Absorption of Physiologically Relevant Compounds in UHMWPE

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- Chemical species absorbed into UHMWPE implants during in vivo use, such as fatty acids and other lipids, may play a role in biodegradation of UHMWPE [1-4]
- Little is known about the effect of antioxidant stabilizers currently being added to orthopedic devices on the absorption of species into UHMWPE
- Absorptivity is reported for a representative material, Isopropyl myristate (IM, Figure 1), similar in chemical structure to many biological compounds into various formulations of UHMWPE
- UHMWPE formulations were soaked at elevated temperatures for up to six weeks in IM and the relative bulk concentration of IM was determined using FTIR

Materials

- Consolidated GUR 1050 material was prepared using five different processing conditions described in Table 1
- Crosslinking: three highly crosslinked ("VE-HXPE", "HXPE", "Extracted"), two gamma sterilized ("VE-PE", "UHMWPE")
- Antioxidant content (Vitamin E, VE): two without VE ("HXPE", "UHMWPE"), two blended with VE (V"E-HXPE", "VE-PE"), one initially blended and then extracted, with an assumed minimal concentration ("Extracted")

Methods

- Five 10 mm cubes of each material were aged in 100% IM (Sigma-Aldrich, St. Louis, MO) at 60°C
- Samples were withdrawn at 1, 2, 3, 5, and 6 weeks for analysis
- Crosslink density: 3 mm cubes analyzed by swell ratio before aging, ASTM F 2214-02 [5]
- Crystallinity: 200 μm slice from center of sample analyzed by differential scanning calorimetry (DSC) before aging, ASTM F 2625-07 [6]
- IM index: 200 μm slice from center of sample analyzed by FT-IR at aging timepoints, ratio of height of IM peak at 1738 cm^{-1} to height of polyethylene peak representing C-H overtones at 4322 cm^{-1}

Results & Discussion

- Figure 2 shows the absorption of IM into the bulk of each material at aging time points up to 6 weeks.
- Figure 3 shows the crosslink density of each material pre-aging.
- Figure 4 shows the percent crystallinity of each material pre-aging.
- The HXPE materials show a higher initial absorption rate than the VE materials (Figure 2).
  - Counterintuitive, but may be explained by increased free volume in crosslinked and melted materials due to either a greater number of chain ends or a reduced degree of crystallinity
  - The lower crystallinity of the HXPE supports this theory
- The blended materials (VE-HXPE and Extracted) were irradiated at levels intended to yield similar crosslink densities to HXPE despite the presence of free-radical scavengers, supported by Figure 3
- Extracted material indicated similar diffusion rates to the HXPE, which may be due to removal of unbound low molecular weight species leading to more free volume in the sample
- VE-HXPE has a lower initial absorption rate than either the Extracted or the HXPE samples, suggesting that the presence of Vitamin E reduces the absorption rate of otherwise similar materials
- Non-crosslinked materials, VE-PE and UHMWPE, exhibited similar absorption rates, suggesting VE's protection against absorption results from reduced free volume in highly crosslinked samples

Conclusions

- VE may act to physically protect highly crosslinked polyethylene as well as impart oxidative stability.
- Initial diffusion of the IM that is impacted, not the equilibrium concentration at long times.

References

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[6] ASTM F 2625-07. "Standard test method for measurement of enthalpy of fusion, percent crystallinity, and melting point of UHMWPE by means of differential scanning calorimetry". 2007.

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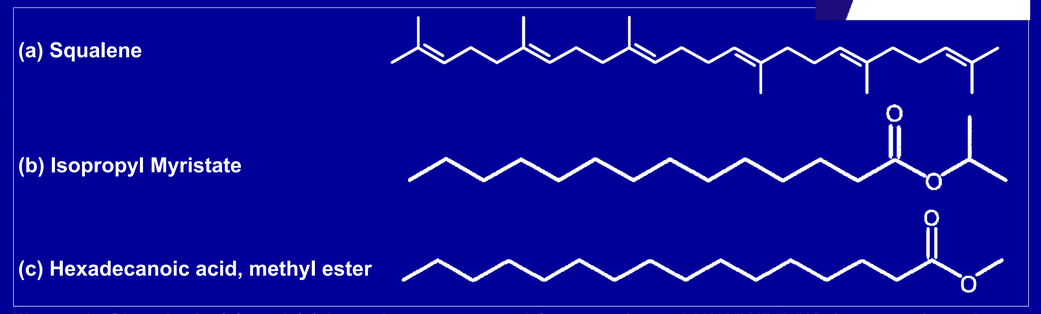

Figure 1: Chemicals (a) and (c) have been extracted from explanted UHMWPE [2]. Isopropyl myristate (b) was used as a model compound in this study.

