Clinical Implications of Crosslinked UHMWPE Implants with Stress Concentrations: A Retrievals Analysis

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Statement of Purpose: Ultrahigh molecular weight polyethylene (UHMWPE) remains the polymer bearing of choice for total joint replacements (TJR).[1] The main limitation in implant longevity, however, is the generation of UHMWPE wear debris, which can initiate osteolysis and implant loosening.[2] Radiation crosslinking of UHMWPE significantly increases its wear resistance[3] but reduces resistance to fatigue and fracture. Moreover, free radicals that are not annihilated through thermal treatment can render UHMWPE susceptible to oxidation and mechanical embrittlement.[4] Such tradeoffs are of clinical concern when TJR are subjected to elevated stresses through design or loading. These compromises are evaluated through failure analysis of several fractured crosslinked UHMWPE retrievals including two tibial posts and two acetabular cups.

Methods: Four fractured clinically retrieved modular total hip and knee components were examined: a Depuy Marathon highly crosslinked acetabular liner with fractured liner locking tabs; a Zimmer Longevity moderately crosslinked acetabular liner with a fractured and deformed liner locking rim; and two Zimmer Legacy Posterior-Stabilized (LPS) NexGen moderately crosslinked tibial plateaus with fractured posts (Fig. 1(a-d)). Patient ages ranged from 58 to 68 years and time *in vivo* ranged from 3 to 9 years. Optical and scanning electron microscopy (SEM) were used to examine fracture surfaces. Oxidative analysis was performed using Fourier Transform Infra-Red (FTIR) spectroscopy.

Results: The fractured surfaces of the crosslinked UHMWPE retrievals demonstrated characteristic features of reduced ductility (Fig. 1e-h).[5] One of the moderately crosslinked LPS tibial posts and the Longevity liner rim both featured classic criss-cross patterns at their fracture sites associated with fatigue crack propagation but revealed little ductile tearing (Fig. 1f-g).[5] On the highly crosslinked Marathon acetabular liner (Fig. 1c), five of the six locking tabs fractured *in vivo* with very limited ductile tearing evidenced in SEM fractography (Fig. 1h). Fractography of the tibial post fractures revealed a brittle fracture associated with oxidation embrittlement on one implant (Figs.1a & 2a) and clamshell markings associated with fatigue crack propagation in the other failed tibial implant. The oxidized post (Fig. 2a) demonstrated white banding along the perimeter characteristic of oxidative degradation that was confirmed through FTIR analysis.[7] Fracture in the other tibial post (Fig. 2b) initiated from both anterior-medial and posterior-lateral corners.

Conclusions: The analysis of fractured retrievals from hip and knee arthroplasty shows similar mechanisms of mechanical failure associated with crosslinking and susceptibility to in vivo oxidation. Designs that incorporate high stress concentrations such as tibial posts or acetabular liner locking mechanisms should take these UHMWPE weaknesses into account.

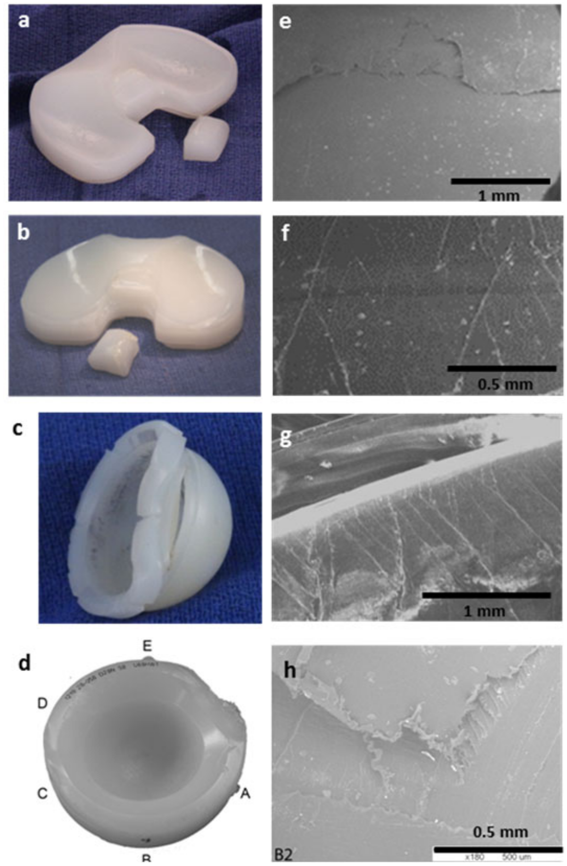

Fig 1. Two LPS tibial post fractures (a-b), the Longevity acetabular liner (c) and the Marathon acetabular liner (d) are shown. SEM images (e)-(h) reveal reduced ductility at the fracture surface of each retrieval.

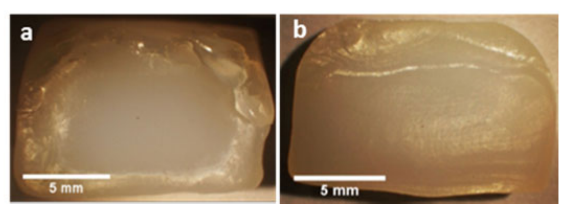

Fig 2. Optical microscopy images of both tibial post fracture sites: (a) one with white banding due to oxidative embrittlement and (b) the other with clamshell markings due to a fatigue-related fracture.

References: [1]Kurtz SM. UHMWPE Biomat Hdbk. 2009; 2nd Ed; [2]Willert HG. J Bio Mat Res. 1977; 11:157-46; [3]Muratoflu OK. Biomat. 1999; 20: 1463-70; [4]Atwood SA. J Mech Beh Biomed Mat. 2011; 4:1033-45; [5]Baker DA. J Biomed Mat Res A. 2003; 66: 146-54; [6]Pruitt LA. Biomat. 2005; 26: 905-15; [7]Currier BH. J Arthroplasty. 2007; 22: 721-31.