J Mater Sci: Mater Med (2011) 22:2413–2427
DOI 10.1007/s10856-011-4435-z

Hydroxyapatite nanorod-reinforced biodegradable poly(L-lactic acid) composites for bone plate applications

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Received: 7 March 2011 / Accepted: 25 August 2011 / Published online: 15 September 2011

Abstract Novel PLLA composite fibers containing hydroxyapatite (HAp) nanorods with or without surface lactic acid grafting were produced by extrusion for use as reinforcements in PLLA-based bone plates. Fibers containing 0–50% (w/w) HAp nanorods, aligned parallel to fiber axis, were extruded. Lactic acid surface grafting of HAp nanorods (lacHAp) improved the tensile properties of composites fibers better than the non-grafted ones (nHAp). Best tensile modulus values of 2.59, 2.49, and 4.12 GPa were obtained for loadings (w/w) with 30% lacHAp, 10% nHAp, and 50% amorphous HAp nanoparticles, respectively. Bone plates reinforced with parallel rows of these composite fibers were molded by melt pressing. The best compressive properties for plates were obtained with nHAp reinforcement (1.31 GPa Young's Modulus, 110.3 MPa compressive strength). In vitro testing with osteoblasts showed good cellular attachment and spreading on composite fibers. In situ degradation tests revealed faster degradation rates with increasing HAp content. To our knowledge, this is the first study containing calcium phosphate–polymer nanocomposite fibers for reinforcement of a biodegradable bone plate or other such implants and this biomimetic design was concluded to have potential for production of polymer-based biodegradable bone plates even for load bearing applications.

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1 Introduction

Diaphyseal fractures are common fracture patterns of the long bones, and the usual strategy in their treatment is to use bone plates to restrain the movement of the fragments. In such an application, the bone plate carries the compressive load applied to the bone fragments throughout the healing process (around 1–1.5 years). The conventional compression plates are made of metals, including stainless steel and titanium as well as alloys such as cobalt-chromium [1–3]. Elastic modulus of human cortical bone is in the range 15–26 GPa, however, that of metals are 5–10 times higher [4]. This modulus mismatch leads to stress-shielding effect, the result of which is decrease of the bone mineral mass leading occasionally to bone fracture after the plate removal. Stress shielding is caused by the absence of load on the healing bone because of the metal plate taking over all the stress transfer. Another problem with the use of metal plates is corrosion and/or accumulation of metallic particles in the vicinity of the implant that may alter osteoblast behavior even at subtoxic levels [5], or at distant body parts including draining lymph nodes, spleen and liver [6]. Finally, a metal bone plate has to be removed by surgery after healing is accomplished.

To avoid the stress-shielding, it is desirable to use plates made of materials with mechanical properties close to those of the bone. The best candidates are polymers,