Femoral Component Stem Shape Can Remain Consistent in Canine Hip Replacement Despite Age and Sex: An Analysis in 314 Portuguese Water Dog Femora

Quinn K. Smith[1,2], Ethan D. Finlinson[2], Weston E. Smith[2], Marshall K. Henrie[2], Meredith G. Luczak[2], Kevin Chase[2], Karl G. Lark[2], John G. Skedros[2]
[1]Tulane University School of Medicine, New Orleans, LA, [2]University of Utah, Salt Lake City, UT
Email of Presenting Author: quinn.k.smith@gmail.com

Disclosures: Q. Smith (N), E. Finlinson (N), W. Smith (N), M. Henrie (N), M. Luczak (N), K. Chase (N), K. Lark (N), J. Skedros (N)

INTRODUCTION: As in humans, noncemented (press-fit) total hip replacement (THR) surgery has become a well established procedure for dogs with severe pain from hip arthritis [1,2]. However, additional research is needed to help enhance the longevity of THRs in specific breeds. Investigations are especially needed in large samples in order to look for potential influences of age, sex, and the magnitude of femoral head arthritis. These studies can also help evaluate new designs/materials for applications in humans. Using a sample of 314 skeletally mature (2-18 year old) Portuguese water dog (PWD) femora, we examined a morphological feature that must be closely matched by a press-fit femoral component: the canal flare index (CFI, **Fig. 1**). CFI is the ratio of the medullary diameter at the proximal aspect of the lesser trochanter to the medullary diameter at the isthmus (i.e., narrowest point the shaft). Femoral morphology that might result in a reduced canal fill for the femoral component is one of the most important concerns of surgeons who use porous ingrowth (noncemented) systems. This is because the percentage of canal fill has been shown to be an accurate predictor of component subsidence in dogs [3]. In that study, components implanted into femora with a stovepipe morphology (CFI <1.8) were found to be six times more likely to subside than implants in femora that had a normal appearance (CFI 1.8-2.5) and 72 times more likely to subside than implants in champagne-fluted femora (CFI ≥2.5), which is common in German Shepherd dogs. In the present study we sought to answer these four questions in our large sample of PWDs, which, unlike German Shepherd dogs are considered medium-sized dogs: (1) Does CFI differ between males and females? (2) Does CFI change with age in either sex? (3) What is the prevalence of stove pipe morphology? (4) Does CFI correlate with the presence of proximal femur arthritis?
METHODS: With IACUC approval, PWD carcasses were autopsied for various organ pathologies in prior studies that are part of a large research effort known as the Georgie Project (http://www.georgieproject.com) [4,5]. Our sample of 314 femora (Male: 130, Female: 184, soft tissue manually removed) were measured directly for various parameters: total bone length (L.total), biomechanical length (L.bio), length from head center to lateral margin of greater trochanter (Lht), length from head center to longitudinal axis of diaphysis (Lhd), femoral head offset length (Lho), cervico-diaphyseal angle (C-D angle), percent length at anterior bow max (%L.ABmax), medullary width at the isthmus (isthwd), and medullary width at the lesser trochanter (L-Twd). The femora were then radiographed in a standardized anterior-posterior projection and digitized radiographs were analyzed using ImageJ (https://imagej.nih.gov/ij/) to measure canal flare index (CFI) in accordance with Casper et al. [6] (**Fig. 1**). Statistical analyses included the use of a Shapiro Test for normality (only %LABmax non-normal) and a robust linear regression analysis. All statistics were estimated using custom scripts in R(1) (http://www.R-project.org/). Pearson correlation coefficients were estimated using the 'cor' function, robust line fitting was done with the 'rlm' function. The significance of the sex difference was estimated using a two-sided, unpaired, unequal variance T test (the 't.test' function).
RESULTS: CFI was independent of sex and age, even across the 16-year age range, and there was no significant difference between males and females: CFI in males = 2.22 (+/- 0.28mm, SD); in females = 2.22 (+/- 0.25) (p=0.8). The lack of a relationships between CFI and age are shown by the regression plot in **Fig.2** (all bones, r = -0.007, p = 0.15) and males vs. age (r = -0.005 p = 0.4), females vs. age (r = -0.008, p = 0.2). CFI did not significantly correlate with any of the other independent parameters that we measured (**Fig. 3**), and was not influenced by the presence of arthritis (indicated by solid dots in **Fig. 2**). When the CFI data were segregated into the three categories (<1.8 = stovepipe, 1.8-2.5 normal, >2.5 champagne fluted) as done in [3], the frequencies were: 5% (stove pipe), 81% (normal), and 14% (champagne flute). There was no evidence of a strong divergence between the three categories.
DISCUSSION: These results show that regardless of age, sex, or the presence of proximal femur arthritis, that CFI is relatively constant in PWD femora. This suggests that a press-fit femoral stem design can have a constant shape and that isometric changes in the stem femoral component would accommodate differences in femur size. Similar to our results, Palierne et al. [7] also found that "the weak variability [in CFI] would allow the design of an implant with a consistent conic shape for all stem sizes." Notably, although they examined 19 breeds and four mongrels, they only examined 41 bones; hence many breeds were likely represented by only one bone. Nevertheless, similar to our results (data not shown), they also found that CFI was less variable than numerous other characteristics of proximal femoral morphology that are important in designing the most proximal portion of femoral components for THRs. It is important to note that segregation of CFI into three categories by [3], while useful in the context of the clinical finding of subsidence in dogs (i.e., CFI of <1.8 was associated with stem subsidence), that Palierne et al. [7] considered CFI of < 3.0 as representing the "stove pipe" morphology when compared to data from human femora. Therefore, additional research is needed to determine if other descriptors for 'categories' of stove pipe morphology could be conceived so that the 'inaccurate description' of three categories by [3] can be rigorously resolved. Finally, in contrast to these past and our current findings in dogs, a recent study of radiographs of modern human femora scheduled for THR, Casper et al. [6] found that significant differences in CFI between young males and females (age 21-40, p = 0.0008) and middle aged males and females (age 41-60, p = 0.0009) but no significant difference between elderly males and females. They also found that age-related changes in lateral cortex thickness were most influential in the age-related CFI changes in human females. Additional studies of lateral cortical thickness vs. medial cortical thickness changes in our PWD femora are needed to determine if changes in cortical robustness change with age even though medullary diameters (which are used to calculate CFI) do not.

