Portuguese Water Dog Proximal Femoral Canal Flare Somatypes: Implications for Translational studies of Total Hip Replacements

J. Hunter Marshall[1], Julia N. Hibbard[1], Angelina J. Skedros[1], Kevin Chase[2], John G. Skedros[1]
[1]University of Utah Department of Orthopaedic Surgery and [2]Department of Biology, Salt Lake City, UT
Email of corresponding author: jskedrosmd@uosmd.com

Disclosures: The authors have nothing to disclose.

INTRODUCTION: Research in human and canine hip replacement (THR) has shown that achieving close proximity between the endosteal cortex and cementless femoral components correlates with durable fixation, which is usually dependent on robust bone in-growth and the distribution of beneficial strains throughout the proximal femur [1, 2]. Failure to achieve initial component stability can interfere with bone in-growth, leading to subsidence of the femoral component and implant failure [3,4]. Lack of initial instability is often attributed to mismatch of implant and canal shapes (i.e., poor "fit and fill") [5]. To account for anatomical variability of the proximal femoral canal, different canal shapes or "somatypes" need to be considered. In a human study, Noble et al. [6] defined "somatypes" as the "medial and lateral [endosteal] contours of the proximal section of the femur." They reported that nine different somatype-based prosthetic components are needed to accommodate the various endosteal contours of the human femur as seen in AP radiographs. Because canines are often used as translational models for human THR for testing femoral components, it is important to draw comparisons of canal morphology in selected breeds. In this study we sought to: (1) define the endosteal profile and somatypes needed to determine the number of femoral prostheses that would be needed in our large sample of Portuguese Water Dog (PWD) femora, and (2) determine if specimen age or sex would influence somatype prevalence.

MATERIALS AND METHODS: PWD carcasses were obtained from animals that had been autopsied for various organ pathologies in our prior studies from "The Georgie Project" [7,8]. With IACUC approval we examined the right femora (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 to 16 years old. Mediolateral endosteal measurements were measured on digital A-P radiographs using ImageJ at the level of the center (apex) of the lesser trochanter (CLT.MD) and at the proximal aspect of the femoral canal (Dist.MD) (**Fig. 1**). To classify the canal endosteal margins into discrete somatypes, we calculated the differences between the medial (M) and lateral (L) distances from the axial midline and the Dist.MD radius to find how far medially and laterally the proximal endosteal width extend beyond the distal endosteal width (**Fig. 1**). The calculated differences were then plotted on a stem-and-leaf plot to visualize the distribution and select cut-off values for the various medial and medullary distances of the somatypes. The medial and lateral endosteal profiles were then combined to create a somatype classification (e.g., M1 with L1= M1L1). The parameters for the medial and lateral endosteal profiles are shown in **Table 1**. Statistical analyses were conducted using the statistical software program NCSS 2020. Comparisons were made with human femoral somatypes described by Noble et al. [6]. In order to test if somatype prevalence was associated with sex we performed a Chi-squared analysis of independence. For the analysis the table rows for M1L1 and M1L2 were combined so then >80% of the cells had expected values greater than 5.

RESULTS: Our data suggest that nine somatypes are needed to accommodate the variability of proximal morphologies based on medullary diameters at the isthmus (**Table 2**). This conclusion is based on the implantation of cementless femoral components. ANOVA testing showed no differences between the ages of the specimens when grouped by somatypes. This suggests that somatype is not influenced by age for either males or females. The Chi-squared analysis showed that sex was significantly associated with femoral canal shape (somatype) ($p= 0.02$). Multivariate analysis showed that neither age nor sex was significantly correlated with the either the CLT.MD or Dist.MD.

DISCUSSION: Three key differences between our study and the human data of Noble et al. [6] include: (1) the endosteal contour of the PWD femur extends further laterally than medially, (2) there were very strong and significant relationships between paired endosteal and periosteal measurements in PWDs, and (3) that there were little age-related changes of the mediolateral endosteal contour of the proximal femoral canal in PWDs. Noble et al. concluded that the human mediolateral endosteal diameter expanded at the rate of 1.3mm per decade at the isthmus, and periosteal expansion was not observed — this was not the case in our sample. Our study showed that: (1) age was not correlated with endosteal changes of the proximal femur, (2) age is not a useful predictor of the particular somatype implant needed for a particular specimen, and (3) sex was significantly associated with somatype. Females proportionally had a greater amount of M2L2 somatype than males, which suggest that female endosteal canals are morphologically more moderate in their dimensions. Highly accurate stem sizing and positioning are critical for a successful outcome of a THR, which is the case also in canine THR [9]. In a canine study, Townsend et al. [10] recommend a mean canal fill of ≥85% while placing the stem in axial alignment in the sagittal and coronal planes. The most important variable that decreased subsidence was increased lateral implant fit in canines ($r= -0.86$, $p= .003$) [5]. This is because the lateral endosteal profile extends further from the axial mid-line in canines, whereas in humans the medial profile extends farther. Notably, in canine THRs, excessive amounts of cement were often used to make the implant fit, and 52.6 % of the acetabular components became loose due to ill fitting components [11]. Although a canal fill around 80% can yield good results in canines, 90% is preferable [5]. To decrease cases of subsidence in canines and reduce the need for excessive use of cement in THRs, our data support the suggestion that there should be a larger variety of hip implant sizes available for THR, at least in PWDs.

SIGNIFICANCE/CLINICAL RELEVANCE: Sex was significantly associated with somatype prevalence. The significant variability in the size of femoral canal in the canine population should be taken into account when designing femoral components for PWDs.

REFERENCES: [1] Pugliese (2014) The Ohio State University Ph.D. Thesis; [2] Brown and Ferguson (1980) Acta Orthop Scand 51:429-; [3] Rashmir-Raven et al. (1992) Vet Surg 21:327-; [4] Tangsataporn et al. (2015) J Arthrop 30:1030-; [5] Pernell et al. (1994) Vet Surg 23:503-; [6] Noble et al. (1988) CORR 235: 148-; [7] Chase et al. (2002) PNAS USA 99:9930-; [8] Chase et al. (2005) Am J Med Genet A 135:334-; [9] Jasty et al. (1997) J Arthrop 12:106-; [10] Townsend et al. (2017) Vet Surg 46:803-; [11] Skurla et al. (2005) JBJS 87:120-.

Figure 1

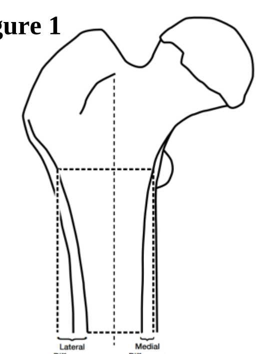

Table 1

Medial Difference			Lateral Difference		
	M1	≤ 3.4mm		**L1**	≤ 5.4mm
3.4mm<	**M2**	≤ 5.4mm	5.4mm<	**L2**	≤ 7.9mm
5.4mm<	**M3**		7.9mm<	**L3**	

Table 2

Somatype	Male	Female	Row Total	Total %
M1L1	2	3	5	1%
M1L2	9	18	27	8%
M2L1	11	11	22	7%
M1L3	9	12	21	6%
M3L1	14	28	42	12%
M2L2	37	75	112	33%
M2L3	30	24	54	16%
M3L2	22	26	48	14%
M3L3	6	1	7	2%
Column Total	140	198	**338**	100%