Will New Metal Heads Restore the Mechanical Integrity of Corroded Trunnions at Revision THR?

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Introduction: Mechanically-assisted corrosion of the head-neck junction presents a dilemma to the surgeon at revision THR whenever the femoral component is rigidly fixed to the femur. Many surgeons remove the damaged femoral head, clean the femoral taper and fix a new head in place to spare the patient the risks associated with extraction and replacement of the well-functioning femoral stem. This study was performed to answer the research questions:
1. Will new metal heads restore the mechanical integrity of the original modular junction after impaction on corroded tapers?
2. Which variables affect the stability of the new interface created at revision THR?

Methods: Twenty-two tapers (CoCr, n=12; TiAlV, n=10) were obtained for use in this study. Ten stems were in pristine condition, while 12 stems had been retrieved at revision THR and showed moderate corrosion damage of the trunnion (grade 4 on the Goldberg scale) without gouges or artefacts caused by stem extraction. Twenty-two new implant-specific metal heads were obtained from each stem manufacturer for use in the study, each matching the design and source of the original component. The following procedures were performed using a MTS mechanical testing machine: 1. Taper assembly, 2. Disassembly, 3. Re-assembly, 4. Cyclic Gait loading and 5. Disassembly. All head assemblies were performed wet using 50% calf serum in accordance to ISO 7206-10. Disassembly was performed through application of a distraction force at a rate of 0.008 mm/sec until separation. Gait loading was simulated with a sinusoidal loading function (230N-4300N) applied at 1Hz for 2,000 cycles and directed at 25° to the trunnion axis in the frontal plane and 10° in the sagittal plane. The relative motion between the head and the trunion was measured via two parallel plates rigidly attached to the base of the head and the femoral neck immediately beneath the trunnion. Six high resolution displacement transducers (±0.6 µm; accuracy: 0.1%; Lord Microstrain) were mounted on the neck plate permitting measurement of the 3D motion of the head plate. Calculations of the overall head motion was performed using custom written Matlab code. Measurement of the rigid body motion of the head was assumed to be completely constrained by the 6 displacement transducers. The motion of the head in the direction of the neck axis was reported as the interfacial motion at the head-neck junction.

The displacement data was independently validated using finite element modeling (FEM) of selected constructs (NX Nastran). CAD models of the trunnion and head designs used in the experiment were generated and the corresponding physical properties of the head and taper were incorporated in the model. Mesh sensitivity tests were performed to determine the mesh density required for a stable, convergent solution. A friction-based sliding interface (mu=0.12) was simulated at the trunnion-head
junction. Just as in the experiment, assembly of the head on the trunnion with an impact load of 4000N along the trunnion axis was initially simulated. This was followed by the application of 230N-4300N simulating stair climbing applied 25° and 10° to the trunnion axis in the coronal plane and sagittal plane respectively. Femoral head displacement, trunnion bending results were used to validate the results of the FEM.

**Results:** The average micromotion of the head vs trunnion interface was greatest at the start of loading and stabilized after approximately 50 cycles to an average of 30.6±3.2µm. For CoCr couples, interface motion dropped by 17% when a pristine head was mounted on a corroded stem compared to a new stem (25.7±2.7µm (pristine stem), vs. 30.1±4.6µm (corroded stem), p= 0.4023) (Figure 1). However, addition of a new CoCr head to a corroded titanium alloy stem led to an 73% increase in interface motion (Corroded: 43.4±9.8µm, Pristine: 25.2±7.0µm, p=0.1661). The resistance to head-neck disruption was 15% higher in TiAlV/CoCr couples compared to CoCr/CoCr (TiAlV: 2558 ±63N, CoCr: 2226±99N, p=0.0111) and was not affected by the presence of corrosion of the trunnion (1% loss of strength in each case) (Figure 2). For one construct modeled, physical testing showed an average micromotion of the head to be 48.7µm with 0.328° of neck bending vs 56.5µm and 0.338° for FEM.

**Discussion:** Corrosion at the trunnion does not disrupt the mechanical integrity of the junction when a CoCr head is replaced on a CoCr taper. Greater variability is seen when placing new heads on damaged TiAlV tapers. Although the pull-off strength of this couple remains high, motion under gait loading was elevated with some TiAlV components. Further work is required to better elucidate the role of dissimilar metals in the mechanical integrity of the head-neck junction.

**Significance:** This study investigates the question, during revision THR with a corroded taper, will a new metal head restore the mechanical integrity of the original modular junction while minimizing risks associated with extraction and replacement of the femoral stem.
Figure 1: Average head-neck interface micromotion during toggling.

Figure 2: Average disassembly force after toggling.