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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: Metal on metal (MoM) total hip arthroplasty describes a hip joint replacement where a metal (cobalt chromium) 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]. The objective of our research was to investigate the effect of horizontal lever arm (HLA), 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. Such increases may be responsible for increases in the potential for fretting wear and subsequent corrosion as described previously [3]. 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: 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). We used 3D scanning technology (Next Engine, Inc. Santa Monica, CA) to generate digital models of the implant and femoral heads for import into ABAQUS (Dassualt Systems, Waltham, MA). The implant and head were then assembled in such a way to simulate a Morse-taper fit where the head is pressed down onto the trunnion and held together by friction in what ABAQUS refers to as a shrink fit. 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. A load was applied on the head as defined by the Bergmann et al. [4]. Four load cases were applied: 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.
Results: The results from the single legged stance simulation do not show a trend between head size (HLA) and trunnion and taper stresses. However, the results from average force from stairclimbing do show increasing trunnion and taper stresses with head size. 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. 1). 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 (Table 1).
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. Since we know 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, results suggests that the stress experienced by the trunnion is dependent on the location of the resultant force. 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. 2). 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.
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.
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References: 1. Smith, Dieppe, Vernon, Porter, Blom, et al. Failure rates of stemmed metal-on-metal hip replacements:analysis of data from the National Joint Registry of England and Wales. *Lancet* 2012; 1199-1203 2. How safe are metal-on-metal hip implants. BMJ 2012; 344. 3. Taper junction failure in large-diameter metal-on-metal bearings. BJR, Vol. 1, No. 4, 56-63. 4.Bergmann G., Graichen F., Rohlmann A., Bender A., Heinlein
B., Duda G.N., Heller M.O.,Morock M.M. Realistic loads for testing hip implants. *Biomed Mater Eng* 2010; 20(2): 65-75.

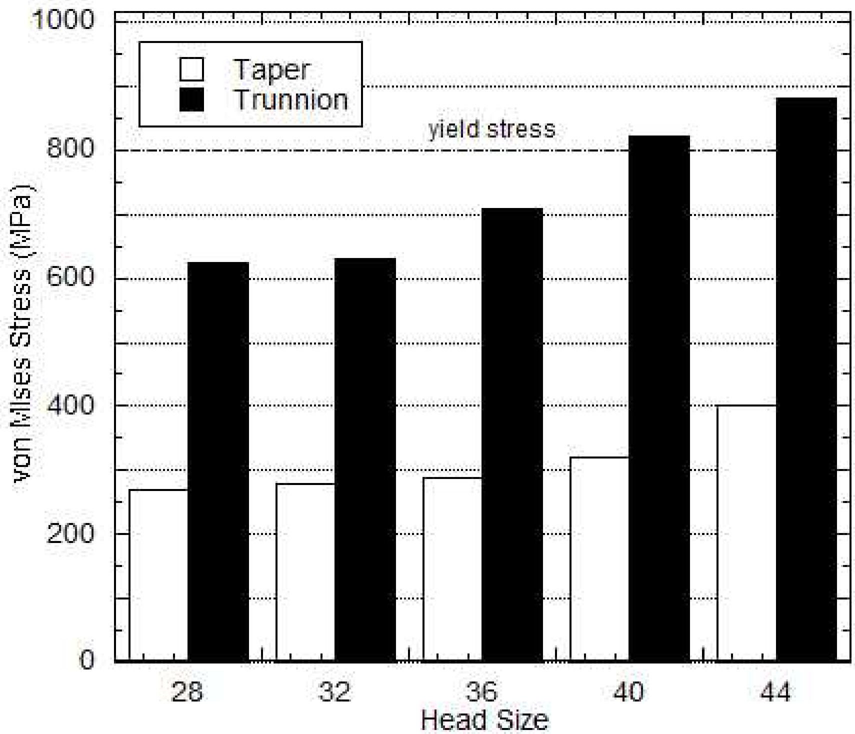

Fig 1. Maximum von Mises stresses while stairclimbing (maximum load)

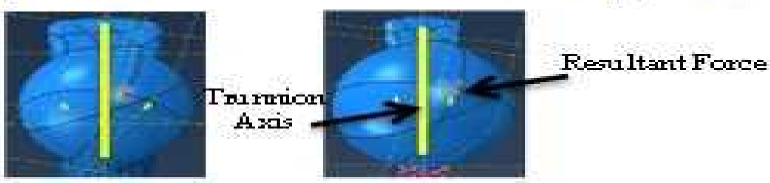

Fig. 2. Resultant force location for stairclimbing for a 28 mm (left) and 44 mm (right) head

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