SIGNIFICANCE/CLINICAL RELEVANCE: Data from our large sample will be useful for advancing designs of femoral stems for THR in canines and for the use of the canine model for applications in humans.

REFERENCES: **1.** Allen (2012) J. Small Animal Practice 53:495-; **2.** Conzemius and Vandervoort (2005) Vet Clin Small Anim 35:1213-; **3.** Rashmir-Raven et al. (1992) Vet Surg 21:327-; **4.** Chase et al. (2002) PNAS 99:9930-; **5.** Chase et al. (2005) Am J Med Genet A.135:334-; **6.** Casper et al. (2012) J Orthop Res 30:1162-; **7.** Palierne et al. (2006) Research in Vet Science 80:243

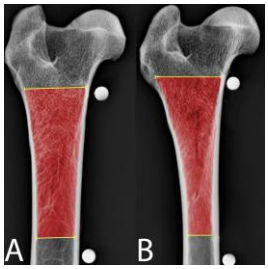

Figure 1

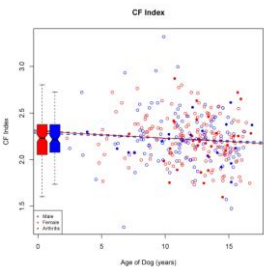

Figure 2

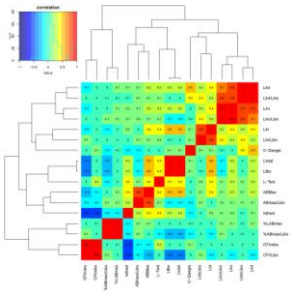
Figure 3