Radiographic evaluation of patellar ligament length after tibial plateau leveling osteotomy in dogs

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OBJECTIVE
To radiographically compare patellar ligament length (PLL) in dogs undergoing tibial plateau leveling osteotomy (TPLO) for unilateral cranial cruciate ligament rupture at preoperative, postoperative, and follow-up evaluations.

ANIMALS
105 dogs that underwent TPLO for unilateral cranial cruciate ligament rupture at a referral veterinary hospital from October 1, 2008, through November 30, 2017.

PROCEDURES
Medical records were reviewed to obtain information on dog signalment, surgical procedure, and radiographically measured PLL at preoperative, postoperative, and follow-up evaluations.

RESULTS
Dogs undergoing TPLO had a shorter PLL at the postoperative and follow-up evaluations, compared with the PLL at the preoperative evaluation. Mean ± SD overall unadjusted PLL decreased significantly by 2.3 ± 3.4% between the preoperative and postoperative evaluation and by 2.8 ± 3.9% between the preoperative and follow-up evaluation. The PLL did not differ significantly between the postoperative and follow-up evaluation; mean PLL decreased by 0.4 ± 3.8% between the postoperative and follow-up evaluation.

CONCLUSIONS AND CLINICAL RELEVANCE
The PLL was shorter after TPLO in dogs, which was similar to changes observed for humans after high tibial osteotomy procedures. Further evaluation of clinical assessments, joint mobility, ultrasonographic assessments, and kinematic results are needed to determine the relevance of the PLL and whether a decrease in ligament length results in decreased mobility and persistent lameness in dogs, as has been reported for humans. (*Am J Vet Res* 2019;80:607–612)

Cranial cruciate ligament disease is one of the most commonly diagnosed stifle joint disorders in dogs.[1-3] The underlying cause of CrCL disease is poorly understood. Variables such as abnormal confirmation and gait, increased TPA, and obesity have been evaluated, but none have been found to be causative.[4-10] A CrCL-deficient stifle joint loses the ability to prevent stifle joint hyperextension, internal tibial rotation, and translation of the cranial portion of the tibia.[11] As a result of these functional changes, injury to the medial meniscus may ensue, with a reported incidence of 33.2% to 77%.[12-14] Injury to the medial meniscus is more common in CrCL-deficient stifle joints, but radial tears of the lateral meniscus have also been identified, with a reported incidence of 77%.[13]

ABBREVIATIONS

CrCL	Cranial cruciate ligament
PLL	Patellar ligament length
TPA	Tibial plateau angle
TPLO	Tibial plateau leveling osteotomy

Surgical stabilization continues to be considered the best interventional option for CrCL-deficient stifle joints.[15] Among the numerous techniques available for stabilization, TPLO remains one of the most commonly performed surgical procedures.[16,17]

The TPLO uses rotation of the proximal portion of the tibia to reduce the TPA.[17] Reducing the TPA neutralizes subluxation of the cranial aspect of the tibia, thus providing a dynamically stable stifle joint. Reports of TPLO in dogs are numerous, and studies[18-22] with radiography and ultrasonography have detected an increased incidence of patellar ligament thickening after surgery. To the authors' knowledge, no long-term evaluations have been performed to assess PLL after TPLO.

A decrease in length of the patellar ligament has been detected after surgical procedures (including high tibial osteotomy, reconstruction of the anterior cruciate ligament, and joint arthroplasty) on the knee joints of humans.[23-26] Extrinsic variables affecting PLL include scarring and contraction of the peripatellar soft tissues, ischemic contracture of the tendons, prolonged immobilization of the knee joint, and weakness or inhibition of the quadriceps muscle secondary to pain or an effusion. Intrinsic factors involving collagen contraction have been suggested as potential mechanisms for the change in PLL.[24,26]

Investigators of a recent veterinary study[27] measured PLL of dogs 4 weeks after stifle joint arthrotomy with and without infrapatellar fat pad resection. The authors found no evidence of patellar ligament contraction and concluded that this lack of change may have been attributable to the short duration of the study.[27] Investigators of a study[26] of humans reported that 5 years after surgery, shortening of the patellar tendon was significantly correlated with the range of movement and that a decrease in length of 1 mm was associated with a decrease of flexion of 0.95°.

The purpose of the study reported here was to radiographically evaluate changes in PLL after TPLO in dogs with unilateral CrCL rupture. Our hypothesis was that there would be a decrease in the PLL immediately after surgery and at follow-up (≥ 5 weeks but < 1 year after surgery) radiographic evaluations.

Materials and Methods

Animals

Dogs that underwent surgical stabilization of a stifle joint after CrCL rupture by means of TPLO between October 1, 2008, and November 30, 2017, were identified by review of medical records of the veterinary teaching hospital at the Washington State University College of Veterinary Medicine. Surgeries were performed by board-certified veterinary surgeons or residents supervised by board-certified veterinary surgeons.

Dogs were included if TPLO was performed on a single limb. If a dog required surgery on the contralateral limb during the study period, data for the second limb were excluded from analysis to maintain independence of observations for statistical purposes. Additional inclusion criteria included a complete radiographic history, including preoperative, immediate postoperative, and follow-up radiographs. Follow-up radiographs included only those that were obtained ≥ 5 weeks but < 1 year after surgery.

Medical records review

Data collected from the medical records included signalment at the time of surgery (sex, age, body weight, and breed) and details of the surgical procedure (left vs right limb, preoperative TPA, use of arthroscopy or arthrotomy, size of the saw blade, size of the TPLO plate, extent of CrCL tear [partial vs complete], status of the medial meniscus, and surgeon experience).

Radiographic assessment

Radiographic requirements included orthogonal mediolateral and caudocranial digital radiographs obtained before, immediately after, and ≥ 5 weeks but < 1 year after surgery. Acquisition was performed by personnel in the radiology section at the Washington State University College of Veterinary Medicine. Standardized guidelines were used to acquire 90° flexion radiographs for the mediolateral view of the stifle joint. All lateral views (x-ray beam directed medial to lateral) were obtained with the limb directly on the table; therefore, magnification was the same for each image for each particular patient. When actual measurements were necessary (eg, calculating the correct size for an orthopedic implant), the degree of magnification was calculated by use of a standard 10-cm biomarker that was included in the radiographic field of view and positioned at the level of the anatomic structure of interest. For radiographic assessments of TPLO, the biomarker was elevated with thin foam pads (typical thickness of 1.27 to 2.54 cm) to match the center of the stifle joint; the x-ray beam was centered on the stifle joint or as close to the stifle joint as possible. For larger dogs, the available field of view (maximum dimension of the image plate, 43.18 cm) limited centering on the stifle joint because radiographic evaluation after TPLO must include the distal portion of the femur as well as the tarsus and metatarsus. The stifle and tibiotarsal joints were both positioned at 90° and held in place with positioning devices. The focus-film distance for all images was 101.60 cm, and the focus-object distance was the same for all images (the digital imaging plate was placed in the holder under the x-ray table and was located approximately 6.35 cm from the table top). To ensure a minimum of variation for the follow-up radiographs, preoperative, postoperative, and follow-up images of a single arbitrarily selected dog were evaluated to ensure consistency in positioning (degree of flexion), center or angle of the radiographic beam, focus-film distance, and focus-object distance.

The PLL was measured digitally on the mediolateral radiographic views by 1 of the investigators (MRJ). Measurements were obtained retrospectively; the investigator was aware of the stage of healing as a result of the presence of postoperative changes but was not aware of the source (ie, dog) because the order of images was randomized by use of conventional spreadsheet software.[a] The TPA was obtained from the medical records (surgeon measurements for the TPLO). The PLL was measured digitally on mediolateral radiographs.

The PLL was defined as the length along the cranial margin of the patellar ligament between a proximal landmark at the level of the distal portion of the patella where the distinction in the cortical patellar bone was visible and a distal landmark at the most cranial point of the tibial tuberosity at the level of the Sharpey fibers **(Figure 1)**. Contrast level was adjusted digitally as needed to improve the ability to visually identify these anatomic landmarks. Dogs were excluded from the study when concurrent fractures of the femur, patella, or tibial tuberosity were identified.

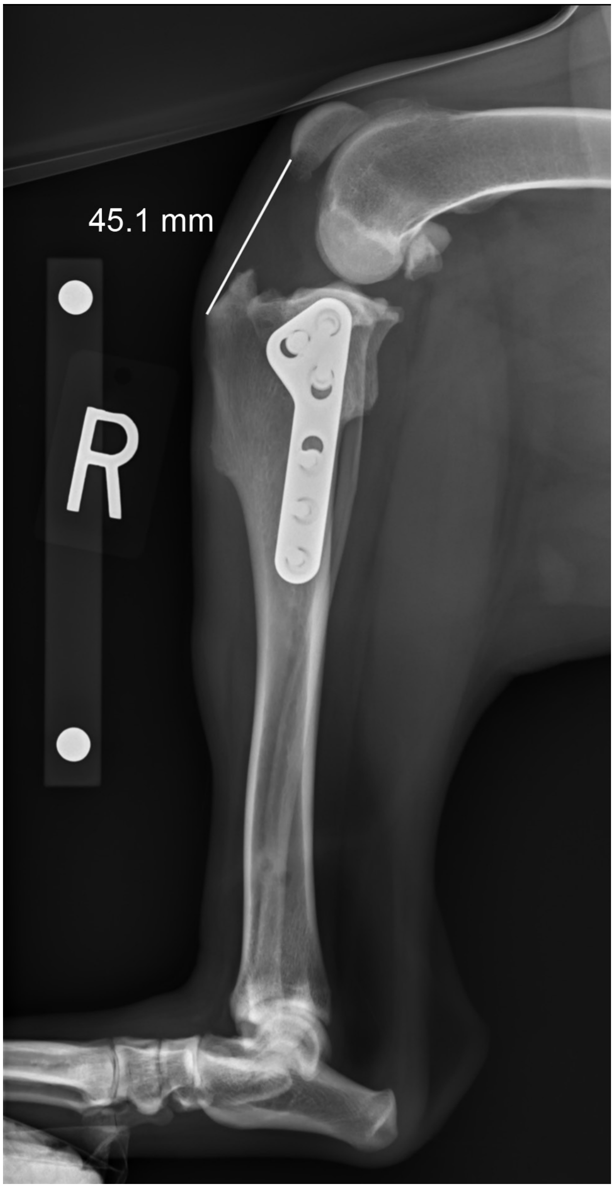

Figure 1—Representative mediolateral radiographic view of the stifle joint of a dog with CrCL rupture after repair by means of TPLO. The PLL was the length along the cranial margin of the patellar ligament (white line) between a proximal landmark at the level of the distal portion of the patella where the distinction in the cortical patellar bone was visible and a distal landmark at the most cranial point of the tibial tuberosity at the level of the Sharpey fibers. R = Right.

Statistical analysis

Mean, SD, and percentages were used for descriptive statistics. To model PLL over time, a repeated-measures longitudinal analysis with an unstructured covariance matrix[b] was performed. The distributions of the data were examined visually by use of histograms, Q-Q plots, and residual plots from the linear mixed model to ensure adequate normality. Covariates that were considered for inclusion in the model included signalment characteristics (sex, left vs right limb, age in years, and body weight in kilograms at the time of surgery). Surgical characteristics, including arthroscopy versus arthrotomy, preoperative TPA, size of the saw blade, size of the TPLO plate, degree of CrCL tear (partial or complete), and condition of the medial meniscus (intact, partially torn, or completely torn) were also considered. Each variable was separately tested in the repeated model for influence on the intercept or slope of the PLL. Variables with values of $P < 0.25$ for the intercept or slope were included in a multivariable model. A backward elimination process was used in which the covariate with the highest P value at each step was removed and the remaining coefficients evaluated for evidence of confounding. Only factors that had values of $P < 0.05$ for the intercept or slope were retained in the final model.

