Bioactive Portland Cement Porous Scaffolds

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Introduction: Degenerative diseases, trauma or genetic predisposition can lead to large bone defects or injuries. Currently available treatments for these problems include the use of bone autografts, allografts, and synthetic grafts (e.g. metallic, ceramic, and composites). However, these treatments present several potential disadvantages such as host rejection, reduced osseointegration, and poor mechanical properties, among others. These limitations have impelled the development of tissue engineering, which aims to induce the regeneration of damaged tissues using therapies based in the implementation of cells, growth factors, and scaffolds. An ideal bone tissue engineering scaffold should be biocompatible, bioactive, osteoconductive, osteoinductive, and should also be able to support loads in the physiologic range without affecting the natural bone turnover process. In this work, we proposed the implementation of novel biocompatible and bioactive Portland cement porous scaffolds for load-bearing bone tissue engineering applications.

Methods: The porous scaffolds were obtained by combining foaming and particulate leaching methods. The scaffold material, White type I Portland cement, was mixed with distilled water, sodium chloride and hydrogen peroxide at a ratio of 1:0.5:0.2:0.02 respectively. The mixture was homogenized, molded into cylinders, and heated at 60 °C for two hours. After setting, the scaffolds were demolded and hydrated at 37 °C, 90% relative humidity and 20% CO_2 for 8 days, in order to reduce the alkalinity of the cement and thereby improve the biocompatibility of the scaffolds[1]. Finally, the scaffolds were immersed in a calcium phosphate solution for 8 days to induce surface precipitation of apatite-like crystals.

The morphology of the scaffolds and surface chemistry were evaluated via stereo microscopy, scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). Porosity was measured using the liquid substitution method. Mechanical characterization of the scaffolds was conducted via compressive tests. The biological performance (cytocompatibility, cell viability, proliferation, and function) of the scaffolds was evaluated using mouse embryonic stem cell cultures via alamar blue, and alkaline phosphatase (ALP) activity readings. Tissue culture polystyrene (TCPS) was used as control for these experiments. Additionally, cell adhesion, spreading and morphology were characterized via SEM.

Results / Discussion: Biocompatible and bioactive Portland cement porous scaffolds were successfully obtained. The scaffolds presented adequate morphological characteristics for bone tissue engineering applications (porosity value of 70.83 ± 2.46 % and an average pore size of 432.76 ± 176.05 μm), according to previous literature reports[2]. Scaffolds showed appreciable interconnectivity and uniform pore distribution along the surface. The mechanical properties of the scaffolds were comparable to those reported for human cancellous bone[3], with an average compressive strength of 2.14 ± 0.72 MPa, yield strength of 2.58 ± 0.53 MPa, and elastic modulus of 244.84 ± 203.74 MPa. Surface precipitation of amorphous apatite-like crystals (high content of carbon, calcium and phosphorus) on the scaffolds was observed after 8 days of immersion in the calcium phosphate solution. These findings were confirmed by SEM and EDS. SEM imaging showed stem cell aggregates extending processes and interacting with the scaffold. Alamar blue reading showed enhanced (≥2 fold) cell proliferation on the scaffolds in comparison with TCPS controls. No significant differences in ALP activity were found after 14 days of culture. We are currently conducting long-term studies (≥30 days) to evaluate differentiation of the embryonic stem cells towards the osteogenic lineage.

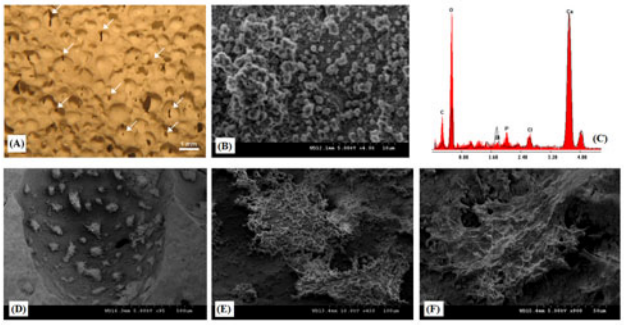

Fig.1. (A) stereomicroscopy image of the porous scaffold (scale bar 1mm), (B) SEM image showing apatite-like crystals deposition, (C) EDS spectra of scaffolds with (red line) and without (black line) CaP solution treatment, (D)-(F) ES cells cultured on CaP-treated scaffolds after 7 days.

Conclusions: The present work shows the potential application of Portland cement as scaffolding material in bone replacement/regeneration procedures. We were able to obtain biocompatible and bioactive Portland cement scaffolds with mechanical and morphological properties that resemble those of human cancellous bone. This fabrication technique provides a simple method to develop bone tissue engineering scaffolds with load-bearing capabilities, using a material that is easy to process, economical, and widely available.

References:

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