Corrosion and Fretting and Damage at the Head-Neck Taper is Reduced with Ceramic Femoral Heads: a Retrieval Study

**Introduction:** Modular head-neck total hip arthroplasty (THA) offers several benefits for orthopaedic surgeons in certain joints, including intraoperative flexibility and the ability to change the head at revision surgery [1]. However, modularity at the head-neck taper, especially the use of metallic heads and stems, can lead to fretting and corrosion at the taper junction, leading to metal ions and debris released into the joint [2]. Adverse local tissue reactions from this taper junction have reportedly been reported [3]. There are comparatively few reports about taper corrosion with ceramic heads on metallic stems compared to cobalt-chromium alloy (CoCr) heads on metallic stems [4,5]. The purpose of this study is to determine whether the use of ceramic femoral heads resulted in less fretting and corrosion damage, relative to CoCr femoral heads, on the neck taper of titanium alloy femoral components.

**Materials and Methods:** As part of our ongoing IRB-approved retrieval program, all available Quatro M and Quatroluc femoral stems (Ti-6-4 alloy; Signal Medical Corp.) that had been implanted for at least 6 months were included in this study (Table 1). All stems had been plasma sprayed with commercially pure titanium except for the oldest (13.5 years in vivo), which had a sintered bead coating, and were implanted without cement. The femoral stems had been implanted with zirconia (seven Mg-P52Z (Xylon) and two Y-TZP (CermetTeC)) or wrought CoCr (four Signal Medical Corp.) femoral heads. Of the ceramic heads, seven were 28mm diameter and two were 32mm, while the CoCr heads included two that were 22mm in diameter (as part of a bipolar prosthesis), one 28mm, and one 32mm.

The femoral neck tapers were divided into four quadrants (anterior, posterior, lateral, medial) and examined for fretting and corrosion damage under a dissection microscope at 10x-35x magnification. The neck tapers were characterized using the scoring technique described by Goldberg et al. with a score of 1 indicating no fretting or corrosion, and 4 indicating severe fretting or corrosion [6]. Each quadrant of the neck tapers were scored by the first three investigators to ensure consistency, then averaged together. Total score was calculated by adding the corrosion and fretting scores, where a total score of 1 would indicate no detectable fretting or corrosion, and a score of 32 would reflect severe corrosion and fretting in each quadrant. After sorting the data by femoral head material (ceramic vs. CoCr), average scores were compared by t-tests with p < 0.05 for significance. Total score was also correlated to time in vivo by linear regression, as the corrosion process at the neck-taper junction has been shown to progress with time [7].

**Results:** We observed fretting damage on all but four tapers (all with ceramic heads), and corrosion damage on all of the femoral neck tapers (Figure 1). Tapers with ceramic femoral heads had an average fretting score of 5.8 and an average corrosion score of 7.3 for a total score of 8.1, while the average scores of tapers with CoCr heads were higher at 9.6 (p = 0.30), 9.6 (p = 0.10), and 19.2 (p = 0.17), respectively. Plotting total score vs. time in vivo, the regression line for tapers with ceramic heads was close to a horizontal line (r² = 0.014), while the slope of the regression line for tapers with CoCr heads was 32 times larger (Figure 2).

**Discussion:** We found that femoral stem neck taper fretting and corrosion scores were lower for tapers implanted with ceramic heads compared to tapers implanted with CoCr heads. The decrease in total score for tapers implanted with ceramic heads appeared to be mainly due to reduced fretting damage. However, the use of ceramic heads also eliminates the galvanic corrosion that would occur when using CoCr heads on titanium alloy stems.

Our results agree with previous studies. An *in vitro* study reported lower fretting corrosion debris in zirconia ceramic-CoCr modular junctions compared to CoCr-CoCr modular junctions, either due to reduced micromotion at the ceramic-CoCr interface or enhanced release of CoCr ions at the CoCr-CoCr interface [4]. Huot Carlson et al. reported lower corrosion score in the necks of stems with ceramic heads compared to those with metal heads [8]. In a matched cohort retrieval study, fretting and corrosion scores were reported to be lower for tapers in ceramic head-metal stem pairs compared to metal-metal pairs [5].

This study has several limitations. First, we examined only one taper design from one manufacturer, and thus our findings might not apply to other taper designs. In addition, our sample size is small for tapers with CoCr heads, and the longest-term taper implanted with a CoCr head was revised due to fracture of the stem, which may have increased fretting and corrosion damage at the taper as the crack in the stem progressed [8]. Finally, there were too few specimens to fully evaluate hip offset, where increased offset has been correlated to increased fretting damage [9], or to discern the effects of femoral head size, where larger head size has been shown to increase the corrosion score [10].

**Significance:** We found that the tapers of titanium alloy femoral stems exhibited less fretting and corrosion damage when they were implanted with ceramic femoral heads, compared to those implanted with CoCr heads. Thus, THA patients with ceramic femoral heads should have a decreased risk of developing adverse local tissue reaction from metal debris released from the taper junction. However, the use of ceramic femoral heads did not completely eliminate fretting and corrosion damage.

**Table 1.** Summary of the femoral heads evaluated in this study.

<table>
<thead>
<tr>
<th>Femoral Head Material</th>
<th>Time in vivo (years)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic (n = 9)</td>
<td>5.42</td>
<td>7 Mg-P52Z, 2 Y-TZP</td>
</tr>
<tr>
<td>CoCr (n = 4)</td>
<td>2.96</td>
<td>2 bipolar heads</td>
</tr>
</tbody>
</table>

**Figure 1.** Examples of fretting and corrosion damage on tapers implanted with A. a ceramic femoral head (13.3 years *in vivo*); and B. a CoCr femoral head (5.73 years *in vivo*). Magnification: 16x

**Figure 2.** Plot of total fretting and corrosion score vs. time *in vivo* for tapers implanted with ceramic (dashed regression line) and CoCr (solid red regression line) femoral heads.

**References:**
2. Cooper et al., *Semin Arthro* 2012;23; 273.  
3. Cooper et al., *JBJS Am* 2012;94; 1655.  
6. Goldberg et al., *CORR* 2002; 401; 149.  
Corrosion and Fretting Damage at the Head-Neck Taper is Reduced with Ceramic Femoral Heads: A Retrieval Study

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INTRODUCTION

- Modularity at the head-neck taper of hip arthroplasty, especially the use of metal heads with metallic stems, can lead to fretting and corrosion at the taper junction, releasing metal ions and debris into the joint.
- The purpose of this study is to compare whether the use of ceramic femoral heads resulted in less damage from fretting and corrosion, relative to cobalt-chromium alloy (CoCr) femoral heads, on the neck taper of titanium alloy femoral components.

MATERIALS AND METHODS

- All available retrieved Quatro M and Quatroloc cementless femoral stems (Ti-6Al-4V alloy; Signal Medical Corp.) implanted for at least 6 months were included.

<table>
<thead>
<tr>
<th>Femoral Head Material (n)</th>
<th>Time in vivo (years)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic (n = 9)</td>
<td>5.42 0.868 - 13.3</td>
<td>7 Mg-PSZ, 2 Y-TZP</td>
</tr>
<tr>
<td>CoCr (n = 4)</td>
<td>2.96 0.717 - 5.73</td>
<td>All wrought CoCr</td>
</tr>
</tbody>
</table>

- Ceramic heads: seven 28mm, two 32mm diameter
- CoCr heads: two 22mm (as part of a bipolar prosthesis), one 28mm, and one 32mm diameter.

RESULTS

- We observed fretting damage on 5 of 9 tapers that had ceramic heads, and all 4 tapers with CoCr heads.
- Corrosion damage was observed on all of the femoral neck tapers, regardless of head material.

<table>
<thead>
<tr>
<th>Average Score</th>
<th>Femoral Head Material</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ceramic (n=9)</td>
<td>CoCr (n=4)</td>
</tr>
<tr>
<td>Fretting</td>
<td>5.8</td>
<td>9.6</td>
</tr>
<tr>
<td>Corrosion</td>
<td>7.3</td>
<td>9.6</td>
</tr>
<tr>
<td>Total Score</td>
<td>13.1</td>
<td>19.2</td>
</tr>
</tbody>
</table>

- The regression line for tapers with ceramic heads was close to a horizontal line ($r^2 = 0.014$; $p = 0.76$).
- With just four specimens, the regression line for tapers with CoCr heads was a much better fit ($r^2 = 0.92$; $p = 0.04$).
- The slope of the linear regression line for tapers with CoCr heads was 32 times larger ($p = 0.018$) than that of tapers with ceramic femoral heads.

DISCUSSION

- Among retrieved neck tapers with a common femoral neck geometry, fretting and corrosion scores were lower for tapers implanted with ceramic heads compared to tapers implanted with CoCr heads.
- Plotting total score vs. time in vivo and performing linear regression, the slope (rate of increase) of tapers with CoCr heads was more than an order of magnitude higher than that of tapers with ceramic heads.
- Previous studies have shown similar results:
  - Hallab et al. (2004) found lower fretting corrosion metal debris in ceramic-metal modular junctions compared to metal-metal modular junctions.
  - Huot Carlson et al. (2012) observed lower corrosion scores in the necks of stems with ceramic heads compared to those with metal heads.
- A matched cohort retrieval study (Kurtz et al., 2013) reported fretting and corrosion scores to be lower for tapers in ceramic head-metal stem pairs compared to metal-metal pairs.
- Limitations:
  - We examined only one taper design from one manufacturer, thus our findings might not apply to other taper designs.
  - Our sample size is small for tapers with CoCr heads, and the longest-term specimen with a CoCr head was revised due to fracture of the stem.
  - There were too few specimens to allow sorting by femoral head size.

CONCLUSIONS

- The tapers of titanium alloy femoral stems exhibited less fretting and corrosion damage when implanted with ceramic femoral heads, compared to those implanted with CoCr heads.
- Tapers with CoCr heads accumulated fretting and corrosion damage at a higher rate than tapers with ceramic heads; however, the clinical significance is unclear and the sample size is small.
- Hip arthroplasty patients with ceramic femoral heads should have a decreased risk of developing adverse local tissue reaction from metal debris released from the taper junction.

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