Fatty-acid absorption detrimentally changes the physical properties of ultra-high molecular weight polyethylene

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Introduction

Retrieval studies have demonstrated that lipids and fatty acids in synovial fluids are adsorbed by the surface of ultra-high molecular weight polyethylene (UHMWPE) joint replacements[1]. James *et al.* also confirmed the presence of esterfied fatty acids within the surface of retrieved implants[2]. However, the effect of fatty acids on the physical properties of UHMWPE is poorly understood. Octadecadienoic acid is one of the main components of the synovial fluid representing approximately 80% of the total fatty acid content[3]. The aim of this study is to investigate the effect of octadecadienoic acid on the percentage crystallinity, melting point and tensile properties of UHMWPE.

Materials and Methods

Five tensile test samples were doped in cis-9,cis-12-Octadecadienoic acid (Sigma Aldrich) for 24h at 100ºC. The elevated temperature was used to accelerate the diffusion of the octadecadienoic acid into the UHMWPE samples. An additional set of control samples (n=5) were heated to 100ºC in air. Before and after immersion, the dimensions and weight of each sample were measured.

The surface of each sample was analysed using an infrared spectrometer (Perkin-Elmer Frontier L1280032 with ATR, 32 scans, from 4000 to 600 cm^{-1}). The presence of octadecadienoic acid was confirmed from the peak located at 935 cm^{-1}. Approximately 5 mg was taken from the outer surface of each sample for differential scanning calorimetry (DSC) (TA Instruments 250). DSC was performed from 20ºC to 200ºC at a heat flow rate of 5 ºC /min. The crystallinity of each sample was measured from the area under the endothermic peak. Tensile tests were performed in accordance with ISO527 using an electromechanical testing machine (Instron 5965) and a contact extensometer, at a rate of 50 mm/min.
Statistical analysis was performed using Mann-Whitney U tests to assess differences between the groups.

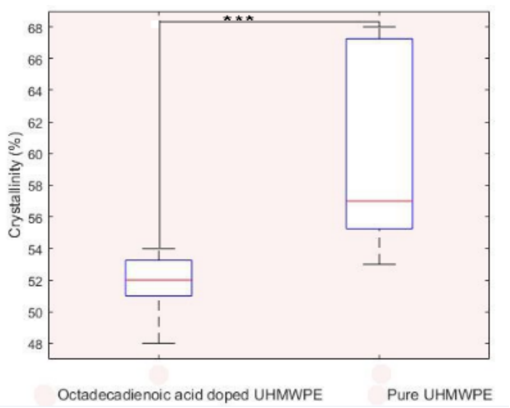

Figure 1. The percentage crystallinity of samples doped in octadecadienoic acid significantly

Results and Discussion

Octadecadienoic acid doped samples showed an absorbance at 935 cm^{-1} which was absent in the control samples, which confirmed diffusion of octadecadienoic acid into the surface of the UHMWPE. Our results showed both cross-sectional area and weight increased after doping (area increase: 1.3%±0.2, P=0.006, weight increase: 3% ±0.28,P=0.006). DSC results indicated doping significantly decreased the crystallinity (p=0.028 ,n=5) and the melting temperature (p =0.01, n=5). Reduction in the crystallinity may reduce the wear resistance of the material[4].

A significant reduction was observed in the yield stress of the doped samples (p=0.012, n=5). This could be due to the plasticising effect of fatty acids on UHMWPE or the lower crystallinity[4]. There was a slight decrease in the elongation at failure, modulus and ultimate stress of the Octadecadienoic acid doped samples; however, the decrease was not statistically significant.

Conclusions

The present study investigated the potential changes in the physical properties of UHMWPE caused by synovial fluid fatty acids. The results demonstrated the absorption of octadecadienoic acid, which happens over time *in vivo*, alters UHMWPE dimensions, reduces crystallinity, melting temperature, yield stress, and elongation at failure. Consequently, it is important that the effect of fatty acid absorption is taken into account when performing *in vitro* tests of UHMWPE components, such as wear testing. The dimensional change also has implications for some of the current orthopaedic designs which include close fitting components.

References

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4. Oral *et al.* J. Appl Polym Sci. 1:518-524, 2012