Self-initiated surface graft polymerization of poly(2-methacryloyloxyethyl phosphorylcholine) on PEEK and carbon fiber reinforced PEEK for orthopaedic and spinal applications

INTRODUCTION:
Poly(ether-ether-ketone) (PEEK) is considered to be promising novel polymer biomaterial for orthopaedic and spinal applications, because PEEK exhibits excellent mechanical properties, chemical stability, non-magnetic nature, and compatible with reinforcing agents such as carbon fibers, as compared with polyethylene or metallic materials. However, since conventional PEEK cannot satisfy these requirements: e.g., wear resistance and biocompatibility for use as an artificial joint or intervertebral body fusion cage. Therefore, study on the PEEK as implants study has also been focused on lubricity and biocompatibility of the polymer, either as reinforcing agents, or as a surface modification.

In this study, we have demonstrated the fabrication of highly hydrophilic and biocompatible nanometer-scale modified surface by photo-induced graft polymerization of 2-methacryloyloxyethyl phosphorylcholine (MPC). The new and safer polymerization system was found out, that is, “self-initiated surface graft polymerization.” We hypothesize that the cell-membrane-like surface obtained with surface modification of biocompatible polymers (MPC) (PMPC) [1] exhibits excellent biocompatibility and hydrophilicity under physiological conditions. In addition, the self-initiated surface graft polymerization by the generation of semi-benzopinacol containing radicals of the benzophenone units in PEEK, which acts as a photo-initiator during the grafting polymerization. This polymerization system is conducted in the absence of photo-active low molecular compound and in aqueous medium; this is human friendly and excellent biocompatibility.

METHODS:
The preparation of PMPC-grafted PEEK is schematically illustrated in Fig. 1. PEEK and carbon fiber reinforced PEEK (CFR-PEEK) specimens were machined from an extruded bar stock, which was fabricated without stabilizers. PEEK and CFR-PEEK specimens were immered in the 0.5 mol/L aqueous MPC solution. Photo-induced graft polymerization was carried out at 60°C for 90 min on the surface under UV-irradiation with an intensity of 5 mW/cm². The wettability of PMPC-grafted PEEK and CFR-PEEK is considerably greater than that of the untreated PEEK and CFR-PEEK, because of the presence of a nanometer-scaled PMPC layer: MPC is a hydrophilic compound, while PMPC is water-soluble. The coefficient of dynamic friction was dependent on the wettability. A significant reduction in static water-contact angle of PMPC-grafted PEEK resulted in a substantial improvement in friction property. In addition, the amount of BSA adsorbed on the PMPC-grafted PEEK was considerably lower than that of the untreated PEEK. The presence of water-fluid film and hydration PMPC layer is responsible for easy detachment of proteins and the prevention of consequential changes in the adsorbed proteins. These imply that the PMPC-grafted PEEK is biocompatible in terms of tissue and blood compatibility, because PMPC modified surfaces are known to exhibit in vivo biocompatibility [1].

The novel and simple self-initiated surface graft polymerization on the PEEK surface making unique properties such as lubricity and anti-protein adsorption by PMPC grafting is novel phenomena in the field of orthopaedic and spinal surgery (Fig. 3), and the fabrications of the PMPC-grafted PEEK and CFR-PEEK can result in the next-generation orthopaedic and spinal applications.

DISCUSSION:
We successfully demonstrated the fabrication of highly hydrophilic and biocompatible nanometer-scale modified surface by PMPC grafting onto the surface of a self-initiated PEEK and CFR-PEEK. The wettability of PMPC-grafted PEEK and CFR-PEEK is considerably greater than that of the untreated PEEK and CFR-PEEK, because of the presence of a nanometer-scaled PMPC layer: MPC is a highly hydrophilic compound, while PMPC is water-soluble. The coefficient of dynamic friction was dependent on the wettability. A significant reduction in static water-contact angle of PMPC-grafted PEEK resulted in a substantial improvement in friction property. In addition, the amount of BSA adsorbed on the PMPC-grafted PEEK was considerably lower than that of the untreated PEEK. The presence of water-fluid film and hydration PMPC layer is responsible for easy detachment of proteins and the prevention of consequential changes in the adsorbed proteins. These imply that the PMPC-grafted PEEK is biocompatible in terms of tissue and blood compatibility, because PMPC modified surfaces are known to exhibit in vivo biocompatibility [1].