Introduction. The benefits of using highly crosslinked ultra high molecular weight polyethylene (UHMWPE) in total joint replacements have been encouraged by the low wear rates observed during extensive experimental mechanical simulation. However, the low in-vitro wear rate is not necessarily indicative of how the material will perform in vivo. Recent studies have reported that the articulating surface of the early retrieved components showed evidence of surface damage [1,2,3]. The point of contention among these studies was the interpretation of the observed damage. Muratoglu et al. [1] claimed that the majority of the observed features were due to plastic deformation. This was justified by low magnification (24-30x) images taken before and after melt annealing of the acetabular liners. Images taken after annealing showed the disappearance of surface scratches and the resolution of the original manufacturing machining marks, thereby substantiating the claim that the observed damage was mostly due to plastic deformation. Edidin et al. [2] presented high magnification (12,000x) images of the articulating surface of early acetabular liner retrievals. Fibril shaped particles and surface cracks were observed, suggesting that the surface damage was due to fatigue, adhesive, and abrasive wear mechanisms. Bradford et al. [3] also utilized electron microscopy and revealed that surface cracking and fatigue processes dominated these early retrievals. Since the acetabular liners in these studies were not melt annealed, it was unclear whether the surface features observed were due to plastic deformation or polyethylene wear. The purpose of this study was to provide more detailed information involving this point of uncertainty. In order to assess the nature of the surface damage processes in these devices, early retrieved highly crosslinked and non-crosslinked acetabular liners were observed using scanning electron microscopy (SEM) prior to and after melt annealing.

Methods. A total of 24 ultra high molecular weight polyethylene (UHMWPE) acetabular liners were available for examination; 22 were highly crosslinked UHMWPE (DurasulTM, Sulzer Orthopaedics, Austin, TX) and two were ethylene oxide sterilized non-crosslinked liners to be used as a control for this study (Smith & Nephew, Memphis, TN). All specimens were obtained after revision total hip arthroplasty. None of the components failed due to UHMWPE wear or osteolysis but were acquired as a result of Sulzer’s 2000 hip recall. All specimens were observed with SEM prior to melt-annealing in a previous study [3]. Four of the highly crosslinked specimens and the two non-crosslinked specimens were melt-annealed and observed again using SEM (JEOL 6300). The average time in-vivo for the selected highly crosslinked specimens was 8.7 months with a range of 5 to 14 months, and the average time in-vivo for the non-crosslinked specimens was 9 months with a range of 8 to 10 months. Melt annealing, using a hotplate, heated the retrievals above the melt temperature of UHMWPE (approximately 150°C). The specimens were slowly heated until the entire cup appeared visually transparent. The specimens were then cooled in air and imaged again in their post-melt-annealed condition using SEM.

Results. In the non-crosslinked specimens, the dominant damage mode was multidirectional scratching of the surface. Minimal recovery of the machine marks was observed at low magnification (Figure 1). In contrast, for crosslinked specimens that initially contained large regions lacking machining marks, low magnification images revealed that machining marks were more distinct after melt annealing (Figure 2a). Upon inspection of these marks at high magnification (150x, 550x, and 4000x), large amounts of residual damage were still present (Figure 2b). For the same specimens, there were also large regions where no recovery of the machining marks was observed (Figure 2a). The types of surface features observed at high magnification included micro-cracks (>2 microns), pits (5 microns), and tufts (2 microns) (Figure 3). Fibril formation was evident in both the crosslinked and non-crosslinked specimens.

Discussion. When a thermoplastic polymer such as UHMWPE is heated through its melting temperature, the thermal energy it acquires is sufficient in order to reverse the plastic strain it may have acquired. Since wear mechanisms contribute to material loss, heating will not restore the material to its original pre-wear condition. Similarly, fractures or micro-cracks would not be expected to recover through this melt process. In the present study, fibril formation and the lack of machining mark recovery is suggestive of material loss due to wear. In addition, it was found that low magnification images were not sufficient to accurately determine the extent of machining mark recovery. It was found that high magnification images showed significant residual damage and wear of the partially recovered machining marks.

The cracking and pitting observed in both the present study and by Edidin et al. [2] are damage features that have not, in past retrieval studies, been dominant for acetabular components manufactured from non-crosslinked UHMWPE. The scratched surface of the non-crosslinked specimens observed in this study, however, is consistent with previous reports [4]. Although the consequences of the observed surface features on the long-term success of the acetabular components are not known, their presence warrants additional observation.


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