INTRODUCTION:

Osteolysis of the pelvis is a common and well recognized complication associated with total hip arthroplasty. Radiographic images of lytic lesions may lead to an underestimation of the size of lesion found during revision surgery. While the size and position of a lesion drives the choice of surgical response, surgeons rely on lesion found during revision surgery. While large uncontained defects may require heroic treatment methods, and small contained defects may be readily filled with bone cement or other implantable filler materials, surgeons have no guidance on how large a defect may grow before the surgical treatment modality changes.

This investigation begins to address that question by examining periprosthetic stress in a pelvis without a lytic lesion and in pelvis models with increasingly larger artificial lesions.

METHODS:

The FE model of a human pelvis is based upon CT scan data from a patient in Switzerland, with muscle load and joint contact force information from the laboratory of Dr. Bergmann et al. in Berlin. In this instance, muscle and joint contact data that were readily available are from stair climbing. The CT-scan data was rendered as a solid geometric model using the Unigraphics CAD program. Some smoothing of the surfaces, intended to improve the downstream FE mesh, was performed using Raindrop Geomagic Studio (rev. 8) and then the smoothed CAD model was imported into Patran (rev. 2005r2) for meshing, load application and the definition of constraints and contact interaction between bone and implant components.

A modular porous coated acetabular prosthesis (UHMWPE, Ti-6Al-4V and Trabecular MetalTM) was virtually implanted into the pelvis model prior to importation into Patran. A simplified two-material model was generated for the pelvis itself.

The solid pelvis model was meshed with 10-node tetrahedral elements which represented the cancellous bone (E = 70 MPa). A skin of shell elements was added to represent a cortical bone (E = 17000 MPa) layer with 1mm thickness. It was assumed that subchondral bone would be removed by acetabular reaming, so shell elements were excluded from the prepared acetabular surface. The implant to bone interface was modeled with sliding-contact behavior assuming a friction coefficient µ=0.75.

Figure 1 shows an overview of the model with the lines of action of joint and muscle forces displayed.

The nonlinear static FEA was performed using Abaqus/Standard (rev. 6.5). Results were then post-processed in Patran. Following the baseline analysis with no periprosthetic lesion, artificial defects of 26 and 32mm diameters, with depth of approximately 4.4mm were created in successive models analyzed with the same loading. Then each defect was filled with a commercially available Trabecular MetalTM filler implant known as an acetabular restrictor and the analysis was re-run to determine whether the filling of the defect had an appreciable effect upon local bone stress.

DISCUSSION:

Because the artificial defect has a regular geometry with sharp features, the local stresses predicted in this FEA study are somewhat exaggerated. It is appropriate, therefore, to compare relative stress results rather than focusing on the absolute values shown.

This analysis predicts that periprosthetic acetabular bone loss leads to an appreciable increase in local mechanical stress adjacent to a THR. Further, when a hollow defect is filled with a structural implant, the stress is reduced greatly, almost to the level of the “no defect” condition. It is not clear from this analysis that the defects have been made sufficiently large so as to create a risk of pelvic fracture, although the highest stress predicted is at a value above the strength of trabecular bone (iliac crest data). In analyses done for this study, the defect size was not increased to the extent that it perforated the ischium creating an opening into the abdominal cavity. Such a defect would be expected to increase the risk of pelvic fracture and require more extensive treatment, a subject for further study.

REFERENCES: