Wear Resistance of Polycarbonate Urethane Acetabular Cups as Compared to Cross-Linked Ultra High Molecular Weight Polyethylene

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Statement of Purpose: Research into improved hip prosthesis bearing surfaces to reduce wear continues to be of importance due to the consequences of the tissue response to wear particles and the resultant impact on the success of the prosthetic joint replacement. Devices with larger femoral heads have advantages in terms of reduced tendency for hip dislocation but larger femoral heads have been reported to lead to higher rates of wear. The development of lower-wear crosslinked ultra high molecular weight polyethylenes (UHMWPE) has lead to the opportunity to look again at systems using larger head sizes. Additionally, there is interest in investigating more compliant materials for the acetabular component that may change the lubrication mechanisms that are active between the head and cup. This study builds upon a previous study (1) comparing non-crosslinked UHMWPE with identical cups manufactured from a polycarbonate urethane material (PCU). In this study, heads with an improved surface roughness are utilized to compare the results for PCU with crosslinked UHMWPE in components of identical design under the same testing conditions.

Methods: Ten 46 mm crosslinked UHMWPE cups and ten polycarbonate urethane (PCU) cups of identical design were mounted and tested on an eight station orbital bearing type hip wear simulator (MTS Systems Corporation, Eden Prairie, MN) using 50% bovine calf serum supplemented with EDTA as lubricant and controlled at 37 degrees C. Identical 40 mm cobalt/chromium alloy femoral heads were used for both types of cups. Two of each type of cup were utilized as loaded soak controls to correct for fluid absorption. One of each type was used as an unloaded soak control and one was stored unopened for comparison after testing had been completed. A Paul hip loading curve with a maximum of 3000 N was applied at the rate of one cycle per second. All samples were subjected to a total of at least 5 million cycles, stopping after approximately every 500,000 cycles for cleaning, drying, and weighing. Weight losses due to wear for each cup subjected to wear was calculated after adjustment for the weight changes due to fluid uptake of the respective soak controls. Additionally, after completion of testing, the PCU cups were allowed to equilibrate overnight under laboratory conditions and weights compared to the un-tested device. Furthermore, all ten samples were vacuum dried and re-weighed in an attempt to quantify the fluid uptake during testing, at equilibrium in laboratory conditions, and after forced drying under vacuum. Surface morphology was characterized for each cup using a laser scanning confocal microscope (LSCM).

Results: The wear rates of the two types of acetabular cup were nearly identical (Figure 1). The wear rates appeared to be linear throughout testing with no initial wear-in at a higher rate. The average wear rate for the PCU cups was 22.7 mg/million cycles (mg/mc) as compared with the crosslinked UHMWPE which had a wear rate of 23.6 mg/mc.

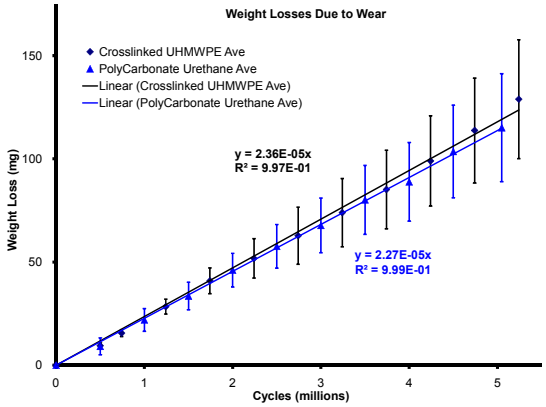

Figure 1

There was sufficient variation in the individual sample wear rates that the wear properties of the two materials were considered to be identical. The previous study had shown wear rates of 80 mg/mc for uncrosslinked UHMWPE and 30.7 mg/mc for PCU. LCSM imaging of the femoral heads from the two studies confirmed visible improvement in surface finish of the femoral heads. The non-loaded soak control samples of UHMWPE underwent initial weight gain due to fluid uptake but this ended early in the study, while the loaded samples continued to gain weight. Similar conclusions for the PCU controls could not be drawn due to the nature of the cleaning protocol. For the PCU soak control cups, there was about a 4% weight increase during testing and about 2.3% increase after vacuum drying. Comparison of the UHMWPE loaded soak controls with those that were not loaded showed that plastic deformation of the machining ridges in the cups occurred despite the fact that no wear occurred.

Conclusions:

1. Polycarbonate urethane acetabular cups can be created with equivalent wear properties to crosslinked ultra high molecular weight polyethylene
2. It appears necessary to utilize loaded soak controls in hip simulator wear testing since the unloaded controls do not appear to model the fluid uptake of loaded samples
3. Changes in the surface morphology of femoral heads can have a measurable effect on the wear properties of PCU acetabular components
4. It is apparent that PCU should be pursued as a material of manufacture of acetabular cups. Further testing of other sizes of heads with appropriately sized cups should be pursued.

References:

(1) St. John et al., SFB 2009, Abstract # 69.