Complications and Long-Term Outcomes after Combined Tibial Plateau Leveling Osteotomy and Tibial Tuberosity Transposition for Treatment of Concurrent Cranial Cruciate Ligament Rupture and Grade III or IV Medial Patellar Luxation

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Abstract

Objectives This study aims to report complications and long-term outcomes of combined tibial plateau leveling osteotomy and tibial tuberosity transposition (TPLO-TTT) for treatment of concurrent cranial cruciate ligament rupture and medial patellar luxation (MPL).

Study Design This is a retrospective study. Dogs that underwent TPLO-TTT for treatment of combined cranial cruciate ligament rupture and grade III or IV MPL were included. Signalment, fixation method, and complications were recorded. Long-term outcome assessment (minimum 1 year postoperatively) was performed through clinical and radiographic reexamination at the authors' institution.

Results Twenty-four stifles (22 dogs) were included. Twenty-one stifles had a grade III MPL, and 3 stifles had grade IV MPL. Four major complications consisting of surgical site infection ($n = 3$) and recurrent grade II MPL ($n = 1$) were observed. Dogs with surgical site infections were successfully treated with implant removal and oral antibiotics. No additional surgery was performed for the patient with recurrent MPL as no signs of lameness were observed. Minor complications occurred in five cases. At long-term evaluation (median: 27 months; range: 12–67 months), 21/22 dogs were clinically sound and 23/24 stifles had a complete resolution of MPL.

Conclusion TPLO-TTT can be considered as an effective surgical option to treat patients with concurrent cranial cruciate ligament rupture and MPL with a relatively low major complication rate. Owners should be warned of the potential need for implant removal.

Keywords
- tibial plateau levelling osteotomy
- tibial tuberosity transposition
- cranial cruciate ligament rupture
- medial patellar luxation
- dog

Introduction

Cranial cruciate ligament rupture and medial patellar luxation (MPL) are common causes of lameness in dogs and may occur concurrently.[1] In dogs with MPL, cranial cruciate ligament rupture is recognized in up to 25% of cases.[2] As a result, a combination procedure to stabilize the stifle and treat the patellar luxation is often necessary.

Several surgical methods for treating concomitantly cranial cruciate ligament rupture and MPL have been reported,

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including extracapsular stabilization and tibial tuberosity transposition (TTT),[3] tibial plateau leveling osteotomy (TPLO) and TTT (TPLO-TTT),[4] TPLO with lateral translation of the distal tibial segment,[5,6] TPLO and additional transverse osteotomy,[7] TTT advancement,[8,9] and modified triple tibial osteotomy.[10] These techniques have been described either alone or in combination with additional procedures such as trochleoplasty or soft-tissue (retinacular) release or imbrication. To date, only one report has documented clinical outcomes of TPLO-TTT surgery for treatment of concurrent cranial cruciate ligament rupture and MPL in dogs.[4] In that study, all 11 dogs (15 stifles) were reported to have mild or no lameness at their last follow-up 8 to 10 weeks after surgery. No catastrophic or major complications occurred that required additional surgery and patellar re-luxation did not develop in any of the 13 stifles available for in-hospital follow-up. However, data regarding long-term complications and outcomes associated with TPLO-TTT technique were not reported.

Our objective was to report complications and long-term clinical and radiographic outcomes of TPLO-TTT surgery in conjunction with ancillary procedures (e.g., trochlear block recession, lateral capsulorrhaphy, and lateral parapatellar fascial imbrication) in dogs concomitantly affected by cranial cruciate ligament rupture and MPL.

Materials and Methods

Case Selection Criteria

The medical records database of Centre Hospitalier Vétérinaire Anicura – Aquivet was searched to identify dogs that underwent TPLO-TTT for treatment of concurrent cranial cruciate ligament rupture and MPL between September 1, 2016 and May 31, 2021. Dogs were included in the study if preoperative, immediate postoperative, and follow-up radiographs were available for review, and follow-up examinations were performed by the primary surgeon 6 to 10 weeks postoperatively (short-term follow-up) and at least 1 year postoperatively (long-term follow-up). Data were collected a minimum of 1 year from the time of surgery to allow sufficient time for complications to develop. For two dogs that had staged bilateral stifle surgery with an interval of more than 1 year between the two procedures, each limb was considered individually. Patients with grade I or II MPL and those that had femoral or tibial osteotomy or ostectomy for correcting femoral or tibial torsion, respectively, were excluded. Informed consent was obtained from the pet owners. All patients were clinically managed according to contemporary standards of care.

