The intercondylar fossa indices of male and female dog femora

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Summary
The intercondylar fossa (ICF) indices can be used to evaluate fossa geometry, which may in turn affect the function, pathology and intracapsular surgical repair of the cranial cruciate ligament. The measurements of digital images of the distal femur of 44 dogs were used to calculate the fossa width, shape, height and area indices. The mean values of fossa width index were found to be 0.19, 0.28 and 0.37 at the cranial, central, and caudal levels of the fossa, respectively. The mean values for fossa shape, height and area indices were found to be 0.71, 0.33, and 0.16, respectively. The differences in ICF indices between male and female dog were not significant. Therefore, it is suggested that gender differences related to ICF geometry may not have any effect on incidence of cranial cruciate ligament injury in dogs.

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Introduction

The intercondylar fossa (ICF), which is located between the femoral condyles, is also known as the intercondylar notch; the cranial cruciate ligament (CrCL) is located within this fossa (1). Changes in the shape or size of the ICF may affect the function, pathology and intracapsular surgical repair of the CrCL (2). Because there is a significant correlation between the size of the ICF and the cross-sectional area of the midsubstance CrCL, then the risk of CrCL injury or presence of ICF stenosis can be associated with ICF size and shape (3–6). LaPrade et al. indicated that a careful assessment of the size of the ICF should be undertaken prior to performing a widening intercondylar notchplasty. Therefore, various techniques for evaluation of ICF geometry have been used in humans and dogs (2, 4–12). Although the measurements of dimensions alone and some shape analysis methods can be used for evaluating fossa geometry, ICF indices are more valuable because they are independent of distal femoral size (2, 4, 5, 7–9, 12). For this purpose, the fossa width index (FWI) is one of the most preferred indices (2, 4, 5, 8, 13). The fossa shape index (FSI) is another important index of ICF which may be used to evaluate fossa shape (8, 9, 11). The fossa height index (FHI) and the fossa area index (FAI) are not commonly used indices (2, 8, 9, 11). However, the existing range of the ICF indices that are used in the dog are inadequate to indicate ICF stenosis. In a previous study, the FWI in Greyhounds was calculated from radiographs and by calliper measurements directly from bones (10). The FWI and FHI have been calculated for mixed-breed dogs and Greyhounds via the same methods (2). The FWI, FSI and FHI indices of the Labrador, Golden Retriever and Greyhound were also calculated from direct bone measurements via calliper (11). Computed tomography images of dog ICF geometry was also evaluated at different levels within the intercondylar fossa (5, 12, 13). To the best of our knowledge, there are not currently any calculated values for FAI in the dog.

Anterior cruciate ligament injury has been observed more frequently in women than men. The ICF geometry is one of the intrinsic factors suspected to predispose individuals to anterior cruciate ligament injury, and it may be different in men and women (8, 9). However there is no consistency in the variation of the ICF indices with regard to gender. Tilman et al. indicated that only the FSI value is greater for men than women. On the other hand Murshed et al. indicated there was not any gender difference in FSI. Some studies of dogs found a higher incidence of CrCL rupture in females, as is seen in humans (14–16). However a gender difference was not observed in young, large breed dogs suffering from CrCL rupture (17). The reports on ICF geometry in dogs were focused to examine body weight, breed characteristics, and the evaluation techniques of fossa morphology (2, 5, 10–13).

We proposed that a study comparing ICF geometry between male and female dogs may supply additional knowledge because one aetiological factor for CrCL rupture in dogs may be gender difference. Therefore, the aim of this study was to compare ICF geometry of male and female dogs.

Materials and methods

The material used for this study was obtained from Veterinary Anatomy Departments of Adnan Menderes and Istanbul Universities in Turkey. A total of 88 cleaned femora derived from 44 dogs (23 male, 21 female) were used. While the gender and

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Table 1 Description of measured and calculated parameters of the distal femur (adapted from Fitch et al. and Tillman et al. [2, 8]).

Morphometric parameter	Abbreviation used	Description
Cranial fossa width	FWcr	The fossa height was divided into three equal parts and the width of the fossa at the central of each third was measured.
Central fossa width	FWcn	
Caudal fossa width	FWca	
Fossa height	FH	The fossa height was measured from the most cranial point of the fossa to the most caudal point of the distal femur.
Condylar width	CW	The total condylar width was measured between the epicondyles at the widest point.
Condylar height	CH	The height of the distal femur was measured from the proximal extent of the trochlear ridge to the caudal articular surface of the condyles.
Fossa area	FA	The area of the intercondylar fossa was measured by tracing the outline of the fossa.
Condylar area	CA	The area of the articular surface of the distal end of the femur was measured by tracing the outline of the condyles.
Cranial fossa width index	FWIcr	Cranial fossa width (FWcr) ÷ condylar width (CW)
Central fossa width index	FWIcn	Central fossa width (FWcn) ÷ condylar width (CW)
Caudal fossa width index	FWIca	Caudal fossa width (FWca) ÷ condylar width (CW)
Fossa shape index	FSI	Central fossa width (FWcn) ÷ fossa height (FH)
Fossa height index	FHI	Fossa height (FH) ÷ condylar height(CH)
Fossa area index	FAI	Fossa area (FA) ÷ condylar area (CA)

