OMICS Group Conferences
Accelerating Scientific Discovery

3rd International Conference on
Nanotek & Expo

December 02-04, 2013 Hampton Inn Tropicana, Las Vegas, NV, USA

Magnesium oxide nanoparticles improve cell functions for tendon to bone insertion applications

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There are about 100,000 ACL reconstruction surgeries performed every year in the United States, with a failure rate ranging from 5-25%, depending on the criteria of the study. It is believed that this high rate of failure is a result of insufficient healing at the tendon-to-bone insertion site (TBI). The TBI disperses critical stress concentrations that arise naturally between ligaments and bone by providing a compositional and mechanical transition from ligaments, through a fibrocartilaginous zone, to bone. However, this complex, inhomogeneous, and avascular tissue is incapable of regenerating following surgery. Therefore, there is considerable interest in the development of a nanostructured biomaterial that is capable of directing healthy regeneration of spatially controlled tissue across the TBI.

In this study, magnesium oxide (MgO) nanoparticles were used to mineralize poly(l-lactic acid) (PLLA) and tested for their ability to improve the attachment and growth of TBI-related orthopedic tissue. Magnesium is an essential mineral in bone which is thought to regulate the size and density of hydroxyapatite (HA) crystals, and further, Weng and Webster demonstrated that nano-rough MgO increased bone cell density three-fold compared to bulk MgO. Presently, the ability of materials to promote tissue growth at the TBI was characterized via cell adhesion and proliferation experiments with fibroblasts and osteoblasts. Materials were also tested for their mechanical properties, and further characterization was performed using SEM, TEM, XRD, FTIR, EDS, and contact angle tests.

Results indicated for the first time that MgO nanoparticles in plain PLLA or PLLA/HA composites significantly increased osteoblast and fibroblast adhesion on PLLA. Interestingly, both cell lines followed the same general trend of adhesion on each sample, indicating that variations in only the secondary phase of a scaffold material will not be sufficient to direct the formation and maintenance of spatially controlled tissue heterogeneity at the TBI. However, nano-MgO can be used to mineralize different polymer phases to promote the formation of bone tissue at one end of the scaffold and fibrous tissue at the other end.

Mechanical tensile testing revealed that the addition of a secondary nano-phase to plain PLLA hardened the polymer, reducing the material elongation and increasing its elastic modulus. Moreover, the observed changes in mechanical strength of PLLA seemed to be dictated by the size and shape of its secondary nano-phase, indicating that the mechanical properties of PLLA composites can be tailored to align with the strength of bone or ligament tissue.

Biography

Daniel J. Hickey received his Bachelor of Science degree in Chemical Engineering in 2012 from UC Santa Barbara. He joined Professor Thomas Webster's Nanomedicine Lab at Northeastern the following fall to pursue his Ph.D., in Chemical Engineering. He is the treasurer of the Northeastern chapter of the Society for Biomaterials, and he is the winner of the Boston area ISPE poster competition.

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