Medical Records Review

Data obtained from the medical records included signalment, limb affected, lameness score (preoperative and reexamination), MPL grade, radiographic findings, surgical approach, surgical findings, type of implants used for TPLO-TTT, any ancillary procedures performed, postoperative complications, and duration of follow-up. Lameness was scored on a numerical rating scale from 0 to 5, as previously described: 0 (clinically sound), 1 (barely detectable), 2 (mild), 3 (moderate), 4 (severe), and 5 (non-weight-bearing).[11]

Preoperative Planning

Orthogonal preoperative radiographs of the femur and then of the tibia were obtained to identify any frontal or sagittal plane bone deformities, size of the TPLO, TPLO location, tibial tuberosity linear osteotomy location, and for TPLO-TTT implant templating. Surgical planning was performed either using acetate templates or digital templating (vPOP Pro; VETSOS Education Ltd, Shrewsbury, United Kingdom). The TPLO location was planned with the osteotomy centered on the intercondylar tubercules. Two distances (D1 and D2) were measured from the preoperative plan as previously described.[12] The tibial tuberosity linear osteotomy was planned to extend from the most proximal and cranial aspect of the radial osteotomy for the TPLO to the distal aspect of the tibial crest without cutting its distal cortex. Measurements of D3 was determined (►**Fig. 1**). Distance D3 was measured on the mediolateral radiographic view along a line perpendicular to the cranial border of the tibia and is the distance from the patellar ligament attachment to the linear osteotomy line. D3 was desired to be approximately 20 to 30% of the distance between the insertion of the patellar ligament and the caudal tibial cortex to ensure the osteotomized tibial tuberosity was of sufficient size to be reattached with implants of acceptable size. These three (D1, D2, and D3) measurements were used for intraoperative reference during osteotomy positioning. Radiographs included a 10-cm linear marker. Preoperative tibial plateau angle (TPA) was calculated as previously described.[13]

Surgical Technique

Preanesthetic blood tests were performed dependent on patient's signalment and comorbidities. Dogs were anesthetized for surgery according to standard protocols used in our clinic. Analgesia was provided with morphine (Morphine; Lavoisier, Paris, France) (0.2 mg/kg intravenous [IV]). Cefazolin (Céfazoline; Mylan S.A.S., Saint-Priest, France) (22 mg/kg IV) was administered 30 minutes before skin incision and every 90 minutes throughout the surgery. All procedures were performed by the same board-certified surgeon (JGG).

After routine preparation for aseptic surgery, animals were positioned in lateral recumbency to expose the medial surface of the affected tibia. The surgical field was further protected with a sterile, adhesive, clear plastic incision drape. The stifle joint was explored by lateral arthrotomy, and adjunctive surgical techniques to correct MPL, including trochlear wedge recession, medial retinacular release, and lateral capsular imbrication, were performed. Meniscal injuries were documented and treated, if necessary.

Briefly, the Slocum TPLO was centered close to the intercondylar tubercles. The accuracy of osteotomy positioning was assessed repeating the D1 and D2 measurements on the tibia. The TPLO was partially completed, cutting entirely through the cis-cortex, but not the trans-cortex in standard fashion using a radial saw blade. No jig was used. The tibial

