Influence of Stem Type on Material Loss at the Metal-on-Metal Pinnacle Taper Junction

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Introduction: The clinical importance of material loss at the head-stem junction is unknown. Previous studies have speculated that there are multiple implant factors that can influence the rate of material loss at the female head taper surface [1].

The Pinnacle (DePuy) metal-on-metal total hip replacement has been widely implanted in patients worldwide. This design has primarily been paired with a Corail (DePuy) or S-ROM (DePuy) stem; these two designs are known to differ in their geometry and surface topography. Comparison of retrievals between stem types provides the opportunity to understand the importance of the taper junction in failure.

The purpose of this study was to measure volumetric material loss of head tapers of a single Pinnacle design that had been paired with two distinctly different stems (Corail and S-ROM), and then analyse the individual effect of stem design on material loss after multivariate analysis including other influencing factors.

Methods: This was a retrieval study with a case control design involving the analysis of 60 surfaces (cup, head bearing and head taper) of a single cobalt-chromium Pinnacle (DePuy) MOM-THR design that had been paired with 2 different titanium (Ti) stems; Corail (DePuy) and S-ROM (DePuy), Table 1. The hips were matched for head size (all 36mm), gender, age, time to revision and head neck length (+6 or +5). The two stems differed in relation to their taper type (11/13 vs 12/14). The median Co/Cr ratio of the Corail and S-ROM hips was 1.95 (0.95-8.25) and 1.03 (0.27-2.38) respectively; this difference was significant (p=0.0341).

A Contour GT-K 3D optical profilometer (Bruker, UK) was used to examine the retrieved stems (n=3) to determine the height and pitch of the machined thread on the surface of the trunnions.

The head taper surfaces were examined macroscopically and microscopically to assess the severity of corrosion, using a scoring scale of 1 (no corrosion) to 4 (severe corrosion). This method has been shown to be both repeatable and reproducible.

The volume of material loss at the cup and head bearing surfaces and the head taper surfaces was determined using a Zeiss Prismo (Carl Zeiss Ltd, Rugby, UK) coordinate measuring machine (CMM) and a Talyrond 365 (Hobson, Leicester, UK) roundness measuring machine, using previously published methods.

An independent samples t-test was performed to assess the significance of differences in material loss per year between the two stem groups. Following this, a univariate ANOVA test was performed for taper material loss rate with the inclusion of covariates which are expected to influence material loss: (1)
taper engagement length, (2) bearing surface wear, (3) cup edge wear, (4) increased vertical femoral offset.

**Results:** The median vertical femoral offset with an S-ROM and Corail stem was 69mm (63-82) and 70mm (59-103) respectively. There was no significant difference between the two stems (p=0.44). Edge wearing of the cup occurred in 5 hips with an S-ROM and 5 with a Corail. The S-ROM and Corail trunnions had a median taper engagement length of 14mm (10.5-14), at the longest point of engagement in the medial-lateral plane, and 10.5mm (10-11) respectively; this difference was significant (p<0.001). The median taper engagement length of the S-ROM trunnions in the regions of the scallops was comparable to that of the Corail stems, Figure 1. All tapers were found to have evidence of corrosion; statistical analysis revealed that the differences were not significant (p=0.0769).

The median material loss of the combined cup and head bearing surfaces of hips with an S-ROM and Corail stem were 3.92 mm³/year (1.20-7.81) and 3.21 mm³/year (0.87-62.12) respectively. There was no significant difference between the two groups (p=0.3192).

The median material loss rate of the head tapers with an S-ROM and Corail was 0.132 mm³/year (0.015-0.518) and 0.238 mm³/year (0.0002-2.178). The Corail group had significantly more material loss than the S-ROM group (p=0.036) however this significance did not remain following inclusion of the other influencing covariates (p=0.276).

