Diamond-on-Diamond Hip Simulator Study With Distraction

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Statement of Purpose: Hard-on-hard bearing surfaces are finding increasing application in total hip replacements for wear reduction. Polycrystalline Diamond Compacts (PDCs) offer several potential advantages, including ultimate hardness, reduced metal ion release compared to metal-on-metal (MoM) articulations and increased strength/toughness compared to ceramic-on-ceramic (CoC). This study investigates in-vitro wear and friction for a 28mm diamond-on-diamond (DoD) system under normal walking gait and also with distraction.

Methods: Six sets of 28mm PDC femoral heads and 28/41mm PDC acetabular liners (Dimicron, Utah) were tested on a hip simulator (AMTI, Boston). Radial clearances were 18-42 microns. Specimens were mounted anatomically with the cups superior and mounted at 45 degrees. All stations were lubricated with 37°C bovine serum diluted to 17g/l protein concentration. Components were subjected to a 3kN walking cycle (ISO14242-1) for 5 million cycles (MC). This was followed by 2MC of distraction testing with a reduced swing-phase load of 120N, an applied side force of 129N and with the abduction motion disabled. This produced approximately 0.5–0.7mm of horizontal displacement of the center of the head. The lubricant was changed and the components cleaned, dried and weighed at 0.5MC intervals.

Results: All heads and liners gained weight during each portion of the test. Potential mechanisms (still under investigation) include protein adsorption and hydration of metallic phases within the diamond compact. The weight gains were found to be somewhat reversible after drying in vacuum for extended periods (60-90 hours). However, the standard 1 hour drying cycle used for weight measurements during the test was found to be inadequate. Therefore, only the "dry weights" measured after 64-92 hours of vacuum drying at the beginning and end of each test portion were used to compute wear rates.

Figure 1 shows overall wear rates for heads and liners for the 5MC of normal gait, the 2MC of distraction testing and for the whole 7MC. 95% confidence intervals are plotted for each set of six heads and liners. Weight changes were converted to volumetric wear using a density of 3,800kgm^{-3}. Even after extended drying, the liners all showed small weight gains. The heads apparently wore slightly during the normal walking cycle but gained weight during the distraction cycle. Overall, the heads showed a small wear rate of 0.17±0.09mm^3/MC and the liners showed a small 'negative' wear rate of -0.11±0.07mm^3/MC. Due to the uncertainties involved in the drying procedure, it is concluded that DoD wear rates were unmeasurably low for this test.

Distraction is known to increase wear rates for CoC systems [1] and might reasonably be expected to have a similar effect for DoD, due to the high elastic modulus of diamond. However, the 2MC of distraction testing produced only small weight gains. The heads showed no evidence of 'stripe wear' as reported for CoC systems.

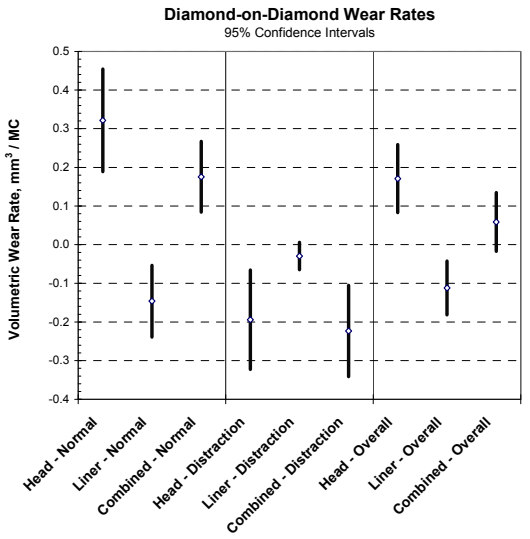

Figure 1. Volumetric Wear Rates Calculated from Dry Weights for Each Portion of the Test

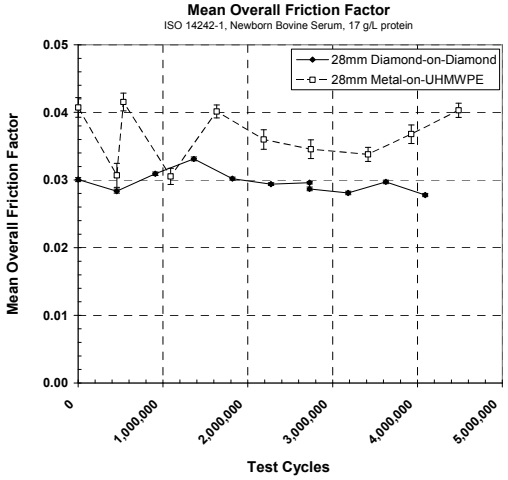

Figure 2. Friction Factors for DoD and Metal-on-UHMWPE, Normal Walking Gait

Friction factors were calculated from forces and torques measured on each station, using the method described in [2]. Values were slightly lower than those measured for 28mm metal-on-UHMWPE (Figure 2).

Conclusions: DoD wear rates were found to be unmeasurably low for an anatomical hip simulator test with and without distraction. Friction factors for DoD were slightly lower than for metal-on-UHMWPE.

References: 1. "Microseparation of the Centers of Alumina-Alumina Artificial Hip Joints During Simulator Testing Produces Clinically Relevant Wear Rates and Patterns", J. Nevelos, E. Ingham, C. Doyle, R. Streicher, A. Nevelos, W. Walter and J. Fisher, J Arthroplasty, Vol 15, 793-795 (2000), 2. "A Novel Way to Measure Friction of Total Hip Replacement Systems During a Walking Cycle on a Multi-Station Hip Simulator", J.N. Weisenburger, M.G. Naylor, D.W. Schroeder, B.F. White, A. Unsworth, K.L. Garvin and H. Haider, ISTA 2007