Table 1: Description of UHMWPE GUR 1050 materials examined in the study.

Material	Description
VE-HXPE	VE blended; e-beam crosslinked
HXPE	gamma crosslinked; post-melted
Extracted	VE-HXPE; extracted with hexane (3 days) and IPA (3 days)
VE-PE	VE blend; gamma sterilized
UHMWPE	gamma sterilized

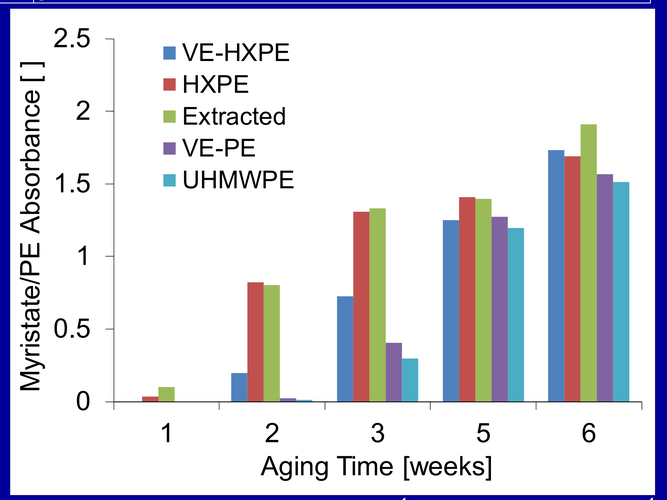

Figure 2: Ratio of IM peak at 1738 cm^{-1} to PE peak at 4322 cm^{-1} as a measure of IM absorption versus aging time.

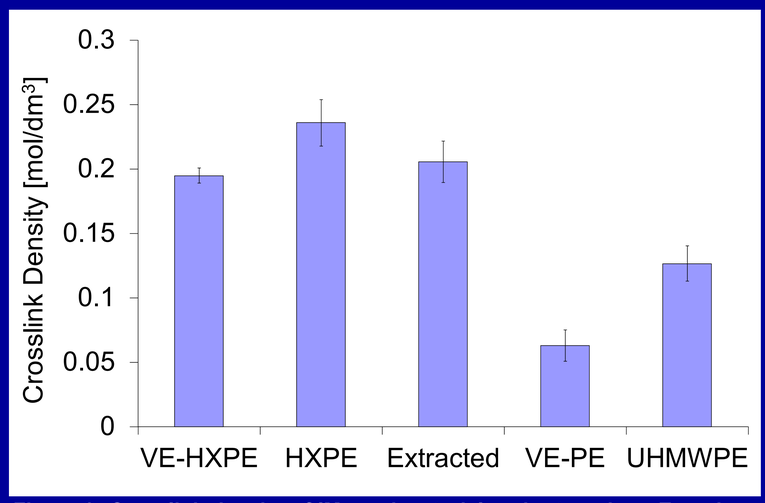

Figure 3: Crosslink density of IM aged materials prior to aging. Error bars = 1σ.

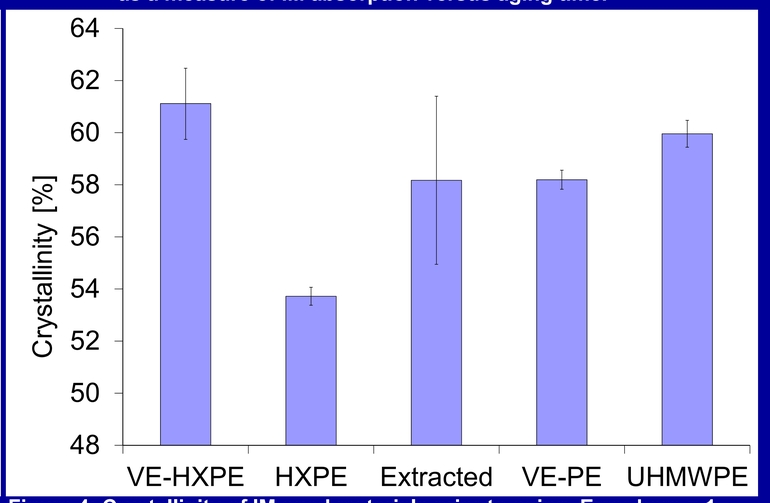

Figure 4: Crystallinity of IM aged materials prior to aging. Error bars = 1σ.