderate, obvious weight-bearing lameness with noticeable change in gait; 3 = severe weight-bearing lameness with 'toe-touching' or non-weight bearing lameness. Extent of CCL damage (complete or partial rupture), meniscal damage and treatment (none, medial menisectomy or MMR), implant type (plate and screws), postoperative antibiotic drug therapy, and duration of clinical follow-up were also reported. Contralateral CCL rupture was documented by re-examination or surgery at our hospital and by owner telephone interview. If the dog did not develop lameness in the contralateral limb and was considered normal by the owner at the time of the telephone interview, the CCL was presumed to be intact. The follow-up period in dogs without contralateral rupture was defined as the period between initial diagnosis of unilateral CCL rupture and telephone interview with the owner. The minimum follow-up period was 24 months.

Radiographic assessment

Both stifles were assessed radiographically at the time of initial CCL rupture diagnosis and the presence of signs of osteophytosis and joint effusion were reported. Pre- and postoperative TPA were measured. Subjective assessments of axial alignment and tibial torsion using Slocum's criteria were made by surgeons during the surgical procedure, and by reference to the pre- and postoperative radiographs (14). Immediate postoperative radiographs were also assessed for surgical implant positioning (plate, screws and anti-rotational Kirschner-wire when present). Osteotomy healing was assessed subjectively by evaluation of the two-month follow-up radiographs. Retrospectively, femoral varus (mechanical lateral distal femoral angle) and postoperative tibial varus (mechanical medial proximal tibial angle) were measured on radiographs of the dogs which developed a postoperative 'pivot shift', as previously described (15–18).

Procedures

All dogs underwent standard medial parapatellar arthrotomy for exploration of the stifle joint. Remnants of the CCL were removed at the discretion of the surgeon and the menisci were inspected. When a meniscal injury was evident, the torn component was removed by menisectomy. When the meniscus was intact, the caudal horn of the medial meniscus was left intact or a MMR was performed at the discretion of the surgeon. Medial meniscal release was accomplished by radial transection of the caudal midbody of the medial meniscus. The TPLO surgical procedures were performed by one of the two surgeons according to the technique of Slocum and Slocum. (1, 14). Variations in procedure among both surgeons were minor. A jig was always used for all the procedures and axial alignment and torsion of the tibia were corrected when judged necessary by the surgeon as previously reported (1, 14). Cortical, cancellous (for the proximal tibial segment), and locking screws were used at the discretion of the surgeon with either 2.7, 3.5, or ((broad)) 3.5 mm TPLO plates[a] during the initial period of this study or locking TPLO plates[b]. A pressure bandage was applied and maintained for four to six days after surgery, depending on the surgeon's preference and the dog's conformation and tolerance of the bandage. Dogs were typically discharged from our hospital the day after the surgery. Dogs were returned for bandage and suture removal at either four to six days or two weeks respectively after the surgery. The dogs were re-evaluated at two and four months after surgery, with radiographic examination performed two months postoperatively. Administration of medication, such as analgesic and antimicrobial therapy after surgery and physiotherapy, were at the discretion of the surgeon.

Complications

Type and outcome of complications were recorded. Postoperative complications were defined as any unexpected, undesirable developments that occurred after surgery that were confirmed by physical or radiographic examination of the dog at our hospital. Major complications were defined as those requiring a subsequent surgical intervention, whereas minor complications

[a] Slocum TPLO plate: Slocum Enterprise, Eugene, OR, USA
[b] TPLO plate: New Generation Devices, Medina, OH, USA

were defined as those not requiring additional surgical treatment. The postoperative occurrence of the 'pivot shift' phenomenon and its progression over the follow-up period, were also reported. Postoperative infection was defined as a wound having purulent drainage or an abscess, and a wound dehiscence associated with pain and swelling over the surgical site of the stifle joint together with severe lameness. Positive bacterial culture results were considered to be an indication of an infection, but a negative bacterial culture result did not preclude the diagnosis of infection when the other criteria mentioned above were met.

Outcome assessment

Clinical outcome was subjectively reported as poor, fair, good or excellent based on the orthopaedic examination obtained at the final follow-up. The owners were contacted for follow-up phone interviews so that data about subsequent surgical procedures, lameness, activity level, length of time after surgery to peak function of the limb, medication used and overall outcome could be obtained (▶Follow-up questionnaire available online at www.vcot-online.com). The minimum follow-up period for the phone interview was 24 months. The responses were subsequently tabulated and used for statistical analysis.

