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Measurement of the Tibial Plateau Angle in Normal Small Breed Dogs

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Abstract : This study measured the tibial plateau angle (TPA), a value that predicts cranial cruciate ligament rupture (CCLR) and a prerequisite for dynamic stabilization, in small breed dogs. The cadavers of 32 skeletally mature small breed dogs without CCLR were used to measure TPA. Differences were evaluated between males and females, left and right limbs, and among breeds. The mean TPA of all dogs was 26.13° ± 2.33°. The mean TPAs of left and right limbs were 26.00° ± 2.23° and 26.26° ± 2.45°, respectively, which was not a significant difference. The mean TPAs of male and female dogs were 26.01° ± 1.57° and 26°.22 ± 2.80°, respectively, which was also not significant difference. The mean TPAs in Maltese, Poodle, Shih Tzu, and Yorkshire terrier were 26.06° ± 2.96°, 25.21° ± 1.38°, 26.65° ± 2.96°, and 26.27° ± 1.61°, respectively. Differences in these means were not statistically significant. The TPA measured from this study could provide important information for further investigation of the pathogenesis of and surgical techniques for CCLR in small breed dogs.

***Key words* :** tibial plateau angle, small breed dogs, CCLR.

Introduction

Cranial cruciate ligament rupture (CCLR) is one of the most common causes of hind limb lameness in dogs (10). The main function of the cranial cruciate ligament is to resist cranial tibial thrust generated during weight bearing, which causes cranial tibial translation relative to the femur (17). Other functions of the cranial cruciate ligament are to prevent internal rotation of the tibia relative to the femur and hyperextension of the stifle (1). Failure of the cranial cruciate ligament leads to stifle joint instability and subsequent degenerative joint disease and meniscal injury (11).

It is reported that the tibial plateau angle (TPA) could predispose dogs to CCLR through the creation of excessive cranial tibial thrust (18). A study by Read and Robins (14) first described TPA and its relationship with CCLR. Slocum presented a report showing that 22.6° of TPA was steep and could drive dogs to CCLR (18). That report also described how a cranially directed force in the stifle joint during weight bearing depends on the amount of tibial compression and the tibial plateau slope. Warzee *et al*. (21) postulated that tibial thrust increases as a result of an increase in TPA, leading to greater stress on the cranial cruciate ligament, which contributes to rupture. A report by Morris *et al*. (12) showed that the TPA of dogs with CCLR was 23.76°, whereas it was 18.1° in dogs without CCLR. Contrary to Morris *et al*., reports by Caylor *et al*. (3) and Reif *et al*. (15) found that the TPA of dogs without CCLR was 23.5° and 25.0°, respectively. Those reports had many limitations. For example, they did not consider a dog's the condition of the cranial cruciate ligament.

Therefore, even though several reports have shown that steeper TPA could be associated with CCLR in dogs, controversy continues to exist. A canine cadaver study that investigated the effect of tibial plateau leveling revealed a relation between the magnitude of TPA and the amount of cranial tibial thrust during axial tibial loading (16). In other words, a high TPA could increase the stress exerted on the cranial cruciate ligament, leading to increased risk of CCLR. Morris *et al*. (12) hypothesized that TPA could be used to predict which dogs will be predisposed to CCLR. Dynamic stabilization has been developed to treat stifles with CCLR by altering the slope of the tibial plateau. Therefore, TPA can be a prerequisite for dynamic stabilization for the treatment of CCLR. Therefore, it is worthwhile to measure TPA in dogs and make a reference table for each breed to help veterinarians know which breeds are predisposed to CCLR and make surgical plans.

Although many studies evaluated TPA in large breed dogs, few studies have assessed TPA in small breed dogs. The objective of this study was to determine TPA in small breed dogs without CCLR. To our knowledge, no references in the veterinary literature assess TPA in small breed dogs.

