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

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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.

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.

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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 butress. Dogs that had evidence of either a cranial drawer sign or medial butress 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.

Figure 1—Lateral radiographic view of the stifle joint of a dog with no cranial cruciate ligament injury. The tibial plateau angle was measured 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 (point A) and a point on the caudal margin of the lateral condyle of the tibia where the caudal cruciate ligament attaches (point B). A second line is then drawn between the centers of the tibial intercondylar eminences (point C) and the center of the talus (point D). The tibial plateau angle is measured between a perpendicular to line C/D and slope of the tibial plateau A/B. Θ = Tibial plateau angle of 18°.

Figure 2—Lateral radiographic view of the stifle joint of a dog with a cranial cruciate ligament injury. The tibial plateau angle was measured as described in Figure 1. Θ = Tibial plateau angle of 30°.

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. The central limit theorem was used to predict a 95% upper prediction limit for normal TPA, using the dogs in group 2.

**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 Vizsla. 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, 23.66°) of group 1 (n = 38) with those of group 2 (mean, 17.81°; 29), a significant difference was detected between the angles measured. When comparing TPA measured in the right hind limbs (mean, 22.75°) of group 1 (n = 28) with those of group 2 (mean, 18.37°; 31), a significant difference was detected between the angles measured.

**Comparison of groups 1a and 2**—When comparing TPA measured in group 1a with TPA measured in group 2, a significant difference was detected between the angles measured. Dogs in group 2 had a significantly smaller TPA than dogs in group 1a. When comparing TPA measured in the right hind limbs (mean, 23.18°) of dogs in group 1a (n = 11) with those of group 2 (mean, 18.37°; 31), a significant difference was detected between the angles measured. When comparing TPA measured in the left hind limbs (mean, 30.33°) of dogs in group 1a (n = 3) with those of group 2 (mean, 17.81°; 29), a significant difference was detected between the angles measured.

**Breed-specific comparisons of groups 1 and 2**—The most common breeds seen in both groups were Labrador Retriever, Golden Retriever, and Rottweiler. Mean ± SD for 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 of the TPA measurements of the Labrador Retrievers, Golden Retrievers, and Rottweilers in group 2 were 18.87 ± 3.27°, 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 a 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.12 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.13 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.14 However, Read et al15 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.16 The inference in that study was that the tibial plateau deformity contributed to the rupture of the CrCL.17 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. Schwarz18 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.19 The TPA, as measured in this study, were large breeds that are predisposed to rupture of the CrCL followed because of abnormal strain on the CrCL.16 The inference in that particular study, the author measured the TPA in 15 dogs with CrCL injuries; the mean TPA was 30° (range, 23 to 36°).

We hypothesize that a greater TPA (ie, >21.2°) increases the stresses applied to the CrCL and predisposes a dog to CrCL injuries. 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.

References