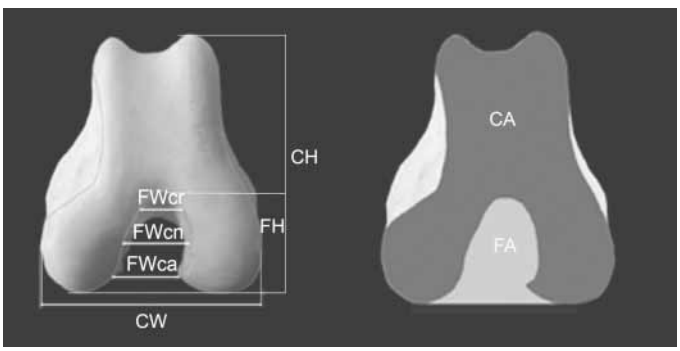


Fig. 1 Measurements of the canine distal femur (adapted from Fitch et al. and Tillman et al. [2, 8]). FWcr = Cranial fossa width; FWcn = Central fossa width; FWca = Caudal fossa width; FH = Fossa height; CW = Condylar width; CH = Condylar height; FA = Fossa area; CA = Condylar area.

breed records of the all the dogs were known, any other information was lacking. The breeds of dogs included mixed breed (n = 10), Anatolian Shepherd Dog (n = 9), Boxer (n = 5), Doberman (n = 4), Terrier (n = 4), German Shepherd (n = 4), Saint Bernard (n = 3), Rottweiler (n = 3), and Siberian Husky (n = 2). Approximately 77% of the dogs were purebred, and 91% were medium and large sized dogs. The bones of skeletally immature dogs, of unknown sex, or with gross pathological changes were not used.

The general morphometric parameters of femoral length (between the proximal end of the great trochanter and the distal edges of the condyles), and the cranio-caudal and medio-lateral diameters of the mid-femur were measured with digital callipers, while the femoral circumference of mid-femur was measured with a tape-measure.

For the morphometric measurements, standard digital images (3456 x 2304 pixels, 72 dpi) of the distal end of each femur were obtained with a digital camera[a]. Each femur was placed horizontally on the surface of a table, with special reference to the longitudinal axis of the bone being parallel to the table (8). The digital camera was fixed on a tripod and focused on the most cranial point of the ICF, and the photographs were taken using a calibration scale for each image. The digital images were transferred to a personal computer in JPEG format. Each image was analysed by the use of software program[b]. The morphometric measurements taken of the distal femur in each image after calibration were the following: the cranial (FWcr), central (FWcn), and caudal fossa width (FWca); the condylar width (CW); the fossa height (FH); the condylar height (CH); and the fossa (FA) and condylar area (CA). The indices of the distal femur were also calculated as the cranial fossa width index (FWIcr), central fossa width index (FWIcn), caudal fossa width index (FWIca), FSI, FHI, and FAI from the distal femur measurements (▶Table 1, Fig. 1).

[a] Canon EOS 350D: Canon, Tokyo, Japan
[b] AutoCAD: Autodesk, San Rafael, CA, USA

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The same investigator (FSK) completed all measurements in an attempt to eliminate any concerns about the possibility of interobserver variability. For assessment of repeatability of the measurements, five images were obtained from a randomly selected repositioned femur and each was measured independently (18). The coefficient of variation was then calculated for each measurement as standard deviation/mean.

The statistical analyses were performed using a statistical package program[c]. Right and left femora were compared using the paired t-test. The differences between the right and left femora were not significant, therefore the averaged data of right and left sides were used in the statistical analyses. The mean value, standard deviation, range (minimum to maximum values), and coefficient of variation were calculated for each parameter. Finally, the Student's t-test was used to compare data from male and female dogs. Statistical significance was accepted for values of $p < 0.05$.

Table 2 The ranges, mean values, standard deviations (SD) and coefficients of variance (CV) of measurements and indices of distal femur in the dogs (n = 44).

	Parameter*	Range	Mean ± SD	CV
Measurements (mm)	FWcr	3.20 - 9.40	6.23 ± 1.37	0.22
	FWcn	4.85 - 13.30	9.19 ± 1.76	0.19
	FWca	5.70 - 15.35	11.83 ± 2.21	0.19
	CW	16.25 - 43.00	32.48 ± 5.65	0.17
	FH	6.30 - 18.55	13.16 ± 2.61	0.20
	CH	17.80 - 53.80	39.85 ± 6.77	0.17
	FA	3.20 - 22.25	12.62 ± 4.34	0.34
	CA	17.40 - 137.80	81.44 ± 25.81	0.32
Indices	FWIcr	0.15 - 0.25	0.19 ± 0.02	0.12
	FWIcn	0.22 - 0.34	0.28 ± 0.03	0.09
	FWIca	0.30 - 0.45	0.37 ± 0.04	0.11
	FSI	0.53 - 0.88	0.71 ± 0.09	0.13
	FHI	0.28 - 0.38	0.33 ± 0.02	0.08
	FAI	0.12 - 0.20	0.16 ± 0.02	0.12

Key: *The listed parameters are defined in Table 1.

