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

*Ezzet K A; *Hermida J C; *Steklov N; *Colwell Jr C W; +D’Lima D D
+*Scripps Center for Orthopaedic Research & Education, Scripps Clinic, La Jolla, CA
ddlima@scripps.edu

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 (TKA). Wear properties of this material in TKA are under investigation and have been encouraging under relatively benign kinematics and loading conditions.1 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. The knee components were subjected to five million gait cycles based on ISO recommendations with the following modifications. The mediolateral distribution of the vertical tibial load was increased to 75:25 (from the ISO recommended 60:40 distribution) to represent the distribution of load due to the mechanical axis of the knee passing more medially through the joint line. Further, the magnitude of tibial axial rotation was increased to 20°. These conditions were chosen to simulate an athletically active patient with less than optimal knee 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 displacement sensor. Volumetric wear was converted to weight loss by multiplying with the nominal density of UHMWPE.

The nonparametric Wilcoxon Rank Sum 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 55% relative to CoCr components under high rotation and increased medial loading (Table 1). Volumetric wear was measured between 2.5 million cycles and 5 million cycles to reduce the effect of creep which largely occurs during the first million cycles. Volumetric wear was slightly lower than gravimetric wear (Fig 2).

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

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<tr>
<th>CoCr</th>
<th>OxZirc</th>
<th>p value</th>
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<td>38.55 (1.27)</td>
<td>17.20 (1.21)</td>
<td>p &lt; 0.05</td>
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DISCUSSION
We have previously shown that tibial polyethylene wear was substantially reduced when oxidized zirconium femoral components were tested under relatively benign testing conditions. Compared to the previous study, increased tibial rotation together with increased medial loading, almost doubled the wear in the cobalt-chrome (from 20–39 mg/million cycles) groups. The wear rate also increased in the oxidized zirconium group, although by a smaller percentage (from 12–17 mg/million cycles). The oxidized zirconium group therefore maintained their advantage of lower wear even under aggressive testing conditions (approximately 55% reduction in wear).

The distribution and morphology of the wear scars are important factors in knee wear. Volumetric wear calculated from surface mapping slightly underestimated the gravimetric measurement in both groups. The volumetric measurements were made between the 2.5 million and the 5 million cycle time points. Polyethylene inserts creep very little after 2.5 million cycles. Hence, volumetric change after 2.5 million cycles could be almost entirely attributed to wear. On the other hand, only the articular surface was mapped. Any backside wear was not accounted for in the volumetric measurements, which may explain the slight underestimation relative to gravimetric wear. Nevertheless, the oxidized zirconium groups wore significantly less based on either gravimetric or volumetric measurements.

Alternative bearing surfaces such as ceramic-on-ceramic, metal-on-metal, and highly crosslinked polyethylenes 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 articular 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 promising alternative bearing surfaces for TKA prostheses.


Figure 1. Top: Photograph of insert (CoCr group) showing wear scars on both condyles. Bottom: Surface map of the same insert showing the depth of each wear scar.

Figure 2: Comparison between gravimetric and volumetric measurements of wear rate. Volumetric wear showed very similar relative reduction in wear rates in the OxZirc group.