Hip Simulator Wear Testing Of Polycarbonate Urethane Acetabular Cups as Compared to Ultra High Molecular Weight Polyethylene Cups

Kenneth R. St. John[1] Nadim J. Hallab[2], Steven M. Kurtz[3]
[1]University of Mississippi Medical Center, [2]Bioengineering Solutions, Inc., [3]Exponent, Inc.

Statement of Purpose: It has been theorized that the use of an elastomeric material with the capability to take up fluids may yield total joint bearing surfaces with improved wear resistance compared to the polyethylene materials currently used in total hip replacements. This study was intended to test the null hypothesis that a compliant elastomeric bearing surface would undergo excessive wear due to friction between the metallic femoral head and the elastomeric cup as compared to an identically designed and sized Ultra-High-Molecular Weight Polyethylene (UHMWPE) acetabular cup.

Methods: Four 46 mm polyethylene cups and four 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. One of each type of cup was utilized as a loaded soak control to correct for fluid absorption. 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 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. The head-to-cup clearances of the tested PCU cups were measured and compared to that for the loaded soak control sample. Serum from one of the UHMWPE cups from the final 500,000 cycles was digested and the particles sizes and shapes measured and compared to results for serum taken from the first 500,000 cycles and the last 500,000 cycles for two of the PCU cups, using a scanning electron microscope (SEM).

Results: The weight loss results (Figure 1) showed that the weight losses for the polyethylene cups exhibited an early "wearing-in" period of higher weight loss followed by a period (after 2,000,000 cycles) of lower linear weight loss. Conversely, the weight losses due to wear of the PCU cup were essentially linear throughout testing. The wear rate of the UHMWPE samples was 80.3 mg/million cycles for the last 3,000,000 cycles while the rate for the PCU cups was 30.7 mg/million cycles.

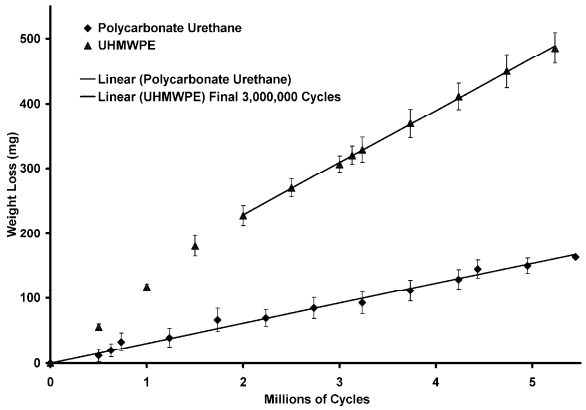

Figure 1 – Average Wear Rates

Measurements of particle sizes from digested serum, using the SEM gave values for average particle sizes of 0.52 µm for the UHMWPE sample at 5.2 million cycles, 0.70 µm for the PCU sample at 500,000 cycles, and 0.50 µm for the PCU sample at 5.4 million cycles. The distribution of particle sizes for the three serum analyses was similar but some slight differences were noted.

Conclusions: The wear rates of the PCU acetabular cups were lower than for the UHMWPE cups of the identical size and design, with the rate for PCU shown to be about 38% of those for the UHMWPE cups. The experimental results reject the null hypothesis and it can be concluded that "When all other test parameters were held equal, the compliant elastomeric bearing surface studied had less wear than UHMWPE". Despite the high loads and 5 year's worth of simulated walking and the use of an elastomeric material, the radial clearance between the cup and head was essentially unchanged over the duration of the test.

These wear results are encouraging and suggest that further study of PCU as a total hip bearing surface is warranted.

Acknowledgement: This research was supported by Active Implants Corporation, Memphis, TN.