24 Weeks Accelerated Aging study for HALS and Vitamin E stabilized 100 kGy irradiated UHMWPE

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Introduction: Several studies have shown that the antioxidant vitamin E effectively scavenges remaining free radicals within irradiation crosslinked UHMWPE materials and thereby preventing oxidative degradation without the need for remelting or annealing (1). However if the vitamin E is applied to the UHMWPE powder prior to the molding and irradiation, it interferes with the crosslink process (2). Part of the vitamin E will be consumed during irradiation, which results in a lower crosslink efficiency. HALS stabilizers have shown not to reduce the crosslink efficiency (3). In this study the chemical and mechanical properties, including wear before and after accelerated aging, are investigated for a 100 kGy UHMWPE containing respectively 0.10 wt.% HALS or Vitamin E.

Methods and Materials: GUR1020 resins doped respectively with 0.10 wt.% HALS or Vitamin E were compression molded into 80 mm thick sheets (Meditech, USA). The material was machined into 1.0 meter bars and then gamma irradiated with 100 kGy (BGS, Germany). After annealing the bars, the test specimens for all subsequent analyses were machined from the bar stock. Accelerated aging was conducted in accordance with ASTM F2003 (70°C, 5 bar O_2). Swell ratio, crosslink density and molecular weight between crosslinks were determined according to ASTM F2214. During aging the oxidation index was followed per ASTM F2102. Tensile properties (yield stress, ultimate stress and percent elongation) were monitored per ASTM D638. The wear resistance was tested using DSM's 100 station POD wear tester (4).

Results: The 100 kGy HALS material was found to have a lower swell ratio, higher crosslink density, and lower molecular weight between crosslinks when compared to the Vitamin E material.

Table 1; Swell ratio, crosslink density and Mw between crosslinks for 100 kGy GUR1020 with HALS and Vitamin E.

Material	Swell Ratio, q_s	Crosslink Density, V_d [mol/dm^3]	Molecular Weight Between Crosslinks, M_c [g/mol]
HALS	3.05 ± 0.15	0.205 ± 0.020	4510 ± 430
VITE	4.04 ± 0.07	0.121 ± 0.004	7610 ± 240

Tensile properties were not affected by 24 weeks of aging for both the HALS and Vitamin E materials. The percent elongation values for the 100 kGy HALS material were lower than those for the 100 kGy Vitamin E material for both non-aged and all aged samples. All oxidation values for the 100 kGy HALS and 100 kGy Vitamin E materials, even after 24 weeks of aging, were low (<1.0). In comparison, the control 25 kGy GUR1050 material demonstrated critical oxidation (>3.0) after 4 weeks of accelerated aging (Figure 1). The wear was significantly lower for the 100 kGy HALS material as compared to the Vitamin E material. Both materials' wear rates were not affected by the 24 weeks of accelerated aging (Figure 2).

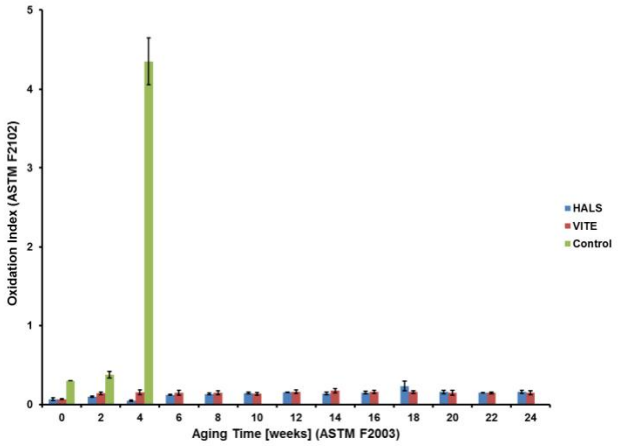

Figure 1: Average maximum OI for the 100 kGy GUR1020 with HALS, 100 kGy GUR1020 with vitamin E, and 25 kGy GUR1050 control materials after accelerated aging. Error bars represent one standard deviation. At six weeks, the 25 kGy 1050 material was too oxidized to perform FTIR.

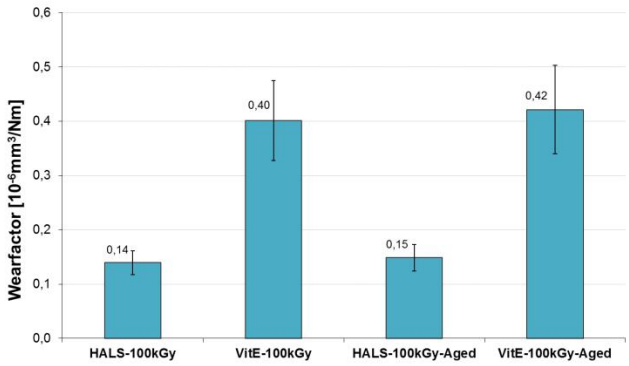

Figure 2; POD wear factor; Total distance 60,480 km (2 million cycles multiaxial motion). Lubricant water-serum (1:1). Pressure on each pin ~70N (~1,1MPa). Test temperature 20°C.

Conclusion: The crosslink density for the HALS material is significantly higher as compared to Vitamin E at the same irradiation dosage of 100 kGy. This is also reflected by the lower elongation values for the HALS material, indicating a higher crosslink density as well. Both HALS and Vitamin E stabilized materials maintained their tensile properties, wear resistance and low oxidation index values even after 24 weeks of accelerated aging. The higher crosslink density resulted in a significantly lower wear for the 100 kGy HALS material as compared to the 100 kGy Vitamin E material.

References

1. Kurtz, S.M. The UHMWPE Biomaterials Handbook 2nd edition. New York: Elsevier, Inc. Academic Press, 2009.
2. Oral, E et al, Biomaterials (2005), 26(33), 6657-6663
3. Gijsman P et al, Biomaterials 31 (2010) 6685 - 6691
4. Saikko, V. Proc. IMechE 2005, 219 Part H:J. Eng. in Medicine, 309-318.

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