Comparative anatomy of the proximal tibia in healthy Labrador Retrievers and Yorkshire Terriers

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Keywords
Tibia, stifle, cranial cruciate ligament, Yorkshire Terrier, Labrador Retriever

Summary
Objectives: 1) To provide specific quantitative data of tibial conformation in Labrador Retrievers and Yorkshire Terriers; 2) To compare the tibial conformation of these two breeds; and 3) To compare these data with previously reported data.

Methods: Mediolateral radiographs of the stifle were obtained from 30 consecutive Labrador Retrievers and 30 consecutive Yorkshire Terriers with an angle of extension of 135°. The tibial plateau angle (TPA), the angle between the tibial plateau and the patellar tendon (PTA), the Z angle, the distal tibial axis/proximal tibial axis angle (DPA), and the relative tibial tuberosity width (rTTW) were measured and compared among the two breeds.

Results: The breed had a significant effect on all of the measured variables (p <0.01): Labrador Retrievers had a lower TPA (25 ± 3° compared to 30 ± 4°), a lower Z angle (58.8 ± 3.2° compared to 69.2 ± 4.5°), a lower DPA (4.5 ± 2.3° compared to 10.8 ± 4.3°), and a lower rTTW (0.74 ± 0.1 compared to 0.86 ± 0.1) than Yorkshire Terriers. The PTA was greater in Labrador Retrievers compared to Yorkshire Terriers (106.9 ± 3.9° compared to 103.7 ± 6.5°). Four correlations were found to be significant: the DPA angle was correlated with the TPA, the Z angle, and the rTTW. The TPA was also correlated with the Z angle.

Clinical significance: The variation in tibial conformation between breeds should be taken into account when studying the role of each measured parameter in the pathology of cruciate disease. When the relevance of each of the aforementioned measured parameters is better understood, it may help determine the most appropriate surgical treatment.

Introduction
Cranial cruciate ligament insufficiency is one of the most common causes of lameness in dogs (1). Partial or complete cranial cruciate ligament rupture causes stifle joint instability and triggers a cascade of secondary pathological changes including progressive osteoarthritis and subsequent meniscal injury (2, 3). Numerous surgical techniques have been described to manage cranial cruciate ligament insufficiency, each having potential or proven advantages and disadvantages (4). Over the past 25 years, the focus has shifted to the concept of creating dynamic stability in the cranial cruciate ligament-deficient stifle by altering the bone geometry. The superiority of dynamic stabilisations over extracapsular techniques is not proven, but many surgeons prefer these techniques for large breed and athletic dogs. However, tibial osteotomies are increasingly performed on small breed dogs and tibial tuberosity advancement (TTA) has been reported in cats (5, 6). While tibial morphometry of large-breed dogs has been extensively studied, very few publications have described the tibia of small-breed dogs and none have focused on the tibia of Yorkshire Terriers; this is a fairly common breed in which cranial cruciate ligament rupture is frequently diagnosed in our institution (5, 7-11).

The impetus for this study was the observation that the shape of the proximal portion of the tibia varies in dogs affected by cranial cruciate ligament rupture and particularly between different breeds. In addition to tibial plateau angle (TPA) and patellar tendon angle (PTA), three other measurements have been previously described in different publications: the relative tibial tuberosity width (rTTW), the distal tibial axis/proximal tibial axis angle (DPA), and the angle between the mechanical axis of the tibia and a line joining the tibial tuberosity to the intercondylar eminence (the Z angle) (7, 12, 13). The purposes of our study were: 1) to provide specific quantitative data of tibial conformation in Labrador Retrievers and Yorkshire Terriers, 2) to compare the tibial conformation of these two breeds, and 3) to compare these data with the previously reported data (7, 12, 14). Our hypothesis was that existing measured parameters of tibial conformation would reveal differences between breeds, and that the differences...
would be in agreement with the greater prevalence of cranial cruciate ligament disease in Labrador Retrievers than in Yorkshire Terriers in our practice.

Materials and methods

Mediolateral and craniocaudal radiographs were obtained from 30 consecutive Labrador Retrievers and 30 consecutive Yorkshire Terriers admitted between February and June 2008 at our institution (Centre Hospitalier Vétérinaire Atlantia, Nantes, France) for reasons unrelated to the stifles. Dogs were included in this study if they had neither history of cranial cruciate ligament rupture nor the presence of cranial drawer on orthopaedic examination. Radiographs were excluded if there was evidence of disease in the affected stifle, if the patient was skeletally immature, or if the radiographic beam was not centred over the stifle sufficiently to allow for observation of the intercondylar eminence proximal to the tibial plateau. The age, sex, breed and weight of the dogs were obtained.