Statistical analysis

Data were reported as mean ± SD for normally distributed data, or median and range for non-parametric data. Distributions of categorical data were compared by use of χ^2 test. Continuous variables were compared by use of independent *t* tests. Odds ratio (OR) with confidence interval (CI) was calculated when a significant difference was reported. Data on activity level, time to peak function and outcome between the intact meniscus group, the medial meniscal release group, and the medial menisectomy group were compared for statistically significant differences using the Cochran-Mantel-Haenszel test and post-hoc tests with the Bonferroni correction. Statistical analyses were performed with a commercially available statistical software[c] and a level of significance of 0.05 was used throughout the study.

Results

Signalment

Three hundred and forty-eight dogs fulfilled the criteria for inclusion in this study. A hundred and twenty-eight of the dogs underwent bilateral TPLO, for a total of 476 TPLO surgical procedures performed. Bilateral TPLO performed during the same anaesthetic episode were not considered in this study. The 348 dogs that underwent TPLO surgery consisted of 199 (57.2%) neutered females, four (1.1%) intact females, 138 (39.7%) neutered males, and seven (2%) intact males. Median age of dogs at the time of surgery was five years (range, 1 to 11.5 years), and median body weight was 36 kg (range, 16.3 to 76 kg). Thirty-nine breeds of dogs were represented in the study population. Thirty-five (10%) were mixed breed dogs. The most common breeds were Labrador Retriever (n = 87; 25%), Golden Retriever (n = 53; 15.3%), Rottweiler (n = 26; 7.5%) and Bernese Mountain Dogs (n = 25; 7.2%).

Radiographic characteristics and findings

A diagnosis of contralateral CCL rupture was made in 131 of the 348 (37.6%) dogs 10 ± 8.5 months (mean ± SD) after the initial diagnosis of unilateral CCL rupture. A hundred and eleven of 192 dogs (57.8%), which had evidence of effusion or osteophytosis of the contralateral stifle joint at the initial diagnosis of unilateral CCL rupture, subsequently ruptured the contralateral CCL 9.2 ± 8.3 months after initial diagnosis. Twenty of 156 dogs (12.8%), which did not have any evidence of effusion or osteophytosis of the contralateral stifle joint at the initial diagnosis of unilateral CCL rupture, subsequently ruptured the contralateral CCL 14.3 ± 8.9 months after initial diagnosis. Twenty-three of the 348 dogs had an initial diagnosis of bilateral CCL rupture.

[c] Version 9.1 of SAS: SAS, Cary, NC, USA

Surgery and surgical findings

Two surgeons (JD, JP) performed all of the TPLO surgical procedures that were reviewed in this study. Craniomedial arthrotomy with evaluation of the CCL and menisci was performed for all surgical procedures. Menisci were always carefully assessed by probing the menisci with mosquito forceps or a probe for all procedures. A complete tear of the CCL was reported for 286 (60.1%) TPLO procedures. The occurrence of complete or partial CCL rupture was not influenced by the duration of preoperative clinical signs (p = 0.33) but was significantly associated with the severity of the lameness (p = 0.0001). Debridement of partial CCL ruptures was performed in 163 (85.8%) stifles at the discretion of the surgeon. Meniscal injury was noted in 173 (36.4%) stifles and it was associated with an audible meniscal 'click' at the clinical examination in 54 (31.2%) stifles. A meniscal tear was diagnosed in conjunction with complete CCL rupture in 155 (89.6%) stifles and with partial CCL rupture in 18 (10.4%) stifles. Meniscal injury occurrence was not influenced by the duration of preoperative clinical signs (p = 0.14) nor by preoperative TPA (p = 0.36) but it was significantly associated with a severe lameness (p = 0.0001; OR = 7.64 [95% CI = 4.28–15.41]) and a complete CCL rupture (p = 0.0001; OR = 9.97 [95% CI = 5.96–18.03]) (▶Table 1). Partial or hemi-menisectomy to treat meniscal injuries was performed in 173 (36.4%) stifles. During the initial phase of this study, a MMR was performed in all TPLO surgical procedures when menisci were intact; this represented 92 (19.3%) TPLO procedures. Simultaneous partial menisectomy and MMR were performed in 21 (4.4%) stifles. The medial meniscus was found to be intact in 211 (44.3%) stifles. Routinely, cefazolin (22 mg/kg) was administered to all dogs perioperatively and 208 (43.7%) dogs were treated with oral cephalexin (22–30 mg/kg) for 10 days postoperatively by one of the

