Preparation and characterization of biodegradable metal particle incorporated polycaprolactone nanofibers

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Statement of Purpose: Biodegradable metals like Magnesium (Mg) and Zinc (Zn) are best researched metals for a variety of clinical applications. As these metals degrade, they release metal ions and other degradation products, which are beneficial for injured tissues. Both Mg and Zn ions are essential trace elements in the body. However, if supplied in excess both can damage tissues and cells. To control metal degradation and release, and to improve tissue recovery, metal particles are incorporated into electrospun composite nanofiber meshes. In this research, we used electrospinning technology to incorporate Mg and Zn particles into PCL nanofibers. Physical properties of the meshes were analyzed. In vitro release of metal ions was investigated in cell culture conditions for up to 21 days and quantified through colorimetric assay and ICP mass spectrometry.

Methods: Suspensions of Mg and Zn nanoparticles in PCL solutions (Mg/PCL and Zn/PCL solutions) were created by first dispensing Mg and Zn metal powders in trifluoroethanol (TFE) under an inert atmosphere and then adding dry PCL pellets. Proportions were adjusted to give different w/w proportions of the two dry ingredients. The weight of PCL was kept at 10% of the weight of TFE. All solutions were subjected to constant magnetic stirring for 24 h at room temperature to achieve homogeneity before electrospinning. Electrospun nanofiber meshes of PCL and PCL/metal particles were prepared as described in our previous publication [1]. The fibers, deposited onto am aluminum foil-wrapped rotating ground collector, were left overnight at room temperature, to allow complete solvent evaporation. The nanofiber meshes were removed from the collector and detached from the aluminium foil for physical, chemical, and biological characterization.

Results: Electrospun PCL nanofiber meshes were made containing increasing amounts of Mg and Zn metal microparticles. Before electrospinning, the as-received Mg and Zn particles were characterized by scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR), and X-ray diffractometry. After electrospinning into meshes, Mg and Zn particles were either embedded within individual PCL nanofibers or attached to the surface of fibers coated with PCL (Figure 1). Physiochemical properties of the meshes were analyzed by SEM, FTIR, mechanical tensile testing, XRD, UV-VIS spectrophotometry, and ICP. The presence of metal particles was confirmed by EDS mapping and XRD analysis. The nanofiber structure (was not obscured by attached metal particles) was uniform and smooth. In vitro release of metal ions was investigated up to 21 days and quantified. Under mammalian cell culture conditions, metal-containing meshes released relative amounts of free metal ions that reflected the metal particles/PCL ratios.

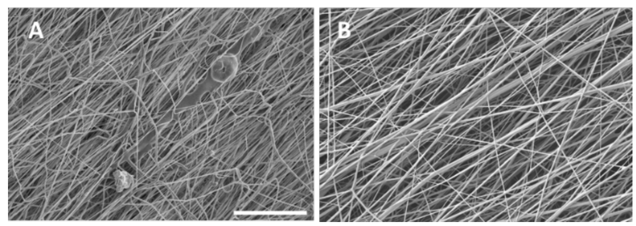

Figure 1. (a) SEM images PCL/Mg fibers. (b) SEM images of PCL/Zn fibers.

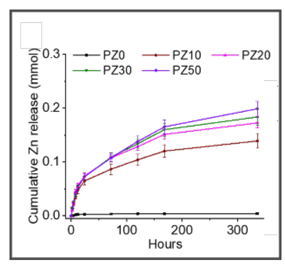

Figure 2. Release profile of free zinc ion

This research was focused on the preparation and characterization of biodegradable metal incorporated PCL nanofibers. Our initial analysis of physical properties and cell toxicity suggest that the inclusion of Mg and Zn metal could improve the biocompatibility of the existing biomaterials. Thus, this new composite nanofiber meshes have promising material properties, thus providing a suitable matrix for use in clinically relevant tissue engineering and wound healing applications.

References: Adhikari, U. et al. Act Biom. 2019; 98:215-234