Radiographic methods

All radiographs were made on sedated dogs or after euthanasia. A computed radiography system was used. Radiographs of both stifles were obtained and collimated to include the femur from the greater trochanter and the tibia to the talus. The angle of extension was assessed using the ‘eminence landmarks’ as the landmarks of this method are readily identifiable and commonly used in our practice (15). All radiographs that did not match an angle of extension of 135 ± 5° were repeated until a correct angle was obtained. The beam was centred over the stifle in order to visualise the intercondylar eminence proximal to the tibial plateau and to obtain superimposition of the femoral condyles. All data were measured with a digital radiographic viewing program.

The TPA and the PTA were evaluated using a method used in previous reports on proximal tibial conformation (7, 12, 13). Briefly, the mechanical axis was a line extending from the centre of the intercondylar eminence to the centre of the talus. The cranial tibial plateau landmark was identified as the proximal aspect of the cranial extent of the medial tibial plateau. A line was drawn connecting the cranial and caudal extents of the tibial plateau to identify the tibial plateau slope. The TPA was measured as the angle between a line perpendicular to the tibial long axis and the tibial plateau slope. The PTA was measured as the angle between the tibial plateau slope and a line drawn from the cranial most aspect of the patella to the cranial most aspect of the tibial tuberosity.

The angle between the mechanical axis of the tibia and a line joining the tibial tuberosity to the intercondylar eminences...
was defined as the Z angle (Figure 1) (13). The diaphyseal tibial axis/proximal tibial axis angle (DPA) (Figure 2) and the relative tibial tuberosity width (rTTW) (Figure 3) were measured as has previously been described (7, 12).

**Statistical analysis**

The statistical analysis was performed using statistical software. A multivariate general linear model was used to evaluate the effect of the independent variables (side and breed) and their interactions on the dependent variables TPA, PTA, rTTW, DPA angle, and the Z angle. Pearson correlations between the continuous dependent variables were evaluated. A p-value of less than 0.05 was considered significant.

**Results**

The 30 Labrador Retrievers comprised 19 males (17 entire, 2 neutered) and 11 females (7 entire, 4 spayed). Mean age was 6.8 years (range: 1 to 13 years) and mean weight was 32 kg (range: 24 to 42 kg). The 30 Yorkshire Terriers comprised 12 males (all entire) and 18 females (14 entire, 4 spayed). Mean age was 7.6 years (range: 1.5 to 16 years) and mean weight was 3.9 kg (range: 1.4 to 7.5 kg). All data measured are summarized in Table 1. The breed had a significant effect on all of the measured variables.

No effect of the side (p >0.68) nor on the interaction breed with side (p >0.55) was found. Four correlations were found to be significant: the DPA angle was correlated with the TPA (Pearson correlation of 0.67), the Z angle (Pearson correlation of 0.76), and the rTTW (Pearson correlation of 0.54). The TPA was also correlated with the Z angle (Pearson correlation of 0.67).

Eighty percent of Labrador Retrievers and 60% of Yorkshire Terriers had a difference <2° in measured TPA between the left and right limbs.

![Figure 3 Relative tibial tuberosity width (rTTW). The following points were identified on the medio-lateral radiographs: A = most cranial point of the tibial plateau; B = most caudal point of the tibial plateau, represented by the midpoint between the medial and lateral tibial condyles; C = most proximal point of the margo cranialis tibiae; D = cross point of a circle with the centre B and the radius AB, and the line BC. The rTTW is defined by the ratio CD/DB.](image)

**Discussion**

In this study, we found a significant difference between the two breeds of dogs for each of the five tibial parameters. Although the relevance of TPA has been previously investigated, the relevance of the other four measured parameters is unknown. In the future, more consideration to these measured parameters may help us to determine the most appropriate surgical technique on a case-by-case basis.

The etiology of cranial cruciate ligament rupture is unknown. A great deal of research has focused on TPA or PTA as potential factors contributing to cranial cruciate ligament rupture, but to date most of the studies on the topic are inconclusive (10, 16-18). Moreover, the choice of a procedure (TTA, tibial plateau levelling osteotomy [TPLO], triple tibial osteotomy [TTO], extracapsular) to treat cranial cruciate ligament rupture is mainly based on surgeon experience, although it is clear that differences in tibial conformation exist which could help select the appropriate surgery to perform in the future. Furthermore, many studies comparing dogs with and without cranial cruciate ligament rupture based on tibial conformation do not consider breed differences, which introduces a bias in the conclusions (7, 12-14, 19, 20). Indeed, very few studies focused on breed specificity, and the inclusion of dogs with different tibial conformations could induce type II errors. The association between proximal tibial conformation and cranial cruciate ligament rupture is not recent (21). However, this relationship is complex and little has been done to correlate these anomalies with the most appropriate surgical technique (5, 21-23).

