Wear Reduction of Large Head Metal-On-Metal Implants in a Hip Simulation Study

Liao, Yen-Shuo
DePuy Orthopaedics, Inc., PO Box 988, 700 Orthopaedic Drive, Warsaw, IN 46581-0988

Statement of Purpose: The purpose of this study was to demonstrate the effect of implant diameters on the wear of modern metal-on-metal hip implants using a hip simulator.

The metal-on-metal hip has shown greater wear reduction than the metal-on-polyethylene hip system [1]. Lab simulation showed that most of the metal-on-metal wear occurred during the break-in period, then, followed by lower wear due to the establishment of fluid film lubrication [2]. To further minimize the initial wear of a modern metal-on-metal hip system, one can increase the head size and reduce the diametrical clearance [3].

Methods: High-carbon CoCrMo (ASTM F1537) wrought femoral heads and acetabular inserts were tested. The test specimens were arranged in two groups (N=4 for each) according to their nominal head/insert sizes, including Group A: 28 mm (the small head), and group B: 44 mm (the big head). The actual diameters for the implants were measured using a CMM (Brown & Sharpe, North Kingstown, RI). Each diameter was calculated by randomly taking 50 points on the spherical surface of the implants. The diametrical clearances were calculated as the difference between the diameters of the inserts and heads. A head-and-insert match was performed to ensure the similar diametrical clearance for each group. The initial clearance for the small head group and the large head group were 65.5 ± 4.4 µm, and 94.2 ± 7.3 µm, respectively. Surface metrology was performed using a NewView 5000 Interferometer (Zygo Corporation, Middlefield, CT). All articulating surfaces were polished to an Ra of 0.01 µm.

The wear test was performed on an 8-station hip joint simulator (MTS, Eden Prairie, MN) using the Paul-type physiological loading (3000 N max, +/- 23° biaxial rocking motion at 1 Hz), with an inverted position (i.e., the head located on top of the insert) for 6 million cycles. The interface was lubricated with bovine serum (HyClone Lab, Logan, UT), which contained 0.2% sodium azide and 20mM EDTA. The protein concentration was 17 mg/ml (approximately 25% of original serum protein concentration). Wear was assessed by measuring the weight loss every half million cycles. The weight loss was converted to volumetric wear using a density of 8.86 g/cm^3 [2]. One additional weighing was performed at 0.25 million cycles (MC) to observe the early wear-in of the components. The surface morphology was evaluated using light microscopy.

Results/Discussion: The wear results for the small head group consisted of a rapid break-in period (0-0.5MC) and a stabilized period (1-6MC, Figure 1), which were consistent with the trends in previous studies [3-5]. The wear for the large head group was low and appeared to be linear over the six million cycles, suggesting the large head with tight clearance control reached stable wear without the break-in period. During 2.5 to 3 million cycles, there was one pair of 28 mm specimens that ran dry due to serum leakage. The test was resumed with replenished serum for the failed station but the data from the failed station was excluded from the analysis.

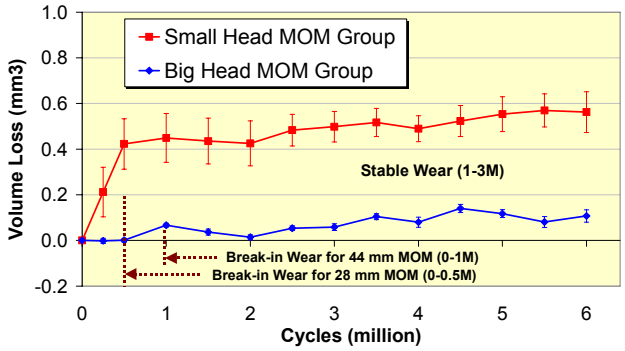

Figure 1. The accumulated wear over six million cycles

The total volumetric wear over 6 million cycles were 0.56 ±0.12 and 0.11 ±0.02 mm3 for the small head group and large head group, respectively (Figure 1). The wear rates during the break-in period were 0.85 ±0.36 (0-0.5MC) and 0.07 ±0.02 mm^3/MC (0-1MC) for the small head and large head group, respectively; suggesting a wear reduction of 92%. The stabilized wear (1-6MC) was comparable between two groups, about 0.03 ±0.04 and 0.02 ±0.00 mm^3/MC for small and large head group, respectively. The diametrical clearance for each couple remained similar before and after the wear test.

On the station that ran dry, the test specimens experienced high wear and roughened bearing surfaces. A new stabilized state, however, was reached after another half-million test cycles, suggesting a "self-polishing" characteristic of the metal-on-metal bearings (figure not shown). The scratches produced during the event were gradually removed, as observed using light microscopy as the test progressed. Further investigation is needed to evaluate the extent and progress of self-polishing.

Conclusions: The current study demonstrated a 92% of wear reduction during the break-in period for using large head, with well controlled diametrical clearance, metal-on-metal total hip prostheses. This is clinically significant in that reducing the wear rate reduces metal ion release and potentially reduces osteolysis associated with wear of total hip arthroplasty [2].

References: [1] Dobbs, JBJS Br 1980, v62, p168. [2] Liao et al., ORS 2006, p506. [3] Dowson et al, JOA 2004, v19, n8, s3, p124. [4] Chan et al., CORR 1999, 369: p10-24. [5] Liao et al., ORS 2004, p1454.