Poster 726 Society for Biomaterials, 2013

A Comparison of Small Punch Results on Aged Highly Crosslinked UHMWPE

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Statement of Purpose

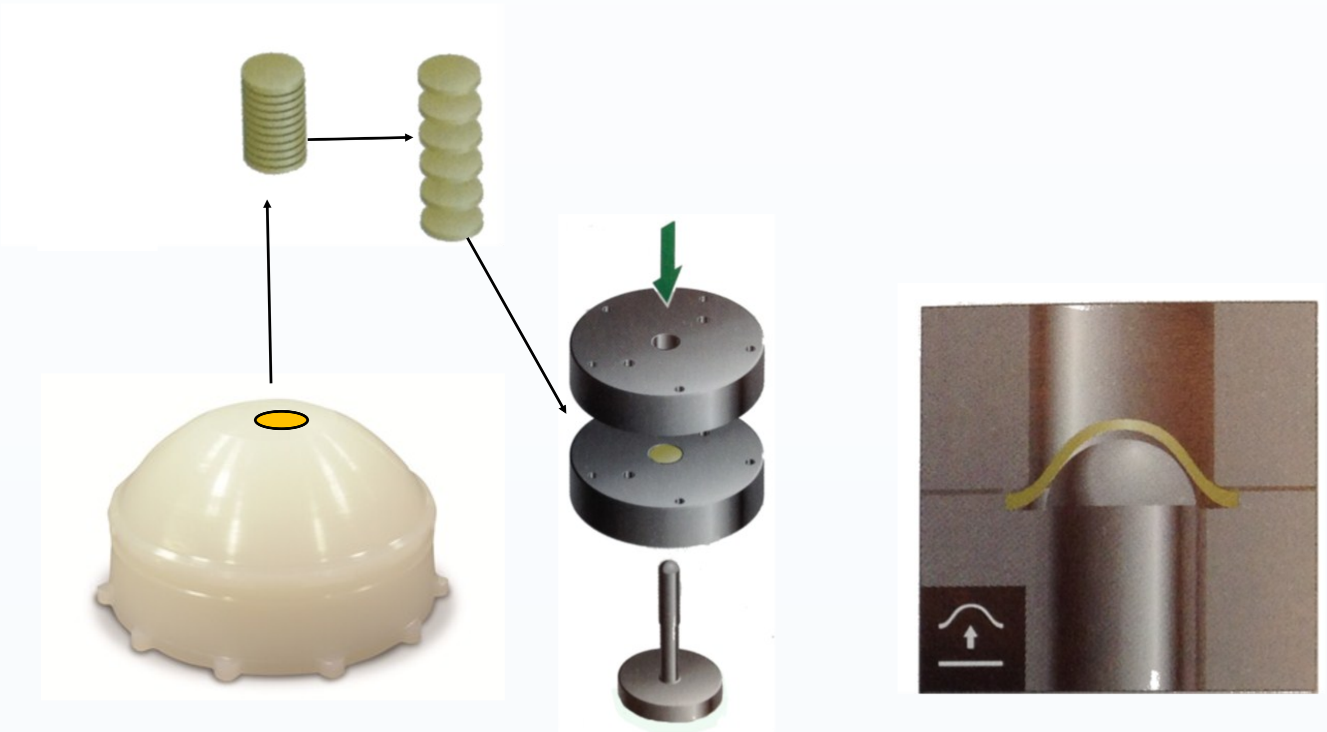
Highly crosslinked ultra high molecular weight polyethylene (UHMWPE) has been used effectively as a bearing surface in total hip and knee arthroplasties since the late 1990s.

Stryker introduced X3™ in 2005, a GUR 1020 resin irradiated to 30 kGy, annealed at 130ºC, and then re-irradiated and re-annealed twice more to reduce free radical content [1]. Zimmer introduced Vivacit-E® in 2012, a Vitamin E blended GUR 1020 that is then radiation crosslinked. Both these materials were developed to provide good wear behavior while being resistant to oxidation.

The resistance to oxidation of these two materials was assessed with small punch testing following accelerated aging.

