Anterior Bow and Isthmus in a Large Sample of Portuguese Water Dog Femora in the Context of Total Hip Replacement

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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]. To help enhance the longevity of THR in specific breeds, additional studies in large samples are needed to look for potential influences of age, sex, and the magnitude of femoral head arthritis. Using a sample of 314 skeletally mature (2-18 year old) Portuguese water dog (PWD) femora, we examined morphological features that must be carefully considered in a press-fit femoral component: the location of the isthmus (i.e., narrowest portion of medullary canal) and the location of the maximum anterior bow. In a clinical and an experimental setting, the longevity of a THR is dependent upon a close fit between the femoral component and the surgically prepared supporting bone [3-5]. Therefore, knowing the morphology of the bone is essential [6]. Studies show that when press fit at the isthmus is achieved there is fixation by bone ingrowth in 93% of cases as compared to 69% of cases when a press fit at the isthmus was not achieved [7]. Cortical contact and fit of a femoral endoprosthesis in the proximal medullary canal are important indicators of fixation, and thus the differences between breeds of canine in the curvature of the femora must also be considered for THR designs [6]. In the present study we provide a database of femoral anterior bow morphology and location of isthmus for use in THR designs for PWDs and comparative studies between humans and canines in the context of THR. We sought to answer these questions in our large sample of PWDs: (1) Does percent length at anterior bow max (L.AB) differ between males and females? (2) Does L.AB change with age in either sex? (3) Does the location of the isthmus differ between males and females? (4) Does the location of the isthmus change with age in either sex?

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) [8,9]. Our sample of 314 femora (Male: 130, Female: 184, soft tissue manually removed) were measured directly for various parameters: Total bone length (L.tot), biomechanical length (L.bio), percent length at anterior bow max (%L.ABmax), and anterior bow index (Abi) were measured in accordance with Kuo et al. [6]. 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 the distance from the 50% of the length of the bone to the isthmus (D.isth). The D.isth is the narrowest transverse diameter of the medullary canal. Additional measured parameters included: 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), medullary width at the isthmus (isthwd), and medullary width at the lesser trochanter (L-Twd). Statistical analyses included the use of a Shapiro Test for normality (only %L.ABmax 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: D.isth was independent of sex and age, even across the 16-year age range, and there was no significant difference between males and females: D.isth in males = 9.6mm superiorly (+/- 5.7mm, SD); in females = 9.7mm superiorly (+/- 5.5mm, SD) (p=0.8). Of note, only 3% of bones had an isthmus that extended inferiorly beyond 50% of the bone length (where 0% is upper end of bone and 80% is lower). The lack of a relationship between D.isth and age is shown in **Fig. 1** [all bones, r = 0.03, p = 0.7; males vs. age (r = 0.08 p = 0.6), females vs. age (r = 0.02, p = 0.9)]. D.isth did not significantly correlate with any of the other independent parameters that we measured. L.AB was independent of sex showing no significant difference between males and females: L.AB in males = 49% (+/- 8%, SD); in females = 50% (+/- 11%, SD) (p=0.8). Females showed a significant negative relationship with age (r= -0.35, p=0.05), while L.AB in males was independent of age (r<0.1, p=0.2). The relationship between L.AB and age can be seen in the regression plot in **Fig. 2**. L.AB did not significantly correlate with any of the other independent parameters that we measured. **Fig. 3** shows that the location of the maximum anterior bow of the shaft in the PWD and human are similar, and that of adult greyhound dogs is more distal (non-PWD data are from [6]); proximal shaft is left and distal shaft is right in this figure).

DISCUSSION: These results show that regardless of age or sex that D.isth is relatively constant in PWD femora. This consistency is informative to the veterinarian reaming a femur for distal fixation of a THR in a PWD. The consistency of L.AB across age and sex in male PWDs suggests that in male PWDs 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, while the change in L.AB seen in female PWDs with age, suggests a need for multiple stem shapes in THR of the female PWD and the consideration of the age of the dog receiving a THR. In studies of the human femur, the L.AB has been found to be located at 55% of the biomechanical length [7]. Our work shows that the L.AB in PWDs is a close approximation of L.AB in humans, and therefore the use of the PWD as a model for THR may provide a closer approximation of THR design and material performance in humans than the use of other canines where the anterior bow max is more distal (middle plot in **Fig. 3**) [7]. Additional analysis is needed to see if there are genetic factors contributing to the change in L.AB seen in female PWDs with age. Understanding the genetics underlying this relationship may further elucidate our understanding of human bone aging. This detailed analysis is currently underway in our lab.

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.

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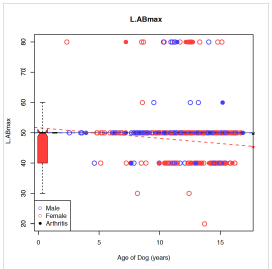

Figure 1

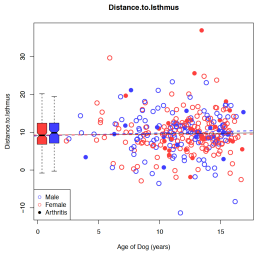

Figure 2

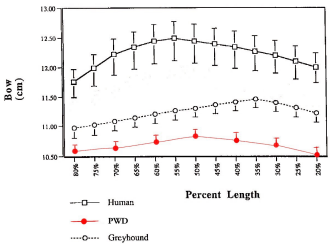

Figure 3