A novel technique for studying proximal femoral bone morphology for hip implant design

+1Wuestemann, T; 1Bastian, A; 1Schmidt, W; 1Cedermark, C; 1Parvizi, J; 2Rothman, R
1Stryker Orthopaedics, Mahwah, NJ; 2Rothman Institute of Orthopedics at Thomas Jefferson University, Philadelphia, PA
Senior Author thies.wuestemann@stryker.com

INTRODUCTION:
Clinical experience has shown that addressing variations in bone morphology are important in the development of successful hip implant designs [1, 2]. Numerous studies of femoral bone morphology have been published utilizing various techniques [3, 4, 5, 6, 7, 8]. An opportunity exists for the development of a method which consistently measures large quantities of 3-dimensional digital femura geometry segmented from CT scans. This study demonstrates a software tool that can accurately make anatomical measurements from images obtained using computer tomography (CT). We believe this software has value in evaluation of different morphology of femur in patients undergoing total hip arthroplasty. Further, the findings of this study have clinical relevance in evaluation of different femoral stem designs with regard to fit and fill.

METHODS:
Computer tomography (CT) images of left femora on five hundred fifty six left femora (57% male, 43% female), consisting of 69% Caucasian, 16% Asian and 14% unknown were analyzed. These patients underwent CT scan for investigation of problems unrelated to the hips. The average age was 66 years, ranging from 40 to 93 years. The scanning protocol called for CT scan slice thicknesses ranging between 0.7 to 1.5mm, the result of which was a collection of precise bone geometry. Segmentation of the outer cortical, inner cortical, and marrow boundaries were consistently performed over all CT scans.

An analytical tool was developed to facilitate reproducible measurements for individual bones using a template bone as a reference. The positions identified on the reference bone are transformed to the equivalent position on the clinical bone images, from which the dimensional data is extracted and stored.

The mediolateral width (MLW), medial offset (MO) and lateral offset (LO) were measured in 10mm increments, ranging from 20mm above the lesser trochanter (LT) to 130mm below the lesser trochanter (Fig 1). The measurements were taken in a plane aligned to the femoral neck axis. The canal flare index was defined as a ratio of the mediolateral width at a section 20mm above the lesser trochanter to the mediolateral width at the isthmus level.

RESULTS:
The mean values of the mediolateral width at 20mm above the lesser trochanter and at the isthmus level are reported in Table 1. Mean values of previous studies by Noble, Husmann, and Laine are shown as a reference. The mean medial offset at a section 20mm above the lesser trochanter was 25.1 ± 2.9 (16.7-33.4). In the study by Husmann, a mean of 25.0 ± 5.2 (19.4-45.5) was reported. The mean canal flare index was 4.49 ± 0.8. Noble reported a mean canal flare index of 3.80 ± .074, Husmann 3.81 ± .83 and Laine 4.3 ± .93. The canal flare distribution of our study is shown in Figure 2 compared to previous studies. The canal flare index varies inversely with the mediolateral width (r=0.77) as previously shown by Noble (r=.39). See Figure 3.

DISCUSSION:
In general, the study showed minor differences to published data of proximal bone morphology. However, this study has shown that there is a higher mean canal flare index as determined by Noble and a similar mean canal flare index as determined by Laine. As reported by Laine, the canal flare index varies significantly with the placement of measurements in the canal. In this study the measurements were performed in a plane oriented by the femoral neck as a hip stem would be placed. The CFI over the isthmus width showed a greater correlation than previously shown by Noble. This study showed that a larger population size is important to characterize bone morphology as a basis for hip implant design. The novel software tool allows for anatomical measurements that can be applied to an unlimited population size enabling further applications and studies.

REFERENCES:

Table 1. Mean values, standard deviation and range of mediolateral width compared to previous studies (All dimensions in millimeters), *Neck oriented study

<table>
<thead>
<tr>
<th>Study (n=556)</th>
<th>MLW at 20mm LT</th>
<th>MLW at Isthmus</th>
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<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
</tr>
<tr>
<td>Noble (n=200)</td>
<td>45.4</td>
<td>5.3</td>
</tr>
<tr>
<td>Husmann (n=310)</td>
<td>46.3</td>
<td>6.9</td>
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<tr>
<td>Laine* (n=50)</td>
<td>47.1</td>
<td>4.9</td>
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Figure 1. A. Measurements shown on template bone in anteroposterior view, B. Measurements shown on template bone aligned to neck axis, C. Measurement locations translated to actual bone geometry derived from CT scan.

Figure 2. Distribution of canal flare indexes as compared to previous studies

Figure 3. Canal flare index as a function of the isthmus width