Roughness of Retrieved Cobalt-Chromium Femoral Components: Influence of Age in vivo and Bone Cement
Marcel E. Roy¹, Arun M. Sebastian², and Leo A. Whiteside¹,³
¹ Missouri Bone & Joint Research Foundation, St. Louis, MO; ² Biomedical Engineering, Duke University, Durham, NC; ³ Signal Medical Corp., St. Louis, MO

Introduction: Cobalt-chromium alloy (CoCr) is widely used as a bearing surface in joint replacement, but is subject to corrosion and roughening in vivo [1,2]. The purpose of this study was to determine whether the roughness of cast cobalt-chromium alloy (ASTM F75) femoral components retrieved from revision total knee replacement increased with age in vivo. We hypothesized that the roughness of CoCr retrievals would increase with age in vivo, and femoral components affixed with methyl methacrylate (bone cement) would roughen more rapidly than cementless (affixed via bone ingrowth) components.

Materials and Methods: Femoral components were retrieved from revision total knee arthroplasty, disinfected with hydrogen peroxide, and thoroughly rinsed. Retrievals were included in this study if they were manufactured by Smith & Nephew and had been implanted more than four months, for n = 31 specimens (Table 1), including nine specimens examined previously [3]. Reasons for revision included loosening (n = 13), infection (n = 10), bone fracture (n = 5), and instability (n = 3). Three never-implanted CoCr femoral components (Genesis II, Smith & Nephew) provided "baseline" measurements.

The condyles of each specimen were scanned in flexion by optical profilometry at a magnification of 10x (632 µm x 475 µm scan area, six scans/specimen). After subtracting macroscopic curvature, roughness statistics (average roughness Sa, skewness (polarity) Ssk, and bearing ratio parameters Sk, Spk, and Svk) were calculated and correlated to age in vivo, with p < 0.05 for significance. Slopes of regression lines were compared by GraphPad Prism, and means of groups were compared by t-tests.

Table 1. Summary of the 31 retrievals examined.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Cementless</th>
<th>Cemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designs (n)</td>
<td>Profix (11), Genesis (3)</td>
<td>Genesis (12), Genesis II (4), Profix (1)</td>
</tr>
<tr>
<td>Age in vivo</td>
<td>Range 0.77-9.16 years, Mean 3.17 years</td>
<td>Range 0.45-12.3 years, Mean 4.49 years</td>
</tr>
</tbody>
</table>

Results and Discussion: The surface topography of all specimens was dominated by carbides, with retrievals also exhibiting scratches (Figure 1). Roughness increased with age in vivo, but the regression lines were not significant and their slopes were not significantly different (Figure 2; p = 0.277). The data were similar to previous studies of short-term retrievals [3-6], but the lack of significant roughening up to 12 years in vivo was unexpected.

After pooling all retrieval data, there was no significant correlation between roughness and age in vivo (p = 0.156). Carbides exerted more influence on the polarity of the surface (positive skewness) than small scratches formed by either extracted carbides or other third bodies, such as bone chips or bone cement particles. Comparing each group, "baseline" roughness statistics were higher than the cemented and cementless retrievals, but only the baseline "core roughness" Ssk was significantly higher (p < 0.05; Table 2). The lower Ssk values in both cemented and cementless retrievals suggests that normal articulation in vivo, coupled with the corrosive environment inside the knee, serves to slowly polish the surface, extracting embedded carbides but also exposing new carbides [1].

Conclusions: This study did not find a significant increase in roughness with age in vivo, regardless of whether cemented or cementless femoral components were used. The surface topography was characterized by positive features (carbides) rather than scratches. Future work will include additional measurements on the same specimens to evaluate patellofemoral contact areas.

Acknowledgements: The authors thank Abraham Salehi, Ph.D (Smith & Nephew Orthopaedics Inc., Memphis TN) for loaning the three never-implanted specimens.

Roughness of Retrieved Cobalt-Chromium Total Knee Femoral Components: Influence of Age In Vivo and Bone Cement

M.E. Roy1, A.M. Sebastian2, L.A. Whiteside1,3
1Missouri Bone and Joint Research Foundation, St. Louis, MO; 2Biomedical Engineering, Duke University, Durham, NC; 3Signal Medical Corp., St. Louis, MO

Introduction

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- The purpose of this study was to determine whether the roughness of cast cobalt-chromium alloy (ASTM F75) femoral components retrieved from revision total knee replacement increased with age in vivo.
- The authors hypothesized that roughness of CoCr retrievals would increase with age in vivo, and femoral components affixed with methyl methacrylate (bone cement) would roughen more rapidly than cementless (affixed via bone ingrowth) components.

Materials and Methods

- Femoral components were retrieved from revision total knee arthroplasty, disinfected with hydrogen peroxide, ultrasonically cleaned, and thoroughly rinsed.
- Retrievals were included in this study if they were manufactured by Smith & Nephew and had been implanted more than four months, for n = 31 specimens, including nine specimens examined previously.

Results and Discussion

Figure 1. Typical retrieval topography of cemented (left, 12.3 years) and cementless (right, 9.2 years) femoral components. The surface topography of all specimens was characterized by carbides, with retrievals also exhibiting scratches.

Table 1. Summary of the 31 retrievals examined.

<table>
<thead>
<tr>
<th>Designs (n)</th>
<th>Age in vivo (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
</tr>
<tr>
<td>Cementless:</td>
<td>0.77-9.16</td>
</tr>
<tr>
<td>Genesis (3)</td>
<td></td>
</tr>
<tr>
<td>Cemented:</td>
<td>0.45-12.3</td>
</tr>
<tr>
<td>Genesis (4), Profix (1)</td>
<td></td>
</tr>
</tbody>
</table>

- Reasons for revision included aseptic loosening (n = 13), infection (n = 10), bone fracture (n = 5), and instability (3).
- Three never-implanted CoCr femoral components (Genesis II, Smith & Nephew) provided “baseline” measurements.
- The condyles of each specimen were scanned in flexion by optical profilometry at a magnification of 10x (632 µm x 475 µm scan area, six scans/specimen).

- After subtracting macroscopic curvature, roughness statistics were calculated:
  - average roughness Sa
  - root-mean-square roughness Sq
  - skewness (polarity) Ssk
  - bearing ratio parameters Sk, Spk, and Svk
- Roughness statistics were correlated to age in vivo, with p < 0.05 for significance.
- Slopes of regression lines were compared by GraphPad Prism, and means of groups were compared by t-tests.

Table 2. Roughness statistics (mean ± S.D.) by group.

<table>
<thead>
<tr>
<th>Roughness statistic</th>
<th>Baseline (n = 3)</th>
<th>Cementless (n = 14)</th>
<th>Cemented (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sa (nm)</td>
<td>62.4 ± 6.0</td>
<td>52.5 ± 16</td>
<td>53.8 ± 13</td>
</tr>
<tr>
<td>Sq (nm)</td>
<td>82.4 ± 9.2</td>
<td>69.3 ± 21</td>
<td>70.9 ± 17</td>
</tr>
<tr>
<td>Ssk</td>
<td>0.520 ± 0.12</td>
<td>0.526 ± 0.48</td>
<td>0.434 ± 0.38</td>
</tr>
<tr>
<td>Sk (nm)</td>
<td>88.0 ± 5.4</td>
<td>69.6 ± 23</td>
<td>73.4 ± 19</td>
</tr>
<tr>
<td>Spk (nm)</td>
<td>65.1 ± 9.1</td>
<td>53.9 ± 13</td>
<td>52.8 ± 12</td>
</tr>
<tr>
<td>Svsk (nm)</td>
<td>38.2 ± 3.9</td>
<td>32.2 ± 11</td>
<td>32.1 ± 8.6</td>
</tr>
</tbody>
</table>

- Roughness increased with age in vivo, but the regression lines were not significant and their slopes were not significantly different (p = 0.277).
- The data were similar to previous studies of short-term retrievals, but the lack of significant roughening up to 12 years in vivo was unexpected.
- After pooling all retrieval data, there was no significant correlation between roughness and age in vivo (p = 0.156).
- Carbides exerted more influence on the polarity of the surface (positive skewness) than small scratches formed by either extracted carbides or other third bodies, such as bone chips or bone cement particles.

Conclusions

- This study did not find a significant increase in roughness with age in vivo, regardless of whether cemented or cementless femoral components were used.
- On average, roughness decreased after implantation.
- The surface topography was characterized by positive features (carbides) rather than scratches.

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