Introduction

One of the major problems in total hip arthroplasty is the osteolysis secondary to particulate debris and eventual component loosening. This particulate debris is primarily generated through the wear of ultra-high molecular weight polyethylene (UHMWPE) acetabular liners. Radiation crosslinking has been demonstrated to significantly improve the wear resistance of UHMWPE during in vitro simulated gait studies. Several different methods are currently in use to crosslink UHMWPE for clinical use in total hip arthroplasty. Early clinical experience with these components has demonstrated no adverse affects on device performance due to increased crosslink density, and there have been no reported instances of early increased wear. A few revisions have been performed at our institution for sepsis, recurrent dislocation secondary to implant malpositioning or acetabular loosening with the highly crosslinked UHMWPEs. These early retrievals provide a unique opportunity to evaluate the highly crosslinked UHMWPE articulating surfaces for early wear damage or material failure.

Materials and Methods

We analyzed 16 conventional and 13 highly crosslinked acetabular liners that were surgically retrieved. In the highly crosslinked group, 3 were revised for sepsis, 7 were revised for acetabular component loosening due to lack of bone ingrowth, 2 were revised for implant malpositioning with recurrent dislocation, and 1 was revised because of abduction contracture. Seven of 13 patients had hip pain, which was secondary to acetabular component loosening. In this group there were 3 male and 10 female patients. In the conventional group, 9 were revised due to dislocation, 3 because of surgical malpositioning, 3 due to infection, and one from sciatic nerve palsey. The male to female ratio was 6 to 10. All patients in both groups were active and were walking without support. The range of in vivo duration for the highly crosslinked liners was 1-18 months. The highly crosslinked group consisted of 1 Crossfire liner (Stryker-Osteonics-Howmedica), 9 Durasul liners (Sulzer Orthopedics), and 4 Longevity liners (Zimmer). The range of in vivo duration of the conventional liners was 14 days to 10 months. Care was taken to remove the liners with minimal damage. The liners were marked at the twelve o’clock position at the time of explantation to note the orientation of the liners with respect to the pelvis. Surface findings were documented by optical microscopy.

Results and Discussions

The articulating surfaces of both the highly crosslinked and conventional components were characterized by a slightly dull appearance unlike the polished appearance that is commonly observed on the articulating surfaces of highly worn long-term retrievals. There were no delaminations or cracks on any of the surfaces and there were no gross deformations of any of the liners. Optical microscopy showed multidirectional scratches at the articulating surface in all components (Figures 1a and 1b). In the highly crosslinked group, 12 out of 13 displayed remnants of the original machining at the dome and supero-posterior quadrant of the articulating surfaces (Figure 1a). In the conventional group, the machining marks were no longer visible at the domes of 6 of 16 retrievals (Figure 1b).

The dull appearance of the articulating surfaces of both highly crosslinked and conventional liners resulted from the increase in surface roughness through the generation of multi-directional scratches. The morphology of these scratches suggested third body abrasive wear. Possible sources of this third body wear include retained fragments of poly(methyl-methacrylate) bone cement or small pieces of bone. The mechanism of surface scratch formation could include material removal, i.e. wear, and/or the reconfiguration of the surface topography through accumulation of plastic deformation.

When UHMWPE undergoes plastic deformation, the well-known “memory effect” (e.g. heat-shrink tubing) can be used to reverse the deformation by heating the polymer above its melting temperature. To qualitatively determine if the surface scratching was resulting in material removal or plastic deformation, we melt-annealed the highly crosslinked and conventional retrievals. Figure 2 shows the surface of a typical, highly crosslinked retrieval before and after melting. Upon heating of the liners to the melt temperature and cooling, the surface scratches disappeared and the original machining marks, which were made during fabrication, reappeared. This indicated that any material removal through third body damage on the highly crosslinked UHMWPE liners was minimal and that there was essentially no wear during this early time period up to 18 months. Loss of material or wear was negligible: instead of wear and material removal, the scratches were the result of plastic deformation of the surface. The melting of the conventional UHMWPE retrievals produced variable results: some liners showed partial recovery of machining marks, while others showed no recovery, thus indicating sufficient adhesive/abrasive wear for removal of at least 30μm of surface material (the typical height of machine marks).

Figure 2: Crosslinked retrieval (a) before and (b) after melting

Although there is extensive experimental wear data on the new highly crosslinked UHMWPEs, there is little data on the wear performance of these materials in vivo. The findings from the group of surgically retrieved, highly crosslinked UHMWPE liners included in this study showed that there is no adverse wear at 1 to 18 months and there were no material failures due to wear, delamination, or cracking. There were numerous multidirectional scratches in all of the highly crosslinked components, which gave the dull surface appearance. The scratches were formed by plastic deformation and there was no significant material removal with the original machining marks present on the articulating surfaces.