Evaluation of the Effect of Femoral Head Size on Sequentially Cross-linked Acetabular Liners

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Statement of Purpose: Prosthetic dislocation is a major complication after total hip arthroplasty (THA)[1,2]. It is known that larger femoral heads reduce the incidence of hip dislocation [3,4] and impingement [3-5]. But the wear of acetabular liners is a function of contact area and therefore head size [3,4]. Larger heads also reduce liner thickness, and there is a general concern about increased wear [6,7]. Previous laboratory [3,8] and clinical studies [9] of large diameter femoral heads suggest low wear of highly cross-linked polyethylene regardless of head size. A sequential crosslinking and annealing process for treating ultra-high molecular weight polyethylene (UHMWPE) has been developed and previously described [10]. The purpose of this study is to evaluate the influence of polyethylene thickness and femoral head size on the wear performance of this material.

Methods: A total of 5 sets of liners were evaluated. Trident® design (Stryker Orthopaedics, Mahwah, NJ) liners with internal diameters ranging from 32mm to 52mm and wall thicknesses from 3.8mm to 7.9mm were evaluated (n=19). These liners were machined from compression molded GUR1020 UHMWPE that had been γ-irradiated to 30 kGy followed by annealing 3 times (total dose=90 kGy, X3®). After machining inserts were gas plasma sterilized. A set of control samples (n=12) was machined from GUR 1050 UHMWPE, packaged in a nitrogen environment and then γ-radiation sterilized (30 kGy). The control liners had an internal diameter of 32mm, with a wall thickness of 7.9mm. Appropriate diameter CoCr femoral heads were mated against the inserts.

A hip joint simulator (MTS, Eden Prairie, MN) was used for testing with the cups positioned anatomically and oriented at 50° of abduction. Testing was run at 1 Hz with cyclic Paul curve physiologic loading applied axially, at a maximum of 2450N[12]. 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). The serum solution was replaced and inserts were weighed for gravimetric wear at least every 0.5 million cycles. Dynamically loaded soak control specimens were used to correct for fluid absorption with weight loss data converted to volumetric data (by material density). Statistical analysis was performed using the Student's t-test ($p<0.05$). Testing ran for 5 million cycles.

Results/Discussion: Results are shown in Figure 1. Statistically significant wear rate reductions of more than 90% were seen for all X3® inserts compared to the control ($p<0.009$ for all). An average of all X3® liner wear rates (all sizes) showed a 96% ($p=0.00001$) reduction compared to the control. Figure 2 shows wear rates plotted against both head size and liner thickness, with no correlation found with either ($R^2=0.2751$ and $R^2=0.0055$). Wear rate did not statistically increase as liner thickness decreased or femoral head size increased. No significant effect of head size was found due to low 44mm wear, despite the physical reality of increased contact. This is due to low X3®wear values that are within measurement noise. No cracking or fatigue damage was observed on any liner.

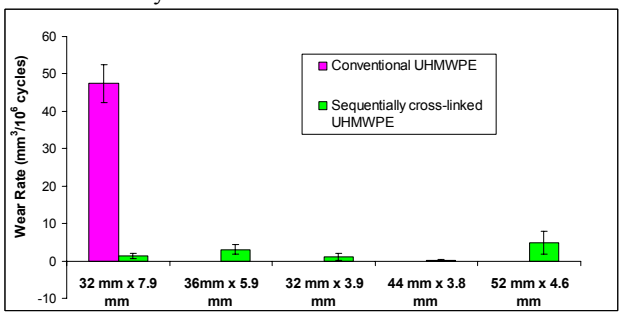

Figure 1: Plot of wear rate

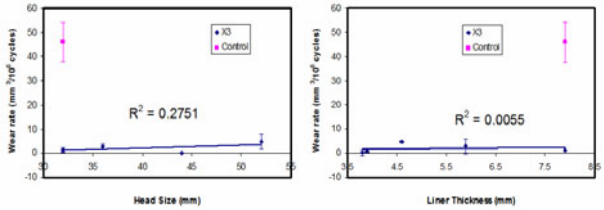

Figure 2: Wear rate against head size and liner thickness

Conclusions: Wear results demonstrate that during this test, head size or liner thickness did not statistically change wear rate or volume loss for the X3® liners. Previous studies have shown that highly cross-linked polyethylene decreases wear substantially compared to non-cross-linked or moderately cross-linked polyethylene [8]. The present study is consistent with these previous results and found significantly lower wear rates for the sequentially cross-linked material compared to conventional γ-sterilized liners ($p<0.009$). Sequentially cross-linked liners up to 52mm in inner diameter and down to 3.8mm in wall thickness may offer an alternative to large thin metal-on-metal bearings and the associated uncertainty of metal debris and ion release.

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