Materials and Methods

Cadaver Preparation

Small mature canine cadavers euthanized for humane reasons unrelated to this investigation and free of orthopedic and neurologic disease were collected. The dogs were of various breeds and were similar in size and body weight (average

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6.2 ± 1.34 kg). Physical examinations were performed to assess any abnormalities in their hindlimbs. Standard radiographic examinations (craniocaudal and mediolateral) were obtained for each limb to determine that the stifle joints showed no radiographic evidence of osteoarthritis. Cadavers with cartilage erosion or damage on stifle joint, coxofemoral joint and tarsal joint was excluded using gross examination after finishing the study. All hairs of the pelvic region and hind limb were clipped so that the greater trochanter, lateral condyle of the femur, and lateral malleolus could contact the radiographic table as closely as possible. The cadavers were stored at −14°C and were left at room temperature (approximately 25°C) for twelve hours before testing. The body weight, sex, and breed of each dog were recorded.

Limb Positioning and Radiographic Methods

To obtain lateral radiographic views of the stifle joint and tibia, each cadaver was positioned in lateral recumbency on a radiographic table. The stifle and tarsal joint were placed at an angle of 90°. The greater trochanter, lateral condyle of the femur, and lateral malleolus were positioned in contact with the table. The opposite limb was slightly displaced cranially or caudally to be avoided in the radiographic projections. Digital radiography (PACS) was used in this study. Radiographs including stifle joint and tibia were taken with the beam centered over the stifle joint. Radiographs were included in the analysis if the femoral and tibial condyles were superimposed or minimally separated caudally, distally, or cranially. Radiographs of each limb were repeated until precise projections were obtained. The radiographs of the opposite limb were taken in the same manner.

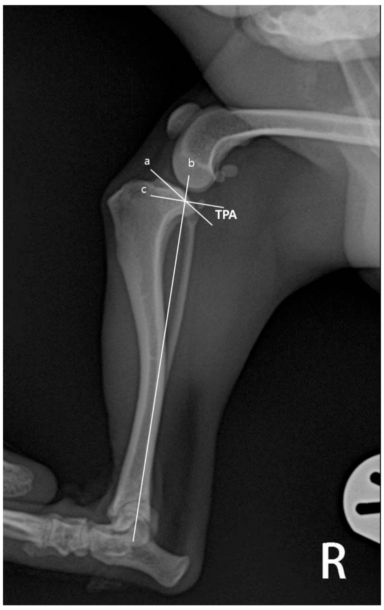

Fig 1. Measurement of TPA. A line connecting the cranial and caudal extents of the tibial plateau was drawn to determine the tibial plateau slope (line a). A second line was drawn from the center of the intercondylar eminences to the center of the talus (line b). Line b is the long axis of the tibia on sagittal plane. A third line (line c) was drawn perpendicular to the tibial long axis at the intersection of lines a and b. The TPA was measured as the angle between linesa and c.

Measurement of TPA

A single examiner who was unaware of signalment of dogs measured each limb for TPA (Fig 1). The cranial tibial plateau landmark was identified as the proximal aspect of the cranial extent of the medial tibial plateau, and the caudal landmark was identified as the caudal extent of the medial tibial plateau. A line connecting the cranial and caudal extents of the tibial plateau was drawn to determine the tibial plateau slope (line a). A second line was drawn from the center of the intercondylar eminences to the center of the talus (line b). Line b is the long axis of the tibia on the sagittal plane. A third line (line c) was drawn perpendicular to the tibial long axis at the intersection of lines a and b. The TPA was measured as the angle between lines a and c. The mean of triplicate measures was used for statistical analysis.

Statistical Analysis

TPAs were summarized as mean ± standard deviation (SD). To determine the differences between limbs from male and female dogs, and from left and right limbs, a paired t-test and the Wilcoxon-signed rank test were performed. A one way analysis of variance (one way ANOVA) was performed and values of $p < 0.05$ were considered significant,to determine the differences among breeds. All analyses were performed using commercial statistical software (GraphPad Prism v5.0, GraphPad Software Inc., USA).

