Biocompatible Phospholipid Polymer Grafting Improves the Wear Resistance of Artificial Hip Joints Regardless of the Degree of Cross-linking

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Statement of Purpose: Total hip arthroplasty is an effective treatment for patients with severe arthritis whose number has been increasing due to the expansion of the elderly population. Despite improvements in the implant design and surgical technique, the aseptic loosening secondary to periprosthetic osteolysis remains one of the most serious problems limiting their survivorship and clinical success. Pathogenesis of periprosthetic osteolysis is known to be a consequence of the host inflammatory response that is initiated by the foreign-body reaction of macrophages to wear particles mainly from the interface between the acetabular polyethylene (PE) liner and the femoral head. Hence, there are two approaches to prevent aseptic loosening; one is to reduce the amount of PE wear particles and the other is to suppress the subsequent bone resorptive responses. Aiming at the reduction of the wear particles and the elimination of periprosthetic osteolysis, we have developed a new technology, surface grafting (100 -150 nm in thickness) of artificial joints with a biocompatible polymer, poly(2-methacryloyloxyethyl phosphorylcholine) (PMPC) (Figure 1). We have demonstrated its efficacy using a hip-joint simulator in combination of cross-linked PE (CLPE) liners and cobalt-chromium alloy (Co-Cr) femoral head components. In the present study, we examined whether its beneficial effects were affected by the degree of cross-linking.

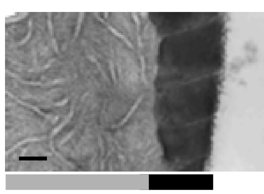

Figure 1. TEM images of PMPC-grafted CLPE.
Scale bars, 100 nm.

Methods: We prepared PE liners with or without cross-linking (PE/CLPE) and photoinduced grafting of MPC onto the surfaces (PMPC-PE/PMPC-CLPE). For the grafting, liners were placed in the MPC aqueos solution (0.5 mol/L), and photoinduced polymerization on the surface was carried out with UV-irradiation of 5 mW/cm^2 for 90 min at 60°C. The friction coefficient was measured against Co-Cr femoral head. To assess the amount of wear, gravimetric measurement of the liners was performed every 0.5 x 10^6 cycles during 5 X 10^6 cycles hip joint simulator test (comparable to 5 to 10 years of physical walking). A mixture of 25% bovine serum was used as lubricant. In this measurement, we corrected the weight loss for fluid absorption by subtracting the weight gain that occurred in the load-soak liners. The surfaces of the liners and femoral heads, as well as the wear particles in the lubricant were analyzed by confocal scanning laser and electron microscopies (SEM), and three-dimensional morphometry.

Results: The friction coefficient in the liners with PMPC grafting was about 80–90% lower than in those without grafting. The loss of liner weight (mg) after 5 X 10^6 cycles of loading in the hip simulator was PE/Co-Cr= 99.6, CLPE/Co-Cr= 18.9, PMPC-PE/Co-Cr= –5.9, PMPC-CLPE/Co-Cr= –6.9. The PMPC grafting abrogated the wear amount, independently of cross-linking. The weight gain in the PMPC-grafted liners was confirmed to be due to water absorption, since it was similarly seen in all liners with and without PMPC grafting during load-soak in the lubricant. Three-dimensional morphometric analyses and the confocal scanning laser microscopic analyses confirmed a marked enhancement of wear resistance by PMPC grafting. In addition, SEM analyses showed that the number of wear particles was decreased by PMPC grafting (Figure 2).

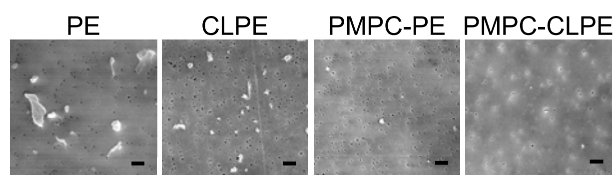

Figure 2. SEM pictures of the wear particles.
Scale bars, 1.0 µm.

Conclusions: The results of this study clearly demonstrate that the PMPC grafting diminished the wear production, independently of the liner cross-linking. This is probably because a comparable hydrated layer is formed on the liner surface. In addition, we previously reported that PMPC-grafted wear particles, even if produced, are biologically inert with respect to phagocytosis by macrophages and subsequent bone resorption. Taken together, we believe that this new technology will extend the longevity of artificial hip joints. A large-scale clinical trial is now underway in Japan.

References:

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3. Ishihara K, et al., Polym J 1990; 22, 355-360.