Factor	p-value*
Ligament status (cranial cruciate ligament complete or partial)	<0.0001
Lameness grade	<0.0001
Preoperative duration of clinical signs†	0.14
Preoperative tibial plateau angle†	0.36

Key: Results are for χ^2 tests, unlise indicated otherwise. † Results are for *t* tests. * Values were considered significant at p <0.05.

Table 1 Factors potentially associated with development of meniscal tear with cranial cruciate ligament rupture.

Factor	p-value*
Breed	0.32
Sex	0.73
Age†	0.42
Body weight†	0.27
Ligament status (cranial cruciate ligament complete or partial)	0.99
Unilateral or bilateral cranial cruciate ligament rupture	0.32
Side (right or left)	0.53
Order (1st stifle or 2nd stifle surgery)	0.46
Preoperative duration of clinical signs†	0.44
Preoperative tibial plateau angle†	0.32
Postoperative tibial plateau angle†	0.37
Postoperative antimicrobial drug therapy	0.48

Key: Results are for χ^2 tests, unlise indicated otherwise. † Results are for *t* tests. * Values were considered significant at p <0.05.

Table 2 Factors potentially associated with development of postoperative complications after tibial plateau levelling osteotomy surgery.

surgeons. Locking screws (median of 2 locking screws per surgery, and ranging from 1 to 4) were used in 186 (39.1%) procedures. Locking TPLO plates and conventional TPLO plates were respectively used in 365 (76.7%) stifles and 111 (23.3%) stifles. Mean preoperative TPA was 28.7 ± 3.3 (range: 19 to 40) and mean postoperative TPA was 5.8 ± 1.7 (range: 1 to 13). Three hundred and eighteen of the 389 (81%) stifles without complication and 29 of the 41 (70%) stifles with complications were recorded as being radiographically healed by eight weeks without significant difference (p = 0.27).Two hundred and eleven of the 244 (86%) stifles without locking screws and 136 of the 186 (73%) stifles with locking screws were recorded as radiographically healed by eight weeks postoperatively without significant difference (p = 0.23).

Re-evaluation and clinical outcome

Mean duration of clinical follow up was 32 weeks (median 16; range: 6 to 252 weeks). Overall, an excellent or good clinical outcome was recorded in 446 (93.7%) stifles. Of the 431 stifles without any complications and the 45 stifles with complications, 405 (94%) and 41 (91%) respectively were recorded with an excellent or good outcome at the final follow-up clinical examination; there was not a significant difference between the two groups (p = 0.14).

Complications

Forty-six (9.7%) complications resulting from 45 of the 476 TPLO procedures were recorded. Twenty (4.2%) were classified as major complications requiring an additional surgical intervention, and 26 (5.5%) as minor complications. There were not any predisposing factors for postoperative complications found in our study (▶Table 2).

Overall, fourteen (2.9%) dogs developed a postoperative infection. Of those, 12 (87.5%) had not been treated with oral cephalexin postoperatively. The infection rate for dogs treated postoperatively with cephalexin (1%) was significantly lower than dogs that were not (4.5%) (p = 0.02; OR = 4.03 [95% CI = 1.05–44.78]). Infection was detected within the first year after surgery in all above cases, with most dogs (n = 11) developing an infection within six weeks after surgery. Septic arthritis was diagnosed and confirmed by positive bacteriological culture in three stifles. Five stifles underwent revision surgery. Treatments included exploration of the stifle joint and joint lavage (n = 5) combined with implant removal (n = 5); antimicrobial drug was prescribed in all cases (n = 14).