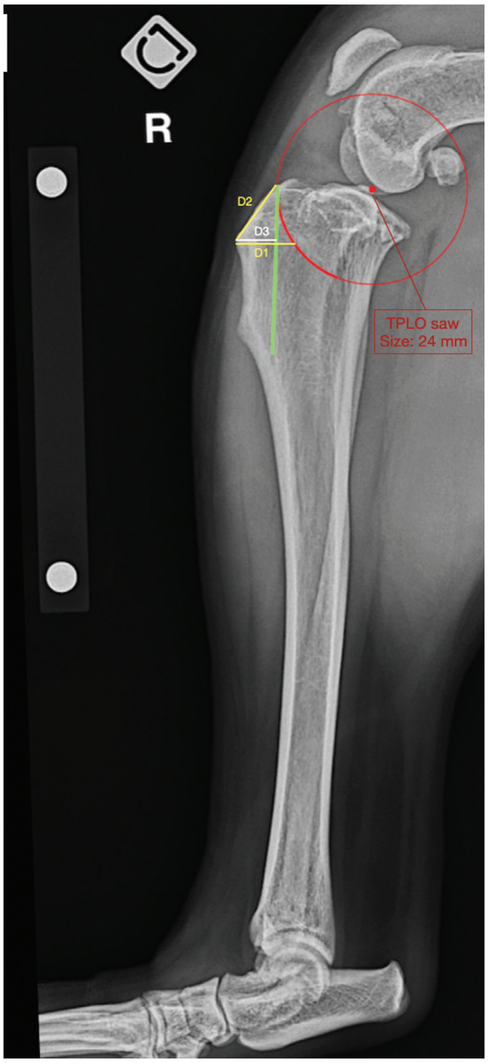

Fig. 1 Preoperative mediolateral radiographic image of a 2.5-year-old, 43 kg, Labrador Retriever (case 18) with a complete rupture of the cranial cruciate ligament and a concurrent grade III medial patellar luxation of the right hindlimb that has been treated with combined tibial plateau leveling osteotomy and tibial tuberosity transposition (TPLO-TTT). This figure demonstrates precise osteotomy positioning. The TPLO location (*red circle*) was planned with the osteotomy centered on the intercondylar tubercules. Distances D1 and D2 (*yellow lines*) were measured from the preoperative plan as previously described. The tibial tuberosity linear osteotomy (*green line*) was planned to extend from the most proximal and cranial aspect of the radial osteotomy for the TPLO to the distal aspect of the tibial crest without cutting its distal cortex. Measurements of D3 (*white line*) was determined. Distance D3 was measured on the mediolateral radiographic view along a line perpendicular to the cranial border of the tibia and is the distance from the patellar ligament attachment to the linear osteotomy line. D3 was desired to be ~20 to 30% of the distance between the insertion of the patellar ligament and the caudal tibial cortex to ensure the osteotomized tibial tuberosity was of sufficient size to be reattached with implants of acceptable size. These three (D1, D2, and D3) measurements were used for intraoperative reference during osteotomy positioning.

tuberosity linear osteotomy was then partially performed using an oscillating saw by cutting through the cis-cortex but not the trans-cortex. The TPLO was then completed, and the proximal tibial plateau segment rotated to the desired amount. The rotated proximal tibial plateau segment was stabilized to the tibial tuberosity segment using one temporary pin (generally 1.0- to 1.6-mm diameter depending upon the dog's size) placed in a cranial to caudal orientation and originating from proximal to the patellar ligament insertion. A TPLO locking plate (DePuy Synthes (DePuy Synthes, Raynham, Massachusetts, United States) Biomedtrix (Biomedtrix, Whippany, New Jersey, United States) or Veterinary Orthopedics Implants (Veterinary Orthopedics Implants, Orly, France)) was applied using three or four locking screws (2.0-, 2.4-, 2.7-, or 3.5-mm diameter) in the head of the plate and three or four cortical screws (2.0-, 2.4-, 2.7-, or 3.5-mm diameter) in the body of the plate (DePuy Synthes, Biomedtrix, or Veterinary Orthopedics Implants). Then, the temporary pin was removed, and the tibial tuberosity linear osteotomy was completed leaving a distal cortical and/or periosteal attachment. The tibial tuberosity was then transposed laterally to visually align the patellar ligament with the trochlea sulcus. The tibial tuberosity was secured to the rotated tibial plateau segment using two or three pins (1.0–1.6 mm) depending upon the dog's size (DePuy Synthes). At the surgeon's discretion, one large gauge (0.8–1.5 mm), figure-of-eight tension band wire was placed and secured using a single twist (Aesculap Surgical Instrument, B. Braun, Hessen, Germany).

