**Effect of Femoral Head Surface Roughness on Acetabular Liner Polyethylene Wear - A Postmortem Retrieval Study**

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**Disclosures:**

**Introduction:** Achieving and maintaining a smooth surface finish on the femoral head in hip prosthetic bearings have long been considered important for reducing the wear of the ultrahigh molecular weight polyethylene (UHMWPE) acetabular cup. This notion is based on laboratory tests showing that the wear rate of UHMWPE can increase more than linearly with the counterface surface roughness [1]. However, there is a paucity of data on the effect of head surface roughness in vivo, and most laboratory studies applied artificial head roughening procedures of uncertain in vivo relevance. There is also a question as to whether the commonly used surface parameter Ra is the most suitable to assess this effect. In this study we examined the effect of head surface roughness on the wear of a set of acetabular liners, which were well functioning at the time of retrieval. We hypothesized that (1) that the annualized wear of the polyethylene liner will increase significantly with head surface roughness, and (2) the bearing ratio Rk will provide a better correlation to cup liner wear than Ra.

**Methods:** In an IRB approved postmortem retrieval study, twelve Harris-Galante II (HG II) (Zimmer Inc, Warsaw, IN) and eleven Trilogy (Zimmer Inc) retrieved acetabular liners and their matching femoral head were evaluated for liner wear and head surface roughness. All the couples entailed 28 mm diameter Co-Cr-Mo heads articulating against UHMWPE. All the HG II liners were fabricated from ram-extruded GUR 4150 UHMWPE and were gamma-sterilized in air, as were seven of the Trilogy liners, the balance having been gamma-sterilized in nitrogen. There was also a switch to slab-compression molded GUR 1050 UHMWPE that affected three Trilogy liners. Liner wear was determined using a 3D coordinate measuring machine (CMM) (SmartScope Flash, Optical Gaging Products, Rochester, New York) by a method previously reported [2]. The femoral head surface roughness was determined using a NewView 6300 scanning white light interferometry microscope (Zygo Corporation, Middlefield, Connecticut) using a 20X Mirau objective. The heads were probed in five spots centered about the pole. Two surface roughness parameters are reported here: Ra (nm), the arithmetic average, and Rk (nm) the core height in the bearing ratio curve (Abbott Firestone Curve). The effect of surface roughness on cup liner wear was analyzed using multivariate general linear regression to separate the effect of roughness from the possible effect of other factors such as cup type, sex, and liner shelf time, and correct or “normalize” for them. The wear rates were log-transformed for variance stabilization. The statistical analyses were performed in Excel (Microsoft Corp, Redmond, CA, USA) and IBM SPSS Statistics for Windows (IBM Corp. in Armonk, NY, USA). All reported p values are two-sided.

**Results:** The mean wear rate of the liners at 31.4 mm³/yr (Table 1) was well within the range of wear rates reported in the literature for polyethylene liners articulating against metal heads [3]. The mean Ra surface roughness of the Co-Cr-Mo heads and even the maximum value (Table 2), as determined in the polar area, was within the specification of 50 nm maximum specified by ISO 7206-2 Standard for new heads. The multivariate regression model revealed a positive linear correlation of the log of the liner wear rate with the surface roughness parameters Ra and Rk, with slopes of 0.019 per nm (Fig. 1) and 0.0036 per nm (Fig. 2). Thus, the wear rate W was found to be related to the surface roughness parameter R (Ra or Rk) by the equation \( W/Q = 10^{kR} \), where k is the slope and Q is a normalization term that depends on the other factors influencing the system, such as the sex of the patient. The statistical significance of the correlation was stronger for Rk (p = 0.004) than for Ra (p = 0.028). Fig. 1. The normalized wear rate versus surface roughness Ra.

**Discussion:** As expected, the acetabular liner wear rate was found to increase with increased femoral head surface roughness. In support of our hypothesis and of particular interest is that Rk, the bearing ratio core height parameter, yielded a more convincing correlation to the wear rate than Ra, the mean arithmetic average surface roughness, which is typically used. This finding is consistent with the concept that Rk represents the roughness of the core region that bears the load after run-in of the bearing surfaces. This difference between Rk and Ra appeared even though the two parameters were highly correlated (r-squared = 0.965, p < 0.0001). It is also of interest that the strong correlation of wear to surface roughness was found for smooth heads (Ra ≤ 43 nm). Based on the model, an increase in Ra from 25 to 50 nm will result in a 3-fold increase in the wear rate. By comparison, a study of Charnley cups retrieved at revision [4] and another conducted in a hip simulator [5] found the polyethylene wear rate to be approximately proportional to the square root of the head surface Ra, so that an increase in Ra from 25 to 50 nm will result in a 1.4-fold increase in the wear rate. In conclusion, this study of well-functioning hip liners suggests that (1) surface roughness is a significant factor for in vivo liner wear even for smooth heads; and (2) the bearing ratio parameter Rk may be more appropriate than Ra to assess the effect head surface roughness on clinical wear.
Significance: This study sheds light on the effect of head surface roughness on well functioning liners, as opposed to liners retrieved at revision. In addition, the study presents evidence suggesting that the bearing ratio parameter Rk may be superior to the commonly used parameter Ra for evaluating the metal counterface.

Acknowledgments:

References:

Table 1. Descriptive statistics for the wear rate and surface roughness parameters Ra and Rk.

<table>
<thead>
<tr>
<th></th>
<th>Wear Rate(mm³/yr)</th>
<th>Ra(nm)</th>
<th>Rk(nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Mean</td>
<td>31.4</td>
<td>17.7</td>
<td>47.8</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>19.8</td>
<td>9.6</td>
<td>27.2</td>
</tr>
<tr>
<td>Minimum</td>
<td>6.2</td>
<td>3.8</td>
<td>11.6</td>
</tr>
<tr>
<td>Maximum</td>
<td>76.4</td>
<td>43</td>
<td>120</td>
</tr>
</tbody>
</table>
Normalized Wear Rate (mm³/yr) vs. Ra (nm)

\[ y = 0.0192x + 1.0683 \]
\[ R^2 = 0.4627 \]

Normalized Wear Rate (mm³/yr) vs. Rk (nm)

\[ y = 0.0081x + 1.0219 \]
\[ R^2 = 0.6004 \]

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