Ceramic-on-Metal vs. Metal-on-Metal Bearings in Hip Simulator Study

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Introduction: With total hip replacement (THR) patients getting younger and more active, the longevity of the THR bearings becomes increasingly important. However concerns remain related to potential metal ion release in metal-on-metal (MOM) THRs [1] and ceramic liner fracture in ceramic-on-ceramic (COC) THRs. A simulator study of 28mm hybrid ceramic-on-metal (COM) indicated much reduced wear and metal ion release compared to MOM [2]. The purpose of our study was to compare simulated wear, and Co and Cr ions for 32 and 38mm alumina heads, both bearing on CoCr cups to a control 32mm MOM.

Materials and Methods: Our control THR was a standard 32mm MOM. The femoral heads of 32mm alumina (Biolox-deltaTM: CeramTec AG, Plochingen, Germany) and 38mm alumina (VitoxTM: Morgan Advanced Ceramics, UK) were coupled with high-carbon CoCr cups (Biomet Inc., Warsaw, IN). The diametral clearance of the bearings averaged 60 μm. Our orbital simulator (Shore Western Manufacturing Inc., Monrovia, CA) used the standard anatomical set up to 3.5 million cycles (Mc) duration. The lubricant was 25% alpha calf serum (HyClone Inc., Logan, UT) with 400ml volume chambers. Wear measurements were taken and serum replaced every 0.2 Mc up to 1.0 Mc, and every 0.5 Mc in steady-state phase. We determined the levels of Co and Cr ions in lubricant by EPA 200 Series Methods (Weck Laboratories, Inc. City of Industry, CA) at 0.2, 1.0 and 3.0 Mc durations.

Results: The THR run-in and steady-state phases for control MOM averaged 7.78 and 0.77 mm3/Mc, the latter representing a 90% wear reduction (Fig. 1). The 32mm COM wear for run-in and steady-state phases averaged 1.12 and 0.20 mm3/Mc, respectively (Fig. 1). The 38mm COM sets wore slightly lower averaging 1.01 and 0.10 mm3/Mc, respectively (Fig. 1). In terms of ball: cup ratios, there was a dramatic cup representation that averaged 84% of the total THR wear for all durations. Overall wear rates were 1.58 mm3/Mc for MOM, 0.38-0.39 mm3/Mc for 32mm COM and 38mm COM (Fig. 1). Overall, our studies of 32mm and 38mm COM bearings clearly showed a lower range of wear-rates compared to our control THR.

For MOM, Co-ion levels (to 3.0 Mc) were in range 10-41 ppm and Cr-ion levels were 4-20 ppm (Fig. 2). The ratio of Co to Cr ions was satisfactory at 7:3. The levels of Co/Cr ion by 1.0 Mc showed 70-80% reduction in this run-in phase (Fig. 2). There were no significant changes in ion levels between 1.0 and 3.0 Mc (Fig. 2). Our COM bearings showed very low metal ions concentration throughout the test (Fig. 2). The previous study [2] also investigated COM metal debris, which were found to be smaller than MOM bearings. Overall our study was therefore basically in agreement with prior published COM concepts showing reductions in both wear levels and ion concentrations compared to control.

Discussion: The only published COM study [2] concluded that COM pairing had approximately 100 times less wear than MOM pairing. Taking ‘overall’ wear as one criterion, our MOM and COM averaged 1.58 and 0.38 mm3/Mc, respectively, which represented only a 4-fold reduction. In the patient population, the highest risk lies in the maximum MOM wear-rates. Thus as a ‘worst-case’ scenario, our maximum wear (3.5 Mc: MOM 15.2 vs. COM 2.7 mm3) represented a 5-fold risk reduction for COM compared to our MOM control. So why this big discrepancy between two similar studies? Comparison with our data showed that our MOM wear rates were comparable overall. The main difference was that measured extremely low wear with 28mm COM [2]. Of the many confounding parameters present, one effect could be in the degree of biofilm contamination present with COM bearings. Bio-film contamination has confounded many MOM studies [3]. Biofilm will reduce any wear estimate made with the gravimetric technique and on occasion can completely mask the weight-loss due to wear [4]. Therefore we could agree with the overall COM wear being less than MOM wear but not with such a large difference in magnitude.

It was clear that the ion studies could also be a useful surrogate method of assessing wear. Our Co and Cr ion assessments from the serum yielded the ratio 2.6 which corresponded well to the parent alloy, signifying that the recovery process was stable [5]. It was therefore interesting that ion levels from COM sets were at least 5-fold less than our low-wear MOM and 20-fold less than our high wear MOM.

Thus we concluded that our first hypothesis was proven, that COM bearings provided lower overall wear and reduced the concentrations of Co and Cr ions compared to our control MOM. Overall we would conclude that the COM bearings appeared to be promising alternate bearing to MOM as first proposed by Firkins et al [2]. More study will be required to confirm these encouraging data.


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