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Titanium phosphate glass microspheres for bone tissue engineering

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ABSTRACT

We have demonstrated the successful production of titanium phosphate glass microspheres in the size range of ~10–200 μm using an inexpensive, efficient, easily scalable process and assessed their use in bone tissue engineering applications. Glasses of the following compositions were prepared by melt-quench techniques: $0.5P_2O_5$–0.4CaO–$(0.1-x)Na_2O$–$xTiO_2$, where $x = 0.03$, 0.05 and 0.07 mol fraction (denoted as Ti3, Ti5 and Ti7 respectively). Several characterization studies such as differential thermal analysis, degradation (performed using a novel time lapse imaging technique) and pH and ion release measurements revealed significant densification of the glass structure with increased incorporation of TiO_2 in the glass from 3 to 5 mol.%, although further TiO_2 incorporation up to 7 mol.% did not affect the glass structure to the same extent. Cell culture studies performed using MG63 cells over a 7-day period clearly showed the ability of the microspheres to provide a stable surface for cell attachment, growth and proliferation. Taken together, the results confirm that 5 mol.% TiO_2 glass microspheres, on account of their relative ease of preparation and favourable biocompatibility, are worthy candidates for use as substrate materials in bone tissue engineering applications.

1. Introduction

Titanium phosphate glasses have been widely researched for use in orthopaedic applications because of their highly favourable material properties and ability to elicit a positive bone cell response [1–4]. From a materials science perspective, these glasses are of great interest because their physicochemical properties are highly tuneable, so that subtle changes in glass composition allow for major changes in glass structure and consequently in the degradation and ion release behaviour of these materials [5,6]. Changes in titanium phosphate glass chemistry can be brought about by variations in the concentrations of the constituent oxides or the addition of small amounts of metal oxides other than TiO_2 [7–13]. The structure of the glass network has been elucidated using diverse analytical techniques such as differential thermal analysis (DTA), Raman and Fourier transform infrared (FTIR) spectroscopies, X-ray diffraction (XRD), solid state nuclear magnetic resonance (NMR), X-ray absorption spectroscopy (XAS), Ti K-edge X-ray absorption near-edge structure (XANES) and neutron/X-ray scattering [6]. The information gained from all these analyses is beneficial to biomaterials researchers, who are then able to make highly informed choices regarding the specific glass composition required for specific clinical applications.

From a biological perspective, it is now well known that titanium phosphate glasses provide a surface that is quite conducive to the attachment, growth and proliferation of bone cells [14–16]. The fact that oxides of phosphorus, sodium and calcium, which constitute the major components of most phosphate glass compositions, are also found in the mineral phase of bone is a major contributing factor to the bioactivity of these glasses, particularly considering that the ions released from these glasses can exert positive effects on bone cells [17–20]. A range of *in vitro* and *in vivo* studies has been conducted on titanium phosphate glasses and highly promising results have been obtained that offer exciting

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