Wear Performance of Metal-On-Metal and Metal-On-Polyethylene Lumbar Disc Replacements under ISO and Walking Conditions

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Statement of Purpose: Lumbar disc arthroplasty is an alternative to fusion for the treatment of discogenic back pain. In contrast to spinal fusion, total disc replacement (TDR) helps preserve motion at the instrumented and adjacent levels. Numerous designs which incorporate different material combinations for the articulating surfaces have been introduced. The importance of physiologically relevant input data for wear testing of spinal implants has been demonstrated by several authors [1,2] who observed significant differences in wear rate depending on the motion characteristics. Therefore the purpose of this study is to compare the wear performance of metal-on-metal (MoM) and metal-on-polyethylene (MoP) implants, tested under walking and ISO conditions (ISO 18192-1).

Methods: Generic implants with identical ball-in-socket designs were tested. All superior components were concave and manufactured from medical grade (ASTM F1537-00) cobalt chromium (CoCr) alloy. The inferior convex components were made from either CoCr or ultra-high molecular weight polyethylene (UHMWPE). Three MoM and three MoP (with one additional MoP load soak control) combinations were evaluated. Wear tests were conducted using an Endolab® Spine Simulator. The actively-controlled degrees of freedom in the spine simulator were flexion-extension (FE), axial rotation (AR), lateral bending (LB), and axial loading (AL). The input profiles were derived from ISO 18192-1 and from a 3D finite element model (FEM) of the lumbar spine. Load data reported in the literature was used to simulate a complete gait cycle. The motions derived from the finite element model ranged from 1.2° to 4.2° for FE, 0.2°of left to 0.9° of right AR, and 0.2° to 0.9° in the right LB direction only [3]. The load profile was extracted from the data published by Callaghan et al. [4]. All implants were tested for 10 million cycles (MC) at 2 Hz according to ISO and at 1 Hz while applying the walking profile. Phasing between the motions generated crossing-path trajectories on the implant surfaces for both of the input data sets. Wear was assessed gravimetrically every 0.5 MC according to ASTM F732-00. Implant surface characteristics were inspected at each cycle interval.

Results: Both MoM and MoP implants exhibited linear wear throughout the testing period. Interestingly, the CoCr implants did not exhibit the accelerated wear during the run-in period as described for similar ball-in-socket type bearings for total hip arthroplasty [5]. The average volumetric wear rates for the MoM implants tested as per ISO and under walking conditions were 0.19 ± 0.01 mm^3/MC and 0.06 ± 0.03 mm^3/MC, respectively (Figure 1). MoP implants experienced a wear rate of 4.09 ± 0.74 mm^3/MC during the ISO test and 2.65 ± 0.03 mm^3/MC under walking conditions.

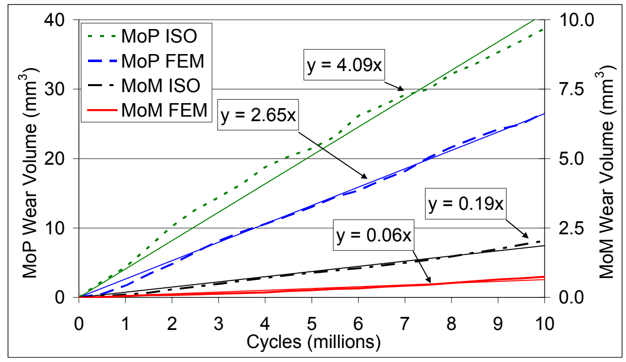

Figure 1: Mean wear plot of the MoM and MoP implants tested under ISO and walking conditions

Conclusions: The wear rate of TDR tested under the ISO and walking conditions were compared. The results indicate a 66% reduction of volumetric wear for the MoM implants when tested under walking conditions compared to the ISO test. A 35% reduction of volumetric wear was observed for the MoP implants tested under the walking conditions compared to the ISO test.

Interestingly, the wear rate for two of the three MoM implants tested under the walking conditions did increase from about 0.06 mm^3/MC to 0.13 mm^3/MC at approximately six MC (Figure 2). Further investigations will be done to elucidate those observations and identify the occurring wear mechanism. In contrast, a constant wear rate was observed by the MoP implants during both ISO and walking tests, as well as by the MoM implants during ISO testing. It will be interesting to compare these wear results based on FEM input data to clinical observations.

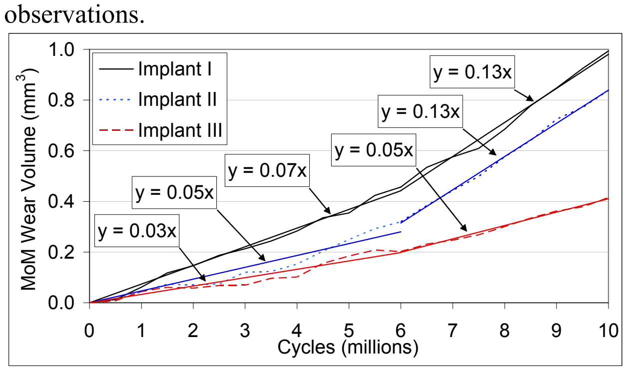

Figure 2: Wear of the MoM implants tested under walking conditions

Furthermore, implant wear is an important performance parameter of any artificial disc design, as it evokes a potential host biological response to wear particles. In future work, the size and shape of the wear debris from these tests will be characterized.

References: [1] Nechtow W. ORS. 2006;0118. [2] Pare PE. Wear. 2007; 263:1055-1059. [3] Natarajan RN. ORS. 2008;1379. [4] Callaghan JP. Clin Biomech. 1999;14:203-216. [5] Chan FW. Clin Orth Rel Res. 1999;369:10-24.