Wear Debris Comparison of Fixed and Mobile Knee Bearings

INTRODUCTION:
Osteolysis induced by UHMWPE debris has historically been one of the major causes of long term failure of total joint replacements [1]. An increase in concentration of polyethylene particles has been linked to an increased incidence of osteolysis [2]. The size and morphology of wear debris particles is typically dependent on the type of polyethylene used, where highly crosslinked polyethylene particles are smaller than conventional polyethylene particles. A sequentially crosslinked and annealed polyethylene has been developed [3] to deliver superior wear performance and aid with decreasing the incidence of osteolysis.

Mobile bearing knee replacements have been designed to lower the contact stresses by increasing the contact area. Reports in literature indicate there is a difference in the occurrence of osteolysis between fixed and mobile bearing knees. One study reveals a 47% incidence of osteolysis in the mobile knee compared to only 13% in the fixed bearing knee [4]. Since polyethylene debris is linked to the onset of osteolysis, the purpose of this study is to characterize and compare the polyethylene debris generated from a mobile bearing knee replacement and fixed bearing knee replacement.

MATERIALS AND METHODS:
The fixed-bearing system (Triathlon®, Stryker Orthopaedics, Mahwah, NJ) consisted of cobalt chrome femoral components and tibial trays, and polyethylene inserts were sequentially crosslinked and annealed [3] (X3®, Stryker Orthopaedics, Mahwah, NJ). Both mobile-bearing systems consisted of cobalt chrome femoral components and tibial trays. Both systems also had polyethylene inserts that were manufactured from GUR 1020 that was sterilized using gamma irradiation in a near vacuum environment (GVF, DePuy, Warsaw, IN). One mobile-bearing system was a CR design (LCS, DePuy, Warsaw, IN), while the other was a PS design (PFC Sigma, DePuy, Warsaw, IN). The three knee systems are shown in Figure 1.

A six-station knee simulator was utilized for testing (MTS, Eden Prairie, MN). All motion and loading was computer controlled and waveforms followed ISO 14243-3 [5]. Testing was conducted at a frequency of 1 Hz for 1 million cycles. The lubricant used was Alpha Calf Fraction serum (Hyclone Labs, Logan, UT) diluted to 50% with a pH-balanced 20-mMole solution of deionized water and EDTA (protein level = 20 g/l) [6]. A serum sample from each testing group was collected after testing. Serum samples were protein digested using heat, hydrochloric acid and methanol following the published process by Scott et al [7]. The digested serum was then filtered through a series of polycarbonate filter papers and sputter coated with gold for analysis using scanning electron microscopy. Image fields were randomized and wear debris was compared in terms of its length, width, aspect ratio (length/width, where length > width), and equivalent circular diameter (ECD).

RESULTS:
A total of 114 PFC, 122 LCS, and 146 Triathlon particles were characterized in this study. SEM micrographs showing the debris for each design is shown in Figure 2. There were only 2 and 6 images respectively to reach 100 particles for PFC and LCS, while Triathlon needed 16 images. The size and distribution of particles are displayed in Table 1 and Figure 3.

DISCUSSION:
The debris analysis and wear rates correlate to one another; the fixed bearing design has the lowest wear rate and produces smaller and fewer particles than the mobile bearing designs. The mobile bearing designs are not available with highly crosslinked polyethylene, while the fixed bearing is available with highly crosslinked polyethylene. The morphology of particles for all designs contains small spherical particles, fibrils, and larger elongated particles. In all comparisons, both mobile bearing designs produce wear debris particles that are statistically different from the fixed bearing design. The average aspect ratio of the mobile bearing designs indicates an increased generation of fibrillar and larger elongated particles than the fixed bearing design. This may be a factor of the distal peg feature of the mobile bearing that is allowed to move freely in the tibial baseplate and/or the mobile nature of the bearing. The increased contact area of the mobile bearing knee combined with the difference in polyethylene, leads to an increase in wear and number of wear particles. This increase in wear particles increases the likelihood of a high concentration of polyethylene particles in any one area of the peri-prosthetic tissue, which will ultimately lead to osteolysis and failure of the implant.

REFERENCES: