Comparison of tibial plateau angles in dogs with and without cranial cruciate ligament injuries

Ethan Morris, DVM, and Alan J. Lipowitz, DVM, MS, DACVS

Objective—To measure and compare tibial plateau angles (TPA) of dogs with cranial cruciate ligament (CrCL) injuries and dogs without CrCL injuries.

Design—Prospective study.

Animals—87 dogs.

Procedure—Stifle joints were measured from lateral radiographic views to determine TPA in 3 groups: group-1 dogs had CrCL injuries, group-1a dogs, a subgroup of group 1, had 1 unaffected stifle joint, and group-2 dogs had no CrCL injuries. Age, sex, breed, body weight, limb injured, and TPA were recorded for each dog.

Results—56 stifle joints were measured in group-1 dogs; mean TPA was 23.76°, and mean age and weight were 5.7 years and 37.91 kg (83.4 lb), respectively. Fourteen stifle joints were measured in group-1a dogs; mean TPA was 24.71°, and mean age and weight were 5.6 years and 38.06 kg (83.8 lb), respectively. Sixty stifle joints were measured in group-2 dogs; mean TPA was 18.10°, and mean age and weight of these dogs were 4.83 years and 35.85 kg (79 lb), respectively. The most common breeds included Labrador Retriever, Golden Retriever, and Rottweiler. The TPA of dogs in group 1 and group 1a were significantly greater than the TPA of dogs in group 2.

Conclusions and Clinical Relevance—Dogs with CrCL injuries have a significantly greater TPA than dogs without CrCL injury. With further investigation, a normal TPA can be determined. In the future, TPA measurements may be used to screen dogs suspected of being susceptible to CrCL injury. (J Am Vet Med Assoc 2001;218:363–366)

CrCL. In 1983, Slocum described the tibial compression and force directed by the slope of the tibial plateau as the cause of most CrCL ruptures. Slocum then used the concept of the tibial compression and its relation to the tibial plateau to develop a surgical procedure to alter the tibial plateau angle (TPA) to eliminate the cranial tibial thrust on the weight-bearing stifle joint in dogs.

The purpose of the study reported here was to determine whether dogs with rupture of the CrCL had a greater TPA than dogs of similar breed, age, size, and weight that did not have a ruptured CrCL. To our knowledge, there are no references in the veterinary literature that document TPA in clinically normal dogs and compare angles with those in dogs with CrCL injuries. We hypothesized that dogs with a ruptured CrCL have a greater TPA; if these dogs do, in fact, have an increased angle of the tibial plateau, this may be a factor in the pathogenesis of CrCL ruptures.

Materials and Methods

Dogs with CrCL injuries—Fifty-six dogs with CrCL injuries (diagnosed on the basis of history, physical examination findings, and surgical exploration of the stifle joint via arthroscopy) were evaluated by the University of Minnesota Veterinary Teaching Hospital (UMVTH) and assigned to group 1. Age, weight, sex, breed, and limb with affected stifle were recorded. All dogs were sedated with a combination of oxymorphone (0.05 mg/kg [0.02 mg/lb] of body weight, IV) and acepromazine maleate (0.01 mg/kg [0.02 mg/lb], IV) or were under isofluorane inhalation anesthesia, and a lateral radiographic view was obtained of each hind limb that had a CrCL injury. Dogs were positioned in lateral recumbency with the affected limb placed down on the film cassette. All radiographs were obtained with the x-ray beam centered on the diaphysis of the tibia. The x-ray beam was coned to include the stifle and tarsal joints. The greater trochanter, head of the fibula, and lateral malleolus were all in contact with the film cassette, ensuring that a true lateral radiographic view of the stifle and hock joints was obtained. A lateral radiograph in the same manner as described was also obtained of the contralateral unaffected stifle joint in 14 dogs (group 1a).

For consistency, TPA was described from the lateral radiographic view by the primary author (EM). The TPA was measured from the lateral radiographic view by drawing a line between a point on the medial plateau of the medial articular surface of the tibial plateau on the cranial intercondylar area where the cranial cruciate ligament inserts and a point on the caudal margin of the lateral condyle of the tibia where the CrCL attaches. A line was then drawn between the centers of the tibial intercondylar eminences and the center of the talus. The center of the talus is located halfway between the distal-most extent of the cranial and caudal articular margins of the talus. The TPA was measured between a perpendicular to that line, which represents joint compression and the cranial tibial thrust across the stifle joint, and the slope of the tibial plateau (Fig 1 and 2).
Dogs without CrCL injuries—Dogs admitted to the UMVTH with conditions unrelated to CrCL injuries were used as controls (group 2). Age, weight, sex, and breed were recorded. Each stifle joint was examined for a cranial drawer sign and medial buttress. Dogs that had evidence of either a cranial drawer sign or medial buttress were excluded from the study. Lateral radiographic views of the stifle joints were obtained as described. Dogs with any radiographic evidence of pathologic changes within the stifle joint were also excluded. Thirty-one dogs were selected as controls, with the owners’ consent. Thirty-one right and 29 left hind limbs were radiographed, and the TPA of each was measured, as described. No dogs in group 2 had a previous history of CrCL injuries or other abnormalities of the stifle.

Statistical analyses—Age, sex, breed, and weight were categorized as independent groups and analyzed by use of 1-way ANOVA. Because it was determined that age, sex, breed, and weight were not significantly different when comparing group 1 and group 2 TPA measurements with each independent group, each independent group had no effect on the outcome of either group with regard to TPA measurements. A t-test for independent samples was used to compare the
measured TPA of dogs in group 1 (CrCL injury) with the measured TPA of dogs in group 2 (control group). Also, measured TPA from dogs in group 2 were compared with the 14 measured TPA of dogs in group 1a by use of a t-test for independent samples. Values of P < 0.05 were considered significant.

Results

Group 1—There were 56 dogs in group 1. Twenty-eight dogs had left-sided CrCL injury, 18 dogs had right-sided CrCL injury, and 10 dogs had bilateral CrCL injuries. There were 6 sexually intact females, 28 spayed females, 5 sexually intact males, and 17 castrated males. Breeds included Labrador Retriever (n = 19), Golden Retriever (9), Rottweiler (7), Newfoundland (4), Bullmastiff (3), mixed-breed (3), German Wirehaired Pointer (2), German Shepherd Dog (2), Chesapeake Bay Retriever (2), and 1 each of Gordon Setter, German Shorthaired Pointer, Alaskan Malamute, Great Pyrenees, and Akita. Sixty-six TPA were measured in group 1. Mean TPA was 23.8°, mean age was 5.7 years, and mean weight was 37.9 kg (83.38 lb).

Group 1a—There were 14 dogs in group 1 with unilateral CrCL rupture that also had the TPA of the unaffected stifle measured. The TPA was measured in 11 unaffected right stifles and 3 unaffected left stifles. There were 2 sexually intact females, 7 spayed females, 1 sexually intact male, and 4 castrated males. Breeds included Labrador Retriever (n = 5), Golden Retriever (6), and 1 each of Rottweiler, German Shepherd Dog, and German Wirehaired Pointer. Mean TPA was 24.7°, mean age was 5.6 years, and mean weight was 38.1 kg (83.82 lb).

Group 2—There were 31 dogs in the control group. The left and right TPA were measured in 29 dogs, and only the right TPA was measured in 2 dogs. There were 4 sexually intact females, 8 spayed females, 6 sexually intact males, and 13 castrated males. Breeds included Labrador Retriever (n = 7), Golden Retriever (5), Rottweiler (4), Greyhound (4), mixed-breed (2), and 1 each of Malamute, Newfoundland, Chesapeake Bay Retriever, German Shepherd Dog, Collie, Boxer, Dalmatian, Saint Bernard, and Viszla. Mean TPA was 18.1°, mean age was 4.8 years, and mean weight was 35.9 kg (78.98 lb).

Comparison of groups 1 and 2—When comparing TPA measured in group 1 with TPA measured in group 2, a significant difference was detected between the 2 groups. Dogs in group 2 had significantly smaller TPA than dogs in group 1. When comparing TPA measured in the right hind limbs (mean, 23.18°) of dogs in group 1a (n = 3) with those of group 2 (mean, 18.37°; 31), a significant difference was detected between the angles measured. When comparing TPA measured in the right hind limbs (mean, 23.21 ± 3.33°; 14.88 ± 3.13°; 23.38 ± 2.71°, respectively. Mean ± SD of the TPA measurements of the Labrador Retrievers, Golden Retrievers, and Rottweilers in group 1 were 23.21 ± 3.33°, 24.88 ± 3.13°, and 23.38 ± 2.71°, respectively. Mean ± SD for the TPA measurements of the Labrador Retrievers, Golden Retrievers, and Rottweilers in group 2 were 18.87 ± 2.77°, 19.20 ± 2.77°, and 16.90 ± 3.26°, respectively. Those breeds that did not have CrCL injury had a significantly smaller TPA than those breeds that had CrCL injuries.

From the data, we determined that the overall mean (± SD) TPA for both stifle joints from all dogs in group 2 was 18.10° (± 4.03°). The overall mean TPA for both stifle joints in dogs from group 1 was 23.76° (± 3.88°). On the basis of these data, a 95% upper prediction limit for normal TPA was determined to be 21.2° (via the Central Limit Theorem).