After the final fixation, intraoperative range of motion and rotational and valgus/varus alignments were subjectively evaluated by aligning the tibial crest and the long axis of the metatarsus and by reestablishing the sagittal plane of the hindlimb, respectively. Indirect cranial drawer sign and patellar stability were also assessed. Closure was routinely performed. After postoperative radiographs were obtained, a modified Robert-Jones bandage was applied.

Postoperative Care

After the first 24 hours, no additional external coaptation was used. Morphine (0.2 mg/kg, IV, every 4 hours) was administered for analgesia during hospitalization. Patients were discharged from the hospital 2 days after surgery with anti-inflammatory (meloxicam (Metacam; Boehringer Ingelheim, Ingelheim, Germany) [0.1 mg/kg orally every 24 hours for 10 days]) and antimicrobial medications (cephalexin (Rilexine; Virbac, Carros, France) [15–25 mg/kg orally every 12 hours] for 5 days). Dogs were confined to a small room or cage. Short leash walks three to four times daily was the only recommended activity during the initial 6 to 10 weeks after surgery until clinical and radiographic evaluation. Activities were gradually introduced over 1 month after the first examination barring any complications or setbacks. After 10 to 14 weeks, unrestricted activities were allowed.

Outcome Assessment

The patients were reexamined at the authors' institution by the primary surgeon 6 to 10 weeks postoperatively for clinical and radiographic examination (short-term follow-up). Lameness was scored using the aforementioned grading system.[11] Signs of pain, crepitus, and range of motion on manipulation of the stifle were documented. Indirect cranial drawer sign, patellar stability, patellar ligament thickening, and signs of pain on surgical site palpation were also recorded. Critical radiographic assessment of implant position and integrity, patellar position, and bone healing and development of osteoarthritis were evaluated. Complications were reported as previously defined as catastrophic, major, or minor.[14] Catastrophic complications were those that caused permanent unacceptable function, death, or euthanasia; major complications were those that required further surgical treatment to resolve (e.g., surgical site infection, implant failure); and minor complications were defined as those treatable through a combination of local care and oral medication without the need for anesthesia (e.g., wound dehiscence). Patellar reluxation after surgery was considered a major complication. Time from surgery to complication was recorded, and, if less than one complication occurred in one patient, each was considered as a separate data point.

The primary surgeon performed long-term clinical examination a minimum of 12 months postoperatively. Lameness was subjectively graded as previously described. Stifle crepitus, pain, range of motion, and patellar stability were recorded. At the time of follow-up examination, radiographs were proposed to the owners for assessment of long-term patellar position, evidence of implant migration, and development of stifle osteoarthritis. On this occasion, the owners were asked to subjectively grade the outcome of their dog as "full," "acceptable," or "unacceptable."[14] The surgeon used a combination of clinical and radiographic assessment, in addition to owner assessment, to determine the level of return to previous activity permitted.

Data Analysis

Data were entered into a spreadsheet (Excel version 2006; Microsoft Corporation). Descriptive statistics were calculated, with median and range reported. Data frequencies in each category were reported.

Results

Twenty-two dogs met the inclusion criteria with a total of 24 stifles (►**Appendix Table 1**, available in the online version). The median age at presentation was 7.5 years (range: 1–13 years) and the median body weight was 23 kg (range: 3.2–43 kg). There were 12 spayed females, 2 castrated males, 3 intact females, and 4 intact males.

Twenty-one stifles had a grade III MPL and 3 stifles had a grade IV MPL.

Surgical Procedure

A TPLO-TTT was performed in all 24 stifles. Twelve stifles had a complete rupture of the cranial crucial ligament, and 12 stifles had a partial rupture. Two stifles (dogs 9 and 13) had a medial meniscal injury ("bucket handle tear") that required partial meniscectomy (caudal horn removal). Trochlear wedge recession, medial retinacular release, and lateral capsular imbrication were performed in addition to TPLO-TTT in all 24 stifles.

Implants used for TPLO-TTT are reported in ►**Appendix Table 1** (available in the online version). A tension band wire was used in 21/24 stifles. No intraoperative complications occurred. Postoperative radiographs obtained for all stifles confirmed appropriate postoperative TPA (median: 4.4 degrees; range: 1–6 degrees), patellar position, and positioning of the implants (►**Fig. 2**).

