Impingement Wear Testing of a Dual Mobility Hip

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INTRODUCTION:
Dual mobility hip designs have been developed to increase stability and decrease the incidence of dislocation in THA. The free nature of the polyethylene insert allows femoral-neck/acetabular-insert impingement with minimal resistance by allowing the insert to displace upon contact. This movement combined with the large outer diameter of the polyethylene insert helps increase stability in the dual mobility hip [1].

In the case where the outer bearing may encounter resistance to movement, the effect of femoral-neck/acetabular-insert impingement will be different than when the insert is free to move. This mode of impingement should increase creep, deformation and wear at the rim of the polyethylene insert. Therefore, we set out to evaluate the wear performance of a dual mobility hip under two different impingement conditions: 1) induced impingement of the acetabular insert against the femoral neck when the insert is free to move, and 2) acetabular-insert/femoral-neck impingement when the insert becomes immobilized at the outer articulation.

METHODS:
The dual mobility hip (ADM, Stryker Orthopaedics, Mahwah, NJ) incorporated a CoCr femoral head (28mm diameter) into a polyethylene insert (28mm inner diameter & 48mm outer diameter) that articulates against a metal shell (48mm inner diameter). The polyethylene for all inserts was sequentially crosslinked and annealed [2] (X3, Stryker Orthopaedics, Mahwah, NJ).

A hip joint simulator (MTS, Eden Prairie, MN) was used for testing with the cups positioned anatomically (superior). Testing was run at 1 Hz with cyclic Paul curve physiologic loading applied axially, at a maximum of 2450 N [3]. Samples were lubricated using Alpha Calf Fraction serum (Hyclone Labs, Logan UT) diluted to 50% with a pH-balanced 20-mMole solution of deionized water and EDTA (protein level < 20 g/l). To create the impingement conditions when the acetabular insert is unconstrained (mobile impingement), the femoral neck was positioned at 17° and the acetabular component was placed at 45° of inclination. At these angles, impingement occurs at either the femoral neck when the insert is free to move, and 2) acetabular-insert/femoral-neck impingement when the insert becomes immobilized at the outer articulation.

RESULTS:

Wear rates after 2.5 million cycles are reported in figure 1 and table 1. During visual observation of the test samples, both impingement testing groups behaved as expected in that the mobile impingement samples impinged during the first cycle of testing and the fixed impingement samples had predictable impingement at the same location every cycle of testing.

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Mobile Impingement</th>
<th>Fixed Impingement</th>
<th>Dual Mobility Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wear Rate (mm³/mc)</td>
<td>0.97 ± 0.28</td>
<td>2.62 ± 0.79</td>
<td>0.91 ± 0.69</td>
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</tbody>
</table>

DISCUSSION:
The wear rate for the mobile impingement testing group was 0.97±0.28mm³/mc, which is nearly identical to the dual mobility control at 0.91±0.69mm³/mc. This result indicates the impingement achieved by these samples did not significantly increase wear rate. Although these wear rates were similar, the mobile impingement and the control group produced different wear scars. Mobile impingement samples produced an annular wear scar on the inner articulating surface of the polyethylene insert, while the wear scar of the control samples were located throughout the entire inner articulation.

The mobile impingement testing group was designed to replicate an instance where the dual mobility hip would run in a near impingement/intermittent impingement condition. In these instances, the dual mobility hip behaves as intended and displaces the polyethylene insert upon contact with the femoral neck. This testing strongly suggests wear rates would not differ much from conditions where impingement does not occur.

The fixed impingement samples wore at a higher rate than both the mobile impingement and dual mobility control group. Upon femoral-neck/acetabular-insert impingement the insert no longer had the ability to move freely as it encountered resistance to movement. This resulted in wear and deformation at the point of impingement. Thus the amount of additional wear generated by this impingement model is directly related to the force applied at the rim of the insert, the geometry of the femoral neck, polyethylene rim design, and method of restricting movement of the insert. Additional wear is also generated by sliding and through translation of the load path upon impingement of the rim.

The sequentially irradiated and annealed polyethylene has an effect on the results of this testing. Previous impingement testing using the same model on a single articulating bearing utilizing a conventional polyethylene produced a 90% higher wear than sequentially annealed and irradiated polyethylene [5]. The wear rates for both mobile and fixed impingement conditions are in the range of previously tested single articulation sequentially irradiated and annealed polyethylene [6]. Hence, under these conditions this polyethylene will still provide the same benefit of reducing the total volume of polyethylene particles released within and around the prosthesis when compared to conventional polyethylene.

SIGNIFICANCE:
The effects of impingement on the wear mechanism in THA are not widely understood to date. We will continue to gain further insight on the wear mechanism of dual mobility bearings by using these wear simulator impingement models.

REFERENCES