Assessment of Tribological Properties of Retrieved 1st Generation Annealed Highly Crosslinked UHMPWE Using Multidirectional Pin-on-Disk Testing

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Introduction: In the late 1990’s, highly crosslinked ultra high molecular weight polyethylene (HXLPE) was introduced in total hip arthroplasty (THA) to improve wear resistance and thus reduce the incidence of particle-induced osteolysis [1]. To date, first generation annealed HXLPE has proven clinically successful at reducing both wear rates and the incidence of osteolysis in total hip replacement [1 - 4]. However, patient activity levels (working cycles per year) and been shown to decrease as the patient ages [5]. Given that Archard’s Law states that the total wear volume produced is proportional to sliding distance multiplied by the normal force applied, it is unclear whether the tribological properties of HXLPE are degrading in vivo or if the favorable long-term performance of 1st generation HXLPE can be attributed, at least in part, to the reduction in use as patient activity decreases. Although pin-on-disk testing has traditionally been used as a screening device for prospective new biomaterials for use in total joint replacement, recently it has been used to evaluate the degradation of wear properties due to the harsh in vivo environment in as manufactured historical (gamma air sterilized) and conventional (gamma inert sterilized) UHMWPE liners used in THA [6]. The purpose of this study was to evaluate the wear performance of 1st generation annealed HXLPE with respect to in vivo duration. We hypothesized that wear rates would be higher for retrieved long-term implanted components than for short-term implanted components as assessed through multi-directional pin-on-disk testing of retrieved THA liners.

Methods: Thirteen years ago, we established an IRB approved, multi-institutional implant retrieval program. To date, we have collected 2502 total hip arthroplasty systems. Of these, 103 were 1st generation annealed HXLPE. First-generation annealed HXLPE was chosen for this investigation because it was the first HXLPE commercially available and thus has the longest clinical history. The annealed liners were fabricated from GUR 1050, radiation crosslinked with 75kGy, annealed, and gamma sterilized in nitrogen (Crossfire®; Stryker, Mahwah, NJ). Out of the 103 Annealed liners, 39 annealed HXLPE liners were selected for the present study based on their implantation time and assigned to three equal cohorts (n=13); short-term (1.4 - 2.7 years in vivo), intermediate term (5.2 - 8.0 years in vivo) and long-term (8.3 - 12.5 years in vivo). From each of the 39 retrieved liners, one 9 mm core was obtained from the superior half of the liner and a second 9mm core was obtained from the inferior portion of the liner (n=2 pins per retrieved liner, 78 pins total). Five (5) never implanted control annealed liners were removed from their packaging and 16 cores were obtained from the liners to serve as controls. Additionally, 6 pins were fabricated from unirradiated (uncrosslinked) GUR 1050 resin (NIST reference material) and served as positive controls. Each core was taken such that the surface was as flat as possible and then machined on a lathe to ensure flat surfaces. Thus, the measurements pertain to the wear resistance of material at the articulating surface.

Results: Volumetric wear rates were found to vary based on the aging duration, as well as the pin location (i.e. superior vs. inferior). All of the 1st generation HXLPE cohorts had lower wear rates than unirradiated GUR 1050 pins (p≤0.03). Additionally retrieved HXLPE liners had higher wear rates than the control HXLPE cohort (p<0.001). For the retrieved HXLPE pins, the volumetric wear rates were highest for the pins in the Long-Term in vivo aged cohort (p<0.06). The pins of all specimens showed removal of machining marks as well as burnishing of the articulating surface.
In this study, we sought to determine the effects of in vivo degradation of wear performance of 1st generation annealed HXLPE liners used in total hip arthroplasty. The data in this study suggest that the tribological properties degrade with implantation time as the liner is subjected to the harsh in vivo environment. The clinical implications of this finding, however, are not clear as clinical wear rates of 1st generation HXLPE have remained low and have even been shown to decrease at 10-13 years in vivo [7]. This may be due, in part, to patients lowering their activity level as they age [5,7]. Another important finding of this study was that the superior surface consistently had lower wear rates (but not statistically significant) than the inferior surface, albeit this effect was smaller than the effect of implantation time. We hypothesize that this is due, in part, to the femoral head protecting the articulating surface from oxidizing species in body fluids. These findings for retrieved annealed HXLPE liners will be useful for comparison for evaluating the in vivo wear properties of other formulations of HXLPE, including 2nd generation HXLPE in future research.

Understanding the long-term wear performance of highly crosslinked ultra high molecular weight polyethylene (HXLPE) as it is challenged by in vivo conditions is paramount to improving the long-term survivability of total hip arthroplasty. This study utilizes pin-on-disk wear testing to evaluate the effects of in vivo aging on the wear properties of 1st generation annealed HXLPE.

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