Short-Term Outcome

Median time to first clinical and radiographic reexamination was 6.4 weeks (range: 6–10 weeks). The median lameness score was 1 (range: 0–3; ►**Appendix Table 2**, available in the online version). Five of the 22 dogs were clinically sound. Eleven dogs had grade I lameness, 7 dogs had grade II lameness, and one dog had grade III lameness. All patients were considered to have satisfactory craniocaudal stifle stability based on indirect cranial drawer test. All stifles had a well-positioned and stable patella and all patellae tracked normally within the femoral sulci. Two major complications (cases 3 and 4) consisting of surgical site infection were successfully treated with initial empirical oral antibiotic therapy (cefalexin[i] [15–25 mg/kg PO every 12 hours]) and subsequent orthopaedic implant removal 3 months following surgery. Minor complications occurred in five cases. Four cases (cases 19, 20, 22, and 23) had thickening and pain on palpation of the patellar ligament and one case (case 21) developed semitendinosus and semimembranous muscle contractures that were of undetermined origin. These five cases were successfully treated by physical rehabilitation therapy. The remaining 17 cases had no abnormalities on orthopaedic examination. Radiographic examination revealed adequate patellar position and stable implants in all cases. Four dogs had marked soft-tissue swelling at the level of the patellar ligament. Radiographic healing of the TPLO-TTT osteotomy sites was reached in all cases. Overall, short-term major and minor complications were observed in 2/24 stifles and 5/24 stifles, respectively.

Long-Term Outcome

Median time to final clinical and radiographic reexamination at the authors' institution was 27 months (range: 12–67 months; ►**Appendix Table 3**, available in the online version). All 22 dogs returned for long-term evaluation with 2 dogs that had surgery on both stifles. At the time of final clinical examination, all but one dog were clinically sound and 23/24 stifles had satisfactory stability of the stifle joint without any evidence of pain or patellar luxation on orthopaedic examination. One dog (case 9) had a barely detectable lameness. One dog (case 14, a 3.4-kg Yorkshire Terrier 7.7 years old at the time of surgery) was diagnosed with a grade II MPL without any observed signs of lameness or pain (►**Appendix Table 3**, available in the online version). The owners did not report any trauma between the short- and long-term follow-up appointments. No revision surgery was performed as no

