

THE EFFECT OF CHOLESTERYL ACETATE ABSORPTION ON THE MECHANICAL BEHAVIOR OF CROSSLINKED AND CONVENTIONAL UHMWPE

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Introduction: Recently, researchers have focused not only on the mechanical effects on polyethylene degradation, but the biological effects as well. The presence of synovial biochemicals, namely cholesterol and fatty acids, has been observed in the bulk of retrieved polyethylene acetabular liners [1,2]. Costa et al. identified the substances extracted from retrieved polyethylene components [1]. Using GC/MS, they found squalene, cholesterol and cholesteryl derivative to be the main diffused products. Little is known about the effects of biological compounds on the mechanical properties of conventional and highly crosslinked UHMWPE. A recent study by Greenbaum et al. [3] reported that the presence of the lipids squalene and 3-keto-4-cholestene diffused into the bulk of UHMWPE reduced its elastic modulus by approximately 50%. Furthermore, recent mechanical characterization of long-term retrieved acetabular components has documented substantial (>50%) reduction of ultimate mechanical properties [4]. It remains unclear whether the reduction of ultimate properties observed in the long-term retrievals is due to the absorption of lipids, or some other oxidative mechanism. Consequently, the purpose of the current study was to explore how the mechanical properties of conventional and highly crosslinked UHMWPE are affected by diffusion of cholesterol into the material. We hypothesized that diffusion of cholesterol in the bulk of conventional and highly crosslinked UHMWPE would serve as a plasticizer, resulting in a reduction in its mechanical properties.

Methods and Materials: Based on previous extraction studies [1], cholesteryl acetate ($C_{29}H_{48}O_2$, M.M.=428,8 g/mol) was chosen as the model compound for the diffusion experiments. Miniature disc specimens, 6.36mm wide and 0.5mm thick were machined from rods of the following types of conventional and highly crosslinked UHMWPE: (1) conventional GUR 1050, (2) conventional PE γ -irradiated in nitrogen at 30 kGy (30-N₂), (3) crosslinked PE γ -irradiated in air at 100 kGy and annealed at 110°C (100 kGy-110°C), and (4) crosslinked PE γ -irradiated in air at 100 kGy and remelted at 150°C (100 kGy-150°C). Five discs were machined for each of the eight conditions (soaked vs. control $\times$ 4 UHMWPE materials), totalling 40 specimens for the study. The disc specimens were then immersed in cholesteryl acetate and maintained in an oil bath at 70°C for 42 days in order to achieve complete saturation.

The soaked and unsoaked specimens were mechanically tested by the small punch test at a rate of 0.5 mm/min in an MTS 858 MiniBionix II Test System (Minneapolis, MN), in accordance with ASTM F2183-02. An unpaired t-test was used to compare the unsoaked and cholesteryl-soaked samples for each type of UHMWPE material. Significance was set at 0.05.

Results: Figures 1 and 2 compare the four polyethylene materials soaked in cholesteryl acetate versus their unsoaked samples in terms of ultimate load and elastic modulus, respectively. Soaking significantly ($p=0.03$) reduced the ultimate load of the crosslinked material 100 kGy-150°C by 7.9%. All other samples showed no significant change. Table 1 is a summary of ultimate load values. The crosslinked materials had a decline in elastic modulus of 21.9% for 100 kGy-110°C and 14.9% for 100 kGy-150°C (both comparisons are significant, $p<0.0001$ and $p=0.0116$ for 100 kGy-110°C and 100 kGy-150°C, respectively). The conventional materials had no significant change. Elastic modulus data are summarized in Table 2.

Discussion: Soaking in cholesteryl acetate had a slight, but significant, effect on the elastic and ultimate properties of highly crosslinked, but not the conventional UHMWPE materials. Thus, the large degradative changes in ultimate properties previously measured in conventional long-term retrievals [4] do not appear to be consistent with soaking in a lipid, such as cholesteryl acetate. However, the decreases in mechanical properties observed for the immersed crosslinked materials suggest that biological factors may play a larger role than previously expected for highly crosslinked materials currently used in hip and knee replacements. An extension of this study to other physiologically relevant biomolecules is under way to create a more complete picture of how the *in vivo* biological environment affects UHMWPE implants.

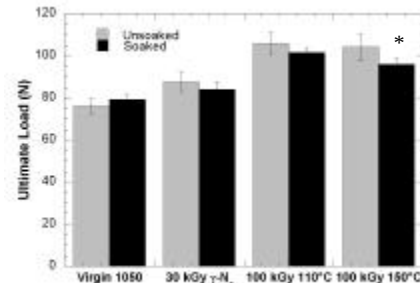


Figure 1: Ultimate load comparison of various types of UHMWPE soaked in cholesteryl acetate. An * denotes a significant change.

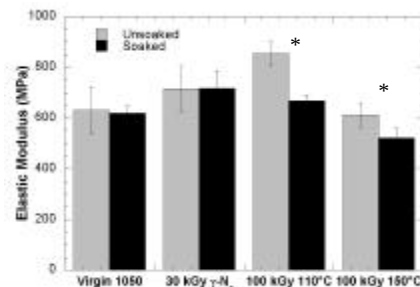


Figure 2: Elastic modulus comparison of various types of UHMWPE soaked in cholesteryl acetate. An * denotes a significant change.

Ultimate Load (N)		
	Unsoaked	Soaked
VIRGIN 1050	76.0 $\pm$ 3.6	79.3 $\pm$ 2.4
30kGy-N ₂	87.7 $\pm$ 4.7	84.1 $\pm$ 3.8
100kGy-110C	106 $\pm$ 6	102 $\pm$ 2
100kGy-150C	104 $\pm$ 7	96.0 $\pm$ 2.8*

Table 1: Summary of small punch ultimate load data for samples soaked and not soaked in cholesteryl acetate. An * denotes a significant change.

Elastic Modulus (MPa)		
	Unsoaked	Soaked
VIRGIN 1050	631 $\pm$ 93	621 $\pm$ 30
30kGy-N ₂	716 $\pm$ 90	718 $\pm$ 70
100kGy-110C	855 $\pm$ 48	667 $\pm$ 25 *
100kGy-150C	613 $\pm$ 49	521 $\pm$ 40*

Table 2: Summary of small punch elastic modulus data for samples soaked and not soaked in cholesteryl acetate. An * denotes a significant change.

References: [1] Costa et al. (2001) Biomaterials, 22:307-315; [2] James et al. (1993) Biomaterials 14:643-647; [3] Greenbaum et al. (2002) ORS, Paper 1028; [4] Edidin et al., (2002) SFB, Paper 25.

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