Validating a Simplified Method for Assessing THA Taper Corrosion Susceptibility with a 15-year Retrieval Database

Patrick Aldinger, BSME, MBA, Bob Jones, BSME, MBA, Jacob L. Cartner, MS.
Smith&Nephew Inc., Memphis, TN, USA.

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Introduction: The use of tapered junctions in total hip arthroplasty (THA) has excellent long term results. Recent findings regarding mechanically assisted crevice corrosion (MACC) artifacts at tapered surfaces have spurred growing interest [1]. A number of testing methods have been employed in an attempt to mimic clinical findings [2-5]. The purpose of this study was to establish a simple methodology based on the existing standards to assess THA susceptibility to taper corrosion using commonly used implants and standard practices. Method validation was assessed based on agreement with measurements obtained from a 15 year retrieval database [6].

Methods: Three (3) +8 mm offset Cobalt-Chromium-Molybdenum (CoCrMo) and three (3) +16 mm offset CoCrMo 28 mm diameter femoral heads (n = 6 total) were assembled onto Ti-6Al-4V stem trunnions using the static assembly method described in ASTM F2009-00 [7]. The 12/14 tapers were measured using a coordinate measurement machine (CMM) and were pre-wet with a saline + HCl solution (pH = 1.5) prior to assembly. Roughly 7 mL of the saline + HCl solution was injected around the taper junction and sealed with silicone tubing. This acidic micro-environment was used in an attempt to accelerate corrosion [3]. The THA constructs were potted at 10 degrees of adduction and cyclically loaded according to ASTM F2068-03 [8] at 5 Hz to 10 Mcycles from 534 to 5338 N using a sinusoidal axial compressive force. A mark in line with the load application was made on the superior aspect of the head/trunnion interface.

Upon completion of testing, test fluid was visually compared to unused fluid. The THA disassociation force was measured using a hydraulic test frame (MTS, Eden Prairie, MN) per ASTM F2009-00 [7]. Tapered surfaces were scored independently by a panel according to the Goldberg system [2] for assessment of corrosion. A score of 1 (none), 2 (mild), 3 (moderate) and 4 (severe) was given to a taper surface depending on the severity of fretting and corrosion. Scanning electron microscopy (SEM) was performed to further evaluate damage. The female tapers were then scanned with a Zeiss Surfcom 1800D Profilometer using a 2 µm 60-degree conical diamond tip (resolution 1 nm). Four measurements were taken around the circumference along the length of the tapers: 0-degrees (superior), 90-degrees (anterior), 180-degrees (inferior), and 270-degrees (posterior). The profile deviation was used to represent the depth of linear material loss. Statistical significance was declared at α = 0.05 using a two-tailed t-test. Validation of the test method was conducted by comparing visual scoring and linear material loss values to those from a 15 year retrieval database [6].

Results: The test fluid for five (5) of the six (6) samples appeared visually cloudy, indicating evidence of corrosion-induced metal particulate debris. All male and all female tapers from these five samples received a Goldberg score of 4, indicating severe corrosion. The average post-test disassociation force was 2248 N, and there was no statistically significant difference between the disassociation force of the
+16 mm and +8 mm offsets (p = 0.21). SEM analyses showed evidence of fretting scars and corrosion by-products. Measureable material loss was found on all head tapers (Figure 1). Evidence of stem trunnion machine line imprints transferred to the head tapers was found. Maximum material loss occurred on the distal inferior side of the head taper for all samples. Material loss of the +16 mm as compared to the +8 mm offsets approached statistical significance (p = 0.053), with +16 mm heads having higher maximum depth of linear material loss (17.4 ± 1.8 versus 13.5 ± 1.7 µm, respectively). These results corroborate with the maximum depth of linear material loss measured on CoCrMo heads from a 15 year retrieval database, which reported values from 1.4 to 102.6 µm, with those having a Goldberg score of 4 averaging 29.4 µm of linear material loss [6].

**Discussion:** CoCrMo femoral heads have 20+ years of clinical success, but are susceptible to taper corrosion. This study utilized a methodology based off consensus standards to quantify THA susceptibility to corrosion. Our results are consistent with previous findings [6] in that MACC is observed on commonly used smaller head diameters (ie, less than 36 mm), and higher offset heads have greater susceptibility to corrosion, which thereby validates that the test method produced clinically relevant results. Our results also suggest that maximum material loss may occur on the inferior aspect of the femoral head, but this would need to be further evaluated for confounding variables such as head size, offset, and potting orientation. A standardized methodology that generates clinically relevant corrosion, such as presented herein, can be employed to further evaluate factors contributing to MACC (taper angular mismatch, impaction force, taper cleanliness, etc.) since these methods were shown to be sufficient to quantify THA susceptibility to corrosion.

**Significance:** The purpose of this study was to establish a simple methodology based on the existing standards to assess THA susceptibility to taper corrosion using commonly used implants and standard practices. A standardized methodology that generates clinically relevant corrosion, such as presented herein, can be employed to further evaluate factors contributing to MACC (taper angular mismatch, impaction force, taper cleanliness, etc.) since these methods were shown to be sufficient to quantify THA susceptibility to corrosion.