High density grafting of nano-polymer makes ultra-longevity for artificial joints

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Statement of Purpose: Osteolysis caused by wear particles from ultra-high molecular weight polyethylene (UHMWPE) in the artificial joints is a serious issue. We recently have developed the nano-polymer of 2-methacryloyloxyethyl phosphorylcholine (MPC) grafted onto the surface of cross-linked polyethylene (CLPE-*g*-MPC) [1], aiming at reduction in wear and suppression of bone resorption. In this study, we investigated the effects of graft polymerization technique on wear-resistant properties of CLPE-*g*-MPC and especially discussed the relationships between wear and characteristics of the grafted MPC polymer layer.

Methods: Compression-molded UHMWPE (GUR1020 resin) bar stock was gamma-irradiated with 50 kGy and annealed at 120°C for 7.5 hours for cross-linking. The CLPE specimens were machined from this bar stock. The CLPE specimens coated with benzophenone were immersed in the 0.5 mol/L aqueous MPC solution. The photo-induced graft polymerization on the CLPE surface was carried out with ultraviolet (350 nm wavelength) irradiation of 5 mW/cm^2 for 10 to 360 min at 60°C. The CLPE-g-MPC specimens were gamma-sterilized with a dose of 25 kGy under N_2 gas.
Surface chemical properties of the CLPE and CLPE-*g*-MPC were examined by Fourier-transform infrared (FT-IR) spectroscopy with attenuated total reflection (ATR) equipment. The relative amount of grafted MPC polymer unit on the CLPE surface was evaluated by quantification of the phosphate (P-O) group which was contained in the structure of MPC unit, as the P-O group index = (1080 cm^{-1} peak intensity) / (1460 cm^{-1} peak intensity). Surface wettability of the CLPE and CLPE-*g*-MPC were examined by the spray method based on the wetting response of the surface of a cup when exposured to a water mist. The *in vitro* wear test was performed using an MTS hip joint simulator. The acetabular component (26 mm inner diameter) was tested with a Co-Cr-Mo alloy femoral head. Testing then continued until a total of 5.0 x 10^6 cycles were completed.

Results/Discussion: Figure 1 shows the gravimetric wear of CLPE-*g*-MPC with various irradiation time during polymerization in the hip joint simulator test. The CLPE-*g*-MPC cups showed significantly less wear than the untreated CLPE cups. The wear of the CLPE-*g*-MPC cups with 23 min irradiation started to increase after 2.5 x 10^6 cycles. After 5.0 x 10^6 cycles, we confirmed that the CLPE-*g*-MPC cups with a P-O group index of 0.32 to 0.48 showed a quite low steady wear rate. The CLPE-*g*-MPC cups with a P-O group index higher than 0.32 achieved >80% reduction in their steady wear rate compared with the untreated CLPE. Since MPC is a highly hydrophilic compound, poly (MPC) is water-soluble [2]. In fact, it was observed that the CLPE-*g*-MPC surface supported a thin film of water (Figure 2), and the water-wettability of the CLPE-*g*-MPC surface was much larger than that of the untreated CLPE surface. Therefore, the artificial joint with the grafted MPC polymer surface showed much higher lubricity than that without the MPC polymer. The long-term retention of the benefits of MPC polymer in the artificial joint is ascribed to strong bonding between the MPC polymer and the CLPE surface, and high density of the introduced MPC polymer. In order to obtain an MPC polymer layer with high density, the irradiation time must be controlled.

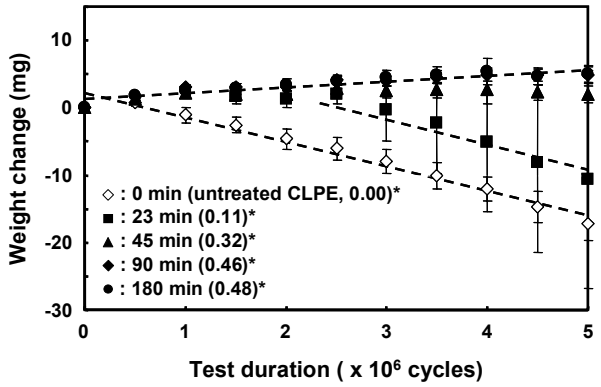

Figure 1. Weight change of CLPE-*g*-MPC cups with various irradiation time during polymerization in the hip joint simulator test. *The P-O group indices are shown in parentheses.

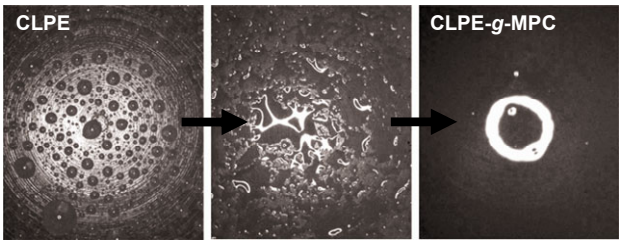

Figure 2. Surface wettability of CLPE and CLPE-*g*-MPC.

Conclusion: Grafting MPC onto CLPE is a useful method for maintaining efficient lubrication of artificial hip joints. High density grafting of MPC polymer is expected to make ultra-longevity for artificial joints.

References: [1] Moro T, et al. Nature Mater 2004;3:829-37. [2] Ishihara K, et al. Colloids Surf B 2000;18:325-35.