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

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Introduction: Modular head-neck total hip arthroplasty (THA) offers several benefits for orthopaedic surgeons, 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 recently 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.

Methods: As part of our ongoing IRB-approved retrieval program, all available Quatro M and Quatroloc 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 (13.3 years in vivo), which had a sintered bead coating, and were implanted without cement. The femoral stems had been implanted with zirconia (seven Mg-PSZ, Xylon; and two Y-TZP, CeramTec) 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 8 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].

Table 1. Summary of the femoral stems evaluated in this study.

<table>
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<tr>
<th>Femoral Head Material (n)</th>
<th>Time in vivo (years)</th>
<th>Notes</th>
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<tr>
<td>Ceramic (n = 9)</td>
<td>Avg. 5.42, Range 0.868 - 13.3</td>
<td>7 Mg-PSZ, 2 Y-TZP</td>
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<tr>
<td>CoCr (n = 4)</td>
<td>Avg. 2.96, Range 0.717 - 5.73</td>
<td>2 bipolar heads</td>
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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 13.1, 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).
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
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.

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10. Dyrkacz et al., J Arthro 2013:28; 1036.