We studied tibial conformation in Labrador Retrievers because it is the most common breed treated for cranial cruciate ligament rupture (24-26). Although the incidence of cranial cruciate ligament rupture in Yorkshire Terriers may be less than other small-breed dogs, it is one of the most common small-breed dogs we encounter with cranial cruciate ligament rupture in our practice. Besides, the difference in proximal tibial conformation between Labrador Retrievers and Yorkshire Terriers is obvious and this allows an easier assessment of the relevance of each parameter studied.

The values of the TPA in Labrador Retrievers are similar to those reported in previous studies (8, 18, 19, 27). In agreement

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**Table 1** Values of the TPA, PTA, Z angle, DPA and rTTW in Labrador Retrievers and Yorkshire Terriers. Data are expressed as mean ± standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>TPA (°)</th>
<th>PTA (°)</th>
<th>Z angle (°)</th>
<th>DPA (°)</th>
<th>rTTW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labrador Retrievers</td>
<td>25 ± 3</td>
<td>106.9 ± 3.9</td>
<td>58.8 ± 3.2</td>
<td>4.5 ± 2.3</td>
<td>0.74 ± 0.1</td>
</tr>
<tr>
<td>Yorkshire Terriers</td>
<td>30 ± 4</td>
<td>103.7 ± 6.5</td>
<td>69.2 ± 4.5</td>
<td>10.8 ± 4.3</td>
<td>0.86 ± 0.1</td>
</tr>
</tbody>
</table>

TPA = tibial plateau angle, PTA = patellar tendon angle, Z angle = angle between the mechanical axis of the tibia and a line joining the tibial tuberosity to the intercondylar eminence, DPA = distal tibial axis/proximal tibial axis angle, rTTW = relative tibial tuberosity width.
with the study of Ritter et al., TPA was considered symmetrical (28). However, Ritter et al. reported that only 10% of mongrel dogs in their study had an absolute difference between left and right of greater than two degrees. Schwandt et al. stated that the PTA was greater in stifles with partial cranial cruciate ligament rupture than in intact stifles (30). However, the PTA results in our two groups of healthy dogs were greater than previously reported for preoperative PTA in dogs with cruciate disease (29, 30). However, in this later study, the population of dogs consisted of 23 different breeds making the comparison with specific breeds difficult. The interobserver variations of the measurement is another limitation to the direct comparison of our respective studies. We speculate that Yorkshire Terriers which have greater TPA associated with greater rTTW would be more amenable to TPLO, whereas Labrador Retrievers with greater PTA and lower rTTW would be more amenable to TTA. Indeed, while elimination of cranial tibial thrust could be achieved with a TTA in Yorkshire Terriers, this would require significant advancement of an already very prominent tibial tuberosity. A tibial plateau levelling technique may therefore be more appropriate. And in those cases with a caudally angled proximal tibia, a cranial closing wedge osteotomy would allow to correct this anomaly.

However, if we consider the Z angle, the significantly more proximal tibial tuberosity in Yorkshire Terriers means that they are better candidates for TTA than are Labrador Retrievers. This illustrates the complex role of tibial conformation in electing the most appropriate technique and our need to better define the relevant parameters. The Z angle was previously used to define the orientation of the tuberosity relative to the stifle joint and to allow direct comparison between dogs of different sizes in a study about TTO (13). The results of that study suggested that the position of the tibial tuberosity was largely responsible for the modification of the calculated wedge size required in specific cases (13). When extrapolated to other techniques, the Z angle is a marker of tibial tuberosity proximodistal position. In TPLO it is recommended to rotate the tibial plateau segment up to, but not below, the point of patellar tendon insertion on the tibial tuberosity to maintain caudal buttress support (23). Consequently, the lower the tibial tuberosity, the more the tibial plateau can be rotated. On the other hand, in TTA, with the current recommendation of placing the cage as proximal as possible, advancement is optimal with a proximal tibial tuberosity conformation. The Z angle characterises the variation of the point of insertion of the patellar tendon between dogs depending on the anatomy of the tibial crest and may help us to decide between TPLO or TTA on a case by case basis.

