**Importance of Clearance on Contact Mechanics of Hemiarthroplasty in Hip Joints**

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**ACKNOWLEDGEMENT:**
Overseas Research Students Awards Scheme

**INTRODUCTION:**
The number of patients receiving hemiarthroplasty has increased in recent years in the United States [1]. However, problems such as cartilage erosion [2] and protrusion [3] are associated with this procedure as the metallic bearing surface interacts with the natural cartilage. The importance of acetabular fit, to maintain the structural integrity and functionality of the cartilage, has been recognised in the clinical performance of hemiarthroplasty [4]. The importance of conformity on the contact stresses and degradation of the cartilage under laboratory conditions has also been shown [5]. Moreover, biphasic lubrication is known to reduce the coefficient of friction due to load partitioning [6] with the fluid phase taking a large percentage of the load, thus protecting the cartilage. However, there have been no previous studies investigating the relationship between fluid load support in cartilage and contact mechanics in the hemiarthroplasty of the hip joint. Cartilage has previously been modelled as a single phase elastic or hyperelastic material. Therefore, the aim of this study was to model hemiarthroplasty in the hip joint with hyper poroelastic acetabular cartilage to understand the role of fluid load support in the contact mechanics of the joint and also to investigate the influence of clearance.

**METHODS:**
The FE model was created from the solid model of left pelvis [7] and femur [8] (Figure 1) by using I-DEAS (ver. 11, Siemens PLM Software, Plano, TX, USA) and ABAQUS (ver. 6.7-1, Dassault Systemes, Suresnes Cedex, France). The analysis was carried out using ABAQUS.

The acetabular cartilage of uniform thickness (2 mm) and spherical bearing surface was meshed using ~15000 8-noded pore pressure elements C3D8RP. Pelvis and femur were modeled with linearly elastic material properties. Pelvis was meshed using ~14000 tetrahedral C3D4 elements C3D8RP. Pelvis and femur were modeled with linearly elastic material properties.  Pelvis was meshed using ~15000 8-noded pore pressure elements. The muscles were not modelled. The radial clearances of 0.0 mm, 0.5 mm and 1.0 mm with acetabular cup were simulated.

A physiological load of approximately 2143.6 N (maximum for average patient when standing on one leg) [9] was applied, as shown in Figure 1, in 3 seconds and was held constant for another 600 seconds. The increase in the contact stresses was due to the decrease in the conformity and the contact area as the clearance increased. However, the fluid load support observed with all 3 clearances was high with decreasing values at higher clearances. This would have the effect of increasing the percentage load supported by the solid with increase in clearance which would increase the frictional coefficient leading to an increase in frictional shear stresses. These increased frictional shear stresses coupled with higher contact stresses would induce cartilage fibrillation leading to its erosion as has been observed in clinical studies [4].

**RESULTS:**
There was an increase in the contact stresses and fluid pressure with an increase in clearance (Figure 2). The contact stresses and fluid pressure were located in the superior dome of the acetabulum with antero-posterior distribution. The contact area decreased as the clearance increased. Maximum contact stresses were 3.19 MPa, 4.41 MPa and 5.40 MPa for the three clearances with the corresponding maximum fluid pressure of 2.95 MPa, 3.94 MPa and 4.67 MPa. The contact stresses were within the physiological range [11].

The total fluid load support soon after load application was found to be 91.27%, 90.05% and 88.49% with 0.0 mm, 0.5 mm and 1.0 mm clearance respectively. The reduction in fluid load support after 600 seconds was not significant.

**DISCUSSION:**
The increase in the contact stresses was due to the decrease in the conformity and the contact area as the clearance increased. However, the fluid load support observed with all 3 clearances was high with decreasing values at higher clearances. This would have the effect of increasing the percentage load supported by the solid with increase in clearance which would increase the frictional coefficient leading to an increase in frictional shear stresses. These increased frictional shear stresses coupled with higher contact stresses would induce cartilage fibrillation leading to its erosion as has been observed in clinical studies [4].

The major limitation of this study was the use of a spherical acetabular cartilage bearing surface. In the future, anatomically correct non-spherical cartilage should be modeled. This would provide better predictions since non-sphericity is likely to increase the local clearance and potentially increase both frictional shear and contact stresses. The daily activities such as walking, climbing stairs, etc. also need to be simulated in order to better understand in vivo joint contact mechanics vis-à-vis fluid load support.

**REFERENCES:**

**Figure 1:** FE model of hip hemiarthroplasty

**Figure 2:** Contour plots of contact stresses and fluid pressure (MPa) after loading for radial clearance of (a) 0.0, (b) 0.5 and (c) 1.0 mm