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Research Article

Intercondylar width index of the tibia in the dogs: A morphological study

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ABSTRACT

Morphological characteristics of the proximal tibia affect the orthopedic balance of the knee region; such as the width of the condyles, tibial plateau angle, position of the patella; as well as the intercondylar width. The objectives of this study are: (1) to calculate the intercondylar width index of the tibia in dogs, (2) to determine if there are gender-related differences in these indexes, and (3) to compare them among the six breeds of dog. For this study, the tibial bones of 84 dogs from 26 different breeds were used. The radiographs of the tibias were taken, and the tibial plateau and intercondylar widths were measured. The intercondylar width index was calculated by using the following formula: (intercondylar width/tibial plateau width) *100. The mean intercondylar width index of the dogs was 19.2±2.72. The index values of male and female dogs were 19.1±3.32 and 19.3±2.02, respectively. The significant differences in the index were not determined between male and female dogs, but among dogs' breeds. The dogs in the high-risk breeds had significantly smaller eminence width index values than the dogs in the low-risk breeds related to the non-traumatic cranial cruciate ligament rupture. The results of this study suggested performing further clinical studies to evaluate whether the difference in intercondylar width index among breeds in dogs is associated with cranial cruciate ligament deficiency.

INTRODUCTION

The femorotibial joint forms between the condyles of the femur and the tibia. The bone shapes of the femoral and tibial articular surfaces allow movement of 180°, but this large capacity of motion is restricted by soft tissues such as ligaments, joints, and muscles (Dye, 1987; Gupte, 2007). The femorotibial joint acts seamlessly as long as the congruency of all components of the joint. One of these components is the cranial cruciate ligament (CrCL) that arises from the caudomedial part of the lateral condyle of the femur and attaches to the cranial intercondyloid area of the tibia (Dyce, 2002; De Rooster, 2006). This ligament is an important joint stabilizer, primarily limiting anterior translation and medial rotation of the tibia relative to the femur as well as limiting hyperextension of the stifle joint (Arnoczky, 1977; Slocum, 1983; Lopez, 2003; Tashman, 2004). The cranial cruciate ligament rupture is one of the most common problems in dogs. Furthermore, it has increased over time, all relevant information as the underlying cause of the cranial cruciate ligament rupture is of utmost importance for breeding strategies, for identifying dogs that are below risk as well as for developing treatment strategies. The non-traumatic CrCL rupture causes hind limb lameness in dogs and its pathogenesis is believed to be multifactorial. Some anatomical characteristics are considered to play a role in this rupture despite lacking a consensus. These anatomic characteristics are the trochlear notch size of the femur (Lewis, 2008; Griffon 2010; Kara, 2011), the distal femoral geometry of the femur (Kara, 2018), the tibial plateau slope (Macias, 2002; Osmond, 2006; Talaat, 2006; Mostafa, 2009; Sabanci, 2014) alignment of the proximal shaft of the tibia (Osmond, 2006; Mostafa, 2009), and the tibial tuberosity size (Guerrer, 2007; Boudrieau, 2009; Inauen 2009; Renwick, 2009; Griffon, 2010). These studies provide important data in assessing the orthopaedical potential risk factors as well as the treatment strategies for the CrCL rupture in dogs. In addition to above mentioned characteristics, the CrCL size may be important because a smaller material in size has less strength than a larger one, assuming that their material properties are similar. Based on this basic biomechanical principle and the assumption that the diameter of the anterior cruciate ligament (corresponding CrCL in dogs) is approximately the same as the tibial intercondylar width, the eminence width index from the tibia was developed in humans (Uhorchak, 2003). This index is calculated by dividing intercondylar width into tibial plateau width and the difference is determined between the groups with and without the nontraumatic CrCL injury in both men and women (Uhorchak, 2003). It is thought that the term intercondylar is more suitable than the term eminence, therefore in the manuscript, the intercondylar width index (ICWI) was used instead of the eminence width index in humans. To the best of our knowledge, the intercondylar width index has not been documented previously in dogs. We

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hypothesized that this index, like human beings, would be an additional variable for the evaluation of CrCL deficiency in dogs. With these in mind, the objectives of the study are to calculate the ICWI in dogs, to determine if there are gender-related differences in ICWI, to compare the ICWI among the six breeds of dogs.

MATERIAL and METHODS

Materials

A total number of 168 tibias were procured from 84 mature dogs, including 41 males and 43 females. The bone materials were obtained from the Veterinary Anatomy Department Collections of Adnan Menderes University and Istanbul University in Turkey. Two criteria, the lack of gross pathological changes, and the fusion of proximal tibial growth plates; were used for inclusion in the study. Twenty-six different breeds were used in this study as follows; the Anatolian shepherd (n=11), German shepherd (n=11), mixed breed (n=11), Boxer (n=6), Rottweiler (n=6), white Terrier (n=6), Doberman (n=4), Pointer (n=4), Cocker (n=3), Collie (n=2), Pekingese (n=2), Setter (n=2), Siberian Husky (n=2), St. Bernard (n=2), and one sample for the following dog breeds: American Staffordshire Terrier, Bulldog, Caucasian shepherd, Chow Chow, Clumber, Dachshund, Great Dane, Golden Retriever, Malamute, Mastiff, Pitbull, and Shar-Pei.

Measurements

The craniocaudal radiographs of the tibias were taken by positioning the caudal surface of the tibias on the film cassette as the caudal ends of both condyles touched the cassette and centering the beam on the middle of two intercondylar tubercles (Comed Medical System, EVA-HF750, Korea). For the measurements of the length and midshaft width of tibias, the radiographic images were transferred to a computer in JPEG format. The JPEG images were transferred to 'ImageJ software' (Wisconsin - USA), with fixed scale and resolution (3456x2304 pixels) for calibrating and measuring. Tibial plateau and intercondylar widths were measured by using a modified method, described in humans (Uhorchak, 2003). A line was drawn between the most proximal parts of the medial and lateral condyles of the tibia, and the width of this line was chosen as the tibial plateau width. Having marked the peaks of the intercondylar tubercles, two lines were drawn perpendicularly from these points to the line of tibial plateau width. The distance between the later lines was designated as the intercondylar width (Figure 1).

Statistical Analysis

After repeating the measurements three times by the same investigator at an interval of 15 days, the three results were compared by repeated ANOVA. Once it was determined that there was no statistical significance among the measurements, the average of the triplicate measures was taken for the statistical analysis. Mean values for the left and right sides were compared by using paired t-test to assess the differences between the right and left sides. After determining that there was no significance between the two sides, the mean of each measurement was then used to calculate the intercondylar width index for each dog. As a result, one value per dog from each variable was obtained for further analysis. The intercondylar width index (ICWI) was calculated, using the formula; (intercondylar width/tibial plateau width) * 100. Mann-Whitney U test was used to determine whether gender-related differences in the index exist or not. The tibial length was also used as a covariate in addition to gender by using ANCOVA. The ICWI was compared among the six breeds consisting of six or more dogs by the Kruskal-Wallis test. Mann-Whitney with Bonferroni correction test was used as post hoc if the differences were significant. Statistical analysis was performed using SPSS statistical package program (SPSS for Windows, version 19.0, California, USA). Summary statistics were reported as the mean, standard deviation (±SD), 95% confidence interval, and percent variation coefficient. The level of significance was set at p values <0.05 for all the analyses.

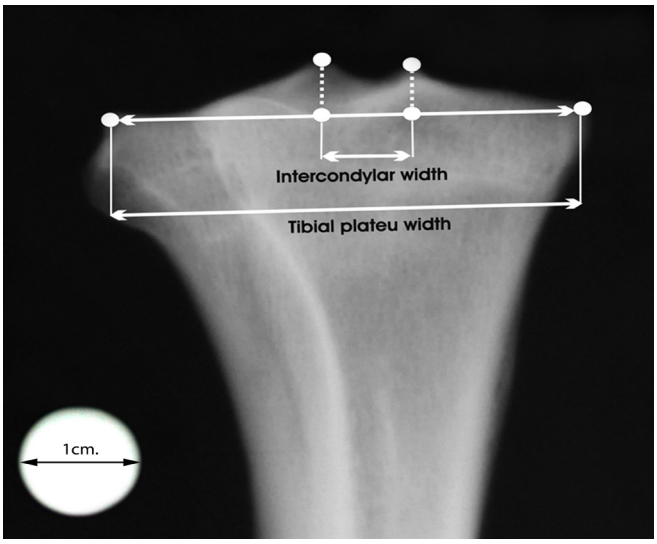

Figure 1. The tibial plateau and intercondylar widths measurements in craniocaudal radiograph of the proximal tibia.