Meniscal injury developed after 10 (2.1%) TPLO procedures with a median postoperative time of 9.5 months (range: 1 to 19). In five stifles, an initial diagnosis of complete CCL rupture was made whereas the other five stifles were found to have a partial CCL rupture, all of which were debrided. If only stifles with intact menisci after the initial surgery were considered, the rate of subsequent meniscal tear would be 3.8% compared to 0.9% for stifles with MMR. A partial menisectomy (either medial or lateral when necessary) was performed in all stifles to remove the damaged portion of meniscus. Clinical outcome was judged as good to excellent in all 10 cases after the revision surgery. The rate of subsequent meniscal tear was not significantly decreased when a MMR was performed during the initial TPLO surgery (one of 113 stifles) (p = 0.29). Median postoperative TPA for stifles with subsequent meniscal tear was 6.5 (range: 5 to 8) which was not significantly different compared to the stifles without subsequent meniscal tear (median 6 ; range: 1 to 13) (p = 0.71).

Implant related complications were recorded after 10 TPLO procedures with eight broken conventional screws (one during surgery and 7 detected on follow-up radiographs), one bent plate and an anti-rotational pin loosening which required an additional procedure to remove the pin. Clinical outcome was reported as good to excellent in all of these 10 TPLO procedures. Malpositioned screws (close to the tibial plateau joint surface) were reported in two stifles. Persistent lameness was recorded for these two stifles until screw removal was performed and the final clinical outcome was considered excellent after the second surgery. Grade 2 (n = 4) and grade 3 (n = 1) medial patellar luxation was recorded after five TPLO procedures. The clinical outcome was reported as good to excellent for the four stifles with a grade 2 medial patellar luxation with surgical correction. The owner declined any additional procedure to correct the grade 3 medial patellar luxation and the clinical outcome was judged as being fair for this dog. Fibular fracture (n = 2) and patellar fracture (n = 1) were associated with transient mild lameness eight weeks and six weeks after TPLO surgery respectively, but this lameness resolved without any additional surgical treatment. Final clinical outcomes for these dogs were considered good to excellent. A multiple tibial fracture with implant loosening also occurred during the first postoperative week in one dog. The owner of this dog elected to have a hindlimb amputation and the clinical outcome of this dog was recorded as being poor. Finally, cranial tibial trust with a positive tibial compression test (postoperative TPA of 13) persisted after surgery in one giant breed dog which also was affected by cervical spondylomyelopathy, and the clinical outcome for this dog was reported as being fair.

Table 3 Factors potentially associated with development of 'pivot shift' phenomenon after tibial plateau levelling osteotomy surgery.

Factor	p-value*
Ligament status (complete or debrided partial vs. undebrided partial cranial cruciate ligament)	0.20
Medial menisectomy	0.02
Meniscal release	0.33
Meniscal integrity (intact, medial meniscal release, or menisectomy)	0.05
Preoperative tibial plateau angle†	0.11
Postoperative tibial plateau angle†	0.06

Key: Results are for χ^2 tests, unlise indicated otherwise. † Results are for *t* tests. * Values were considered significant at p <0.05.

'Pivot shift' phenomenon

Following TPLO surgery, 'pivot shift' was reported in 14 dogs; one dog had a bilateral 'pivot shift' postoperatively. The three most common breeds that developed postoperative 'pivot shift' were Labrador Retrievers (n = 7), Golden Retrievers (n = 3) and Bernese Mountain dogs (n = 2). The stifle joint sustained a tibial internal rotation resulting in cranial subluxation of the tibial plateau in association with a sudden lateral change in direction of the stifle joint during weight-bearing. This phenomenon was more visible while dogs were walking than trotting, and it was always detected during the orthopaedic examination. All the affected dogs had a complete rupture or partially debrided cranial cruciate ligament, however the absence of a CCL after surgery was not identified as a risk factor for the occurrence of the 'pivot shift' (p = 0.20) (▶Table 3). Twelve of the dogs had a medial menisectomy at the initial TPLO surgery. Medial menisectomy was identified as a risk factor for the occurrence of the 'pivot shift' (p = 0.02; OR = 3.33 [95% CI = 1.06–13.19]). Neither of the two dogs with an intact meniscus and postoperative 'pivot shift' developed subsequent meniscal tears. Mean pre- and postoperative TPA (respectively 28.8 and 6.3) were not identified as risk factors for the occurrence of the 'pivot shift' (respectively p = 0.11 and p = 0.06). Postoperative mean femoral varus (mechanical lateral distal femoral angle) was 98.6 and postoperative mean tibial varus (mechanical medial proximal tibial angle) was 92.4 for dogs with postoperative 'pivot shift'. Preoperative internal tibial torsion was present in six stifles with postoperative 'pivot shift' and was corrected in surgery in five stifles as previously described (14). The 'pivot shift' disappeared four to six months postoperatively in four stifles. Ipsilateral thigh muscular atrophy detected by physical examination was reported in thirteen stifles two months postoperatively, and in four dogs four months postoperatively. Clinical evaluation by the surgeon (JD or JP) did not reveal any stifle or limb discomfort upon manipulation.

