Bone Regenerative Nanocomposites of Bioactive Nanofiber and Degradable Polymers

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Purpose of Study: Biomedical nanocomposites constituted of bioactive ceramics and degradable polymers gained great potential for use in the bone regeneration areas [1]. The composition and structural organization of the components are important to determine the cell responses and bone formation process. The author recently developed novel bioactive nanofibers made of glass and informed the nanofibers had excellent bioactivity and bone cell stimulation in vitro [2]. Herein we formulated the bioactive nanofibers into nanocomposites with degradable polymers, such as poly(lactic acid) (PLA) and polycaprolactone (PCL), to ascertain mechanical stability and find a wide range of hard tissue applications such as guided bone regeneration membranes and bone fixation devices. The processing tools to fabricate the nanocomposites and their osteoblastic cellular responses are addressed.

Methods: Bioactive nanofibers were made from the glass by using the sol-gel precursors and electrospinning process. The composition and spinning parameters were described in detail in our previous report [2]. The obtained nanofibers were then thermal-treated at 700 ^oC to stabilize the glass. Degradable polymers, such as PLA and PCL were dissolved in an organic solvent with varying the concentrations. The nanofiber mesh was infiltrated with the polymer solutions and then the mixtures were homogenized and subjected to thermal pressing to make a thin membrane type. The phase and chemical structure of the nanocomposites were analyzed with X-ray diffraction and Fourier-transform infrared spectroscopy, respectively. The morphology and internal structure of the nanofiber were characterized with scanning electron spectroscopy and transmission electron microscopy. For the bioactivity test, the nanocomposites were incubated in a simulated body fluid (SBF) to observe the apatite forming ability on their surface with time. Human osteoblastic cells were cultured on the nanocomposites to investigate the cell proliferation, differentiation and matrix synthesis, according to our protocols (3).

Results / Discussion: Bioactive nanofibers were generated well into nonwoven nanoscale fibers through the electrospinning process. The diameters of the fibers were ranged ~tens to hundreds of nanometers. The polymer-infiltrated nanofibers showed an internal structure being typical of nanocomposites, whereby the nanoscale fibers were distributed evenly within the polymeric matrix (shown in Fig. 1). The nanofiber-polymer nanocomposites induced apatite crystallines on their surface very rapidly (within a few days) following incubation in SBF, whilst the pure polymers could not induce apatite crystals even after a month, suggesting the bioactive nanofiber improved the bioactivity of the composites significantly. Human osteoblastic cells were shown to attach and grow actively on the nanocomposite substrates (shown in Fig. 2). In particular, the nanocomposites were observed to significantly improve the osteoblastic functional activity, by stimulating the bone-associated genes such as alkaline phosphatase and osteocalcin.

Conclusions: Bioactive nanofiber and degradable polymers were produced into nanocomposites. The bioactive composition significantly improved the in vitro apatite forming ability in SBF and stimulated bone cell activity. Further study on the in vivo performance of the nanocomposites is warranted to confirm their usefulness in the bone regeneration areas.

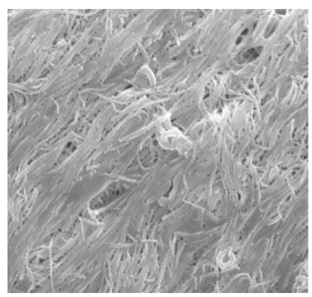

Fig. 1

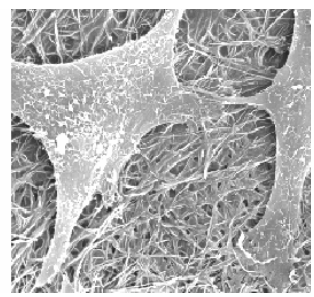

Fig. 2

References:

[1] H.-W. Kim et al. J. Biomed. Mater. Res. A. 2005, 72A, 136.
[2] H.-W. Kim et al. Adv. Funct. Mater. 2006, 16, 1529
[3] H.-W. Kim et al. Biomaterials, 2005, 26, 5221.