Results

Thirty-two cadavers from small dogs met the inclusion criteria. There were 13 Malteses, 5 Poodles, 9 Shih Tzus, and 5 Yorkshire terriers. Sex distribution was 14 male and 18 female. Mean body weight was 2.90 kg ± 1.21 kg (1.32 kg- 5.88 kg). The mean TPA of all dogs was 26.13° ± 2.33° (22.62°-34.93°). The mean TPAs of left and right limbs were 26.00° ± 2.23° and 26.26° ± 2.45°, respectively (Table 1), which was not a significant difference (p = 0.56). The mean TPAs of male and female dogs were 26.01° ± 1.57° and 26°.22 ± 2.80°, respectively (Table 2), which was not a significant difference (p = 0.77). The mean TPAs in Maltese, Poodle, Shih Tzu, and Yorkshire terrier were 26.06° ± 2.96°, 25.21° ± 1.38°, 26.65° ± 2.96°, and 26.27° ± 1.61°, respectively (Fig 2). There were no significant differences among the breeds (p = 0.49).

Table 1. Tibial plateau angle (TPA) of left and right stifle joint

	Left (mean ± SD)	Right (mean ± SD)	*P* value
Tibial plateau angle	26.00 ± 2.23	26.26 ± 2.45	0.56

Table 2. Tibial plateau angle (TPA) of male and female dogs

	male (mean ± SD)	female (mean ± SD)	*P* value
Tibial plateau angle	26.01 ± 1.57	26.22 ± 2.80	0.77

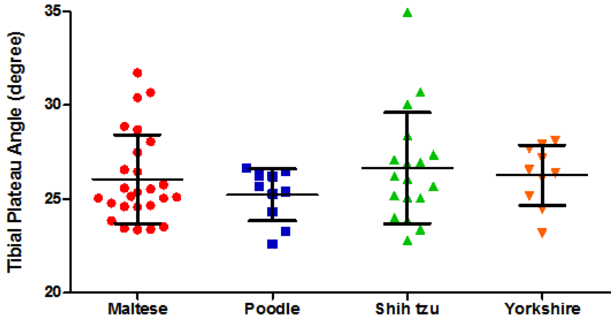

Fig 2. Tibial plateau angle (TPA) among breeds

Discussion

A generally accepted pathogenesis of CCLR has not been determined. It has previously been shown that only one factor is not a sole cause in CCLR. Multiple variables could influence the pathogenesis of CCLR. However, it remains to be defined if TPA may be a causative factor for the initiation of cranial cruciate ligament disease.

Once the tibial compression and resultant forces, cranial tibial thrust, are described, that is thought to be a cause of cruciate injury (9). Because the tibial plateau is directed caudally to the functional axis of the tibia, and the contact point of stifle locates cranial to this axis, tibial compression generates the cranial tibial thrust (19). If the tibial plateau were changed perpendicular to the functional axis, compressive forces would not generate cranially directed force (18). In human literature, there is an increase of degenerative changes of the knee joint with an increase of the posterior slope of the tibial plateau (4). To our knowledge, however, there are no references to normal TPA, compared TPA of stifle joint with CCLR in small breed dogs.

TPA in dogs without CCLR has been reported to range from 16.9° to 25.0° (3,12,18), while reported TPA in dogs with CCLR ranged from 22.6° to 25.5°(18 22]). In a study comparing TPA among large-breed dogs with CCLR treated with TPLO revealed that Labrador Retrievers, Rottweilers, Boxers, and German Shepherd dogs had mean TPAs of 25.9°, 26.2°, 25.9°, and 28.2°, respectively (7). Compared to a previous report, the mean TPA of our dogs is similar to that of dogs with CCLR. According to Petazzoni, the mean TPA in small breed dogs was 27.4° (13). The mean TPA in small-breed dogs is generally higher than that in large-breed dogs, meaning that an increased strain could be exerted on the cranial cruciate ligament in small-breed dogs. However, no cruciate deficient stifles were used in the present study. This could correspond to the findings of a previous study suggesting that many dogs with a steep TPA do not develop cruciate ligament disease (22).

