WEAR OF POLYETHYLENE AGAINST METAL-CERAMIC COMPOSITE FEMORAL COMPONENT: EFFECT OF AGGRESSIVE KINEMATIC CONDITIONS

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INTRODUCTION
Zirconium is a metal with excellent biocompatibility which when oxidized is converted to the ceramic, zirconia. Composite-bearing materials have recently become available consisting of a metal zirconium core with an oxidized zirconia surface. The metal-ceramic composite has the wear characteristics of a ceramic bearing but with a much lower propensity for fracture. This dual advantage makes it an attractive alternative as a bearing surface for total knee arthroplasty. Wear properties of this material in total knee arthroplasty (TKA) are under investigation and have been encouraging under relatively benign kinematics and loading conditions. This study was designed to determine if the advantages of low wear were also seen under aggressive kinematics and loading conditions.

METHODS
Three oxidized zirconium femoral components (OxZirc) and three femoral components of identical geometry made of conventional cobalt-chrome-molybdenum alloy (CoCr) were mounted in a six-station knee wear simulator (AMTI, Watertown, MA). These components were tested against six tibial non-crosslinked polyethylene inserts (sterilized by ethylene oxide) in modular tibial base-plates. Lubricant used was 90% bovine serum supplemented with EDTA and sodium azide. Knee components were sequentially subjected to the following kinematic conditions:
1. Five million cycles of normal gait based on modified ISO recommendations (Benign).
2. Three million cycles of increased tibial rotation (HiRot).
3. Three million cycles of increased tibial rotation with a varus moment of 68 N-m (HiVarus).
The last two conditions were to simulate an athletically active patient with non-optimal component alignment.

Gravimetric wear was measured by weighing the polyethylene inserts at 500,000 cycle intervals. Soaked controls were used to correct for weight gain due to fluid absorption. Volumetric wear was measured by surface mapping the inserts using a laser (Keyence Corp, Los Angeles, CA) before wear testing and at the completion of each of the above wear test conditions. Volumetric wear was converted to weight loss by multiplying with the nominal density of UHMWPE.

The Mann-Whitney nonparametric test was used to test for statistically significant differences in wear between inserts worn against CoCr and OxZirc femoral components.

RESULTS
OxZirc femoral components reduced polyethylene wear by 42% under Benign conditions relative to CoCr components (Table 1). A similar reduction in polyethylene wear (40% to 60%) was also found in the inserts worn against OxZirc femoral components when tested under higher dynamic rotation and increased varus moment. Volumetric wear overestimated wear by a mean of 12% relative to gravimetric wear measurements.

DISCUSSION
Tibial polyethylene wear was substantially reduced through the use of oxidized zirconium femoral components under both benign and aggressive testing conditions. Increased tibial rotation increased wear in both CoCr and OxZirc groups. However, the OxZirc group maintained their advantage (approximately 40% reduction in wear). Under conditions of increased varus moment, wear in the CoCr group was increased by 29%, without any significant increase in wear in the OxZirc group.

Table 1: Mean (SD) Wear Rates per Million Cycles

<table>
<thead>
<tr>
<th>Condition</th>
<th>CoCr</th>
<th>OxZirc</th>
<th>P value</th>
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<tbody>
<tr>
<td>Benign</td>
<td>19.99 (2.07)</td>
<td>11.64 (1.26)</td>
<td>p &lt; 0.05</td>
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<tr>
<td>HiRot</td>
<td>27.8 (5.10)</td>
<td>16.12 (4.12)</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>HiVarus</td>
<td>25.76 (6.02)</td>
<td>10.15 (5.12)</td>
<td>p &lt; 0.05</td>
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</tbody>
</table>

The distribution and morphology of the wear scars are important factors in knee wear. Surface mapping is an effective tool in such measurements. Volumetric wear calculated from surface mapping consistently overestimated the gravimetric measurement by 7%. However, the relative wear measurements between groups were consistent with gravimetric measurements. This could, in part, be attributed to creep, which does not affect gravimetric measurements. On the other hand, gravimetric wear is sensitive to fluid absorption. In this study, soaked controls were used to correct for fluid gain. However, it has been shown that dynamic loading can increase fluid absorption. Since the inserts were all manufactured from the same material, relative differences in fluid absorption due to dynamic loading are probably small. Nevertheless, combining gravimetric and volumetric measurements adds to the validity of the wear data.

Alternative bearing surfaces such as ceramic-on-ceramic, metal-on-metal, and highly crosslinked polyethylene have been shown to be successful in reducing wear rates in hip arthroplasty. In the knee, these bearings may have an unacceptably high failure rate. Ceramic-on-ceramic bearings can fracture under impact or edge loading. Metal-on-metal surfaces perform best within a narrow threshold of tolerance between mating articulating surfaces and would be highly sensitive to the relatively lower conformity in knee design. Finally, there is an increased potential for damage and fatigue failure in highly crosslinked polyethylene. “Metal-ceramic composites” may emerge as the most promising alternative bearing surfaces for TKA prostheses.

**Figure 1:** Left: Photograph of insert (CoCr group) showing wear scars on both condyles. Right: Surface map of the same insert showing the depth of each wear scar. Darker areas are deeper.

**Figure 2:** Volumetric wear rate. Graph of volume loss measured by surface mapping inserts before and after each wear testing condition. Volumetric wear rate showed very similar relative reduction in wear rates in the OxZirc group.