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Preparation, mechanical property and cytocompatibility of poly(L-lactic acid)/calcium silicate nanocomposites with controllable distribution of calcium silicate nanowires

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ABSTRACT

How to accurately control the microstructure of bioactive inorganic/organic nanocomposites still remains a significant challenge, which is of great importance in influencing their mechanical strength and biological properties. In this study, using a combined method of electrospinning and hot press processing, calcium silicate hydrate (CSH) nanowire/poly(L-lactide) (PLLA) nanocomposites with controllable microstructures and tailored mechanical properties were successfully prepared as potential bone graft substitutes. The electrospun hybrid nanofibers with various degrees of alignment were stacked together in a predetermined manner and hot pressed into hierarchically structured nanocomposites. The relationship between the microstructure and mechanical properties of the as-prepared nanocomposites were systematically evaluated. The results showed that CSH nanowires in a PLLA matrix were able to be controlled from completely randomly oriented to uniaxially aligned, and then hierarchically organized with different interlayer angles, leading to corresponding nanocomposites with improved mechanical properties and varied anisotropies. It was also found that the bending strength of nanocomposites with 5 wt.% CSH nanowires (130 MPa) was significantly higher than that of pure PLLA (86 MPa) and other composites. The addition of CSH nanowires greatly enhanced the hydrophilicity and apatite-forming ability of PLLA films, as well as the attachment and proliferation of bone marrow stromal cells. The study suggested that a combination of electrospinning and hot pressing is a viable means to control the microstructure and mechanical properties, and improve the mineralization ability and cellular responses, of CSH/PLLA nanocomposites for potential bone repair applications.
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1. Introduction

Polymer-based composites with incorporated bioactive ceramics have been considered to be the new generation of synthetic biomaterials for bone repair due to their unique mechanical features, allowing them to more closely match host bone compared with conventional bone substitute materials, such as metallic alloys and ceramics alone [1–5]. Polymer/ceramic composites provide an original approach to combining the biodegradation and toughness of ductile polymers (such as poly(L-lactide) (PLLA)) with the bioactivity and mechanical strength of bioceramics (such as calcium silicates) for bone repair applications. Recently huge efforts have been made to develop polymer-based composites with incorporated inorganic constituents as ortheopedic implants [6–9].

It is known that nano-sized fillers such as nanoparticles, nanorods and nanowires should be more beneficial in improving the physico-chemical and bioactivity of composites compared with their microscopic counterparts, due to their nanosized effects [10,11]. Conventional preparation methods for polymer-based nanocomposites mainly involve solvent blending [3,12], compression molding [13] and in situ precipitation [14]. These approaches have proven to be successful in optimizing the degree of nanofiller dispersion within the polymer matrix. For example, Deng et al. fabricated poly(D,L-lactide) nanocomposites incorporating needle-like hydroxyapatite (HA) nanocrystals through solvent blending to produce composites with well-distributed but randomly arranged nanofillers, leading to unsatisfactory exploitation of the full reinforcement potential of inorganic nanofillers [12]. Zhang et al. prepared PLLA/nano-HA composites via in situ precipitation. The synthesized HA nanorods were also randomly distributed throughout the PLLA matrix [14]. Due to this the obtained nanocomposites were mechanically isotropic. To our knowledge current methods cannot efficiently control the degree of alignment and patterns of organization of ceramic nanocomponents of nanocomposites, which is of importance in meeting the mechanical requirements

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