Total Hip Arthroplasty Acetabular Components Stability and Management of Rim-Defect Position in Cementless Fit Technique

Farid Amirouche, PhD, Giovanni F. Solitro, PhD, Mark Gonzalez, MD.
University of Illinois at Chicago, Chicago, IL, USA.

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F. Amirouche: None. G.F. Solitro: None. M. Gonzalez: 1; depuy johnson and johnson. 3B; smith and nephew. 4; orthosensing technology.

Introduction: The objective of this paper is to address a fundamental question in bone loss and rim defect in total hip repair and provide a closer look at defect protrusion position on the rim and when it become inadequate to provide the necessary mechanical support for a cementless cup. We investigated the cementless cup technique without defect reconstruction and whether it resulted in a medial migration and loosening due to induced micromotion at the discontinuity edges of the defect interface with the cup. A rim defect that is greater than 50% is usually viewed as inadequate and a reconstructed with a cage to gain fixation to the pelvis. Total hip arthroplasty in the presence of a significant defect less than 35% and positioned on the posterior or inferior column of the ischium affects both the cementless stability as well as the cup migration. In this study the rim defect is parametrically positioned around the circumference of the rim which is divided into 6 regions. A press-fit against the bony acetabular rim without defect repair was analyzed for different rim defect position and loading conditions. Cup migration was assessed using a FEM model and the corresponding reaction forces used to support the cup were also computed for all cases. Results show a cementless cup with medial and lateral acetabular defect to be favorable, with success rates similar to conventional THA with the rim intact. Other regions of the rim resulted in a reduction of 21% of the reaction forces and a weakening of the acetabulum mechanical support.

Methods: The acetabulum was built based on standard CT imaging and mimics depicting the anatomy of a cadaveric specimen being prepared for testing in the lab. The objective of this research is to investigate how rim defect position within the circumferential diameter of the rim affect the reaction forces of press fit cups and whether the reaction forces at the wall acetabulum interface can be used as a deterministic factor in predicting stability of the cup. We hypothesized that contact between the cup and bone is mostly on the superior plane of the rim as depicted in Figure1. The acetabulum was first reamed with a 58mm sphere according to basic measurements of an orthopedic setting. The contact between the cup and the bone is imposed on a surface of 1248 mm^2 equivalent to the 25.6% of total external cup surface.

Cup insertion is simulated based on imposing a spherical displacement constraint on the bone of 0.5 mm to the contact region for all configurations. We adapted the methodology employed by Taddei (Taddei et al., 2006) and used the relationship between young modulus and ash density proposed by Keller (Keller et al. 1994) for both trabecular and cortical bones. To account for the non-homogeneous bone distribution and strengthen we adapted the CT-scale to the range values of young modulus as described by Taddei, (Taddei et al,) imposing the highest value of Hounsfield scale found in the cortical bone a young
modulus of 17 GPa (Liet al., 2013) assuming a linear relationship between ash density and Hounsfield values. We used this assumption to articulate further the strong correlation (R² of 0.937 and 0.954) for trabecular and cortical bones found by Schileo (Schileo et al. 2008) in the linear regressions between radiological and ash densities. The results are shown in Figure 2.

The defects were created using a Boolean subtraction between the reconstructed bone and a CAD volume. Each defect was 20 mm wide with extension limited to 10 mm and a full rounded edges in order to avoid false stress concentrations. Each defect is positioned with a rotation of 60 degrees around the axis perpendicular to the cup.

**Results:** In view of the contact surface associated with each defect, the highest value of the young modulus is seen to be in the superior part of the rim (defect 1, Figure 3) and the largest reactions forces are found in the opposite direction of the medial and lateral side of ischium (defects 2, 3, 5 and 6) and correspond to less than 17% reduction from the healthy no defect rim. It is also important to note that defect that resulted in greater contact loss seem to the weakest reaction force and hence provide less structural support.

<table>
<thead>
<tr>
<th>Defect position</th>
<th>Contact surface reduction [%]</th>
<th>Average Young modulus [GPa]</th>
<th>Required Load [% of REB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.6</td>
<td>5.78</td>
<td>79</td>
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<tr>
<td>2</td>
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<td>85</td>
</tr>
<tr>
<td>3</td>
<td>20.1</td>
<td>5.71</td>
<td>83</td>
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<tr>
<td>4</td>
<td>31.4</td>
<td>4.27</td>
<td>72</td>
</tr>
<tr>
<td>5</td>
<td>28.6</td>
<td>4.80</td>
<td>85</td>
</tr>
<tr>
<td>6</td>
<td>31.6</td>
<td>4.15</td>
<td>83</td>
</tr>
</tbody>
</table>
Discussion: Cementless cup repair of rim defect less than 20% can be have the same advantage as a healthy acetabulum resulting in a similar bone cup fixation and stability. Weaker bone or osteoporosis might need to be treated differently with a structural support such as allograft or mechanical augmentation to provide better initial mechanical stability.

Significance: The objective of this paper is to address a fundamental question in bone loss and rim defect in total hip repair and provide a closer look at defect protrusion position on the rim and when it becomes inadequate to provide the necessary mechanical support for a cementless cup.

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