Results

Animals

During the study period, there were 450 cases of CrCL repair by means of TPLO, and 105 dogs met the inclusion criteria. Dogs comprised 2 (1.9%) sexually intact females, 50 (47.6%) spayed females, 4 (3.8%) sexually intact males, and 49 (46.7%) neutered males. Mean ± SD age of the dogs was 5.7 ± 2.6 years (range, 1 to 11 years). Mean body weight was 35.5 ± 11.5 kg (range, 9.5 to 65.4 kg). Breeds represented included Labrador Retriever (n = 27 [25.7%]), Labrador Retriever cross (10 [9.5%]), Rottweiler (7 [6.7%]), Golden Retriever (5 [4.8%]), Chesapeake Bay Retriever (4 [3.8%]), American Staffordshire Terrier (3 [2.9%]), American Staffordshire Terrier cross (3 [2.9%]), Australian Cattle Dog (3 [2.9%]), Border Collie cross (3 [2.9%]), German Shepherd Dog (3 [2.9%]), German Shepherd Dog cross (3 [2.9%]), Boxer (2 [1.9%]), Cane Corso (2 [1.9%]), Chow Chow cross (2 [1.9%]) and 25 other breeds (1 each [1.0%]); there were 6 (5.8%) mixed-breed dogs.

The population consisted of 61 dogs with a CrCL-deficient stifle joint of the left limb and 44 dogs with a CrCL-deficient stifle joint of the right limb. Mean ± SD preoperative TPA was 27.5 ± 4.4°. Arthroscopy was concurrently performed on 71 (67.6%) dogs, whereas arthrotomy was performed for joint evaluation on the remaining 34 (32.4%) dogs. Size of the saw blade was size 10 (n = 1 [1.0%]), 12 (3 [2.9%]), 18 (5 [4.8%]), 21 (5 [4.8%]), 24 (62 [59.0%]), 27 (19 [18.1%]), and 30 (9 [8.6%]). Size of the TPLO plate was size 2.0 (n = 2 [1.9%]), 2.7 (5 [4.8%]), 3.5 mini (6 [5.7%]), 3.5 (68 [64.8%]), and 3.5 broad (24 [22.9%]). The CrCL was completely torn in 71 (67.6%) dogs and had a partial tear in the remaining 34 (32.4%) dogs. The medial meniscus was intact in 62 (59.0%) dogs, partially torn in 21 (20.0%) dogs, and completely torn in 21 (20.0%) dogs; status of the medial meniscus was not reported in 1 (1.0%) dog. There was no difference in PLL at any times between dogs with complete versus partial CrCL tears or between dogs with an intact versus a partially torn medial meniscus.

Radiographs were obtained before, immediately after, and ≥ 5 weeks but < 1 year after TPLO **(Figure 2)**. Follow-up radiographs were obtained 36 to 364 days (mean, 88 days; median, 63 days) after surgery. Mean ± SD PLL at the preoperative, postoperative, and follow-up evaluations were 49.8 ± 8.2 mm, 48.7 ± 8.3 mm, and 48.5 ± 8.2 mm, respectively. A decrease in PLL at each subsequent radiographic evaluation was identified. Mean unadjusted overall PLL for all dogs decreased significantly ($P < 0.001$) by 1.1 ± 1.6 mm between preoperative and postoperative evaluation, decreased nonsignificantly ($P = 0.16$) by 0.2 ± 1.8 mm between the postoperative and follow-up evaluations, and decreased significantly ($P < 0.001$) by 1.4 ± 1.8 mm between the preoperative and follow-up evaluations. In terms of percentages, the mean overall unadjusted PLL decreased for all dogs by 2.8 ± 3.9% between the preoperative and follow-up evaluations, 0.4 ± 3.8% between the postoperative and follow-up evaluations, and 2.3 ± 3.4% between the preoperative and postoperative evaluations.

