The Effects of Optimized Bone Model Geometry on Insertion and Stability of the Acetabular Hemispherical Cups.

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INTRODUCTION:
Press-fit acetabular components have become the standard in THA. Initial stability of the cementless implants is achieved by a prescribed press-fit, which varies depending on the particular cup design, patient bone quality and surgeon preference.

Kwong et al. [1] and MacKenzie et al. [2] suggested that acetabular reamer design combined with a surgical technique may introduce an error when attempting to obtain a desired press-fit fixation. In their study, the latter group showed an elongated cavity was created with an average diameter of 0.56 mm larger than the last reamer used. Furthermore, the average bone contact with the implant was less than 20%, with the polar zone of the implant rarely in contact with the bone. The aim of the current study was to prepare cheese-grater and highly accurate machined hemispherical geometries, and compare the effects of geometry on both the introduction of acetabular components and the ability to resist lever-out forces.

MATERIALS AND METHODS:
The experiment consisted of eight 52 mm cementless Ti6Al4V Hemispherical primary solid back shells manufactured and sold by Stryker Orthopaedics, Mahwah, NJ, USA. Z M Jin [3] showed that 30 pcf density polyurethane foam by Pacific Research (Sawbones, Pacific Research Laboratories Inc. Vashon, WA) produced similar acetabular component deformation as in the cadaveric test, and therefore in this study the same 30pcf foam was used to represent the mechanical properties of the acetabulum while minimizing the variability often seen in cadaver studies.

Two groups of test bone specimens were prepared. The first group (n=8) was prepared sequentially with cheese-grater reamers up to size 51mm. The second group (n=8) was prepared sequentially with cheese-grater reamers up to size 50mm, followed by a final cut of 51 mm using a hemispherical Forming Tool. The resulting cavities provided 1 mm press-fit for the 52 mm cementless socket as recommended in the surgical protocol [4] for osteoporotic bone.

The acetabular shells were assembled into the polyurethane blocks using a single axis MTS test machine (Figure 1). Maximum insertion load values were recorded for each specimen. All foam block specimens were equipped with a sensor to detect the shell polar region bottoming within the prepared cavity.

RESULTS:
The hemispherical geometry preparations for both groups were measured via co-ordinate measurement machine (CMM). The average spherical diameter of the cavities prepared with a cheese-grater was 0.17±0.04 mm larger than the marked size of the reamer used, whereas the average spherical diameter of the forming tool blocks was oversized by only 0.04±0.03mm. The average rim diameter of the cheese-grater reamer prepared cavities was undersized by 1.1±0.08mm when compared to the reamer used. In contrast, the average rim diameter of the forming tool prepared blocks was oversized by only 0.1 ±0.06mm.

The average insertion force required to fully seat the cup into cheese-grater prepared cavities was 20% higher than the force required to seat the cups into forming tool prepared cavities (1002±1011 N, and 8382±1321 N respectively). Individual t-test showed that the force difference between both groups was statistically significant (p=0.014).

The blocks reamed by the cheese-grater showed 25% lower average cam-out load resistance than the blocks prepared by forming tool (7923±1095 N, and 9989±1457 N respectively). Individual t-tests showed that the difference in cam-out force resistance between both groups was statistically significant (p=0.006).

CONCLUSION:
This method showed that optimized geometry of the receiving cavity has a beneficial effect on introduction and stability of acetabular sockets. Cups implanted into forming tool prepared cavities exhibited higher resistance to the off-set load than the bone models from the other group. This can be explained by better congruence of the cavity with the implant, which leads to better distribution of retaining forces over larger surface area. In a clinical situation larger contact area would potentially lead to a more stable implant as bone ingrowth would occur over a larger percentage of the hemisphere. A resultant of extra press fit exceeding 1 mm at the rim in cheese-grater models is that higher forces are required to fully seat the sockets. In the clinical scenario it is possible that the “ledge” at the rim can lead to difficulties during implantation such as an inability to fully seat the cup and acetabular rim fractures, which both had been reported in the literature.

The measurement data obtained in this study confirmed previous reports that the cavity diameters are enlarged when compared to the last size reamer used. The creation of the “ledge” and its effects leads to the conclusion that more accurate preparation instruments are needed. Future efforts should be directed toward establishing clear correlation between accurate preparation and cup insertion. This will improve implant introduction as well as short and long term implant stability.

REFERENCES:
4 LSP66 Rev.1-Tritanium Primary Acetabular System Hemispherical Surgical Protocol