Results

For the repeatability study, the values of coefficients of variation ranged from 0.004 for CH to 0.026 for FA measurements. It was concluded that this method of measurement was sufficiently accurate for this study.

The femoral length, circumference, and cranio-caudal and medio-lateral diameters were measured as 19.93 ± 3.76 cm, 56.10 ± 8.40 mm, 15.74 ± 3.43 mm and 15.15 ± 2.81 mm, respectively.

The differences in morphometric parameters and indices between left and right sides of femora were not significant.

The ranges, mean values, standard deviations and coefficients of variance of measured and calculated parameters of the distal femur in all dogs are presented in ▶Table 2.

The mean values, standard deviations and minimum to maximum values of the ICF indices on male and female dogs are presented in ▶Table 3. The differences between female and male dogs in any of the ICF indices were not significant.

Table 3 The mean values, standard deviations (SD) and ranges of ICF indices of the male and female dogs.

	Female (n = 21)		Male (n = 23)		
Parameter*	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	
FWIcr	0.19 ± 0.02	0.16 - 0.22	0.19 ± 0.02	0.15 - 0.25	NS
FWIcn	0.28 ± 0.02	0.24 - 0.32	0.28 ± 0.03	0.22 - 0.34	NS
FWIca	0.36 ± 0.04	0.30 - 0.41	0.37 ± 0.04	0.31 - 0.45	NS
FSI	0.71 ± 0.12	0.53 - 0.88	0.71 ± 0.08	0.58 - 0.84	NS
FHI	0.33 ± 0.03	0.28 - 0.37	0.33 ± 0.02	0.30 - 0.38	NS
FAI	0.15 ± 0.02	0.12 - 0.18	0.16 ± 0.02	0.12 - 0.20	NS

Key: * The listed parameters are defined in Table 1. NS = There is not a significant difference between female and male.

Discussion

According to the results of the test of validity, the measurement method used in this study was found to be repeatable. However, the interobserver reproducibility was not evaluated because all the measurements were carried out by the same observer (18).

Because the CrCL runs through the ICF, it has been proposed that the morphology of the fossa could influence its function and the risk of CrCL injury (7). A careful evaluation of the size of the ICF is also required for clinical consideration of fossa stenosis (4, 6). Therefore, numerous studies have examined the relationship between the geometry of the fossa and CrCL injury (2, 4, 5, 10). The ICF size or shape may be evaluated with morphometrical measurements, shape analysis methods, or calculation of ICF indices (2, 4, 5, 7, 8, 11). In morphometric evaluations, indices are more reliable than dimensions because they are independent from bone size (2, 8). In this study, the variance coefficients determined

[c] SPSS 13.0 for Windows: IBM, Chicago, IL, USA

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on indices were small. This result was especially important for dogs, because there are approximately 300 different dog breeds with various sizes (1).

The FWI is the most preferred index to evaluate ICF in dogs while FHI and FSI are rarely used (2, 5, 10–13). To our knowledge, FAI has not yet been used for any studies in dogs. Except for some of the index values recorded by Comerford et al. and Mostafa et al, our index values were similar to most of the reported values gathered by other investigators using different methods in dogs (2, 5, 10–13). A limitation of our study was that the measurements were only done from two dimensional images. Naturally, more valuable data may be obtained from three dimensional geometry of ICF for clinical use. Another point is that the small number of the dogs within each breed made it impossible to compare indices between males and females statistically within a breed.

There were no significant differences between the right and left sides for ICF indices. Therefore, homotypic variation of ICF was not observed in the canine distal femur in this study, just as previously indicated in humans and dogs (9, 18, 19). This result was also important in the design of experimental studies when the contralateral femur is being used as the control.

The ICF shape shows a significant difference with respect to gender in humans (7). Women have a thinner CrCL and a smaller area of intercondylar fossa than men; a significant correlation has also been determined between the size of the ICF and the cross-sectional area of the CrCL (3). An increased incidence of CrCL injury is reported for women in contrast to men (3, 8, 9). However in dogs, there has not been detailed information regarding gender differences of ICF geometry, despite the fact that a higher incidence of CrCL rupture was observed in female dogs in some studies (14–16). According to our results, the difference in ICF indices between male and female dogs was not significant. Two factors may play role for this species difference. First, the geometry of articular surface of the distal femur is different between dog and human, and secondly dogs are quadrupeds in contrast to the bipedal human (20).

In conclusion, this study focused on sexual dimorphism of the ICF geometry of dogs because this may be one of the important factors that predispose individuals to CrCL injury. However, it is well known that the stifle joint is complex and its function depends on the congruency of all components, and CrCL injury is a multifactorial disease in dogs. Since the differences in ICF indices between male and female dog were not significant, we did not find any evidence that gender difference related to ICF geometry has any effect on incidence of CrCL injury in dogs.

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