Surface Characteristics of Retrieved Cobalt Chromium Femoral Heads and the Influence of Adverse Articular Events

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Introduction
Wear debris, generated at the articulating interface of total hip replacements, can trigger a series of biological reactions leading to osteolysis, a condition resulting in long term resorption of the bone around the implant [1]. Studies have shown that polyethylene wear [2] and osteolysis [3] are related to the surface characteristics of the femoral head. Further, it has been reported that surface roughness did not correlate with time in vivo for cobalt chromium (CoCr) femoral heads with/without ion implantation [4]. The goal of this study was to further investigate changes in surface roughness parameters with in vivo duration followed by a comparison to devices having undergone extreme duress (e.g. damage due to dislocation).

Methods
Seventeen retrieved CoCr femoral heads were selected from an IRB-approved database based on the following criteria: (a) design (Smith & Nephew / Richards); (b) head size (28 mm); (c) stem type (uncemented Synergy); (d) articulation (metal-on-polyethylene); and (e) any reason for retrieval except for dislocation or wear-through (fracture of bone, infection, instability, osteolysis, pain). Eight of these retrievals had in vivo durations between 3-5 years while nine had in vivo durations greater than 10 years. These femoral heads were evaluated for surface roughness. Roughness parameters included roughness ($R_{a}$), ten-point height ($R_{1}$), skewness ($R_{sk}$), and kurtosis ($R_{ku}$). Five measurements were taken per head: one at the pole and four around the circumference at 45 degrees inclination. The average, minimum, and maximum value of the roughness parameters were reported. Linear regression models were used when appropriate. Results were compared to six cobalt chromium femoral heads (metal-on-polyethylene systems) based on the following categories: (a) wear through of polyethylene; (b) embedded heads within the acetabular polyethylene; (c) recurrent dislocation; and (d) greater than 20 years in vivo duration with reason for retrieval unrelated to damage to the head.

Results
For the baseline group, measurements showed no correlation between average roughness parameters and in vivo duration ($R_{a} = 0.042$, $R_{1} = 0.874$; $R_{sk} = 0.174$, $R_{ku} = 0.503$; $R_{sk} = 0.076$, $R_{ku} = 0.773$; $R_{sk} = 0.422$, $R_{ku} = 0.092$; Figures 1 and 2). Overall, average roughness ($R_{a}$) and ten-point height ($R_{1}$) of devices subjected to extreme mechanical duress were higher than that of the baseline group (Figure 3). Specifically, $R_{a}$ ranged from 2.7 times to 7.5 times that of the baseline group, and $R_{1}$ ranged from 1.8 times to 21.6 times that of the baseline group.

Discussion
The ISO 7206-2 standard specifies finishing femoral heads to a surface roughness, $R_{a} \leq 0.05 \mu m$. The values measured herein for all locations on all devices in the baseline group achieved this specification. McGory and colleagues originally reported that femoral heads tend to not change roughness over time in vivo [4]. Likewise, the present study employed a controlled group of metal-on-polyethylene heads to demonstrate that, on average, no surface parameter changes with in vivo duration. These results suggest that the bearings in this study are performing as expected, with little to no change in surface roughness. When bearings that have seen adverse articular conditions (e.g. dislocation and articulation on non-stable bearings) are measured, values well outside of the ISO standard are measured. This indicates that the adverse condition likely created a local change in roughness.

It has been well-characterized that a rougher femoral head will increase the wear rate of a metal on polyethylene bearing [2,5]. The baseline group of devices thus would not be expected to have an increased articular wear rate secondary to head roughness changes. However, after an extreme articular event, the present results suggest that higher wear rates of the articular surface can be expected. This was not measured in the present study and will be the subject of a future investigation.

Significance
This study supports previous findings showing no correlation between surface roughness and in vivo duration. Furthermore, our results suggest that higher wear rates of the articular surface are likely dependent on adverse articular events.

References

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![Graphs](Image)