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Taper-Trunion Interface Stresses in Metal on Metal Hip Implants

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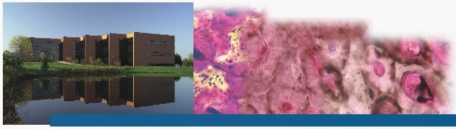

CEDARVILLE UNIVERSITY

Taper-trunnion Interface Stresses In Metal On Metal Hip Implant Systems Become Critical With Ball Size And During Certain Activities

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INTRODUCTION

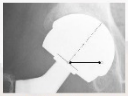
Figure 1 Horizontal lever arm (HLA)

Metal on metal (MoM) total hip arthroplasty describes a hip joint replacement where a metal femoral head articulates against a metal socket. This implant scenario has generally been successful until recently when larger (>36 mm) metal heads have become more popular as a means to reduce the incidence of hip joint dislocation. Today, the number of clinical failures (described by fretting corrosion and a need for revision surgery) of MoM total hip arthroplasty is occurring at unacceptable rates [1, 2, 3]. The objective of our research was to investigate the effect of horizontal lever arm (HLA) (Fig. 1), a geometric variable that increases with femoral head size, on trunnion-taper contact stresses. We hypothesized that trunnion-taper contact stresses increase with head size. We tested our hypothesis by conducting finite element analysis (FEA) of a titanium alloy hip stem and five femoral heads under four different loading conditions.

METHODs

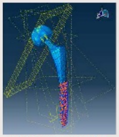
Figure 2 Stem with morse taper

A dual taper press fit stem with a 12/14 trunnion was used in this study along and 5 femoral head ball sizes (28, 32, 36, 40 and 44 mm). Digital models of the implant and femoral heads were generated for import into ABAQUS (Dassualt Systems, Waltham, MA) and were then assembled to simulate a Morse-taper fit (Fig. 2). Both the head and the implant were assigned a Young's Modulus of 105 GPa, Poisson's Ratio of 0.37, and a friction coefficient of 0.4. Four load cases were applied on the head as defined by the Bergmann et al. [4]: the average force experienced during single legged stance, the average and maximum force experience during stair climbing and the force experienced during stumbling. The maximum von Mises stresses experienced at the trunnion-taper interface for each load were compared (Fig. 3).

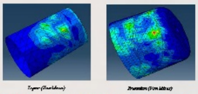
Figure 3 Taper and trunnion contact stresses

RESULTS

The results from the single legged stance simulation do not show a trend between head size (HLA) and trunnion and taper stresses (Fig. 4). However, the results from average force from stairclimbing do show increasing trunnion and taper stresses with head size (Fig. 5). A similar trend exists for the maximum force from stairclimbing with maximum von Mises stresses occurring above yield stress for the 40 and 44 mm heads (Fig. 6). The resultant applied force for stumbling was significantly higher than the other load cases, however, the stresses experienced by the trunnion were less for stumbling than with the maximum force experienced by stair climbing (Fig. 7).

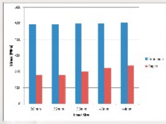
Figure 4 Single legged stance, average peak load

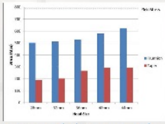
Figure 5 Stair climbing, average peak load

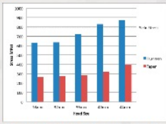
Figure 6 Stair climbing, maximum peak load

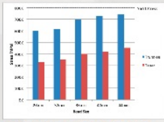
Figure 7 Stumbling, maximum peak load

Table 1. Comparisons between stumbling (ST), stair climbing (SC) and single legged stance (SLS)

Load Case	ResultantForce (N)	% Diff w/SLS	Max Stress (MPa) on 44 mm Trunnion	% Diff w/SLS
SLS	1,800	---------	502	---------
ST	11,000	144	744	35.4
SC (avg)	1,900	5.40	615	20.2
SC (max)	4,200	80.0	876	54.3

DISCUSSION

Our results showed that increasing the head size of the implant increases the stresses experienced by the trunnion and taper for stairclimbing and stumbling but not for single-legged stance. We found that the distance between the location of the resultant force with respect to the trunnion axis increased from the single legged stance to stumbling to stair climbing and that the distance between the trunnion axis and the resultant force increases going from the 28mm to the 44mm heads for the stair climbing loading case (Fig. 8). This increase in perpendicular distance causes a greater bending moment experienced by the trunnion resulting in greater stresses experienced at the trunnion and taper interface. Certain load cases, such as stair climbing and stumbling with a larger HLA, cause the trunnion to experience stresses close to or exceeding the yield strength of the implant material, which may contribute to an increase in fretting wear at the trunnion-taper junction. It was concluded that smaller to mid-sized heads (≤ 36mm) should be used for implants, in order to avoid high trunnion-taper interface stresses that occur for certain loading conditions.

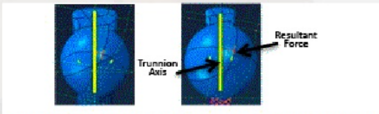

Figure 8 Resultant force location for stairclimbing for a 28 mm (left) and 44 mm (right) head

SIGNIFICANCE

The identification of the effects of varying femoral head size over physiological loading conditions may help elucidate contributing factors to increased fretting wear at the trunnion-taper junction in metal on metal implants.

ACKNOWLEDGEMENTS

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3. Langton, DJ et al., BJR, Vol. 1, No. 4, 56-63.
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