The median thread height for the single S-ROM stem and two Corail stems retrieved in this study were 1µm (1-1.1) and 11.5µm (11.3-11.7) respectively (using 3 different scan regions on each trunnion). The median thread spacing for the S-ROM and Corail stems was 0.099mm (0.955-0.102) and 0.2mm (0.193-0.228) respectively, Figure 2.

**Discussion:** We found that head tapers that had been paired with Corail stems had significantly greater rates of material loss per year than heads paired with S-ROM stems. The only statistically significant difference in the covariates was found to be the taper engagement length: a median of 10.5mm for the Corail group compared with 14mm for the S-ROM group at its greatest length of engagement. The inclusion of this variable in multivariate analysis was found to explain the differences in material loss between the two groups. Whilst the S-ROM trunnion was engaged up to the opening of the head taper (excluding scalloped regions), the Corail trunnion in all cases was found to be seated fully within the taper, such that the base of the trunnion was in contact with the taper surface at a distance from the taper edge, Figure 1. This positioning of the trunnion may increase the susceptibility of it toggling within the taper, resulting in localised regions of increased contact stresses (circled in Figure 3b), suggesting a pattern of mechanical wear not observed with the longer S-ROM trunnion. The significantly greater pre-revision Co/Cr ratios in the Corail group suggest that the taper junction in these hips would have corroded more, with much of the Co ions being retained on the surface of the surface, whilst much of the Cr ions would be released into the blood. The comparable volumes of material loss measured at the bearing surfaces of each group support differences in Co/Cr ratios as being due to corrosion at the taper junction, however this was not revealed during visual inspection. The 12/14 head tapers were found to have evidence of imprinting of the rougher thread of the Corail trunnion; this was not observed in S-ROM tapers. It has been suggested that this is due to galvanic corrosion in which the taper, rather than the trunnion, is preferentially corroded. This corrosion
mechanism coupled with an increase in the risk of toggling and edge loading of the shorter trunnion (when fully seated inside the taper) may explain the greater material loss observed at these junctions.

**Significance:** We have shown that shorter and rougher stems can increase the volume of taper material loss; the consequential release of metal ions from this junction has been implicated in implant failure. We recommend the use of stems with smooth trunnions that utilise a long engagement length to minimise the clinical impact of taper damage. This is the first time this has been shown through retrieval analysis.

Table 1: Implant and patient data showing median (range) values

<table>
<thead>
<tr>
<th></th>
<th>S-ROM Group</th>
<th>Corail Group</th>
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<tbody>
<tr>
<td>Gender (Male : Female)</td>
<td>3 : 7</td>
<td>5 : 5</td>
</tr>
<tr>
<td>Age at Primary Surgery (years)</td>
<td>64.5 (53-74)</td>
<td>63 (26-73)</td>
</tr>
<tr>
<td>Time to Revision (months)</td>
<td>63.5 (40-84)</td>
<td>56 (50-77)</td>
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<tr>
<td>Cup Inclination (°)</td>
<td>36 (31-53)</td>
<td>44 (31-55)</td>
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<tr>
<td>Whole Blood Cobalt (ppb)</td>
<td>4.95 (1.06-24.6)</td>
<td>10.9 (2.3-130)</td>
</tr>
<tr>
<td>Whole Blood Chromium (ppb)</td>
<td>4.51 (1.51-90)</td>
<td>4.81 (1.45-42.4)</td>
</tr>
<tr>
<td>Co/Cr Ratio</td>
<td>1.03 (0.27-2.38)</td>
<td>1.95 (0.98-8.25)</td>
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Figure 1: Schematic illustrations presenting the taper engagement of the S-ROM stem in the (a) medial-lateral and (b) anterior-posterior views. The shorter engagement length of the scalloped regions can be seen. The Corail stem is presented in the (c) distal-proximal and (d) anterior-posterior views (examples of points of elevated stress due to toggling are circled).
Figure 2: Image generated via the optical profilometer of the (a) smooth S-ROM trunnion and (b) rough Corail trunnion

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