Mechanical and biological analysis of compression molded polyetheretherketone-titanium (PEEK-Ti) composites

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Statement of Purpose:
Polyetheretherketone (PEEK) implants are widely utilized in the orthopaedic field. PEEK is well-suited for medical use due to its good mechanical properties, lack of cytotoxicity, and chemical stability [1]. However, PEEK is relatively bioinert, which allows only limited fixation with bone. In efforts to improve the bioactivity of PEEK, PEEK-Ti composites were developed. Titanium has superior biocompatibility and good mechanical properties [2]. Thus by combining titanium and PEEK, the biocompatibility will be improved and the mechanical properties of the composites can be tailored to mimic the human bone more closely. In this study, the biological and mechanical properties of the PEEK-Ti composites were examined for their potential use as implant materials.

Methods:
The samples with varying amounts of titanium contents (0, 15, 30, 45 vol%) were prepared by compression molding the mixed titanium (-325 mesh) and PEEK (avg. particle size: 50μm) powders at 370 °C under uniaxial pressure of 350 MPa. The distribution of Ti powder in PEEK matrix was observed with SEM. The *in vitro* biological properties were determined by observing the MC3T3-E1 preosteoblast cell attachment, proliferation and differentiation. The mechanical properties were evaluated using compression testing of cylindrical specimens.

Results:
The SEM images of the specimens with various Ti content showed well-distributed Ti powders in the PEEK matrix (Fig. 1). The homogeneity of the composite was maintained even after compression molding. The typical stress-strain curves of the composite with different Ti content shown in Fig. 2 exhibit ductile failure behavior. Compressive strength and Young's modulus can be tailored by adjusting the Ti content. PEEK-Ti with 45 vol% Ti has a compressive strength and Young's modulus of 220 MPa and 6.3 GPa, respectively. The cells on pure PEEK showed round morphologies with minimal spreading (Fig. 3(A)). By contrast, the cells adhered and spread well on PEEK-Ti surfaces. As seen in Fig. 3(B), the cells showed increased proliferation from day 3 to day 5 of culturing, suggesting that PEEK-Ti samples are not toxic. Moreover, significantly higher ALP activity was observed on PEEK-Ti composites compared to that of pure PEEK suggesting that titanium enhances the bioactivity of the samples (Fig. 3(B)).

Conclusions:
PEEK-Ti composites were fabricated and evaluated for potential use in load bearing implant applications. Significant increases in cellular response and strength characteristics were observed for PEEK-Ti composites. Our results show that PEEK-Ti composite is a potential alternative to existing polymer-based implant materials.

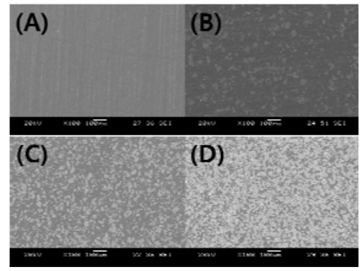

Fig 1. SEM micrographs of PEEK-Ti composites with (A) 0, (B) 15, (C) 30 and (D) 45 vol% Ti.

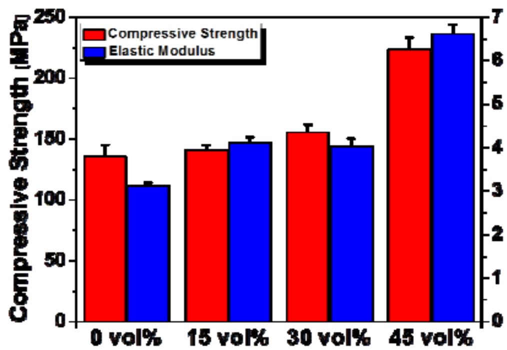

Fig 2. Compressive strength and elastic modulus of 0,15, 30, and 45 vol% PEEK-Ti samples (*n*=3).

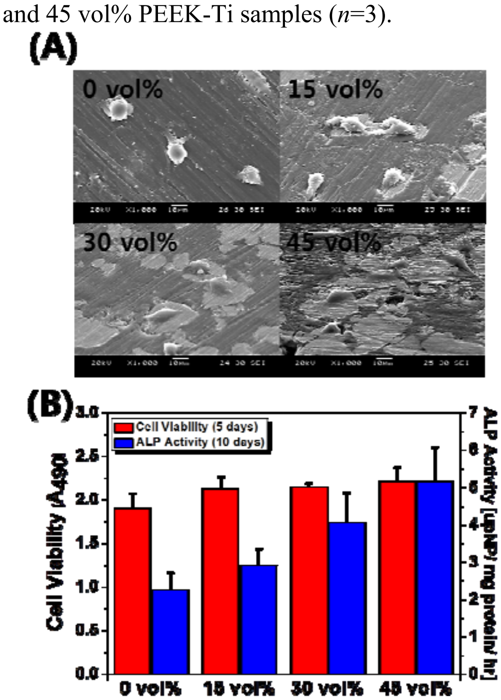

Fig 3. (A) Cell attachment (after 3 h of culturing), and (B) viability and differentiation of the MC3T3-E1 cells cultured on PEEK-Ti composites for 5 and 10 days

References:
1. Kurtz S. M. et al. Biomaterials 2007; **28**; 4845-4869
2. Ryan G et al. Biomaterials 2006; **27**; 2651-2670