Wear Reduction in Total Ankle Arthroplasty Using Highly Crosslinked UHMWPE

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Disclosures:

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Introduction: Bearing couples within total ankle arthroplasty (TAA) typically utilize cobalt chromium alloys articulating on ultrahigh molecular weight polyethylene (UHMWPE). Articulation of these surfaces during in vivo loading can generate UHMWPE wear particles, which may then result in osteolysis and component loosening [1]. Osteolysis has been observed following TAA in 15-22% of patient populations [2,3]. Use of highly crosslinked UHMWPE (HXPE) has been shown to reduce wear in other joint systems [4] compared to conventional UHMWPE (CPE); and thus has the potential to improve wear performance of TAA. The goal of this study was to quantify the impact of crosslinking on wear within TAA using loading parameters biomechanically relevant to the ankle joint.

Methods: Materials: Specimens of a fixed bearing, semi-constrained bicondylar, conical articulation TAA device were manufactured, consisting of a polyethylene talar surface that articulates on a tibial surface machined from CoCrMo alloy (Figure 1). For this research study, polyethylene components were machined both from CPE (GUR 1050 bar stock) and from HXPE (GUR 1050 molded sheet bar stock subjected to warm e-beam irradiation (65 kGy) and melt annealing). All polyethylene specimens were packaged and subjected to ethylene oxide sterilization, prior to testing. For each material group, three specimens were used as wear samples and two as load soak controls.

Wear testing: Wear assessment was conducted using an AMTI (Advanced Mechanical Technology, Inc., Waltham, MA) knee joint simulator with SIMMAC™ control software (Figure 1). All samples were tested for 5.0 million cycles (Mc). Wear samples were rotated between stations every 0.5 Mc. Cleaning and weighing was conducted every 0.5 Mc up to 3.0 Mc and every 1.0 Mc thereafter up to the end of the test. All samples were submerged in lubricant throughout the duration of the test. The test lubricant was a mixture of bovine calf serum (SH30073, Hyclone, Logan, Utah), 3 g/L sodium azide and 7.9 g/L disodium EDTA and diluted with deionized water in order to produce a final protein content of 20 g/L. Each joint was tested in an environmentally sealed chamber where the lubricant was circulated and maintained at 37±3°C.

Biomechanical loading: Applied loads and boundary conditions for the wear simulation were based on the physiological profiles of Bell et al. [5-7], as shown in Figure 2. A peak load of 3188 N (717 lb) was used. Kinematic inputs were as follows: 16° of plantarflexion (-) to 15.2° of dorsiflexion (+), 2° external (-) to 8° internal (+) talar rotation, and 1.5 mm posterior (-) to 1.5 mm anterior (+) translation. All tests were run at a physiological frequency of 1.1 Hz. Load soak samples experienced the same loading profile as the wear samples, but no displacements or rotations were applied.

Analysis: After load soak correction, gravimetric weight loss measurements from 0.5 - 5.0 Mc were linearly regressed against cycle count to produce a final protein content of 20 g/L. Each joint was tested in an environmentally sealed chamber where the lubricant was circulated and maintained at 37±3°C.

Discussion: Previous testing to compare the wear performance of conventional and highly crosslinked UHMWPE within cruciate-retaining total knee arthroplasty designs showed an approximate 80% reduction in wear, depending on the extent of crosslinking and the loading conditions. However, this extent of reduction does not necessarily carry over to other total joint replacement systems, based on the biomechanical loading and component designs that are unique to each joint. Within the TAA design tested here, use of HXPE resulted in approximately 77% reduction in mean gravimetric wear rate as compared to CPE. Aspects of the design other than material selection, including the bicondylar geometry, may contribute to a reduced volumetric wear rate (1.8 mm³/Mc) as compared to results (10.4-16.4 mm³/Mc) from previously reported in vitro tests on other TAA devices [6]; but these differences also may be attributed to variations in test conditions.

Significance: Utilization of highly crosslinked UHMWPE within total ankle arthroplasty implant systems may significantly reduce in vivo wear, potentially improving clinical outcomes through reduced incidences of osteolysis and implant loosening associated

Results: Weight loss values as a function of cycle count are shown in Figure 3. Mean gravimetric wear rates were 7.5 ± 1.0 mg/Mc (mean ± standard deviation) for CPE and 1.7 ± 0.2 mg/Mc for HXPE (p < 0.05), representing a 77% reduction in mean gravimetric wear rate due to use of crosslinked UHMWPE within this design. The mean volumetric wear rate for HXPE, assuming a density of 0.93 mg/mm³, was 1.8 mm³/Mc.
with polyethylene debris.

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