RESULTS

Twenty-six different breeds were included in the study, the majority of the dogs being from the Anatolian shepherd, the German shepherd, and mixed breed. All samples were obtained from adult dogs and the proximal tibial growth plate was fused. The proportion of males and females was almost equal, 49% and 51%, respectively. There was no significant difference in tibial length (p= .186), mid-shaft width (p= .189), tibial plateau width (p= .878) and intercondylar width (p= .541) between the right and left sides. The mean tibial length and mid-shaft width were 197±47.2 mm and 14.5±2.91 mm, respectively. The tibial plateau width was 35.3±6.75 mm and the intercondylar width was 6.73±1.41 mm. The ICWI was calculated as 19.2±2.72 and the 95% confidence interval was from 18.6 to 19.8 for all dogs. The mean ICWI of male and female dogs were 19.1±3.32 and 19.3±2.02, respectively (Figure 2). The difference in ICWI between male and female dogs was not significant (p= .534). When tibial length was

used as a covariate, the gender-based differences were also not determined (p= .727).

Based on the comparison of the ICWI among the six breeds, the lowest ICWI was seen in Rottweiler. There were significant differences between the Rottweiler and Anatolian shepherd as well as between the Rottweiler and Terrier (Table 1). Dot plots for the ICWI in six dog breeds and 95% confidence interval for 84 dogs were presented in figure 3. The ICWI values were below the lower bound of the 95% confidence interval in all Rottweiler and Boxer, except one Boxer

The degree of variation for tibial plateau width, intercondylar width, and ICWI was calculated as 19.1%, 21.0%, and 14.1%, respectively. Among these, the intercondylar width showed the highest variation while the ICWI showed the lowest variation.

Table 1. The intercondylar width index of tibia in six breeds of the dogs.

	Rottweiler (n=6)	Boxer (n=6)	Terrier (n=6)	German shepherd (n=11)	Mixed breed (n=11)	Anatolian shepherd (n=11)	p
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Intercondylar width index	15.8 ± 0.72^{a}	17.2 ± 2.46^{ab}	19.8 ± 4.96^{b}	17.7 ± 2.01^{ab}	19.2 ± 2.01^{ab}	19.9 ± 1.76^{b}	0.009

Different superscript letters in the same line are significantly different ($p<0.05$).

DISCUSSION

The pathogenesis of nontraumatic CrCL rupture is believed to be multifactorial and its prevalence among dogs has increased over time (Witsberger, 2008). Skeletal factors are suggested to be evaluated first in the assessment of the CrCL rupture (Tillman, 2002) because any conformational differences between sexes or individuals are considered as the underlying cause for the susceptibility to stifle instability (Hashemi, 2011). Therefore, conformational characteristics remain an active area of research (Griffin, 2006). However, the great variation in size among breeds and individuals within the same breed causes difficulty in practical usage of the absolute morphometric values in dogs. In this regard, the indices are important for the documentation and comparison of these values. Percent variation coefficients obtained in the present study confirm these observations as the ICWI showed relatively less variation than the tibial plateau and the intercondylar widths as 14.1%, 19.1%, and 21.0%, respectively.