Experimental Procedure

Never-implanted acetabular cups (2) made from X3 were obtained, along with cups made from Vivacit-E. Both sets of cups were placed in an oxygen bomb, pressurized to 5 atmospheres with oxygen, and aged in an oven at 70ºC according to ASTM F2003.Samples were removed from the oven at 2 weeks, 4 weeks. Vivacit-E was aged an additional 29 weeks for a total of 33 weeks. Cores were cut from each cup, and 5 specimens were obtained for each time point, including no aging. Small punch testing was conducted and analyzed according to ASTM F2183-02.



Reproduced from [1]

Stryker Acetabular Cup made from X3™

Zimmer Acetabular Cup made from Vivacit-E®

Result

The raw load-displacement curves for the X3 sample shows a substantial change in form when accelerated aging time is increased (Fig. 1), with shorter displacement and lower ultimate load. In contrast, the Vivacit-E sample shows no measurable difference up to 4 weeks; even at 33 weeks of accelerated aging, the curve is similar (Fig 2). Student's T-test evaluation of the data shows a statistically significant difference between the Ultimate load and Work to Failure between 0 and 4 weeks for the X3 sample (a=0.05, p<0.04), but no statistically-significant difference for the Vivacit-E, even up to 33 weeks (a=0.05, p>0.1) (Fig. 3).

Discussion

The incorporation of Vitamin E into UHMWPE to provide long term oxidative stabilization is well-known [2]. The X3 sample, lacking an antioxidant, shows a 54 to 68% loss in mechanical properties when accelerated aged up to 4 weeks, and had a work to failure that was 2.4 times less than Vivacit-E at 4 weeks of aging. Vivacit-E sample shows no statistical change in properties over 33 weeks of bomb-aging, corresponding to well over 20 years of real-time aging based on a Q10 relationship of 2.0. Typical accelerated aging tests stop at 4 weeks. The results indicate that Vivacit-E is more oxidation resistant than X3 under these conditions.

[1] Kurtz, "UHMWPE Biomaterials Handbook", 2009. [2] Oral et al. JOA 21(4): 580-91 (2006).

