Bioactive injectable nanotube/nano-HA/pHEMA composites for orthopedic applications

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Statement of Purpose: With the increasing number of the orthopedic surgeries worldwide, there are even greater demands for more biocompatible and durable bone implants [1]. Researchers have demonstrated that self-assembled nanotubes are promising for tissue engineering applications with desirable properties such as enhanced cell attachment and tissue formation [2,3]. In this study, a novel implantable material composed of twin-based linker (TBL) nanotubes, hydroxyapatite (HA) nanoparticles and poly(2-hydroxyethyl methacrylate) (pHEMA) was developed for bone repair and regeneration. The characteristics of such composites were close to those of natural bone. TBL nanotubes not only enhanced osteoblast adhesion, but also improved natural repair processes [4,5]. We have further taken the advantage of the combination of pHEMA and HA nanoparticles to improve composite mechanical properties tailored by varying the concentration of HA nanoparticles. At the same time, increasing HA concentration enhanced the nano-roughness of the composites, which can also contribute to favorable cell functions.

Methods: HA nanoparticles were synthesized by a wet chemistry method by stirring $(NH_4)_2HPO_4$ and $Ca(NO_3)_2$ in a NH_4OH solution (pH>10). For a narrow size distribution, the HA precipitates were treated hydrothermally in a Teflon liner at 200 ^oC for 20 h. The polymerization process of the composites with varying HA concentrations was initiated by 2,2'-azobisisobutyronitrile (AIBN) via sonication at 60 ^oC. After solidification, the surface characterization of the composites was conducted by scanning electron microscopy. Compressive and tensile properties were tested following the ASTM standards D695 and D638, respectively. For bacterial tests, PMMA and pure pHEMA were established as the control groups, and three types of bacterial strains (Staphylococcus aureus, Staphylococcus epidermidis, and Pseudomonas aeruginosa) were incubated on the sample surfaces for 1 h.

Results: With increasing HA ratios in the composites, more HA nanoparticles clustered on the surface, therefore generating greater nano-roughness (Figure 1). Moreover, the compressive strength of the composites increased with the weight ratio of HA. The 20% HA composites had the highest strength, which is suitable for orthopedic load bearing applications (Figure 2). Compared to PMMA and pure pHEMA samples, the addition of TBL nanotubes and HA nanoparticles did not alter bacteria adhesion.

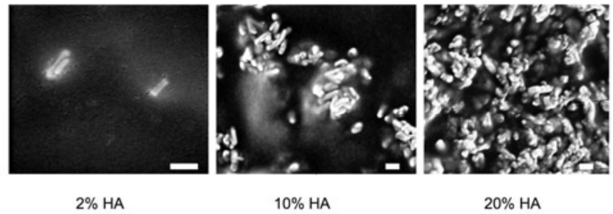

Figure1. SEM images of TBL nanotube/nano-HA/pHEMA composites. Scale bars=200 nm.

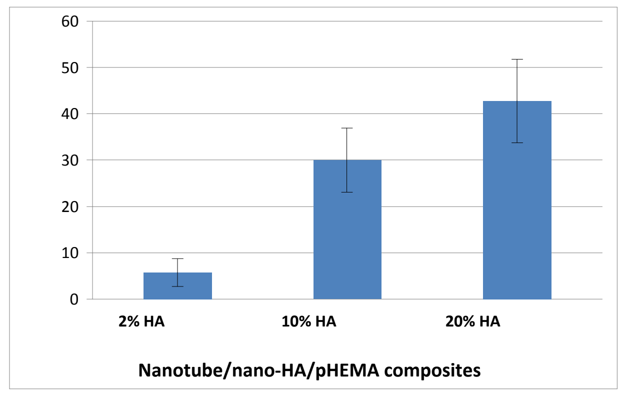

Figure 2. Compressive test results of the TBL nanotube/nano-HA/pHEMA composites. Data= Mean± SEM, n=3.

Conclusions: Combined with pHEMA, HA nanoparticles and TBL nanotubes were utilized here to enhance surface nano-roughness, mechanical properties and biocompatibility for bone implant applications. The mechanical properties of composites were tunable with the HA component, and 20% HA composites had a high mechanical strength, comparable to natural bone. It is thus, promising to further study the potential use of TBL nanotube/nano-HA/pHEMA composites which can be injected as a liquid and solidify in situ simply through exposure to body temperatures.

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