Diametral Clearance Effect on Friction and Wear characteristics of Metal-on-Metal Articulations

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Statement of Purpose: The diametral (or radial) clearance in femoral head/acetabular cup couples has been shown as a critical factor for the effectiveness of metal-on-metal (MoM) total hip arthroplasty (THA) designs. When clearance is too large, the in-vivo wear may be high[1], while high frictional torque, leading to equatorial contact and a mechanical loosening of the cup, may occur when the clearance is too small.[2] Previously the usefulness of a pendulum apparatus in characterizing the frictional torque in Ø32mm MoM couples was reported.[3] The objective of the current study was to characterize clearance effect on frictional torque and wear in a MoM design using a pendulum apparatus and a hip wear simulator[4].

Methods: Pendulum frictional torque was measured in 23 Ø28mm MoM head/cup couples (Metasul™ Gamma system, Zimmer GmbH, Switzerland) with seven diametral clearances (Table 1). All femoral heads and acetabular cups were made of the same wrought high carbon Co-28Cr-6Mo-0.2C alloy (ASTM F1537/ ISO5832-12). The details of the pendulum experiment were reported elsewhere.[3] Bovine serum lubricant containing 33% calf serum diluted by Ringer's solution was used. The test temperature was room temperature, ≈ 21°C. Three pendulum experiments were conducted for each couple. After the test, the average maximum frictional torque data were recorded. Additionally, 12 sets of the same MoM design with three nominal diametral clearances (Table 1) were wear tested on a 12-station AMTI hip simulator (AMTI, Watertown, MA). The simulation followed the ISO 14242-1 standard. The same serum lubricant as in the pendulum experiments was used in the wear experiment. Linear wear was measured at 0, 0.5, 1.0, 1.5 and 2.0 million cycles (mc) using coordinate measuring machine (CMM).[4]

Results/Discussion: The frictional torque results are shown in Fig. 1. A relatively low level of frictional torque was present with diametral clearances larger than 40 µm, while a nearly linearly increasing torque was associated with clearances less than 25 µm. These results suggested that the clearance had a bi-modal effect on frictional torque. A similar functional dependence was observed in an earlier study with Ø32mm MoM parts.[3] Besides the diameter difference, the Ø32mm MoM parts in the earlier study had polyethylene backing in the acetabular cup while the Ø28mm MoM parts in the current study did not. The threshold clearance, defined as the onset of drastic friction increase following the intersect of the bi-modal frictional torque results, was around 20 µm in the earlier study. The data in Fig. 1 suggested that the threshold clearance could be around 30 µm. The two MoM designs did not seem to differ much in their threshold clearance. Figure 2 shows the 2mc wear results. A running-in wear in the first 0.5mc was present in all three cases, and then steady-state afterward, where no significant change occurred. The clearance effect on wear was negligible between the 51- and 71 µm cases, while a higher running-in wear occurred with the 148 µm case.

Conclusions: Combining the friction and wear results, the threshold clearance could be determined using the pendulum apparatus to prevent clamping. Beyond the threshold clearance, the clearance effect was better characterized by wear simulation.

References: 1. McKellop H. et al. CORR, 1996;329S: S128. 2. Walker P. & Gold, Wear, 1971;17: 285. 3. Shen M. et al. 51st ORS, 2005; p.1152. 4. Rieker C. et al. 29th SFB, 2003; p.124.

	Nominal dia (mm)	Dia. clearance (µm)	Sample size
Friction experiment	28	-13 ± 2	3
		0 ± 1	4
		13 ± 2	3
		25 ± 1	4
		49 ± 1	3
		68 ± 1	3
		140 ± 1	3
Wear experiment	28	51 ± 4	4
		71 ± 2	4
		148 ± 10	4

Table 1. Samples in the friction and wear experiments (Note: The -13 µm case was an interference fit.)

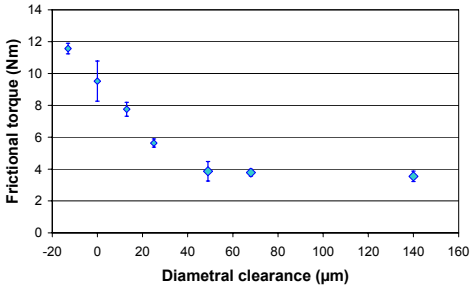

Figure 1. Frictional torque characteristics

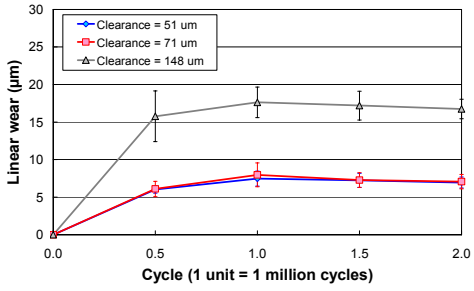

Figure 2. Wear characteristics