Long-term owner-assessed outcome

Two hundred and forty of 348 (69%) owners responded to the phone interview. Thirty-two dogs that had unilateral TPLO were reported by the owners to have undergone surgery of the contralateral stifle for CCL rupture by the end of this study. If we include these data, 186 of the 348 dogs (53.4%) had bilateral CCL rupture during this study. Of those, 27 dogs had radiographic evidence of effusion or osteophytosis of the contralateral stifle joint at the time of the initial diagnosis of unilateral CCL rupture. None of the owners reported having another surgical procedure performed on the contralateral stifle joint other than those performed at our hospital. None of the owners observed a severe lameness of the affected limb since the TPLO surgery. The median follow-up for the owner questionnaire was 32 months (ranged from 24 to 59 months). Owner-assessed outcome for activity level, time to peak function and overall outcome between dogs with intact meniscus, dogs with medial meniscal release, and dogs with menisectomy were reported (▶Table 4).

Discussion

Bilateral CCL rupture was found in 53.4% of the dogs if we considered dogs that underwent TPLO surgery for the contralat-

Table 4 Owner-assessed outcome for activity level, time to peak function and overall outcome between dogs with intact meniscus, dogs with medial meniscal release, and dogs with menisectomy.

	Intact meniscus	Medial meniscal release	Menisectomy
Activity level			
Greatly improved	85.5% (n = 100)	73.3% (n = 44)	52.4% (n = 33)
Mildly improved	8.5% (n = 10)	18.3% (n = 11)	38.1% (n = 24)
Same or worse	6% (n = 7)	8.4% (n = 5)	9.5% (n = 6)
Peak function			
1-2 months	57.3% (n = 67)	50% (n = 30)	39.7% (n = 25)
3-4 months	30.8% (n = 36)	18.3% (n = 11)	36.5% (n = 23)
5-6 months	6.8% (n = 8)	6.7% (n = 4)	7.9% (n = 5)
>6 months	5.1% (n = 6)	25% (n = 15)	15.9% (n = 10)
Overall outcome			
Excellent	83.8% (n = 98)	76.7% (n = 46)	71.4% (n = 45)
Good	13.7% (n = 16)	13.3% (n = 8)	22.2% (n = 14)
Fair or poor	2.5% (n = 3)	10% (n = 6)	6.4% (n = 4)

eral CCL rupture during the time period of this study. This rate is slightly higher than 18% to 37% previously reported and most likely reflects the longer follow-up period in our study (19, 20).

In our study, the overall postoperative complication rate of 9.7% was lower than previously reported; rates of 18.8% to 28%, with 4.2% classified as major complications requiring an additional surgical intervention, and 5.5% as minor complications (3–6). Several previous studies included intra-operative complications as well as minor postoperative bandage and wound related changes like oedema, swelling or bruising, and self trauma; these were not included as complications in our study (3–6). Retrospectively, minor complications represented 12% to 15% of the complications reported for TPLO surgery (3–6). This could certainly explain complication rate differences between retrospective studies. Moreover, different definitions of major and minor complications have been used, making it difficult to directly compare results of each study (3–6). However, if a major complication was defined as only one that required further surgical intervention, then our major complication rate compared similarly to the rates of 1.6% to 8.4% previously reported (1, 3–6, 21–23). In our study, risk factors for postoperative complications were not identified and there was no significant relationship between breed and postoperative complication development; this was contrary to the findings of previous studies, with Rottweilers having more complications than expected (4). Each of the complications recorded in our study have been previously reported in other studies (1, 3–6). Most of these complications responded to appropriate treatments, and as previously reported, a satisfactory clinical and owner-perceived outcome for TPLO surgeries with complications were recorded in this study. (3–6, 24).

