Quantitative Assessment of Taper Damage and Head-Neck Moment Arm on Retrieved Total Hip Replacements with Modular Bore-Cone Taper Junctions

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Statement of Purpose: Total hip replacements (THR) routinely have modular femoral heads to give surgeons intraoperative flexibility. These heads attach to the neck cone on the femoral stem using a bore-cone taper junction. Different bore depths into the head alter the position of the head center on the neck cone. This affects the moment arm at the bore-cone modular junction since the joint reaction force at the hip passes through the center of the femoral head. There are concerns that variations in this head-neck moment arm can negatively impact micromotion and lead to corrosion at the modular bore-cone taper junctions. The broad objective of this study is to understand how changes in component geometry, specifically the head-neck moment arm, may impact bore-cone taper junctions. Explanted modular THR are used to 1) quantify variations in the head-neck moment arm; and 2) characterize corrosion and other changes on the surface damage on the modular bore-cone tapers. It was hypothesized that taper junctions with larger head-neck moment arms would have larger regions of taper surface damage.

Methods: Explanted hip prostheses (n=67) were collected through an IRB-approved implant retrieval program. All prostheses had metal cobalt-chrome modular heads attached to femoral stems using a bore-cone taper junction. These prostheses were explanted from 26 male and 35 female subjects, with an age range of 31–86 years (mean: 64 years). The BMI ranged from 16–44 (mean 28), and the implantation time ranged from 0.2 – 20 years (mean 7.7 years). The reasons for explantation include: loosening (n=22), infection (n=18), fracture (n=4), polyethylene wear (n=4), pain (n=3), subsidence (n=3), metallosis (n=1), other (n=2), not reported (n=14). From this group of hip prostheses, 21 require further disassembly and are excluded from this study. The geometry of the remaining prostheses was measured using calipers, including the parameters of femoral head height (HH), femoral head diameter (HD), and trunnion depth (TD), which were used to calculate the head-neck moment arm (HMA) (Figure 1). Surface damage on the modular bore-cone junctions was assessed qualitatively and quantitatively. Three researchers visually assessed each modular bone-bone junctions using an optical microscope and independently scored the damage severity from 1 to 4, as defined by Goldberg, et al.[1]. Quantitative image analysis was completed using published methods [2] and calibrated high resolution digital images of the cones and ImageJ software to measure damage area as a percentage of cone size.

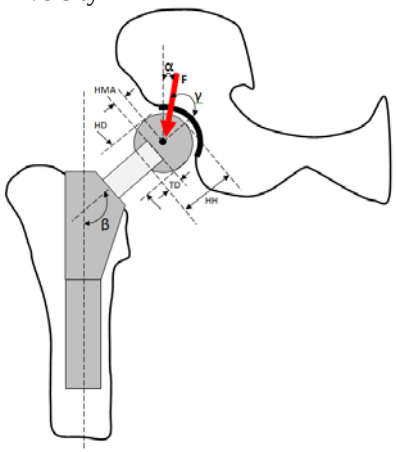

Figure 1. Prosthesis geometry used to calculate HMA

Results: The majority of cones had no damage or mild damage (38/46, 83%). However, there was moderate to severe damage on 8 cones (17%) (Table 1). The femoral heads had diameters of 22 mm (n=2), 28 mm (n=17), 32 mm (n=7), 36 mm (n=6), 38 (n=3), and greater than or equal to 40 (n=11). The head-neck moment arm ranged from 0.09 to 9.13 mm, with the majority of prostheses in the 0.00 – 4.00 mm range (Figure 2).

Table 1: Summary of results

Sample Size (n)	Goldberg score	Average % Damage Area	Average HMA [mm]
19	1 (none)	0.21 ± 0.53	4.27 ± 2.97
19	2 (mild)	6.20 ± 7.97	2.81 ± 2.14
3	3 (moderate)	24.10 ± 25.28	3.98 ± 4.60
5	4 (severe)	32.40 ± 16.17	2.65 ± 2.91

Conclusions: Loading conditions at the modular bore-cone taper junctions in THR are a function of component geometry and material properties, as well as patient body weight and activity. In this study, there was no correlation between the femoral head-neck moment arm and damage score or damage area Most of the explanted THR had minimal damage at the modular bore-cone taper junctions. Future studies will incorporate stem material properties and patient-specific loading conditions to better understand why some modular junctions exhibit moderate to severe damage.

References: [1] Goldberg, et al. Clin Orthop. 2002;401:149-161. [2] Harman, et al. J Biomed Mater Res (part B Appl Biomater). 2011;99(2):431-439.