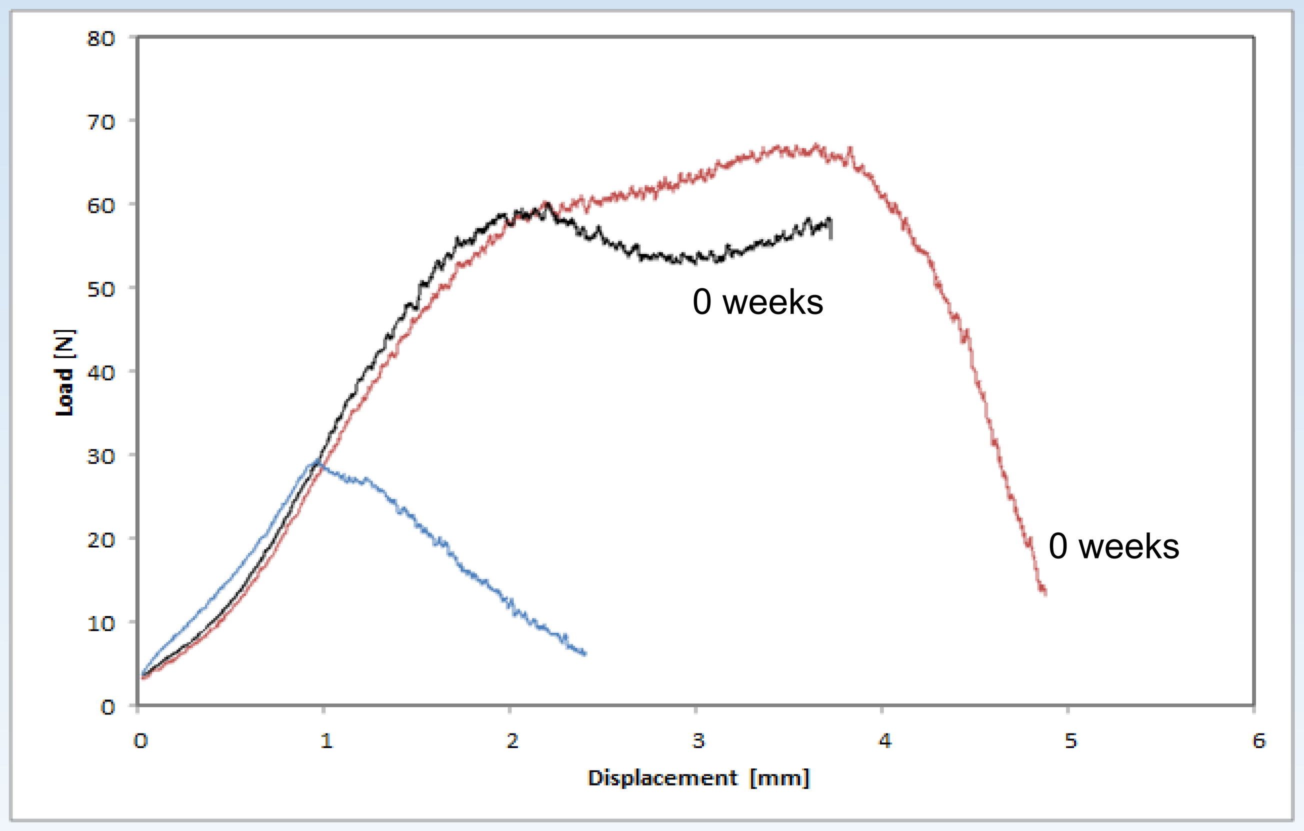


Figure 1: Representative small punch curves for aged X3™. Aging weeks are shown on the figure (0-4 weeks).

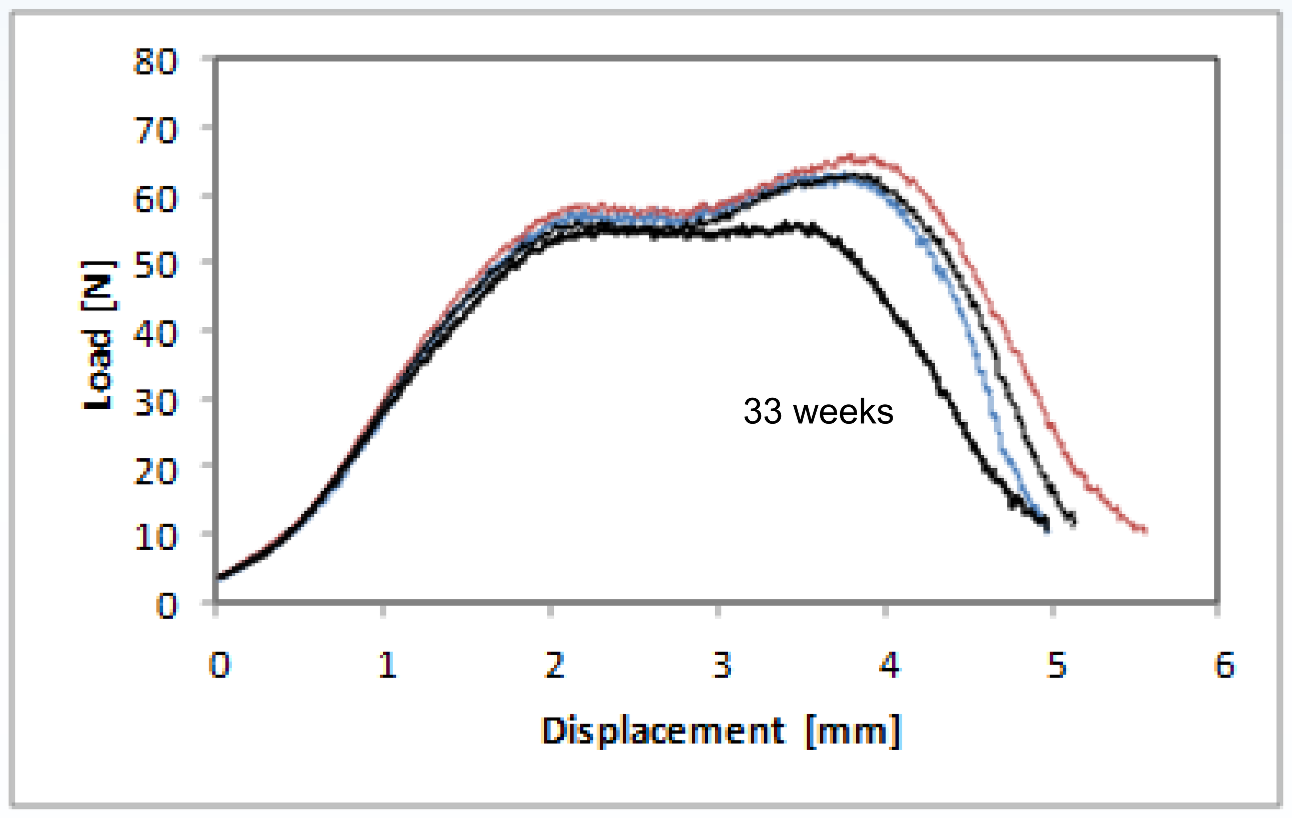


Figure 2: Representative small punch curves for aged Vivacit-E. Aging times through 4 weeks are tightly clustered. The 33 week aging time is indicated.

