Mechanical Properties of Highly-Crosslinked, Vitamin E Infused GUR1020 and GUR1050 UHMWPE

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Statement of Purpose: Vitamin E infused highly crosslinked GUR1050 ultra-high molecular weight polyethylene (UHMWPE) is currently utilized for acetabular components in total hip arthroplasty. The vitamin E infused polyethylene has demonstrated low in vitro wear, good mechanical properties, and excellent oxidation resistance[1]. This study evaluated the mechanical properties of vitamin E infused polyethylenes that utilized GUR1020 and GUR1050 resins as the base materials to determine if the mechanical properties could be optimized for use in total knee arthroplasty.

Methods: Type V dog-bone specimens (per ASTM D638) and IZOD impact specimens (per ASTM F648) were manufactured from isostatically compression molded UHMWPE GUR 1020 barstock and GUR1050 barstock (resin from Ticona, Germany). The material was irradiated to a dose of 100kGy ±10 kGy (Steris, Libertyville, IL), and infused with vitamin E in a two-step process. The specimens were soaked in vitamin E for 0.3 to 1.5 hours at 122°C and the vitamin E was allowed to diffuse through the thickness of the parts in an inert gas oven for 64 to 164 hours at 130°C. The finished test specimens were cleaned in isopropyl alcohol and gamma sterilized in barrier film packaging (25-40kGy, Steris). The α-tocopherol (vitamin E) index of the test specimens was maintained between 0.02 and 0.15.

The control specimens were manufactured from isostatically compression molded GUR1050 UHMWPE barstock, cleaned in isopropyl alcohol and gamma sterilized (25-40kGy, Steris).

In addition to the control material, sequentially crosslinked and annealed (SCA) specimens were created for comparison. GUR1050 specimens were gamma sterilized to a dose of 33kGy (Steris) and annealed at 130°C for 4 hours followed by a 10-hour ramp down to ambient temperature. The process was repeated twice for a total irradiation dose around 100kGy. The SCA specimens were gas plasma sterilized (Biomet, Warsaw, IN).

Half of the specimens from each material group were accelerated aged for 2 weeks at 70°C and 5 atm of O_2 in accordance with ASTM F2003.

IZOD specimens were tested per ASTM F648 (Biomet). The tensile testing was performed per ASTM D638. The vitamin E and the conventional control group was tested at Bodycote (Skokie, IL) and the SCA specimens were tested at Biomet.

Results: The impact strengths and tensile properties are reported in Figures 1 and 2 respectively.

The unaged GUR 1020 vitamin E infused material (1020E) had an impact strength that was 84% higher than that of the unaged GUR1050 vitamin E infused material (1050E). The impact strengths of the two vitamin E infused materials were less than that of the unaged control material. This difference is attributed to the decrease in chain mobility associated with higher levels of irradiation-induced crosslinking.

The ultimate tensile strength and the percent elongation of the 1020E group were greater than that of the 1050E group. There was little difference in yield strength between the two materials.

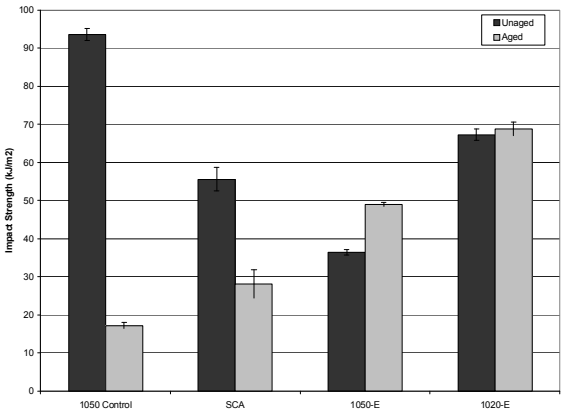

Figure 1. IZOD Impact Strength.

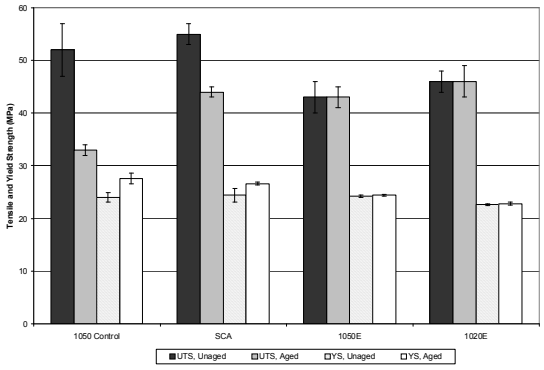

Figure 2: Tensile Mechanical Properties.

After accelerated aging, the 1050E and 1020E groups showed no decrease in impact strength, ultimate tensile strength, and yield strength. In contrast, the 1050 control material and the SCA group showed drops in impact strength and tensile strength after accelerated aging. The vitamin E present in the 1050E and 1020E groups protected the polyethylene from the oxidative degradation that occurred in the 1050 control material and the SCA material after accelerated aging.

Conclusions: With its resistance to oxidation and high impact strength, using 1020 resin as the starting material for highly-crosslinked and vitamin E infused UHMWPE may be advantageous for applications that require high impact strength, such as total knee arthroplasty. Future work should include an evaluation of the wear characteristics of the 1020 material and an analysis of the differences in depth of diffusion between the two resins.

References:

(1) Oral, E. J.Arth. 2006;vol 21, #4:580-591