Wear Resistance of a Chemically Crosslinked UHMWPE/Vitamin-E Blend for Total Joint Arthroplasty Implants

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INTRODUCTION: Gamma irradiation is currently the primary method used to crosslink ultra-high molecular weight polyethylene (UHMWPE) in the production of bearings for total joint arthroplasty. However, due to the limited availability of gamma radiation resources, which must be divided for both sterilization and crosslinking purposes, and the increasing demand for total joint arthroplasty procedures, gamma radiation may not remain a sustainable solution for crosslinking UHMWPE. Chemical crosslinking with peroxides provides an attractive option for fabricating antioxidant-stabilized highly crosslinked UHMWPE as the crosslinking step occurs simultaneously with consolidation of the blended resin and can lead to higher crosslinking efficiency than gamma irradiation in the presence of a free radical scavenger like an antioxidant[1]. In addition, peroxide crosslinking of antioxidant stabilized UHMWPE followed by inert high-temperature melting has been shown to produce material with superior toughness compared to traditional blended or diffused gamma crosslinked antioxidant UHMWPE materials[2]. The objective of this study was to compare the wear rate of a compression molded UHMWPE/vitamin-E/di-cumyl peroxide blend followed by high-temperature melting in an inert gas oven (Activit-E™) with direct compression molded conventional polyethylene (CPE) under accelerated aged conditions. We hypothesized that the Activit-E material would demonstrate superior wear resistance compared to direct compression molded CPE.

METHODS: Pins conforming to ASTM F732-17 were fabricated from Activit-E and CPE materials. The Activit-E samples consisted of a compression molded UHMWPE/vitamin-E/di-cumyl peroxide blend followed by high-temperature melting in an inert gas oven and then terminally sterilized via gamma under vacuum. The CPE samples were fabricated from direct compression molded GUR 1020 knee inserts and gamma sterilized under vacuum. All samples from each material group were aged for two weeks in a pressure vessel (5 atm of pure O_2) placed in a convection oven at 70ºC[3]. A previously described bi-directional pin-on-disc (POD) wear tester was used to measure the wear rate of the specimens articulating against discs lubricated by 250 ml of room temperature bovine serum with a protein content of approximately 7.0 g/dL after preservation with EDTA and a penicillin/streptomycin solution[4]. The discs were manufactured from cobalt chrome polished to Ra ≤ 0.06 µm. The wear test was conducted per ASTM F732-17 Annex A2 with a 10 mm x 5 mm rectangular wear path. Specimens were tested to 1.12 million wear cycles after which a wear rate was calculated via linear regression omitting the initial 0.5 million cycles (MC) of testing and expressed in milligrams per million cycles (mg/MC). A Student's t-test was used to determine significant differences (p<0.05) between material groups.

RESULTS: The calculated linear POD wear rate of aged CPE was 10.4 ± 2.7 mg/MC and the calculated linear POD wear rate of aged Activit-E was 2.6 ± 0.4 mg/MC (Figure 1, Table 1). The lower wear rate of aged Activit-E compared to aged CPE was statistically significant (p=0.0008).

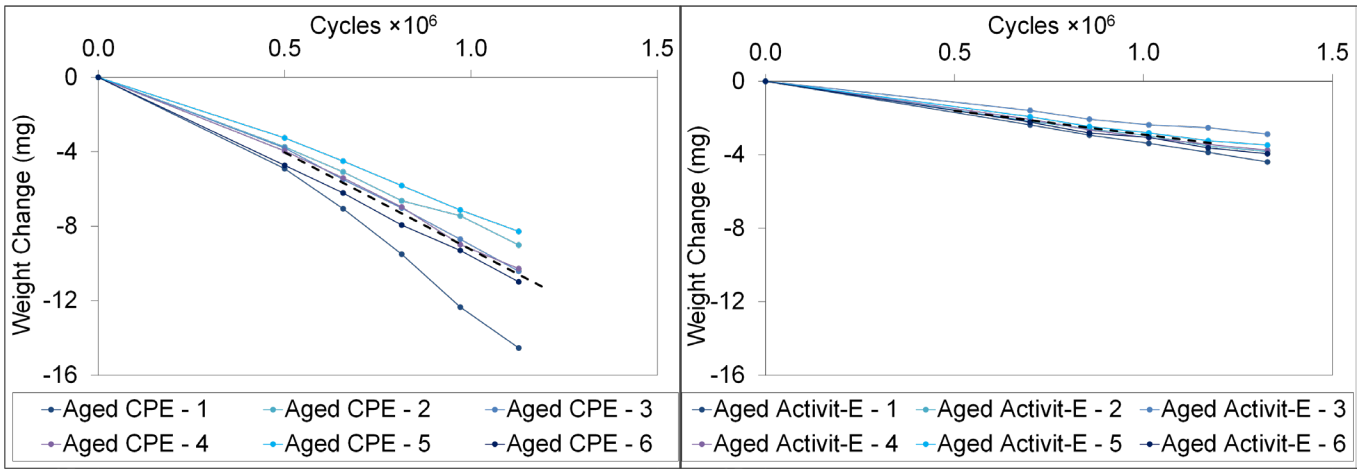

Figure 1: Weight change as a function of test cycles for aged CPE (left) and aged Activit-E (right). The dashed line indicates the average calculated linear wear rate.

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Average	SD
Aged CPE	**15.62**	**8.21**	**10.48**	**10.32**	**8.07**	**9.93**	**10.44**	**2.74**
Aged Activit-E	**3.16**	**2.68**	**1.94**	**2.64**	**2.45**	**2.70**	**2.59**	**.040**

Table 1: Calculated pin-on-disc linear wear rates of aged CPE and aged Activit-E. (Unit: mg/MC)

DISCUSSION: The Activit-E samples demonstrated a significantly lower wear rate as compared to direct compression molded conventional polyethylene. In conjunction with existing literature on the excellent mechanical properties of peroxide crosslinked and antioxidant stabilized UHMWPE, the present study demonstrates low wear rates are achievable; thereby making this material an attractive option for total joint replacement bearings[5].

SIGNIFICANCE/CLINICAL RELEVANCE: Peroxide crosslinked, vitamin-E stabilized and high temperature melted UHMWPE represents an appealing material option due to its superior scalability and production efficiency compared to gamma irradiation crosslinking of UHMWPE. Wear resistance is an important requirement for UHMWPE materials used in total joint arthroplasty. This study demonstrated superior wear resistance of the peroxide crosslinked UHMWPE material compared to conventional UHMWPE.

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