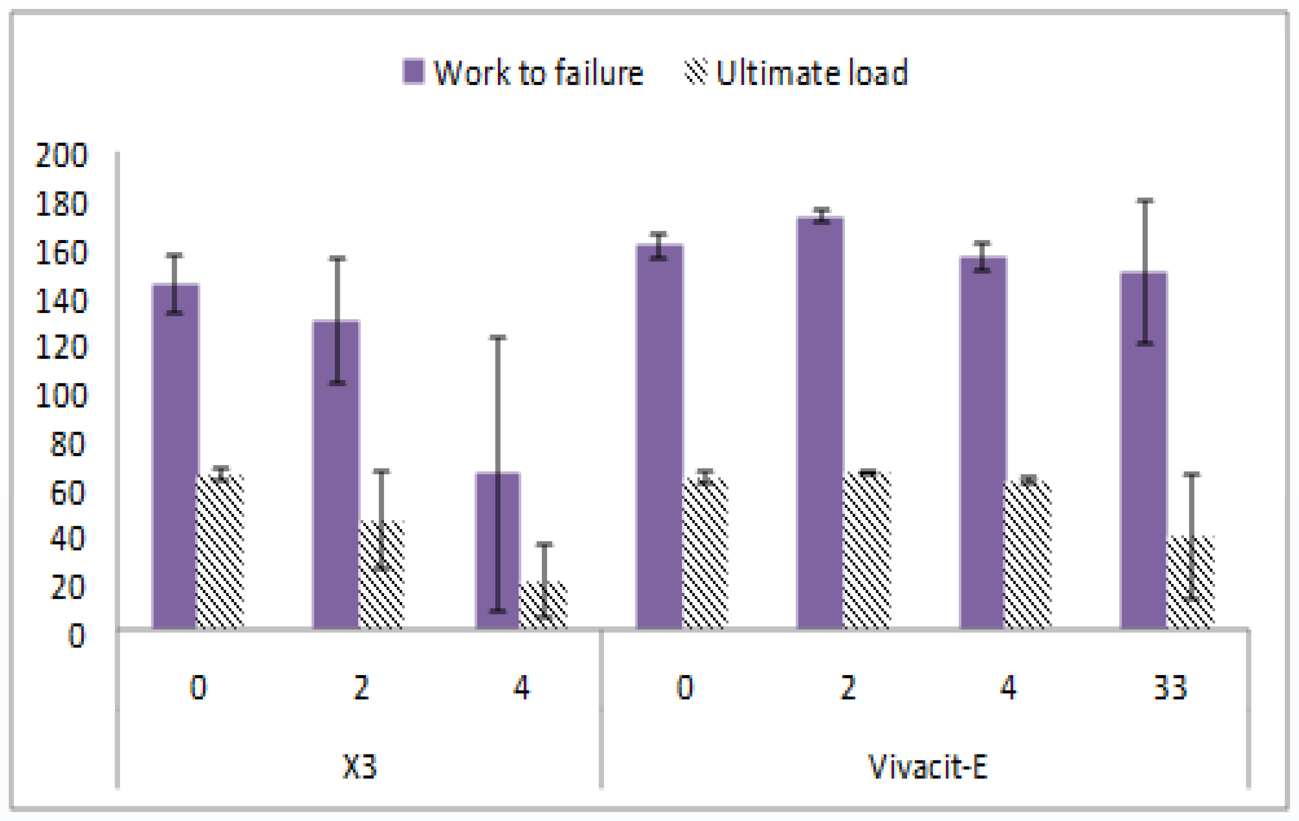


Figure 3: Summary of small punch results as a function of aging time. Results show average +/- 1 std dev.

This work was funded by Zimmer, Inc.

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