In contrast with an older study, but in accordance with a more recent one, a moderate association between DPA and TPA was identified in the current study (7, 14). Osmond et al. reported that a DPA angle greater than 11.23° identifies a distinct population of dogs with a proximal tibial morphology that cannot be identified using the TPA alone (14). Our value of 10.9° in Yorkshire Terriers is very close to this threshold and the significant difference with the Labrador Retrievers confirms the difference in morphology between these two breeds. As suggested by several previous studies, DPA measurement preoperatively may facilitate the optimization of the surgical management of dogs with cranial cruciate ligament rupture (7, 14). The clinical significance of the ability to identify dogs with a proximal shaft deformity is not known. However, dogs with such a tibial shape, may be better candidates for tibial wedge osteotomies than TPLO or TTA.

The last parameter we measured was the rTTW (12). The difference between Yorkshire Terriers and Labrador Retrievers was significant. This confirms our subjective assessment that the tibial tuberosity is more cranial in Yorkshire Terriers. This is probably the main reason that the PTA was less in the Yorkshire Terriers than in the Labrador Retrievers; particularly as the Z angle was greater in the Yorkshire Terriers which would have the effect of increasing the PTA. The decreased rTTW in Labrador Retrievers compared to Yorkshire Terriers may explain the increased incidence of cranial cruciate ligament rupture in the former breed in our practice. However, this is a simplistic interpretation and other theories must be taken into account. As an example, Colborne et al. described the breed-specific pattern of joint kinetics (31). Interestingly our value of rTTW in healthy Labrador Retrievers is comparable to the rTTW of dogs with cranial cruciate ligament rupture in the study of Inauen et al. (12). The different finding could be explained by the fact that in the study of Inauen et al., radiographs were from different breeds of dogs and not only from Labrador Retrievers. When studying tibial conformation, studies should focus on specific breeds to avoid bias due to breed differences. The results of our study contrast with the conclusion of Inauen et al. Indeed they suggested that only dogs with an rTTW greater than 0.9 should be used for breeding. The average rTTW for both our Labrador Retrievers and Yorkshire Terriers was less than 0.9 although there were not any radiographic signs of osteoarthritis.

Our study had several limitations. We did not follow-up on the dogs beyond the time of the radiographs. Consequently, although none of the dogs had signs of osteoarthritis at the time of the study, we did not know which proportion of these dogs ultimately did develop cruciate disease. The measurements were made by a single observer and as such we cannot evaluate interobserver variation. Inter- and intra-observer variations have been studied many times for TPA but to date no study focused on PTA, rTTW, Z angle, or DPA variations (32, 33). It is a possibility that these variations could change the significance of our results. We focused on only two breeds of very different sizes. The aim of this study was to use previously described measured parameters of tibial conformation to compare breed variation. More studies are needed to describe and compare proximal tibial conformation in different breeds. We studied two breeds at risk for cruciate disease, which may render some of our points hard to confirm. However our objective was not to study the role of each marker in the pathology of cranial cruciate ligament, but to demonstrate that they are able to show a significant difference between two breeds with obvious different tibial conformation.

Our discussion, in which we state that cases with lower Z angles and greater rTTW are more amenable to TPLO whereas cases with greater Z angles and greater TPA more amenable to TTA, is based on logic follow-
ing the biomechanical principles and the technical recommendations of each tech-
nique, but remains speculative as long as the re-
nance of each of the marker has not been studied more extensively. As long as ti-
bial conformation is not accurately de-
scribed and assessed, dogs with different proximal tibial conformations should not be sampled together to study correlation be-
tween conformation and cranial cruciate ligament rupture, a major bias will persist and weaken the conclusions drawn. Finally, we used an extension angle of 135° despite differences in standing angles between indi-
viduals and breeds. The use of this angle has already been questioned (13). Using a spe-
cific extension angle for each breed may modify the conclusions on PTA. Besides, as already suggested, it is possible that the variable tibial morphology is related to dif-
f erent standing angles between dogs (13). If this is true, measured parameters of prox-
imal tibial conformation must be normal-
ized in relation with the physiological standing angle of each breed in order to al-
low accurate comparison.

To conclude, the morphology of the proximal tibia was distinctly different be-
tween the two breeds we studied. Using only TPA or PTA to describe proximal tibial conformation may be an oversimplification. A better understanding of the complex rela-
tionship between the shape of the tibia and the pathogenesis of cranial cruciate ligament rupture would help us to determine the best surgical technique for each patient from the existing techniques. To achieve this goal, further measured parameters may be required in addition to PTA and TPA.

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