Multivariable repeated-measures analysis also revealed a significant ($P < 0.001$) decrease in the PLL between the preoperative and postoperative evaluations (adjusted estimate, –0.8 mm) and between the preoperative and follow-up evaluations (adjusted estimate, –1.2 mm). There was a nonsignificant ($P = 0.53$) decrease in the PLL between the postoperative and follow-up evaluations (adjusted estimate, –0.4 mm). In addition, greater body weight was associated with longer ligament length before surgery (an increase of 0.6 mm for each kilogram above the mean body weight), but no correlation was identified between PLL and sex, breed, age, left vs right limb, size of saw blade, or size of TPLO plate. Dogs on which an arthrotomy was performed had a greater decrease in ligament length over time than did dogs on which arthroscopic surgery was performed (an additional –0.9 mm at the postoperative evaluation and an additional –0.3 mm at the follow-up evaluation). For each degree increase in the preoperative TPA over the mean, a greater decrease in

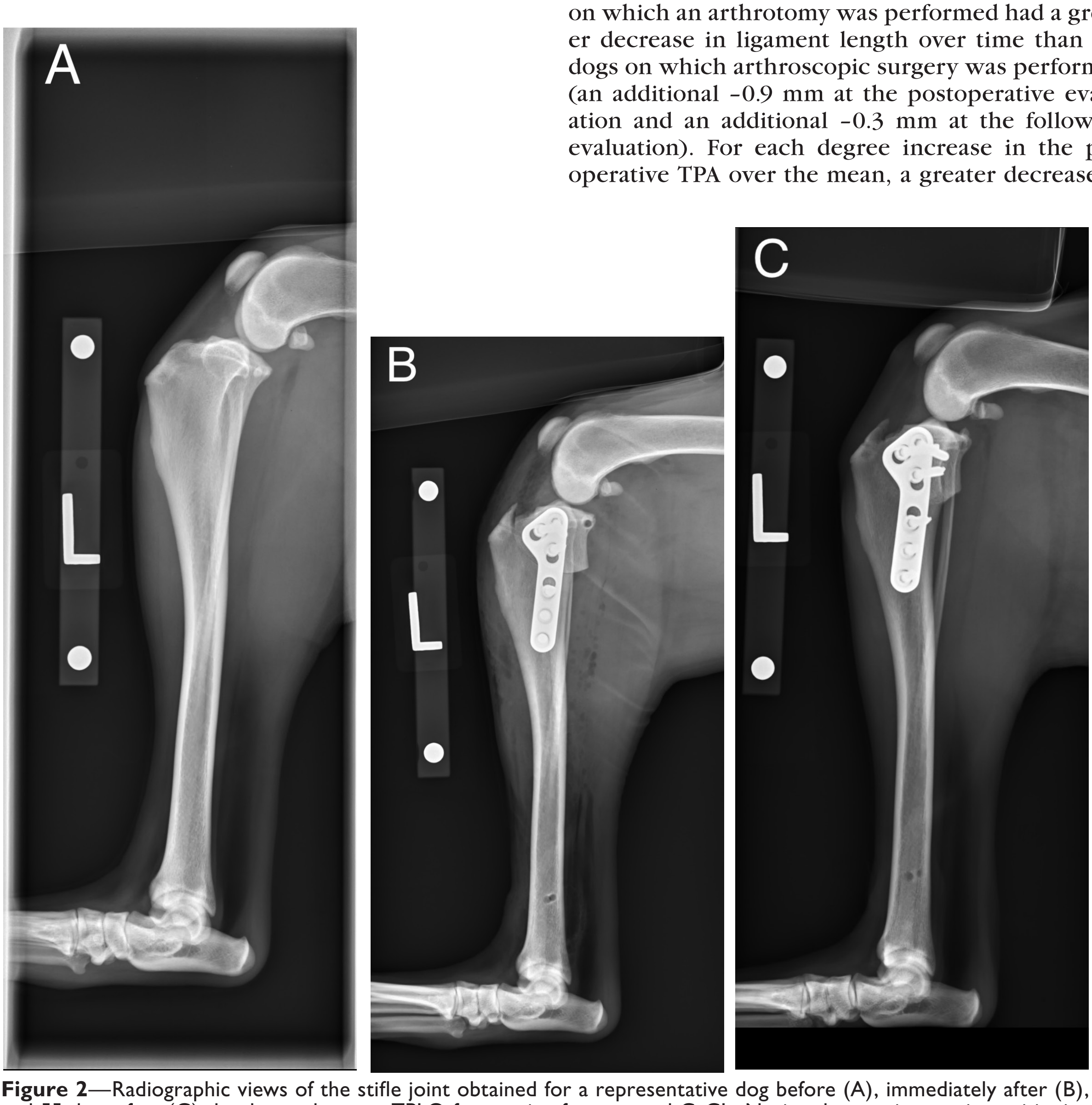

Figure 2—Radiographic views of the stifle joint obtained for a representative dog before (A), immediately after (B), and 55 days after (C) the dog underwent TPLO for repair of a ruptured CrCL. Notice the consistency in positioning and that the PLL is shorter at the postoperative and follow-up evaluations than at the preoperative evaluation. L = Left.

ligament length was detected at the postoperative (an additional –1.3 mm) and follow-up (an additional –1.0 mm) evaluations.

Discussion

The present study revealed that, as expected, the PLL decreased between the preoperative and postoperative evaluations and between the preoperative and follow-up evaluations. Although the PLL continued to shorten between the postoperative and follow-up evaluations, this change did not differ significantly. This finding contrasts with long-term follow-up evaluations of humans, which have revealed a progressive decrease in PLL at every postoperative time point.