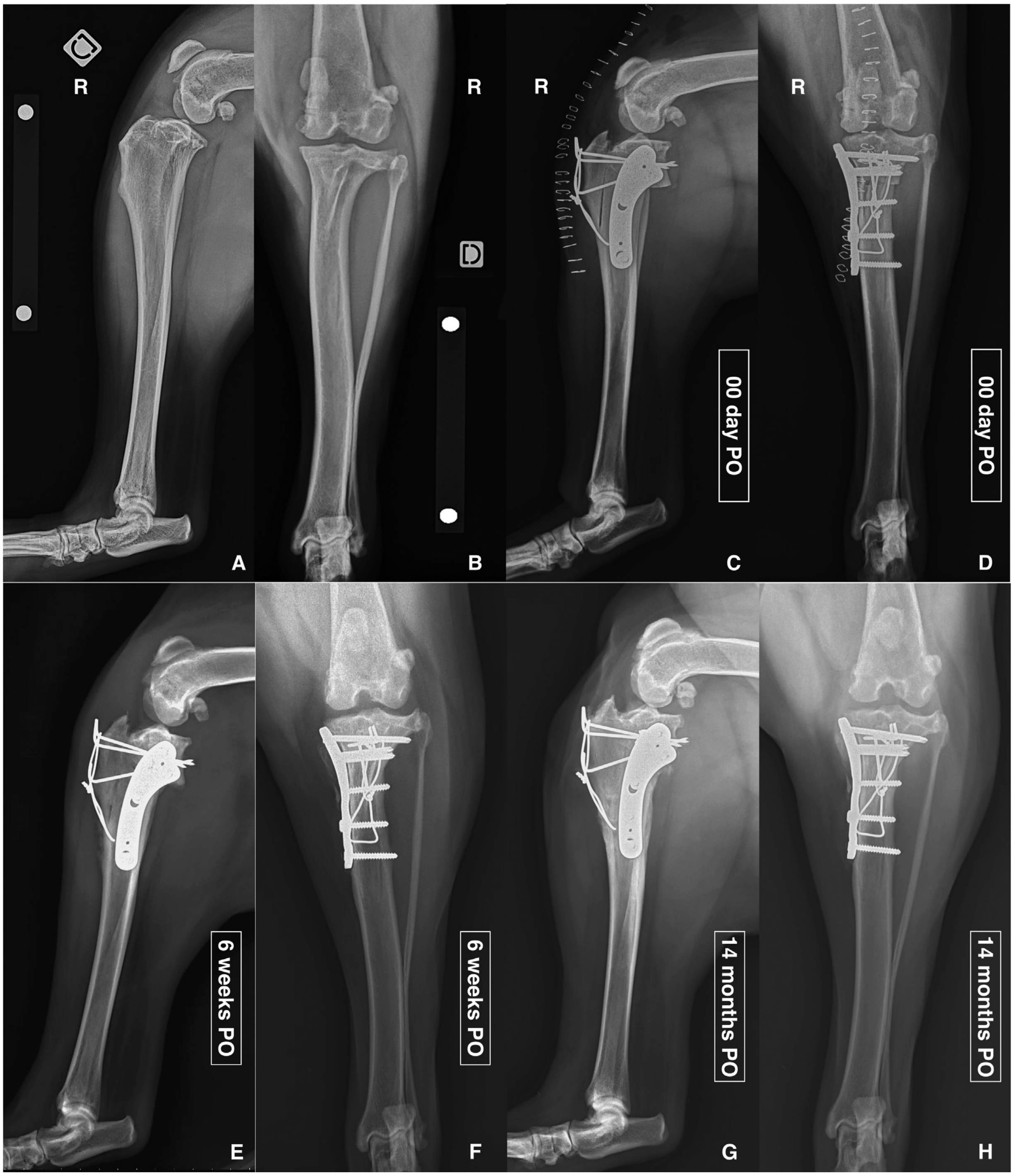

Fig. 2 (**A,B**) Preoperative, (**C,D**) immediate postoperative, (**E,F**) 6 weeks postoperative, and (**G,H**) 14 months postoperative craniocaudal and mediolateral radiographs of the case planned in Fig. 1. The tibial plateau leveling osteotomy (TPLO) was stabilized with a Biomedtrix TPLO plate for 3.5 mm in diameter screws. The tibial tuberosity transposition (TTT) was stabilized with three 1.6-mm diameter pins and a 1.25-mm diameter figure-of-eight tension band wire. At immediate postoperative radiographs, the tibial plateau angle (TPA) was measured at 5 degrees (**C,D**). At 6 weeks postoperatively, the implants were stable and both osteotomies were healed (**E,F**). At 14 months postoperatively, the implants were stable and moderate development of osteoarthritis was observed (**G,H**).

lameness was observed or reported by the owners. One stifle (case 6) developed surgical site infection greater than 1 year after surgery and underwent orthopaedic implant removal (►**Appendix Table 3**, available in the online version). All owners of dogs elected to pursue radiographs. Radiographic examination revealed adequate joint congruency and no evidence of implant migration in all stifles. Development of osteoarthritis was considered as mild in 15 cases and moderate in 9 cases (►**Appendix Table 3**, available in the online version). Retrospective evaluation of preoperative radiographs of the case with grade II MPL reluxation revealed mild internal tibial torsion that was not addressed at the time of surgery and could be the cause of the patellar re-luxation.

The owners subjectively assessed the outcomes of their dogs following surgery (►**Appendix Table 3**, available in the online version). Twenty-one of 22 dogs had full function and 1 dog (case 9) had acceptable function. Overall, long-term major complications were observed in 2/24 stifles.

Discussion

In the present study, 24/24 (100%) stifles with cranial cruciate ligament rupture and concurrent MPL treated with TPLO-TTT had no functional deficit detected during owner and surgeon assessment at last follow-up (>1 year after surgery). The major complication rate was relatively low at only 4/24 stifles after following up with patients for a minimum of 1 year. In our patient population, body weight ranged from 3.2 to 43 kg, suggesting that the technique described may be applied in dogs of different sizes.

