Observation of Slowed Reaction of Polyethylene Radicals in the Presence of Vitamin E

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Statement of Purpose: Vitamin E is used in UHMWPE (ultra-high molecular weight polyethylene) as an alternative to melting in order to eliminate free radicals. Chemical oxidation is a primary factor in limiting the life of UHMWPE prostheses, and free radicals are believed to be precursors to this oxidation via their reactions with oxygen. Vitamin E does improve properties, including oxidation resistance, in UHMWPE; this is thought to be due to vitamin E reacting with radicals in the polyethylene and eliminating them. [1-2]

If a material is not exposed to oxygen then oxidation cannot occur, even if free radicals are present. Our goal is to investigate a way that free radical activity in irradiated UHMWPE is slowed when in contact with vitamin E (α tocopherol). To test this hypothesis, we have left irradiated polyethylene in the ESR sample tube containing vitamin E. Using ESR (electron spin resonance), we monitored free radical activity over a period of 18 months. We evaluated the formation of oxygen-induced radicals, which indicate reactions of oxygen with the primary radicals produced during irradiation. [3]

Methods: UHMWPE (GUR 1050) bar stock was gamma-irradiated (30.1-33.9 kGy, ^{60}Co, Steris Isomedix) at room temperature in nitrogen. The irradiated UHMWPE samples were separated into three groups, as shown in figure 1: (a) those irradiated and left in air without subjecting to heat or vitamin E, (b) those irradiated, then kept in the ESR tube containing vitamin E in air, and (c) those irradiated, then partially vitamin E diffused (1 hour at 100C in nitrogen) and then kept in the ESR tube with vitamin E in air. It has to be emphasized that the inner diameter of the ESR sample tube is 4.8 mm and the sample size is 3x3x8 mm^3. Therefore, only a small layer of vitamin E was in contact with the sample. For comparison of the ESR spectra, one spectrum of vitamin E alone is also shown in figure 1 (d). Free radical activity was analyzed over the course of 18 months at room temperature in air using an X-band Bruker EMX 300 spectrometer operating at 9.8 GHz microwave frequency and 100 kHz magnetic field modulation frequency.

Results: Figure 1 shows ESR measurements at the 18 months. It shows that (b) and (c) - the samples remaining in vitamin E - did not experience the development of radicals indicative of oxygen exposure to nearly the extent as (a) – the sample in ESR tube without vitamin E. The ESR spectrum (b) is similar in structure produced in 12-24 days in the presence of oxygen (air) in compression-molded UHMWPE containing vitamin E [4]. The spectrum (c) is much more reduced because of initial heating (1 hour at 100C in the presence of vitamin E). One can identify which parts of the ESR spectra may be due to vitamin E radicals by comparing with a spectrum of the radicals present in vitamin E alone (d). The primary radicals of polyethylene have seemed to decrease in (b) and (c), but not be totally eliminated. This study clearly demonstrates that the free radical activity slows when the irradiated UHMWPE stays in contact with vitamin E, complete quenching, however, does not occur. For further study, we would like to clean the samples completely of vitamin E on the surface and observe to what extent the oxygen induced radicals (OIR) develop. It is predicted that it will be to a much lesser extent since the intensity of OIRs can depend on the quantity of primary radicals exposed to oxygen. [3]

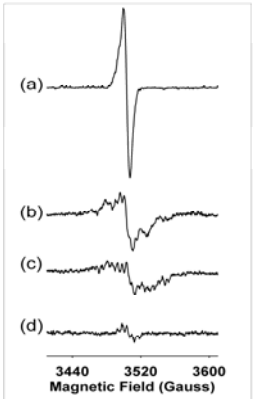

Figure 1, as described in the text.

References:

[1] (Oral, et al.. Biomaterials 2004; 25:5515-22.)
[2] (Oral, et. al. Biomaterials 2006; 27: 5580-7.)
[3] (Jahan, et. al., Radiat. Phys. Chem. 2001; 62: 141-144.)
[4] (Ridley M., Jahan M., Nucl Instrum Meth B 2007; 265(1): 62-66.)

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