In contemporary THA there are two broad approaches to acetabular cup design and materials. One is an all-polyethylene design with polymethylmethacrylate (PMMA) cement. PMMA possesses a modulus of elasticity of about 2 GPa, which is between that of trabecular and subchondral bone. The second more popular approach, especially for active, younger patients, is the porous metal-backed polyethylene design. The porous coatings are commonly plasma sprayed metal powder, sintered beads, or fiber metal mesh, all applied to a solid metal substrate. The resulting porous metal is about 10 to 100 times stiffer than bone, depending on bone and metal type (Co-Cr versus titanium). An undesirable effect of this mismatch in stiffness is non-physiological stressing of bone, especially at the bone-implant interface, which in turn can result in bone densification and resorption within over and under stressed bone, respectively.

A second issue associated with many metal backed cups is third body polyethylene debris emanating from the interface between the liner and metal shell [1]. One solution to this problem is direct compression molding of polyethylene into the porous metal shell, and eliminating the solid metal substrate [2]. The purpose of this study was to utilize a previously employed FEA model [3,4] to characterize the acetabular bony stress induced by a porous shell material with similar stiffness as subchondral bone, and to compare similarly calculated FEA results for three clinically well established designs; namely, titanium and Co-Cr metal backed cups, and a cemented all-polyethylene cup.

**Methods:** The subject acetabular cup was constructed from a three dimensional porous tantalum (‘Hedrocel, Implex Corp.) with a direct compression molded liner, with the polyethylene infiltrating the porous tantalum to a depth of about 2 mm. A previous study showed the bond between the porous tantalum and polyethylene to be integral, and not subject to micro motion or wear [2]. The porous tantalum is an open, fully interconnected 3-D, engineered porous structure with porosity of about 80%, average pore size of 550 μm, and an elastic modulus (stiffness) of 3 GPa, i.e. similar to subchondral bone (1 to 2 GPa). Figure 1 shows the tantalum tantalum structure, and a cross-section of the non-modular cup. The three established acetabular cup designs were: cemented all-polyethylene, and non-cemented titanium and cobalt-chromium porous metal backed cups.

A 3-D model [4] was used for systematic comparisons of the four previously mentioned designs. The model divided each design into five distinct regions; cortical bone, trabecular bone, polyethylene, the inner most backing layer, and outer most layer (Figure 2). Loading was assumed at a cup inclination of 45°, with 15° of anteversion, with maximum resultant loads at heel strike of 744 N posteriorly, 274 N medially, and 648 N superiorly. The model utilized ABAQUS version 5.6. Output was in terms of 9915 elements, with 3-D stress contour plots of (1) cortical bone viewed laterally, (2) the metal or cement layer, (3) trabecular bone viewed infero-laterally, and (4) trabecular bone viewed supero-medially.

For the purpose of this study we are interested in how the various acetabular cup designs will concentrate stress at the acetabular bone cement interface and in the bone and cement region. Using the previously mentioned ‘Hedrocel, Implex Corp.’ tantalum cup, we compare our results to the published data comparing ceramic, Co-Cr, and titanium acetabular cups. We also compare the results to the published data on our tantalum cup with similar modulus as PMMA cement.

**Results:**

In general, the FEA analysis showed the porous tantalum material to produce an acetabular bony stress pattern intermediate to PMMA bone cement and the two metal-backed cases; and most similar to PMMA cement. Based on previous work, the loading of bone by the porous tantalum and bone cement can be considered more physiologically normal than the titanium and Co-Cr metal backed cases [6]. In 1984, an elastic properties evaluation of bone showed the compressive modulus of acetabulum subchondral bone to be 1.4 GPa [5]. Also for reference purposes, the elastic modulus values for cancellous bone and cortical bone range from 0.1 to 17 GPa. This study, and the modulus of elasticity values of bone suggest that a more physiologically normal bony stress pattern can be achieved by a porous fixation material that possesses a modulus of elasticity similar to that of bone, thereby minimizing the materials properties discontinuity at the implant-bone interface.

**Discussion:**

The 3-D FEA model indicated that a low stiffness, porous tantalum backed acetabular cup will produce an acetabular stress pattern in between that of PMMA cement and traditional metal backed designs, and most similar to the PMMA cement case. Based on these results and the clinical literature, the combination of a low stiffness porous tantalum and direct compression molded polyethylene should produce more physiologically normal stress in the acetabulum and eliminate a potential source of polyethylene debris [6].

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**Note:** Hedrocel, patent #5,282,861, Hedrocel Cup, patents pending.

**References:**

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**FINITE ELEMENT ANALYSIS OF PERI-ACETABULAR STRESS OF CEMENTED, METAL-BACKED, AND POROUS TANTALUM BACKED ACETABULAR COMPONENTS**

Figure 1: Scanning electron micrograph of the porous tantalum, and a cross-section of the porous tantalum-direct compression molded acetabular cup.

**Figure 2:** Frontal view of 3-D mesh for 28mm THA. UHMWPE, 8.2 mm thick, inner & outer backings are 1.8 & 2.0 mm thick.

**Table 1:** Peak von-Mises stresses for heel-strike loading.

<table>
<thead>
<tr>
<th>Stiffness (GPa)</th>
<th>Material</th>
<th>Cortical Bone</th>
<th>Trabecular Bone</th>
<th>Material Backing Outer Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GPa - PMMA cement</td>
<td>4.13</td>
<td>0.76</td>
<td>1.39</td>
<td></td>
</tr>
<tr>
<td>3 GPa - porous material</td>
<td>4.07</td>
<td>0.69</td>
<td>1.57</td>
<td></td>
</tr>
<tr>
<td>110 GPa - titanium</td>
<td>3.40</td>
<td>0.33</td>
<td>6.68</td>
<td></td>
</tr>
</tbody>
</table>

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