Do Surface Topography and Contact Area Effect Fretting Corrosion Behavior of the Modular Taper Interface in Total Hip Replacements?


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Disclosures:

Introduction: There has been widespread concern regarding the adverse tissue reactions after metal-on-metal (MoM) total hip replacements (THR). Concerns have also been expressed with mechanical wear from micromotion and fretting corrosion at the head/stem taper junction in total hip replacements. In order to understand the interface mechanism a study was undertaken to investigate the effect of surface finish and contact area associated with modular tapers in total hip replacements with a single material combination of modular tapers.

Methods: An inverted hip replacement setup was used similar to the specified ASTM test (ASTM F1875-98) (figure 1). Cobalt Chrome (CoCr) 28 mm femoral heads were coupled with either full length (standard) or reduced length (mini) 12/14 Titanium (Ti) stem tapers (figure 2). These Ti stem tapers had either a rough or smooth surface finish whilst all the head tapers had a smooth surface finish. Wear and corrosion of taper surfaces were compared after samples were sinusoidally loaded between 0.1kN and 3.1kN for 10 million cycles at 4 Hz. Test 1 rough mini stem tapers were compared with rough standard stem tapers whilst in Test 2 rough mini stem tapers were compared with smooth mini stem tapers. Surface parameters and profiles were measured before and after testing. Electrochemical static and dynamic corrosion tests were performed between rough mini stem tapers and smooth mini stem tapers under loaded and non-loaded conditions.

Results: In Test 1 following the mechanical loading test the surface roughness parameters on the head taper were significantly increased when they were coupled with the mini stem tapers compared to the standard stem tapers (p=0.046). Similarly in test 2 the surface roughness parameters on the head tapers were significantly increased when mini rough stem tapers were used compared to smooth mini stem tapers (p=0.04). Electrochemical corrosion testing showed breaching of the passive film on the rough but not the smooth neck tapers.

Discussion: Modularity is a central design feature of THR implants and is utilized by most manufacturers. Corrosion in the crevice that is formed at the modular junction between the two component parts is a concern. This connection typically consists of a metal-metal or a ceramic-metal conical junction with a tapered femoral trunnion that couples with a head that has a tapered bore. These tapers vary commercially in surface roughness, materials, cone diameter and angles, tolerances, and the surface area of the articulation, and all these factors have an important role in implant performance. In Test 1 the surface profile of the heads with both types of stem tapers showed a significant change with testing, indicating that material from the CoCr surface adjacent to the Ti alloy stem tapers had “eroded” and the surface texture of the stem taper had intact imprinted onto the head taper. This imprinting indicates that the original smooth surface of the head taper was changed to a more roughened surface while the surface finish of the stem taper remained unchanged. This phenomenon has also been observed in retrieved heads from large MoM THRs, whereby the original surface can be clearly identified on these heads and the circumferential grooves approximate the morphology of the stem taper (figure 3). The fact that the morphology on the CoCr affected region is consistent with the machining marks on the Ti alloy surface suggests that this rough finish enhances crevice corrosion by allowing the ingress of fluid along the valleys. This is supported by the observation that the original machine marks were still evident in the affected region between the peaks created by the stem taper. The greatest corrosion was seen at the interfaces where the highest bending movements were generated, suggesting that micromotion contributes to corrosion, as has been previously reported. The fact that pitting was more evident on the mini neck tapers may be partly explained by the reduced contact area compared to that of the standard stem tapers. Forces may be concentrated and exceed the surface oxide fracture strains in the CoCr, leading to accelerated corrosion. Goldberg et al. showed the importance of neck stiffness on corrosion and concluded that larger diameter stem tapers have lower fretting corrosion rates. This may be due to reduced contact pressures resulting from increased moment arm effectively reducing the bending moment at the interface. In the mini neck tapers, the taper diameter was smaller and may explain the greater corrosion. Increasing contact area relative to the loading may reduce stresses and thus fretting corrosion.

Significance: This study has identified enhanced fretting corrosion at the modular taper junction associated with roughened surface finish and small neck tapers, underscoring the concern associated with the use of modular taper connections in orthopaedic implants. Crevice corrosion is identified as the predominant mechanism, with evidence of pitting in all rough mini neck tapers. The greatest wear and corrosion was in the plane where the greatest bending moments were generated, implicating fretting as a mechanism. The rough mini neck tapers have a reduced surface area at the interface and ultimately
bending forces are concentrated here.

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**References:**
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