Women have a greater chance of developing the anterior cruciate ligament rupture than men (Uhorchak, 2003; Chandrashekar, 2005; 2006; Dienst, 2007; Hashemi, 2011). Furthermore, there are reports demonstrating that there exists a relationship between the nontraumatic rupture and the weight and height in humans (Bennet, 1988; Charlton, 2002; Wolters, 2011). However, there is no consensus on the effect of gender to the incidence of the CrCL rupture in dogs. Male (Grierson, 2011), female (Harasen, 1995; Zeltzman, 2005; Wilke, 2006), or neutered dogs (Whitehair, 1993; Duval, 1999; Witsberger, 2008) are reported to be more susceptible to developing the CrCL rupture. In the present study, weight records of dogs were not available, but the ICWI did not differ significantly between male and female dogs. Also, a gender-based difference was not determined when the tibial length was used as a covariate. It would appear from these observations that the tibial length and gender differences may not have any effect on ICWI in dogs.

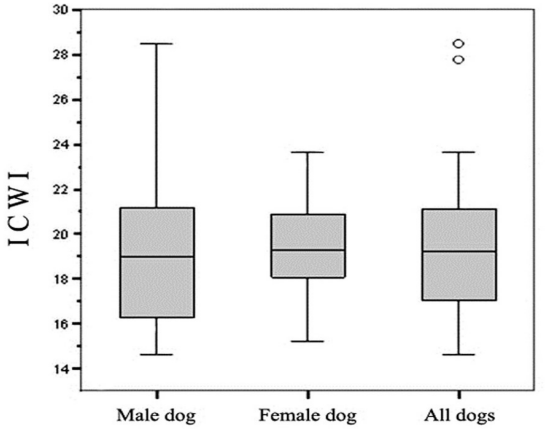

Figure 2. Box plots of the index values in male, female, and all dogs. The median and mean values of the index are the same, and "o" indicates the extreme values. (ICWI: Intercondylar Width Index)

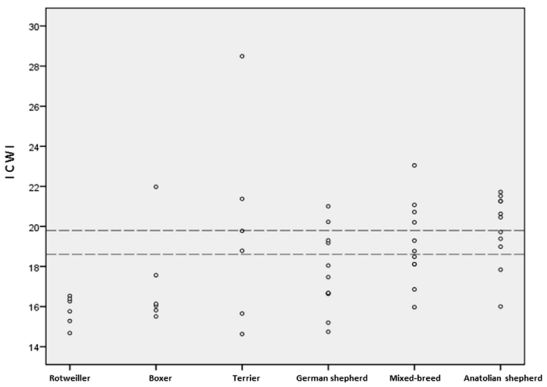

Figure 3. Dot plots of the index values in six breeds of dogs. The interval between two broken lines indicates the 95% confidence interval for 84 dogs. (ICWI: Intercondylar Width Index)

The ICWI developed in humans is based on the assumption that the diameter of the CrCL is approximately the same as

tibial intercondylar width (Uhorchak, 2003). Although there has not been a study that compares the CrCl diameter and the intercondylar width in dogs, the significant differences in ICWI were determined between the Rottweilers and Anatolian shepherd as well as between the Rottweilers and Terriers. In this study design, it was impossible to find out the underlying cause of this difference.

It should be noted that the present study had limitations. We had no records related to the soft tissue injuries of the stifle joint, although only tibias without gross pathological changes of mature dogs were included in the study. However, it is not unlikely that the soft tissue injuries lead to any changes in the intercondylar width lacking gross pathological changes of the tibial plateau.

CONCLUSION

In conclusion, in light of the fact that the prevalence of the CrCL rupture has increased over time in dogs (Witsberger, 2008), all relevant information as for the underlying cause of the CrCL rupture is of utmost importance for breeding strategies, for identifying dogs that are under risk as well as for developing treatment strategies in cases of the CrCL rupture. This study introduces, to the best of our knowledge, the ICWI for the first time in dogs. The lowest ICWI was determined in the Rottweilers and Boxers, but retrospective studies are needed using an adequate number of dogs in each breed with and without risk for nontraumatic CrCL rupture to extend and clarify the results of the present study.

DECLARATIONS

Ethics Approval

Not applicable

Conflict of Interest

The author declares that he has no conflict of interest.

Consent for Publication

Not applicable

Author contribution

Idea, concept, and design: SSS

Data collection and analysis: SSS

Drafting of the manuscript: SSS

Critical review: SSS

Data Availability

The data used to support the findings of the study are included within the article.

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