Discussion

Our results revealed that dogs with CrCL injuries have significantly greater TPA (mean TPA, 23.76°) than those dogs that do not have CrCL injuries (mean TPA, 18.10°). The excess TPA may be a primary developmental or congenital abnormality that leads to a rupture or partial tear of the CrCL. Other conformational abnormalities of the stifle joint have been investigated as possible causes that lead to CrCL injuries. Good et al. and Aiken et al. demonstrated that the intercondylar notch width in dogs with CrCL injuries was significantly smaller, compared with dogs without CrCL injuries, and hypothesized that the notch width impinged on the CrCL causing it to weaken over time. In human medicine, it has been reported that women with a narrow intercondylar notch width have significantly more anterior cruciate injuries than women with wider intercondylar notches.

With the introduction of the tibial compression mechanism and the forces that are exerted on the CrCL, referred to as cranial tibial thrust, it is this force transmitted to the tibial plateau and the CrCL that is thought to lead to cruciate injury. Because the tibial plateau is inclined to the functional axis of the tibia, and the point of contact of the articular surfaces is cranial to this axis, a cranial tibial thrust is generated by tibial compression. Slocum determined that if the tibial plateau were made nearly perpendicular to the functional axis, compressive forces alone would be generated on tibial compression. With the TPA being the static structure in the tibial compression mechanism, as described by Slocum, it was determined that...
by changing the TPA, the tibial compression mechanism could be altered surgically. It has been demonstrated that in humans, the force on the tibial plateau increases in direct proportion with the load on the head of the femur throughout weight-bearing.\textsuperscript{18} Also, in the human medical literature, it has been reported that with an increase of the posterior slope of the tibial plateau, there is an increase of degenerative changes of the stifle joint.\textsuperscript{19} To our knowledge, in the current veterinary literature, there are no references to normal TPA, compared with TPA of dogs with CrCL injuries.

Deformities of the proximal tibia have been associated with CrCL ruptures.\textsuperscript{17} However, Read et al\textsuperscript{17} only had a series of 5 dogs in which the caudal aspect of the proximal tibial physis had what appeared to be a retardation of growth leading to a limb deformity. In that particular report, 5 dogs were recognized as having cranial bowing of the proximal tibia. An attempt to quantify the deformity was made by measuring the angle formed by 2 lines drawn on lateral radiographs of the hind limbs, 1 line bisecting the proximal tibial shaft, and 1 line parallel to the face of the tibial plateau. The angles measured in those 5 dogs were 41, 38, 50, 60, and 42° of the left tibial plateau and 33.5, 39.5, 57.5, 50, and 50° of the right tibial plateau. The cause of the deformities was not discovered; however, the deformity of each limb apparently altered the biomechanics of the stifle such that degenerative joint disease developed and rupture of the CrCL followed because of abnormal strain on the CrCL.\textsuperscript{17} The inference in that study was that the tibial plateau deformity contributed to the rupture of the CrCL. We did not recognize any tibial deformities in any of the dogs in our study; with the exception of increased TPA in the dogs of group 1, Schwarz\textsuperscript{2} also recognized an increase in the TPA in dogs with CrCL injuries. In that particular study, the author measured the TPA in 15 dogs with CrCL injuries; the mean TPA was 30° (range, 23 to 36°).

The purpose of the study reported here was to measure and compare the TPA of dogs with and without CrCL injury. Both groups of dogs that were included in our study were large breeds that are predisposed to rupture of the CrCL.\textsuperscript{18} The TPA, as measured in this study, were significantly greater in dogs with CrCL injuries than in those dogs without CrCL injury. We also observed, when comparing group 1a dogs with group 2 dogs, that there was a significant difference in the TPA of the unaffected stifle of group 1a dogs. This finding suggests that dogs with one-sided CrCL injuries may be predisposed to rupturing the contralateral CrCL. When comparing the most common breeds seen in groups 1 and 2, there was a significant difference in the TPA of the 2 groups. With further investigation of the TPA in specific breeds, we may able to determine whether there is a genetic predisposition to increased TPA within some breeds.

It was recognized that the number of dogs in our study was small and that TPA measurements on many more dogs would be necessary to establish a true normal TPA. It is further recognized that the normal TPA may vary among breeds. Again, the number of dogs in this study was too small to derive normals for the breeds represented.

We hypothesize that a greater TPA (ie, >21.2°) increases the stresses applied to the CrCL and predisposes a dog to CrCL injury. We believe that the information presented in this study could be used to prophylactically screen young dogs prior to CrCL injuries to determine whether they are predisposed to CrCL injuries; it may then be possible to surgically alter their tibial plateau to prevent CrCL injuries from occurring.

\textsuperscript{1}Numorphan, Endo Pharmaceuticals, Chaddsford, Pa.
\textsuperscript{2}Butler Pharmaceuticals, Columbus, Ohio.

**References**


