Are Fretting and Corrosion Reduced in Contemporary Head/Neck Modular Junctions?

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Introduction: Contemporary femoral component head/neck junctions with 12-14, 14-16 or similar taper geometries are now in wide use in total hip arthroplasty. These junctions are of larger diameter to increase flexural rigidity and have improved tolerances and enhanced surfaces relative to earlier designs in which fretting and corrosion were problematic. Although contemporary modular head/neck junctions promise higher resistance to fretting and corrosion, there is a paucity of data on the actual prevalence of fretting and corrosion in retrieved devices. We asked whether fretting and corrosion damage had in fact been reduced in contemporary head/neck junctions relative to a previous study of earlier generation 6º head/neck junctions [1].

Materials and Methods: A total of 269 consecutively retrieved femoral hip stems with 12-14, 14-16 or similar geometry head/neck junctions from 12 different manufacturers were studied using light and electron microscopy. The devices included 151 CoCr head/CoCr neck junctions and 118 CoCr head/titanium-alloy neck junctions. The mean duration of implantation was 41±54 months.

The neck tapers were examined using a reflected light stereo microscope at 10 to 50 X, and were scored for the degree of surface damage due to fretting and corrosion (minimal = 1, mild = 2, moderate = 3 or severe = 4). The data were presented as the mean and standard deviation of the scores. Scores for neck taper fretting and corrosion damage were compared between the different head/neck couples using the Mann-Whitney test. Selected femoral necks were studied using a scanning electron microscope to determine the mechanisms of corrosion. H&E-stained histological sections of the periprosthetic tissues were examined for implants with severe corrosion to characterize the cellular response. Particulate debris in the histological sections was located and identified using back scattered scanning electron microscopy and energy dispersive x-ray analysis.

Results: Overall, the mean scores for fretting and corrosion damage of the neck tapers were relatively low and were of similar magnitude for CoCr/CoCr (1.4±0.9) and CoCr/Ti-alloy (1.5±0.7) couples (p=0.107). Mild to moderate fretting and corrosion damage (scores 2 and 3) of the neck taper was observed in 38% of the CoCr/Ti-alloy couples and 21% of CoCr/CoCr couples (p=0.032). The principal mechanisms of corrosion of the neck taper were mechanically-assisted crevice corrosion for CoCr/Ti-alloy junctions and both mechanically-assisted crevice corrosion and intergranular corrosion for the CoCr/CoCr couples.

Severe intergranular corrosion of the femoral neck taper occurred in 5% of all of the CoCr/CoCr couples and was not observed in any of the Ti-alloy neck tapers. Intergranular corrosion occurred exclusively in CoCr stems that had undergone sintering to bond their metallic head porous coating. The prevalence of intergranular corrosion had in the 82 CoCr stems with sintered bead coating was 10% and occurred in devices from 3 different manufacturers. Intergranular corrosion was not observed in any of the CoCr stems for cement fixation or with a grit-blasted or shot-peened surface.

Intergranular corrosion was limited to the area of the neck taper that had been within the crevice formed by the head/neck modular junction. Intergranular corrosion of the neck taper was characterized by selective corrosion at gain boundaries, grain egression and pitting. These features were generally visible using low power light microscopy (Figure 1A), except for 2 tapers in which the nature of the corrosion could only be confirmed by electron microscopy (Figure 1B). Chromium phosphate corrosion products were deposited around the rim of the head bore and/or the distal neck taper of all the components with intergranular corrosion.

Evidence of adverse effects of metal ion release or particles of corrosion products in the periprosthetic tissues was present in 2 of 6 cases with intergranular corrosion for which histological sections were available. In one case, the histology of the joint pseudocapsule was dominated by marked perivascular and diffuse lymphocytes (Figure 2A) and necrosis, similar to the adverse reaction usually associated with metal-on-metal bearings. The other case which had been revised for aseptic loosening demonstrated sheets of histiocytes and multinucleated giant cells laden with minute chromium phosphate particles (Figure 2B).

Fig. 1A: Light micrograph showing prominent grains and intergranular corrosion of the neck taper of CoCr sintered stem (X20). Fig. 1B: SEM showing intergranular corrosion and pitting of CoCr femoral taper (X550).

Fig. 2A: Lymphocyte-dominated inflammation in joint pseudocapsule surrounding CoCr/CoCr junction with intergranular corrosion (X400). Fig. 2B: Histocytes and multinucleated giant cells laden with minute CrPO₄ corrosion products adjacent to CoCr/CoCr junction with intergranular corrosion (X600).

Conclusion and Discussion: Fretting and corrosion do occur in contemporary femoral tapers, but appear to be reduced both in prevalence and severity compared to previous studies of earlier designs [1]. This was especially so for CoCr/Ti-alloy couples. The relatively high prevalence (10%) of intergranular corrosion of the neck in CoCr stems with a sintered bead porous coating was greater than anticipated. This suggests that some CoCr stems that have undergone sintering to bond their metallic head coatings may be more susceptible to corrosion attack at the head/neck junction. Additionally, the presence of intergranular corrosion implies that fretting, while necessary to initiate the corrosion process, is not required to continue corrosion within the grain boundaries. Clearly, the solution conditions within the intergranular regions and the electrochemical status of the interface result in continued attack.

Severe intergranular corrosion of the femoral necks of CoCr stems with sintered bead porous coating can increase the release of metal ions [2], generate corrosion products in the form of particulate debris [3] and rarely lead to fracture of the neck [4].

Significance: The results of this study provide data on the actual performance of contemporary hip replacement components that are relevant to future implant design, improved laboratory testing of new devices, manufacturing practices, and implant selection.

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