This study found no significant difference in TPA between left and right limbs. To our knowledge, no report shows a significant difference in TPA between the left and right limbs. Because any factors that could affect TPA due to growth retardation of the proximal tibial physis, as mentioned above, are systemic conditions (14), TPA may generally change bilaterally when it occurs.

This study found no significant difference in TPA between male and female dogs. One study reported that neutering before 6 months of age could predispose dogs to excessive TPA (5). However, the present study contained no castrated males or spayed females, so neutering status did not affect the TPA measured in this study. Another study showed an increased risk for CCLR in neutered males and spayed females, compared to sexually intact dogs (6). Although the pathogenesis of CCLR is multifactorial, increased TPA caused by neutering might contribute to an increased risk of CCLR.

This study found no significant differences among the breeds. In a study comparing TPA among large-breed dogs with CCLR treated with TPLO revealed that Labrador Retrievers, Rottweilers, Boxers, and German Shepherd dogs had mean TPAs of 25.9°, 26.2°, 25.9°, and 28.2°, respectively (7). The Hueter-Volkmann Law suggests that bone growth is accelerated by reduced loading, and limited by increased compression (20), which could explain how a different posture of the hindlimbs could cause increased or decreased TPA by accelerating or limiting the growth potential of the tibial plateau. Anecdotally, German shepherds are known to show a more acute standing angle of the stifle than other breeds, which might be the cause of their higher TPA. Where there is a postural difference among breeds or individuals, it is worthwhile investigating the relationship between the standing angle of the stifle and TPA.

Determining TPA accurately not only provides meaningful information in clinical cases but is necessary in studies assessing CCLR risk. Various efforts were performed to determine TPA in dogs accurately. One study tried measuring TPA by collimating on the stifle and hock joints to outline land mark required for measurement of the TTA more precisely (8). That report explained that cranio-proximal dislocation of the limb relative to the beam center causes overestimation whereas caudo-distal dislocation causes underestimation of TPA. In cases with severe degenerative joint disease, TPA measurement has been determined by using a line tangent to the medial tibial plateau (2). In short, practitioners should follow accurate limb positioning relative to the beam center and precise identification of the tibial plateau to determine the correct TPA.

The present study found no statistically significant differences between male and female, left and right limbs or among breeds in 32 small-breed dogs without CCLR. In addition, the TPA measured from the small-breed dogs showed no chasm compared to that measured from large-breed dogs, meaning that dynamic stabilization widely used in large-breed dogs can be also applied in small-breed dog. Because TPA can contribute to risk for CCLR and influence surgical plans, this result provides important information for further investigation of the pathogenesis of and surgical techniques for CCLR in small-breed dog.

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정상 소형 견에서 경골 고평부각의 측정

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요 약 : 본 연구에서는 소형견종에서 전 십자인대 단열과 동적 안정화를 이용한 치료법에서 사용되는 경골 고평부각(the tibial plateau angle)을 측정하였다. 경골 고평부각을 측정하기 위해 성장이 끝난 소형견종 32마리의 사체의 양측 뒷다리를 이용하였다. 성별, 각 양측다리(왼쪽, 오른쪽), 그리고 견종별로 구분하여 경골 고평부각을 평가하였다. 전체 소형견종의 평균 경골 고평부각은 26.13°± 2.33°이었다. 왼쪽 다리와 오른쪽 다리는 각각 26.00°± 2.23°와 26.26 ± 2.45로 측정되었고 성별에 따른 측정에서는 암컷은 26°.22 ± 2.80°로 수컷은 26.01°± 1.57°로 평가 되었다. 견종별로는 말티즈는 26.06°± 2.96°로 푸들은 25.21°± 1.38°로 시추는 26.65°± 2.96°로 요크셔 테리어는 26.27°± 1.61°로 측정되었다. 모든 측정치의 확률적 유의적 차이는 없었다. 본 연구에서 측정된 소형견의 경골 고평부각은 전 십자인대의 병적 상태 평가와 수술 과정에서 중요한 정보를 제공할 수 있다고 사료된다.

주요어 : 경골 고평부각, 소형견종, 전 십자인대