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Reinforcement of Calcium Phosphate Cement with E-Glass Fibre

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Abstract : Calcium phosphate cement (CPC) due to its high bioactivity and optimum bioresorbability shows excellent bone regeneration capability. Despite it has limited applications as bone implant due to its macro-porous microstructure causing its poor mechanical strength. The reinforcement of apatitic CPCs with biocompatible fibre glass phase is an attractive area of research to improve its mechanical strength. Here we study the setting behaviour of Si-doped and un-doped alpha tri-calcium phosphate (α-TCP) based CPC and its reinforcement with the addition of E-glass fibre. Alpha tri-calcium phosphate powders were prepared by solid state sintering of CaCO3, CaHPO4 and tetra ethyl ortho silicate (TEOS) was used as silicon source to synthesise Si doped α-TCP powders. Alpha tri-calcium phosphate based CPC hydrolyzes to form hydroxyapatite (HA) crystals having excellent osteoconductivity and bone-replacement capability thus self-hardens through the entanglement of HA crystals. Setting time, phase composition, hydrolysis conversion rate, microstructure, and diametral tensile strength (DTS) of un-doped CPC and Si-doped CPC were studied and compared. Both initial and final setting time of the developed cement was delayed because of Si addition. Crystalline phases of HA (JCPDS 9-432), α-TCP (JCPDS 29-359) and β-TCP (JCPDS 9-169) were detected in the X-ray diffraction (XRD) pattern after immersion of CPC in simulated body fluid (SBF) for 0 hours to 10 days. The intensities of the α-TCP peaks of (201) and (161) at 2θ of 22.2°and 24.1° decreased when the time of immersion of CPC in SBF increased from 0 hours to 10 days, due to its transformation into HA. As Si incorporation in the crystal lattice stabilised the TCP phase, Si doped CPC showed a little slower rate of conversion into HA phase as compared to un-doped CPC. The SEM image of the microstructure of hardened CPC showed lower grain size of HA in un-doped CPC because of premature setting and faster hydrolysis of un-doped CPC in SBF as compared that in Si-doped CPC. Premature setting caused generation of micro and macro porosity in un-doped CPC structure which resulted in its lower mechanical strength as compared to that in Si-doped CPC. This lower porosity and greater compactness in the microstructure attributes to greater DTS values observed in Si-doped CPC. E-glass fibres of the average diameter of 12 μm were cut into approximately 1 mm in length and immersed in SBF to deposit carbonated apatite on its surface. This was performed to promote HA crystal growth and entanglement along the fibre surface to promote stronger interface between dispersed E-glass fibre and CPC matrix. It was found that addition of 10 wt% of E-glass fibre into Si-doped α-TCP increased the average DTS of CPC from 8 MPa to 15 MPa as the fibres could resist the propagation of crack by deflecting the crack tip. Our study shows that biocompatible E-glass fibre in optimum proportion in CPC matrix can enhance the mechanical strength of CPC without affecting its bioactivity.

Keywords : Calcium phosphate cement, biocompatibility, e-glass fibre, diametral tensile strength
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