[26] The discrepancy for these findings may be attributable to differences in the duration of the follow-up period or in stance angles between dogs and humans. Although the interval between postoperative and follow-up evaluations in the present study was greater than in another report,[27] the lack of additional or lifelong radiographic evaluations on canine patients undergoing TPLO may have limited our ability to obtain additional information about the PLL. To the authors' knowledge, there have been no reports in which biomechanical properties during ambulation of quadrupeds and bipeds have been compared. However, it is likely that differences exist because of variations in stance between these modes of ambulation.

Similar to the procedures used in another study,[22] digital radiographs were used for measurements in the study reported here. One investigator (MRJ) performed all ligament measurements to ensure consistency of measurements. It was possible that this was a limitation because interobserver error could not be evaluated in the present study, and other studies on measurement of the TPA have revealed that significant interobserver variation exists. Investigators of 1 study[28] concluded that interobserver variability was attributable to observer experience and becomes a nonsignificant effect when results for observers with more experience are compared. Investigators of another study[29] failed to corroborate this finding and concluded that although interobserver variability exists, the magnitude of differences among reports could be attributed to study design and the number of observers.[29] It is generally accepted that variability is introduced when obtaining measurements such as the TPA because these measurements require subjective selection of anatomic landmarks. Measuring PLL also requires subjective selection of anatomic landmarks and therefore could be affected by measurement variability. Subtle variation in radiographic positioning of the stifle joint and degenerative changes may alter the appearance of the selected anatomic landmarks, potentially creating another source of measurement error.[28,29] However, the effects of interobserver variability on clinical outcome remain unknown and have failed to undermine the usefulness of anatomic landmarks for surgical planning and postoperative evaluation.[28,29] Further studies are needed to compare intraobserver reliability and interobserver consistency for measurement of PLL.