The short-term outcome reported by Leonard and colleagues[4] was believed to be of sufficient duration to access successful bone healing and implant stability (once the bone is healed, implant migration is very rare), but this time frame was not sufficient to preclude patellar re-luxation and development of delayed complications such as implant irritation (from the Kirschner wires and/or cerclage wires), and long-term surgical site infection. Our study reported a similar high success rate and longer follow-up. We tried to alleviate differences in treatment procedures as much as possible by including only dogs with cranial cruciate ligament rupture and concurrent grade III or IV MPL that were treated by the same orthopaedic surgeon with standardized additional procedures (trochlear wedge recession, medial retinacular release, and lateral capsular imbrication) in addition to the TPLO-TTT surgery.

Surgical site infections can be observed independently with TPLO as well as the various surgical techniques for addressing an MPL.[1] Our surgical site infection rate was similar to that observed with TPLO alone, ranging from 3 to 15.8%.[15] The other major complication encountered in our study consisted of a recurrent grade II MPL. In this case, the grade II reluxation implies that something else needed to be addressed since a reluxation occurred. In this dog, surgical correction of medialization of the tibial tuberosity associated with an internal tibial torsion and cranial cruciate ligament rupture might have been addressed using a modified TPLO where the distal tibial segment was externally rotated (in relation to the osteotomized tibial plateau fragment) and laterally translated, as described previously.[5] We do not believe this grade II patellar reluxation was a limitation of the TPLO-TTT technique, but rather an inadequate case selection or decision-making. The TPLO-TTT technique is not applicable to every case of patellar luxation, but only cases that have cranial cruciate ligament insufficiency and medialization of the tibial tuberosity with no femoral or tibial torsion.[4] Interestingly, none of the 10 dogs weighing more than 20 kg in our study developed major complications in the long-term follow-up. Our results compared favorably with some previous studies reporting up to 10% major complication rate (patellar re-luxation, implant failure) for MPL surgery in large-breed dogs.[16,17]

Patellar ligament thickening was the most frequently encountered complication in 8/15 stifles at the time of the 8- to 10-week in-hospital evaluation in a previous study.[4] In contrast to our results, only one of these eight stifles developed clinical signs of discomfort. Whether this patellar thickening was due to the surgical trauma (trauma by the saw blade, placement the pins through the distal patellar ligament), early excessive activity, a change in stifle biomechanics, or a combination of these remains unknown. Similar findings have been previously described with TPLO or TTT when performed alone.[17,18]

Tibial plateau leveling osteotomy and concomitant TTT have been described as a predisposing factor to tibial tuberosity fractures, implant migration, and delayed or complicated bone healing.[7,19–22] Similar to Leonard and colleagues' study,[4] we did not observe any tibial tuberosity fracture in our case series and all stifles exhibited clinical union at short-term follow-up with no implant migration at the last follow-up examination. We do believe that an adequate width of the tibial tuberosity segment remains one of the key issues when performing the TPLO-TTT to lower the likelihood of tibial tuberosity fracture and allow the placement of robust and secure fixation.[19]

One limitation of the present study is the small number of cases that prevents determination of outcomes representative of a larger population with cranial cruciate ligament rupture and concurrent MPL. Retrospective design precludes standardization of the surgical technique, postoperative treatment, and follow-up. We tried to control for certain variables by only including dogs with cranial cruciate ligament rupture and grade III or IV MPL that were operated on and seen on reexamination by the same experienced orthopaedic surgeon. We also excluded dogs treated that had femoral or tibial osteotomy or ostectomy for correcting femoral or tibial torsion, respectively. Long-term prospective studies that utilize force plate analysis for objective gate assessment are advised.

In conclusion, cranial cruciate ligament rupture and concurrent MPL (associated with medialization of the tibial tuberosity) may be managed in dogs using a single-stage TPLO-TTT procedure in combination with additional procedures such as trochleoplasty and soft-tissue (retinacular) release or imbrication.

Authors' Contribution
G.R. provided the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article, revised it critically for important intellectual content, and final approval of the version to be submitted. J.G.G. helped in the conception and design of the study, supervised G.R. along all the study, performed all the surgeries and the orthopaedic recheck, critically revised the article for important intellectual content, and gave final approval of the version to be submitted.

Conflict of Interest
None declared.

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