Revision Total Hip Replacement in Pelvis with Severe Acetabular Rim Defects

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Introduction: Several types of bony defects within or around the acetabulum can be the result of osteolysis of the pelvis after total hip replacement (THR) [1]. Based on the extent and location of the host bone loss, these defects are classified into various categories [2, 3]. A severe acetabular rim defect, classified as a Paprosky type IIIA cavity defect can result in superior migration of the cup (Figure 1-a). Treatment options include structural allograft, custom implants or reconstruction cage [4, 5]. A new reconstructive technique uses a modular Trabecular Metal™(TM) augment (Figure 1-b) to fill the superior rim defect at the time of revision THR. A regular hemispheric uncemented cup such as TM modular cup or TM revision cup is used in conjunction with it. (Figure 1-c).

Materials and Methods: A patient specific CAD model of a pelvis was created from CT data [8]. The CAD model of the left half of the pelvis was imported into FEA software to create the intact model. For the defect and revision models, material was removed from the superior rim area of the acetabulum to mimic the Paprosky type IIIA cavity defect. While primary THR components were implanted in intact and defect models, revision THR components and TM augment were implanted in the revision model. All materials were modeled using linear elastic material properties. The pelvic cancellous bone (E=70 MPa) was meshed using 10-node tetrahedron elements. Matching 6-node triangular shell elements were used to model a 1mm thick cortical shell (E=17000 MPa) around the reamed areas of pelvis (Figure 2-a, 2-b). All the implants used in this study are commercially marketed by Zimmer (Warsaw, IN). A TM modular cup (TM layer shell) and polyethylene liner (Figure 2-c) were virtually implanted in the reamed acetabulum. The superior rim defect in the Revision model was filled with a TM acetabular augment (Figure 2-d). The reconstruction surgical technique calls for packing morselized bone graft into the augment window and placing bone cement across the concave surface of the augment that will contact the TM modular cup. Since the linear elastic material properties of bone graft and bone cement are similar (E=2.2 GPa), both these materials were modeled as a single solid (Figure 2-e). Interfaces between head-liner and shell rim-pelvis were modeled using friction coefficient of 0.05 and 0.3 respectively. Interfaces between cup-pelvis, cup-cement and TM augment-pelvis were modeled with friction coefficient of 0.75. All other interfaces; liner-shell, shell-cup, cement-TM augment and cement-pelvis were modeled as bonded contact. Muscle load and joint contact force data for stair climbing case were obtained from the laboratory of Dr. Bergmann [9, 10]. Fixed support conditions were assumed at the sacroiliac joint and the pubic symphysis. Nonlinear static FEA was performed using ABAQUS ver. 6.7 (Simulia, Providence, RI) software.

Results: Peak von-Mises stress in the acetabulum of intact model was predicted to be 34 MPa, while the peak stress in the acetabulum of Defect model was predicted to be 80 MPa, which is at least 2.3 times higher than the intact model. The peak stress in the acetabulum of Revision model was predicted to be 50 MPa, which is at least 1.5 times lower than the Defect model. The peak stress in the acetabulum of Revision model is significantly lower than the peak stress in the acetabulum of Defect model.

Discussion: FEA predicted excessive displacement and rotation of the TM cup and elevated stress levels in the acetabulum with a Paprosky IIIA cavity defect, which may lead to implant dislocation and/or pelvis fracture. This study predicted that the use of a TM modular cup in conjunction with a TM augment in revision THR can significantly reduce the stresses in the pelvic host bone while providing potential for biological fixation.

References: