THE EFFECT OF VALUE OF UNDER-REAMING ON PRESSURE DEVELOPMENT IN THE ACETABULUM FOLLOWING TOTAL HIP REPLACEMENT

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INTRODUCTION:
Significant micromotion of the acetabular cup at the bone prosthesis interface can preclude bone ingrowth resulting in loosening and threatens long term fixation. Proposed research addresses clinically relevant issue of implant initial stability of press-fit cups following total hip replacement. It is found that increase in reaming results in high hoop stresses at the acetabular rim, where eventual crack failure might occur.
Finite element (FE) model was developed and is based on an experimental investigation where twelve cadaver hemi-pelvises were implanted with uncemented acetabular cups with 2mm under-reaming using hemispherical reamers. Axial force and torque were applied to the cup through a customized jig, simulating peak loads produced during femoro-acetabular impingement. Micromotion at the cup bone interface was quantified with six displacement sensors placed on the rim of the acetabular cup. A mathematical tool was developed to automatically generate a 3D solid model and mesh of the acetabular bone from CT scan data based on the cadaveric specimens used in the experiment.
The model is currently being used to further study analyze the conditions affecting the initial stability and loosening of the interface for different loading conditions and to determine if adjunctive screw fixation is needed to improve prosthesis longevity and reduce revision. This will permit preoperative planning, diagnostics and computer aided surgery to optimize fixation and enhance patient care.

METHODS:
We studied twelve acetabula that had been obtained from fresh-frozen cadavers that were kept at -20^{o} C. No musculoskeletal abnormality or structural abnormality of the bone was seen on radiographic or visual inspection on any of the specimens. Cadaveric specimens were implanted with non-cemented acetabular cups using a 2mm under-reaming technique [1]. Micromotion at the cup bone interface was quantified with six displacement sensors placed on the rim of the rim of the acetabular cup.
Due to the limitation of number of cadavers validated 3D FE model was used to investigate the stability of the cup/bone interface. FE model was built based on computed tomography (CT) scan data in the characterization of bone geometry and heterogeneity to achieve greater precision in the validation of the rotational micromotion of acetabular cup. CT data were retrieved for every specimen used in the experiment with a standard clinical CT scanner. This data was later utilized to generate patient-specific FE model (figure 1). An image-processing package, SeSCAN 3.0, was designed for this purpose.
The experimental results were than challenged in the finite element model by using values of under-reaming which are above and bellow the standard 2mm in increments of 0.2mm.

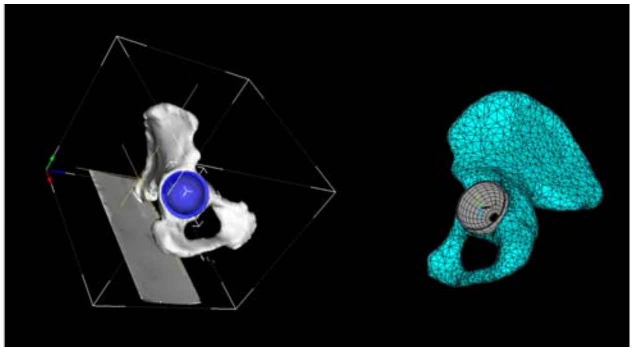

Figure 1: Finite Element model of the hemi pelvis implanted with acetabular cup. Model is based on CT scan data retrieved for every specimen

RESULTS AND DISCUSSION:
As expected, the results of FE analysis suggest that micromotion associated with lower value of under-reaming is greater compared with that for large under-reaming as shown at figure 2. When the acetabulum is under-reamed by 1.6mm, while keeping constant cup size, more relative micromotion was observed at the interface which will lead to decrease in stability by 7.57% compared to 2mm. By consistently increasing the value of press-fit, less motion is detected in the region leading to increase in stability by 4.82%, for 2.4 mm interference. Although the higher values of cup/bone interference are theoretically conductive to better implant stability, the reaction forces generate high rim stress in the surrounding bone bed and may result in pelvic damage.

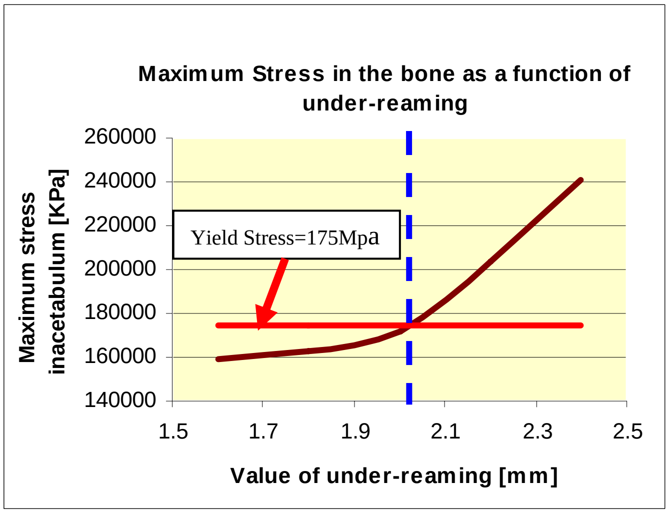

Figure 2: Relation between amount of cup over-sizing and maximum stress in insertion obtained from finite element analysis

The results of the experiment indicate that pubis provides the largest amount of support of stability at bone-implant interface. On the other hand, micromotion detected at the ilium side of acetabulum is significantly greater that at pubis and ischium. These findings suggest that ilium can be considered as a critical structure tended to compromise the initial fixation, which can be important when adjunctive screw fixation is considered, while pubis and ischium provide support for stability.

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