Consistency of Femoral Metaphyseal Shape in Portuguese Water Dogs: Implications for Femoral Component Design in THA

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INTRODUCTION: In both canines and humans, total hip arthroplasty (THA) is a commonly used procedure for reconstructing hip joints that are deranged as a result of arthritis, dysplasia, or fracture. The success of THA, using cementless femoral components, is strongly correlated with achieving adequate fit-and-fill between the prepared bone and the femoral component [1]. Variations in femoral canal shape can be seen on anterior-posterior (AP) radiographs as one of several canal flare indices (CFI) (a common CFI shown in **figure 1A**). However, these CFIs are not adequate for evaluating shape for metaphyseal fixation of femoral implants, which is critically important for achieving rotational stability for many femoral component designs [2-4]. The metaphyseal canal flare index (MetaCFI, see **Fig. 1B**) has been studied in various dog breeds by Palierne et al. [5] ranging from 2 to 65 kg mass; they concluded that the metaphyseal endosteal shape remains very consistent across various breeds. The metaphyseal region in the breeds that they studied had a similar metaphyseal shape, but varied in size. In the present study, Portuguese Water Dog (PWD) femora were evaluated to determine femoral medullary geometry for applications in canine THA and for translational studies for human THA. We evaluated correlations between the MetaCFI with the CFI of the entire proximal femur (**Fig. 1A** vs. **1B**).

METHODS AND MATERIALS: PWD carcasses were obtained from animals that had been autopsied for various organ pathologies in prior studies from "The Georgie Project" [6,7]. With IACUC approval, the right femora were examined (total sample= 415, males= 145, females= 207, unknown sex= 63) from the remaining skeletally mature animals that had been donated for these studies. Age range: 2-16 years old. Transverse mediolateral metaphyseal diameters (for determining MetaCFI and CFI) were measured digitally on ImageJ from AP radiographs. A scale was established using a 5mm ball, which marked the center of the lesser trochanter. The measurements were made ±7.5mm from the center of this ball to indicate the upper boarder of the lesser trochanter (UBLT) and lower boarder of the lesser trochanter (LBLT). CFI was calculated as shown in **figure 1A**. MetaCFI was calculated as shown in f**igure 1B**. In order to control for the confounding affects of specimen size (i.e., length of femur and body mass) on the measured parameters multiple regression analyses were conducted using the statistical software program NCSS 2020. The coefficients of variation (CV) are reported, which are calculated as the standard deviation (SD) divided by the average (CV= SD/AVG).

RESULTS: The total, male, and female; averages, medians, SDs, and CVs are reported in **Table 1**. The multivariate analysis showed that age was not a significant factor in explaining the variations of the parameters reported in this study. Both the total length of femur (Ltot) and body mass, however, were significantly related to the transverse diameters of the UBLT and LBLT. However, the effect of the Ltot on the UBLT and LBLT was conditional on sex with females showing a smaller effect of Ltot (regression coefficient Ltot*sex= -0.07 and -0.05 respectively) (**Table 2**). Variations in CFI showed no correlation with age, sex, or weight. The model explained very little of the variation in CFI (2%), suggesting that CFI was independent of size despite the significant slope associated with Ltot. MetaCFI was not significantly correlated with CFI.

DISCUSSION: Achieving adequate fit of the metaphyseal region can assure initial implant stability in both canines and humans [8-10]. Therefore, understanding the shape and size of the metaphysis is critical for designing femoral prosthetics. Our data mirror the results of Palierne et al. [5] showing very low variation in MetaCFI when compared to CFI (current study CV= 0.07, SD= 0.1; Palierne et al. [5] CV= 0.08, SD= 0.1). Our sample, on average, had a larger MetaCFI in comparison to what was reported by Palierne et al. [5] (1.6 and 1.3 respectively), which is most likely attributable to variations in methods. Palierne's study measured the UBLT at the radiographic superior base of the lesser trochanter (often unclear to locate), whereas our study estimated the superior base as +7.5mm from the CLT because the lesser trochanter in most instances in our sample is not visible with true AP radiographs. Hence, our method is more reliable than Palierne et al. [5]. In our sample, the effect of age is minimal, but sex was conditionally significant. Our models showed significant interactions between Ltot and sex. This interaction was interpreted to suggest that in the female subset, the UBLT and the LBLT were less dependent on Ltot. Despite the significant interaction, however, the effect was minimal (regression coefficient UBLT= -0.07; LBLT= -0.05, see **Table 2**). Our study suggests that PWDs, once skeletally mature, undergo minimal age- and sex-related changes in the metaphyseal region of the femoral endosteum.

SIGNIFICANCE: The metaphyseal region in PWD femora remains relatively consistent with age, with most of the variation explained by femur length. Femoral stem shape for the PWD can be relatively consistent with varying sizes to accommodate larger or smaller animals.

REFERENCES: [1] Rashmir-Raven et al. (1992) Vet Surg 21:327-; [2] Nunn et al. (1989) JBJS 71:452-; [3] Ohl et al. (1993) CORR 287:135-; [4] Hua and Walker (1994) JBJS 76:95-; [5] Palierne et al. (2006) Res Vet Sci 80:243-; [6] Chase et al. (2002) PNAS USA 99: 9930- ; [7] Chase et al. (2005) Am J Med Genet A. 135:334-; [8] Pernell et al. (1994) Vet Surg 6:503-; [9] Laine et al. (2000) J Arthro 15:86-; [10] Townsend et al. (2017) Vet Surg 46:803-.

Figure 1

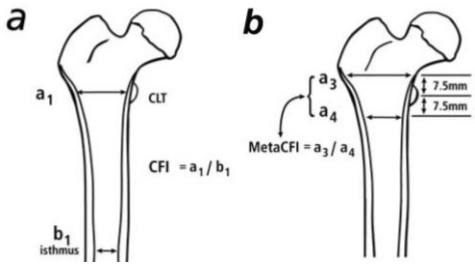

Table 1

	Descriptive Statistics			
	MetaCFI	UBLT	LBLT	CFI
Mean				
Total	1.63	23.9	14.7	2.07
Male	1.61	24.7	15.4	2.09
Female	1.65	23.4	14.2	2.06
Median				
Total	1.61	23.8	14.6	2.06
Male	1.60	24.7	15.3	2.08
Female	1.65	23.3	14.2	2.06
STDEV				
Total	0.11	2.3	1.8	0.22
Male	0.10	2.5	1.9	0.22
Female	0.11	1.9	1.4	0.22
CV				
Total	0.07	0.10	0.12	0.11
Male	0.07	0.10	0.12	0.10
Female	0.07	0.08	0.10	0.11

Table 2

	Adj. R^2	Ltot	Body Mass	Ltot*Sex	Ltot*Age*Sex
UBLT	0.19	**0.1*** **	**0.03** **	**-0.07***	**0.01***
LBLT	0.31	**0.1*** **	**0.03** **	**-0.05** **	N/A
MetaCFI	0.16	**-0.01*** **	N/A	N/A	N/A
CFI	0.02	**0.01** **	N/A	**-0.01***	N/A