Effect of Simulated Intraoperative Damage of Oxidized Zirconium Knee Femoral Components on Polyethylene Wear

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INTRODUCTION
Surface analysis of retrieved knee femoral components has demonstrated damage of the articular surface on the posterior condyles (Figure 1). During Total Knee Replacement surgery at the time when the polyethylene component is inserted into the tibial tray, surface damage of the femoral component was identified due to unintended contact between the femoral component and posterior aspect of the tibial tray at high flexion.
The purpose of this study was to evaluate the effect of surface damage of the oxidized zirconium (OXINIUM™ or OxZr) femoral component on the wear performance of polyethylene and compare it to the wear performance of polyethylene against pristine CoCr femoral components.

MATERIALS AND METHODS
Three LEGION™ cruciate retaining (CR) CoCr femoral components were tested in pristine condition, whereas three LEGION™ CR OxZr femorals were surface damaged to simulate the damage observed on retrieved OxZr femoral components. Surface analysis of retrieved OxZr femoral components showed damage due to contact with the tibial tray on the posterior condyles in the flexion range of 73-112°. This damage location is beyond typical flexion range of normal gait. None of the retrievals were revised for wear.

To simulate a worst case scenario for gait, the damage was created in the flexion range of 45° to 60°. To simulate the roughness parameters quantified on OxZr retrievals, dents were created on the medial and lateral condyles of OxZr femoral components by dropping a weight of 2 lb (2” diameter) from a height of 3 inches so that the edge of the weight came into contact at the peak of medial-lateral curvature of the condyle. After creating the dents, the femoral component was fixed in a biaxial test frame at 30° of flexion and the Ti-6Al-4V tibial tray was fixed at 15° of flexion. The posterior edge of the tray was brought into contact with the femoral component near the anterior dent. The femoral component was dragged in the anterior direction with the load applied so that the tibial tray edge gouged through the dents creating the surface damage. An intentionally damaged femoral component is shown in Figure 1. Surface roughness of the damaged area was measured using a contact profilometer and compared to the retrievals. Least square curve fit and 0.25 mm cut-off wavelength were used for calculating roughness parameters.
The tibial inserts were manufactured from compression-molded GUR 1020 UHMWPE (CPE) and sterilized by EtO. The wear test was conducted on an AMTI knee simulator under displacement control at 1 Hz frequency for approximately 5 Mcycle.

RESULTS
The roughness parameters of the damaged areas of the retrieved and intentionally damaged OxZr femorals were similar (Table 1). The mean Rsk value of the damaged femorals was slightly negative compared to the retrievals, which have slightly positive Rsk with higher standard deviation.
The predominant wear feature on the tibial inserts articulating against pristine CoCr femoral components was burnishing. There were no signs of fatigue wear or delamination. The mean volumetric wear rate (± SD) of the CPE inserts articulating against CoCr femorals was 24.7±5.7 mm3/Mcycle (Figure 3). The tibial inserts articulating against damaged OxZr femoral components showed burnishing in majority of the wear area. Scratching due to articulation with the damaged part of the femorals was noticed in the posterior part of the articular area. The tibial inserts displayed biphasic wear trend (Figure 3). Up to 1.2 Mcycle, the mean volumetric wear rate of the damaged OxZr/CPE couples (17.0±3.2 mm3/Mcycle) was significantly less than the pristine CoCr/CPE couples (26.4±2.2 mm3/Mcycle) (p=0.01). Beyond 1.2 Mcycle, the wear rate reduced significantly to 10.2±0.1 mm3/Mcycle (p=0.02) and is comparable to the wear rates of pristine OxZr/CPE couples published in literature. Overall, the mean volumetric wear rate of the damaged OxZr/CPE couples (10.8±0.2 mm3/Mcycle) was significantly lower than pristine CoCr/CPE couples (p=0.01). The wear rate of damaged OxZr/CPE couples is also lower than the published wear rates of gamma-inert sterilized UHMWPE tibial inserts articulating against CoCr femorals (14-23 mm3/Mcycle).

DISCUSSION
This study demonstrated that OxZr femoral components under surface damaged condition have better wear performance than pristine CoCr femoral components. However, care should be taken to avoid contact between the femoral component and tibial tray during surgery.

Table 1: Surface roughness parameters of the damaged areas (in µm).

<table>
<thead>
<tr>
<th>Femoral</th>
<th>Ra</th>
<th>Rpm</th>
<th>Rp</th>
<th>Rv</th>
<th>Rsk</th>
<th>Rpk</th>
<th>Rvk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieved³</td>
<td>0.6 ± 0.4</td>
<td>1.8 ± 1.1</td>
<td>4.3 ± 2.9</td>
<td>6.2 ± 1.4</td>
<td>0.2 ± 0.1</td>
<td>2.0 ± 1.2</td>
<td>1.9 ± 1.3</td>
</tr>
<tr>
<td>Damaged</td>
<td>0.7 ± 0.1</td>
<td>1.8 ± 0.3</td>
<td>4.7 ± 0.3</td>
<td>5.1 ± 0.3</td>
<td>-0.1 ± 0.2</td>
<td>1.8 ± 0.3</td>
<td>2.0 ± 0.2</td>
</tr>
</tbody>
</table>

REFERENCES

SIGNIFICANCE
In a retrieval study, surface damage of the knee femoral components was identified at high flexion due to unintended contact with the posterior aspect of the tibial tray when the polyethylene components were about to be inserted into the tibial tray. This study demonstrated that OxZr femoral components even under surface damaged condition have maintained better wear performance than pristine CoCr femoral components.