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Research Paper

A comparative study of the effects of different bioactive fillers in PLGA matrix composites and their suitability as bone substitute materials: A thermo-mechanical and *in vitro* investigation

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ABSTRACT

Bone substitute composite materials with poly(L-lactide-co-glycolide) (PLGA) matrices and four different bioactive fillers: CaCO₃, hydroxyapatite (HA), 45S5 Bioglass[®] (45S5 BG), and ICIE4 bioactive glass (a lower sodium glass than 45S5 BG) were produced via melt blending, extrusion and moulding. The viscoelastic, mechanical and thermal properties, and the molecular weight of the matrix were measured. Thermogravimetric analysis evaluated the effect of filler composition on the thermal degradation of the matrix. Bioactive glasses caused premature degradation of the matrix during processing, whereas CaCO₃ or HA did not. All composites, except those with 45S5 BG, had similar mechanical strength and were stiffer than PLGA alone in compression, whilst all had a lower tensile strength. Dynamic mechanical analysis demonstrated an increased storage modulus (E') in the composites (other than the 45S5 BG filled PLGA). The effect of water uptake and early degradation was investigated by short-term *in vitro* aging in simulated body fluid, which indicated enhanced

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water uptake over the neat polymer; bioactive glass had the greatest water uptake, causing matrix plasticization. These results enable a direct comparison between bioactive filler type in poly(α -hydroxyester) composites, and have implications when selecting a composite material for eventual application in bone substitution.

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1. Introduction

Resorbable polymers and ceramics have been developed for orthopaedic procedures, which may encourage bone growth, guiding and supporting regenerating bone for sufficient time such that it is capable of self-support (Cao and Hench, 1996). Ultimately these implanted materials degrade harmlessly in the body (Middleton and Tipton, 2000; Domb et al., 1997; Hench, 1991). However, neither polymers or ceramics, taken separately, have proven entirely suitable for use in bone replacement: polymers may have insufficient mechanical properties (Engelberg and Kohn, 1991), while ceramics often have an unpredictable, low tensile strength so they are unsuitable for use in locations of significant torsion or bending (Bronzino, 1995). Composites have been studied in efforts to obtain a superior bone substitute material, usually polymer matrices with particulate ceramic/glass fillers (Wang, 2003; Rezwan et al., 2006; Boccaccini and Blaker, 2005). These should result in increased mechanical properties over the polymer and impart bioactivity (Boccaccini et al.,

2002). Basic ion releasing ceramics/glasses have a pH buffering effect in the early stages of degradation (Kikuchi et al., 2002; Tsunoda, 2003; Schiller and Epple, 2003), which could reduce the degradation rate of hydrolytically degradable polymers, such as poly(lactide-co-glycolide) (PLGA) and polylactide (PLA) (Blaker et al., 2011).

Whilst numerous composites have been investigated as bone analogues, the optimal composite has yet to be developed due to the complex nature of the intended application (Rezwan et al., 2006). In order to compare different composites accurately, it is necessary to use the same production method and testing regime because differences in these will result in variations in material and mechanical properties. Few examples of this type of comparison have been found (Bleach et al., 2001; Ignatius et al., 2001), making direct correlation difficult. The aim of this study was to compare four different particulate fillers in a PLGA matrix using similar processing routes and testing methods to enable direct comparison of the effects of filler selection on composite properties in the as-made state and during aging in simulated body fluid (SBF).

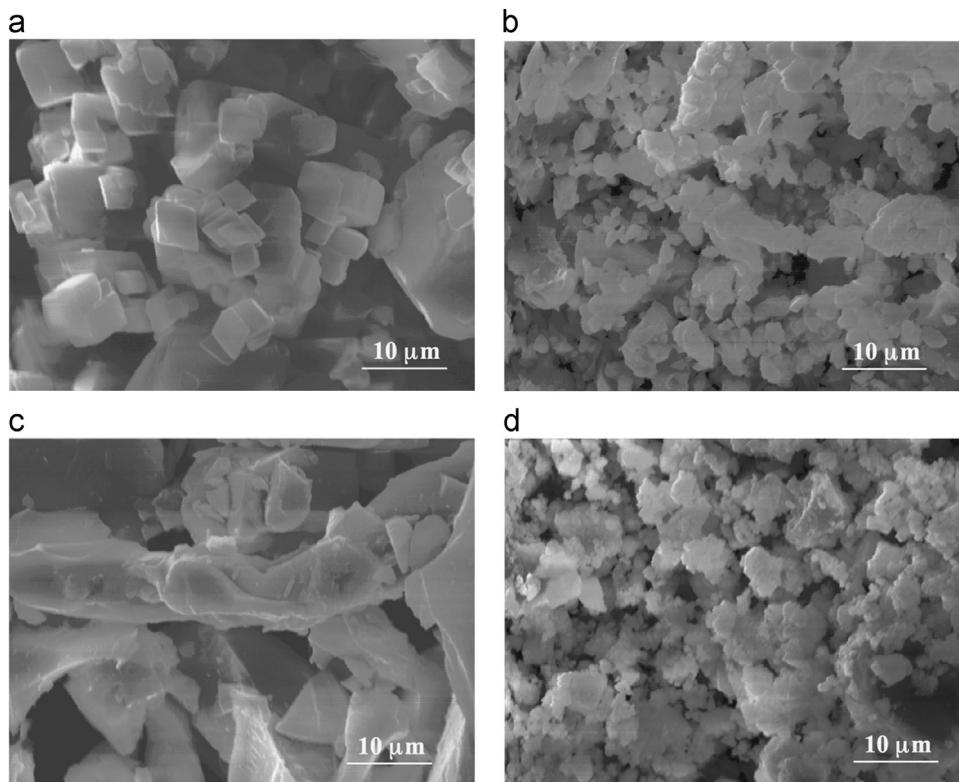


Fig. 1 – SEM images of (a) CaCO_3 (rhombohedral particles), (b) HA with irregular shaped particles, (c) 45S5 BG showing fewer small particles, (d) ICIE4 BG with larger particles dispersed amongst smaller particles.

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