Different definitions of infection have been used, making it difficult to directly compare infection rates between retrospective studies (3–6, 25). However, the overall postoperative infection rate in our study (2.9%) was similar to that of previously published infection rates for TPLO (3–8.9%), and other clean surgical procedures in the veterinary literature (3.6–5.8%) (3–5, 26–30). A recent study suggested that the postoperative oral administration of antimicrobial drugs can decrease the risk of developing infection-inflammation after both extracapsular lateral suture and TPLO procedures (25). This finding is in contrast to recommendations which suggest that prophylactic antimicrobial agents should be discontinued within 24 hours after clean surgical procedures (31, 32). However, given the retrospective nature of our study, dogs with increased risks were not identified and pre-existing infection (pyoderma, chronic skin allergy, parodontal infection, urinary tract infection) as well as confounding variables, such as potential breaks in aseptic technique, were not specifically recorded. These factors may have potentially affected our results and warrant further evaluation.

Meniscal injury associated with CCL rupture has been reported to range from 20 to 80% (7, 33–37). Nearly all clinically diagnosed meniscal tears involve the caudal horn of the medial meniscus (33, 38). In our study, meniscal injury associated with CCL rupture occurred in 36.3% of the stifles, 89.6% had complete CCL rupture. Complete CCL rupture and severe lameness were identified as factors associated with meniscal injury. It is a common clinical impression that dogs with CCL rupture and meniscal tear will have a greater degree of lameness than dogs without meniscal tear (39, 40). It would have been expected that long duration of CCL rupture may potentially increase the risk of associated meniscal injury, even more so with complete CCL rupture which leads to joint instability. However, meniscal injury occurrence was not influenced by the duration of preoperative clinical signs in this study. Additionally, TPA was not found to be associated with meniscal injury, as previously reported (41). However many confounding variables not assessed in this study could have affected our results.

After CCL rupture surgery, any dog presented with a severe lameness or developing acute lameness after having shown improvement, was assumed to have sustained secondary meniscal damage when infection and fractures were excluded (39, 40). Recurrent lameness potentially attributed to subsequent meniscal injury occurs in one to 13.8% of the stifles treated for CCL rupture (4, 7, 34, 35, 42–47). We found an overall rate of 2.1% for subsequent meniscal tear after TPLO in our study but if only stifles with intact menisci after the initial surgery were considered, then the rate of subsequent meniscal injury was 3.8%. In others studies, usually only the overall rate of subsequent meniscal tear has been reported which underestimates the true incidence of this condition (4, 7, 34, 35, 42–47). For example, retrospective studies reported overall and 'true' rates of subsequent meniscal injury with tibial tuberosity advancement as being 8.8% and 21.7% respectively, of 6.3% and 9% respectively for TPLO (7, 46). Controversy still exists regarding the best way of avoiding late meniscal tear in stifles with CCL rupture and a grossly intact medial meniscus at the time of TPLO surgery. The MMR procedure was proposed as a means of averting damage to the caudal pole of the medial meniscus (48). However, multiple functions are attributed to the meniscus which participates in load transmission, energy absorption, rotational and varus-valgus stability, lubrication, proprioception and congruity of the joint surfaces (43, 47, 48). Medial meniscal release resulted in significant alterations in the load transmission function, congruity, as well as stabilization and shock absorption functions of the meniscus affecting the cartilage pressure and contributing to subsequent stifle pathology (10, 11, 49). Medial meniscal release was recently associated with cartilage damage, further meniscal pathology, degenerative joint disease and lameness, and more severe progressive radiographic signs of osteoarthritis was also reported (50, 51). There were not any significant differences noted in this study when comparing owner-reported activity level or time to peak function for dogs with intact meniscus and dogs with MMR in conjunction with TPLO, as has been previously reported (7). However, an intact meniscus should be ideally preserved in CCL rupture stabilized by TPLO, and MMR should only be performed in selected cases as previously suggested (49). The partially intact CCL may limit cranial translation of the tibia during the weight bearing phase of the gait, decreasing the chance of meniscal injury and the development of osteoarthritis in the future. The classic practice is to resect the entire CCL, even in dogs with only partial CCL rupture. However, exceptions can be made for TPLO surgery because TPLO appears to have a protective effect on the CCL in dogs having an early partial CCL tear (13, 52). It has recently been suggested to not debride the CCL fibres for partial CCL tear when most of the CCL appears normal (52). The remaining CCL not only maintains the relationship of the femoral condyles relative to the tibial plateau but also restrains rotational and varus-valgus movements after TPLO, potentially reducing the risk of subsequent 'pivot shift' or meniscal injury.

