Friction of a variety of Total Hip Replacements

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Materials and Methods: Five million cycle (Mc) wear tests were performed on the same size THR but with different material combinations, on a twelve station hip simulator (AMTI, Boston) with friction measured using a novel technique presented previously [1] based on equilibrium of forces and moments measured using the simulator’s six degree of freedom load cell on each station. The 44mm (femoral head diameter) THR samples included 6 metal on UHMWPE (MOP) (3 with conventional UHMWPE and 3 with highly cross linked (HXL) UHMWPE liners), 6 metal on metal (MOM) (3 TiN coated and 3 uncoated), 6 MOM resurfacing (3 standard and 3 with small pockets for lubrication transport), and 3 ceramic on UHMWPE (COP) THRs. All were lubricated with diluted bovine serum with 20g/L protein concentration at 37°C, and subjected to the walking cycle loading and rotations of ISO 14242-1 [2].

Figure 1: Left: A 44mm femoral head used in MOM and MOP (conventional and HXL) THRs. Center: Pocketed resurfacing head. Right: 44mm Ceramic femoral head (metal taper mount).

Results: The conventional and HXL MOPs had steady friction factors of 0.045±0.009 and 0.046±0.003 over 5 Mc, explained by the stability of wear rates of both these MOP types (72.0±2.81 mg/Mc and 14.2±3.57 mg/Mc, respectively). However, during first 0.5 Mc the conventional MOP friction factor rose from 0.047±0.004 to 0.057±0.004 while high wear was occurring (147.1±10.08 mg/Mc). The TiN coated and uncoated MOMs displayed initial friction factors of 0.124±0.117 and 0.039±0.003 respectively. The high standard deviation for the coated THRs was due to coating removal on one specimen which caused scratches and scuffs on its articulating surfaces. This single specimen had a friction factor of 0.260 at 0.028 Mc. By 1 Mc, the TiN coating wore away on the other two coated specimens (friction factors at 1 Mc: coated 0.081±0.036, uncoated 0.050±0.014). Over the 5 Mc test, average friction factors for the coated and uncoated THRs were 0.097±0.020 and 0.049±0.014 respectively. The 44mm standard and “pocketed” MOM resurfacing THRs displayed initial friction factors of 0.038±0.009 and 0.059±0.026 respectively that increased to the same level at 2 Mc (0.094±0.020 and 0.094±0.029, respectively). No difference in wear was detected between the two resurfacing head types (wear rates over 2 Mc: standard 3.32±0.25 mg/Mc, pocketed 2.22±1.76 mg/Mc), but curiously, both types exhibited an equal level of scratching and scuffing on their articular surface. By the end of 5 Mc, the standard resurfacing components displayed a moderately lower friction factor than the pocketed design (0.036±0.012 and 0.072±0.037, respectively) although the pocketed design wore less (not statistically significant at p>0.05). Finally, the three COP THRs exhibited high UHMWPE liner wear over 2 Mc (97.44±0.08 mg/Mc), which slowed to 72.92±11.60 mg/Mc. The friction factor also decreased from 0.091±0.005 to 0.070±0.008 over the same period. Toward the end of the test the friction factor increased again to 0.088±0.004 by 5 Mc coincidental with a small increase of wear (from 3.39±0.39 mg/Mc between 2 Mc and 4.5 Mc to 7.75±2.62 mg/Mc between 4.5 and 5 Mc) of the ceramic femoral head.

Discussion: The initially decreasing friction factor for MOP and COP THRs coincided with a possible “bedding-in” period where the UHMWPE liner conformed to the femoral head. The high initial friction measured on the TiN coated MOM THRs was evidence of a failing coating, and even differentiated which specimen would fail first. In the case of the pocketed resurfacing specimens, it is possible that the pockets on this design marginally increased the friction through viscous shear and fluid transportation into the joint thereby marginally improving wear durability. Finally, the high-wearing COP THR displayed higher friction toward the end of the test when an increase in wear of the ceramic femoral head was observed. Whether this wear was taking place on the articulating surface or at the stem/ head interface is unknown. Friction factors in native cartilage typically range from 0.01 to 0.03, and friction factors in well-designed THRs fall between 0.04 and 0.1, a range into which our measured friction factors indeed do fall. Additionally the method utilized here facilitates on-line sampling throughout the progress of a prolonged wear test, and therefore allows predictions on THR performance/wear to be made. When high friction factors were observed, high wear was measured on THR specimens, or damage to articulating surfaces was seen.

Significance: Measurement of THR friction during hip simulation wear studies successfully predicts wear and could save time and cost over lengthy extended wear studies. Such measurements can help predict coating failure, and potentially predict clearance and clamping issues of metal-on-metal hips.

References: