Influence of vitamin E on UHMWPE tribological performance

Igor Tenório Soares[1)*], Clara Muniz de Almeida[2)], Marcia Marie Maru de Moraes[2)]and Maria de Fátima V. Marques[1)]

[1)]Institute of Macromolecules Professor Eloisa Mano, Federal University of Rio de Janeiro, Brazil
[2)]Materials Metrology Division, National Institute of Metrology, Quality and Technology, Brazil.
*Corresponding author: igor.tenorio.soares@gmail.com

Vitamin E is the most important antioxidant used to stabilize the UHMWPE (ultrahigh molecular weight polyethylene) structure in orthopedic prostheses. Despite its well-known antioxidant effect, the contribution to wear still needs more investigation. This work presents results of creep and reciprocating ball-on-flat dry friction tests to investigate the changes caused by vitamin E on the UHMWPE tribological performance. The results show that the antioxidant forms a new phase in the polymer structure, increasing the wear depth, with contributions of adhesion, abrasion and plastic deformation mechanisms, and formation of transfer film.

Keywords: tribology, UHMWPE, vitamin E, adhesion, plastic deformation

1. Introduction

UHMWPE is one of the most used polymers for articulated prostheses due to its high mechanical properties and low coefficient of friction. Over the last two decades, researchers have shown how important vitamin E is as antioxidant agent to prevent oxidation by thermal degradation during compression molding, radiation cross-linking, shelf storage, and mechanisms active during implantation of UHMWPE prostheses [1]. However, little information is given about its influence on the tribological performance of the polymeric matrix. In this context, this work presents the effects of vitamin E in the structure of UHMWPE on the polymer's wear mechanisms and tribological properties.

2. Methods

UHMWPE (GUR 4150) powder was mixed to 1% wt of vitamin E in a planetary ball mill (370 rpm and 20 min). The mixture was molded into flat plates by hot pressing (483.15 K, 11 tons and 40 min). Reciprocating ball-on-flat dry friction tests were executed with 10 mm wear track, 1 Hz frequency and 15 N normal load. Indentation tests were executed with 100 N normal load for 1 hour. A tribometer (TriboLab Bruker) was used for all the tests, using AISI 52100 chromium steel balls (10 mm diameter) as counterfaces.

3. Results and Concluding Remarks

As shown in Fig. 1a, vitamin E allowed the counterface to get deeper in the UHMWPE, already during the first moments of friction, but was surpassed by the pure UHMWPE after 3,000 friction cycles. However, Fig. 1b reveals higher groove depth in the UHMWPE+vit.E specimen. This behavior is explained considering the images of the balls (Figs. 2a-b), in which a big amount of transferred material is seen in the ball slid against UHMWPE+vit.E sample. That is, vitamin E has increased the polymer to metal adhesion. Results also showed that the increase of the transfer film increases abrasion and plastic deformation wear mechanisms in the polymer. Interestingly, the creep tests resulted in similar indentation depth to both samples (~ 40 µm), meaning that the presence of vitamin E may have enhanced plastic deformation by shear but not by compression mode.

Optical microscopy images of the ball surfaces after indentation tests showed artifacts resembling the polymer's surface finishing, but only in the presence of vitamin E. It was argued that it was caused by the phase separation between polymer grains and antioxidant, which is clear in Figs. 2c-d. Grain-like paths formed in the UHMWPE+vit. E (Fig. 2d) do not appear in the pure UHMWPE sample.

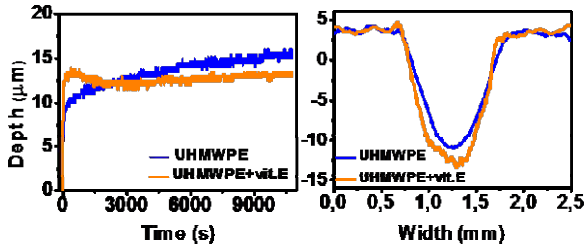

Figure 1: (left) Deepening of the ball on the polymer surface during the friction tests; (right) Depth of the grooves left in the polymeric samples after friction test.

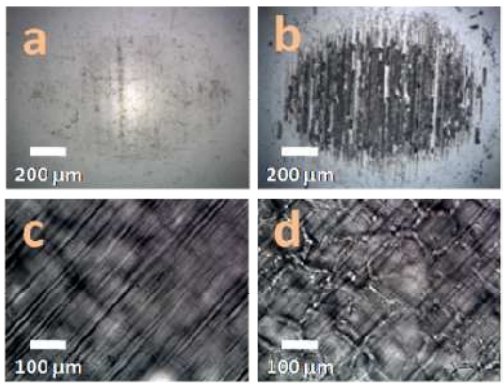

Figure 2: Optical microscopy images of (a,b) balls after the friction tests by reflected light and (c,d) polymeric samples before test by transmitted light. Images in the left side: pure UHMWPE tests; images in the right side: UHMWPE+vit.E tests.

4. References

[1] Kurtz, S.M. et al., Vitamin E-Blended UHMWPE Biomaterials, UHMWPE Biomaterials Handbook: Ultra-High Molecular Weight Polyethylene in Total Joint Replacement and Medical Devices, Elsevier, 2016, 293-294.