No correlation was identified between PLL and sex, breed, age, left versus right limb, size of saw blade, or size of TPLO plate. Additionally, no changes in PLL were identified when the dogs were categorized into those with complete versus partial CrCL rupture or into groups with intact versus torn medial menisci. Interestingly, dogs undergoing TPLO with concurrent arthroscopy for joint evaluation in the present study had significantly less shortening of the PLL than those undergoing joint evaluation by means of arthrotomy. This finding may have been associated with differences in soft tissue injury and thus swelling, inflammation, and tissue contraction. Additional studies are needed to evaluate ultrasonographic differences in tissues during the preoperative and postoperative periods.

The present study also revealed that a greater reduction in PLL was detected in dogs with TPA values greater than the mean TPA. This variation did not correlate with patient size or breed. This finding may have reflected the greater degree of rotation required for dogs with a higher TPA and may have been associated with increased soft tissue mobility and, therefore, inflammation.

A limitation of the present study was its retrospective nature. The follow-up radiographic evaluation was conducted on the basis of standard evaluations for bone healing, and a prospective study would be needed to monitor patients throughout a longer follow-up period. It is possible that variation in the degree of patient consciousness (some dogs were sedated, whereas others were anesthetized) required to enable acquisition of radiographs at the preoperative and follow-up evaluations could have accounted for some of the variation in radiographic measurements. A prospective study to control for this variable may provide additional information about changes in PLL after TPLO.

Another limitation was that clinical condition of dogs and PLL was not evaluated. Investigating a correlation between results of clinical assessment and advanced imaging may reveal associations between persistent lameness or decreased joint mobility and a decrease in PLL, which is similar to results for humans after high tibial osteotomy procedures.

The present study revealed significant decreases in the PLL of dogs after TPLO. Additional studies are needed to determine the clinical importance of the findings.

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Footnotes

a. Excel, version 2010, Microsoft Corp, Redmond, Wash.
b. PROC MIXED, SAS, version 9.4, SAS Institute Inc, Cary, NC.