The phenomenon of 'pivot shift' has not been reported in previous retrospective studies. The cause of 'pivot shift' is unknown but it was thought to be a result of insufficient correction of tibial torsion or angular deformity, or supraphysiological tibial internal rotation (12, 13). Medial menisectomy was the only significant risk factor for development of 'pivot shift' in our study. Although a jig was used for the TPLO procedure in our cases, correction of alignment or torsion of the limb was made when judged necessary; TPLO can induce postoperative genu varus (18, 53). Poor plate contouring, misplacement of the jig, and poor osteotomy positioning can also contribute to postoperative tibial varus (1, 18, 53). Although internal tibial torsion was also corrected in five dogs that subsequently developed postoperative 'pivot shift', incomplete correction or mistakes during subjective evaluation could not be excluded (14). Moreover, it was recently reported that TPLO induced a mild but significant varus angulation in stifle flexion (54). The relative hyperflexion at the level of the femorotibial articulating surfaces due to the TPLO, combined with pronounced stifle flexion, could be responsible for an increased laxity in the lateral collateral ligament, and subsequent decreased lateral support to the stifle as previously suggested (54–56). One can also speculate that chronic CCL rupture with substantial amount of fibrosis around the stifle joint may limit this phenomenon, but we did not find that the duration of clinical signs before surgery was significantly different between dogs, with and without postoperative 'pivot shift'. Overall rates of thigh muscular atrophy were not recorded in this study and preclude any conclusions regarding the role of muscular atrophy in this condition, however the 'pivot shift' phenomenon disappeared four to six months postoperatively in some cases which recovered a satisfactory thigh muscular mass. Further studies need to be conducted to assess the impact of the 'pivot shift' phenomenon on the biomechanics of the stifle, articular cartilage and joint structures as well as the potential effect in long-term follow-up on TPLO surgery.

A good to excellent outcome was reported in 94.6% of our cases, which was similar to the 91% to 94% success rates previously reported after TPLO surgery (3, 6). When comparing owner-reported activity level and time to peak function between dogs with intact meniscus and dogs with menisectomy in conjunction with TPLO, dogs with intact meniscus had a significantly better activity level and a shorter time to peak function. These findings, even if obtained with owner assessment, may suggest that menisectomy could have a deleterious clinical impact for the stifle joint, and may potentially influence the rehabilitation period and final outcome of surgical procedures like TPLO. These results may also suggest that different outcomes could potentially be expected depending on the meniscal status. Therefore, this variable may have to be considered when comparison of surgical techniques or evaluation of surgical outcome is performed.

Several limitations should be considered when interpreting the data of this study. One of the major limitations was the retrospective nature of our study and reliance on the completeness of case records and owners compliance with follow-up phone interviews. The number of confounding variables and potential for bias were also undoubtedly increased when comparison between groups were performed. The amount of meniscus removed when a menisectomy was performed during the TPLO surgery was not consistently recorded and could also influence the outcome, as it was previously reported to be directly related to the amount of joint pathology that will subsequently develop in the joint (11, 57). Moreover, the clinical outcome assessment methods in this study were limited to joint palpation, visual assessment of lameness by two surgeons, and a telephone interview owner-assessment. The use of force plate and goniometry would have increased the objectivity of our outcome assessment but was unavailable in our practice (58). Finally, the method for diagnosis of subsequent meniscal injury also leaves room for error. Meniscal tears were definitively diagnosed by arthrotomy performed only on the dogs re-admitted to our hospital for lameness consistent with meniscal pathology.

Considering the relative low rate of subsequent meniscal injury and reportedly deleterious effects of a meniscal release, systematic meniscal release for TPLO surgery is questionable. Further investigations with prospective, randomized and controlled studies are necessary before drawing any conclusions regarding MMR recommendation with TPLO surgery. A 'pivot shift' is infrequently reported after TPLO surgery and medial menisectomy may represent risk factors for its occurrence. However, this phenomenon deserves further investigation to completely understand its mechanism, to identify its anatomic components and the potential consequences on the stifle joint. Finally, dogs with TPLO surgery without menisectomy may have a better and faster recovery rate than dogs with TPLO and menisectomy based on owner-reported questionnaires.

Conflict of interest

None declared

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