References

1. Kowaleski MP, Boudrieau RJ, Pozzi A. Stifle joint. In: Tobias KM, Johnson SA, eds. *Veterinary surgery small animal*. Vol 1. St Louis: Elsevier, 2013;906–998.
2. Johnson JA, Austin C, Breur GJ. Incidence of canine appendicular musculoskeletal disorders in 16 veterinary teaching hospitals from 1980 through 1989. *Vet Comp Orthop Traumatol* 1994;7:56–69.
3. Whitehair JG, Vasseur PB, Willits NH. Epidemiology of cranial cruciate ligament rupture in dogs. *J Am Vet Med Assoc* 1993;203:1016–1019.
4. Arnoczky SP. Pathomechanics of cruciate ligament and meniscal injuries. In: Bojrab MJ, ed. *Disease mechanisms in small animal surgery*. 2nd ed. Malvern, Pa: Lea & Febiger, 1993;764.
5. Macias C, McKee WM, May C. Caudal proximal tibial deformity and cranial cruciate ligament rupture in small breed dogs. *J Small Anim Pract* 2002;43:433–438.
6. Morris E, Lipowitz AJ. Comparison of tibial plateau angles in dogs with and without cranial cruciate ligament injuries. *J Am Vet Med Assoc* 2001;218:363–366.
7. Read RA, Robins GM. Deformity of the proximal tibia in dogs. *Vet Rec* 1982;111:295–298.
8. Slocum B, Slocum TD. Trochlear wedge recession for medial patellar luxation: an update. *Vet Clin North Am Small Anim Pract* 1993;23:869–875.
9. Lapman TJ, Lund EM, Lipowitz AJ. Cranial cruciate disease: current status of diagnosis, surgery and risk for disease. *Vet Comp Orthop Traumatol* 2003;16:122–126.
10. Vasseur PB, Pool RR, Arnoczky SP, et al. Correlative biomechanical and histologic study of the cranial cruciate ligament in dogs. *Am J Vet Res* 1985;46:1842–1854.
11. Arnoczky SP, Marshall JL. The cruciate ligament of the canine stifle an anatomical and functional analysis. *Am J Vet Res* 1977;38:1807–1814.
12. Casale SA, McCarthy RJ. Complications associated with lateral fabellotibial suture surgery for cranial cruciate ligament injury in dogs: 363 cases (1997–2005). *J Am Vet Med Assoc* 2009;234:229–235.
13. Ralphs SC, Whitney WO. Arthroscopic evaluation of menisci in dogs with cranial cruciate ligament injuries: 100 cases (1999–2000). *J Am Vet Med Assoc* 2002;221:1601–1604.
14. Williams J, Tomlinson J, Constantinescu G. Diagnosing and treating meniscal injuries in the dog. *Vet Med* 1994;89:42–47.
15. Wucherer KL, Conzemius MG, Evans R, et al. Short-term and long-term outcomes for overweight dogs with cranial cruciate ligament rupture treated surgically and nonsurgically. *J Am Vet Med Assoc* 2013;242:1364–1372.
16. Leighton RL. Preferred method of repair of cranial cruciate ligament rupture in dogs: a survey of ACVS diplomates specializing in canine orthopedics. American College of Veterinary Surgery (lett). *Vet Surg* 1999;28:194.
17. Slocum B, Slocum TD. Tibial plateau leveling osteotomy for repair of cranial cruciate ligament rupture in the canine. *Vet Clin North Am Small Anim Pract* 1993;23:777–795.
18. Mattern KL, Berry CR, Peck JN, et al. Radiographic and ultrasonographic evaluation of the patellar ligament following tibial plateau leveling osteotomy. *Vet Radiol Ultrasound* 2006;47:185–191.
19. Kühn K, Ohlerth S, Markara M, et al. Radiographic and ultrasonographic evaluation of the patellar ligament following tibial tuberosity advancement. *Vet Radiol Ultrasound* 2011;52:466–471.
20. Carey K, Aiken SW, DiResta GR, et al. Radiographic and clinical changes of the patellar tendon after tibial plateau leveling osteotomy. *Vet Comp Orthop Traumatol* 2005;18:235–242.
21. Pettitt R, Cripps P, Baker M, et al. Radiographic and ultrasonographic changes of the patellar ligament following tibial tuberosity advancement in 25 dogs. *Vet Comp Orthop Traumatol* 2014;27:216–221.
22. DeSandre-Robinson DM, Tano CA, Fiore KL, et al. Radiographic evaluation and comparison of the patellar ligament following tibial plateau leveling osteotomy and tibial tuberosity advancement in dogs: 106 cases (2009–2012). *J Am Vet Med Assoc* 2017;250:68–74.
23. Scuderi GR, Windsor RE, Insall JN. Observations on patellar height after proximal tibial osteotomy. *J Bone Joint Surg Am* 1989;71:245–248.
24. Dandy DJ, Desai SS. Patellar ligament length after anterior cruciate ligament reconstruction. *J Bone Joint Surg Br* 1994;76:198–199.
25. Tanaka N, Sakahashi H, Sato E, et al. Influence of the infrapatellar fat pad resection in synovectomy during total knee arthroplasty in patients with rheumatoid arthritis. *J Arthroplasty* 2003;18:897–902.
26. Weale AE, Murrary DW, Newman JH, et al. The length of the patellar tendon after unicompartmental and total knee replacement. *J Bone Joint Surg Br* 1999;81:790–795.
27. Fujita Y, Nakajo T, Muto M. Short-term effects on arthrotomy with and without infrapatellar fat pad resection on the normal canine stifle. *Vet Surg* 2017;46:683–690.
28. Caylor KB, Zumpano CA, Evans LM, et al. Intra- and interobserver measurement variability of tibial plateau slope from lateral radiographs in dogs. *J Am Anim Hosp Assoc* 2001;37:263–268.
29. Fettig AA, Rand WM, Sato AF, et al. Observer variability of tibial plateau slope measurement in 40 dogs with cranial cruciate ligament-deficient stifle joints. *Vet Surg* 2003;32:471–478.