Bioresorbable Composite Bone Fracture Repair Plates: Manufacture and Characterisation

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Key words: Bioresorbable composite, Bone repair, Phosphate glass fibres.

Summary. This study reports on Bioresorbable composites manufactured using PLA as matrix and phosphate-based glass fibres as reinforcement. Composites were manufactured with varying volume fraction (from 25% - 45%) and mechanically tested.

1 INTRODUCTION

Current bone repair implants for use within the body are made from metals, which have disadvantages such as stress shielding and can remain in the body permanently. Recently, a move towards degradable composite materials for bone repair applications (to replace metal plate equivalents) has been viewed as extremely favourable.

Phosphate glasses and fibres are fully resorbable materials and their degradation rates can be varied easily over several orders of magnitude [1]. The most common and prevalent components in these glasses are calcium and phosphate ions, which are common constituents of the body and thus no adverse inflammatory responses are expected.

In this study, fully resorbable composite bone repair plates comprising a polylactic acid (PLA) matrix reinforced with phosphate glass fibres (PGF) with increasing fibre volume fraction (Vf) and alternate fibre geometries (random and unidirectional) were manufactured (with and without screw-holes) and their mechanical properties were ascertained.

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2 MATERIALS AND METHODS

Bioresorbable random mat (RM) and unidirectional (UD) fibre composites were manufactured via compression moulding at 210°C and 38 bar, utilising PLA as the matrix and PGF of composition $50P_2O_5$ - 40CaO - $5Na_2O$ - $5Fe_2O_3$ in mol% (referred to as P50) as the reinforcement. Composites with theoretical fibre Vf of 25, 35 and 45% were manufactured with and without screw-holes (see Table 1 below for sample codes and fibre lay-up for the composites produced). Three point bend flexural tests were conducted according to EN ISO 14125:1998 on specimens measuring 40 x 15 x 2 mm. Phosphate buffered saline (PBS) was used as the degradation medium and the mass change of composites was monitored according to BS EN ISO 10993-13:2010. For SEM analysis, specimens were sputter-coated with Pt and examined using a XL30 scanning electron microscope (Philips, U.K.) at an accelerating voltage of 20 kV. Statistical analysis was performed via a one-way analysis of variance (ANOVA),using GraphPad Prism software (Version 5.01).

Sample Code	UD Pre-preg layers	Random mats	PLA Sheets	Fibre lay-up	Vf % (T)	Vf % (A)
25UD8-						
25UD8+	8 thin layers	N/A	9	UD×8	25	24.6 ± 1
25RM-	N/A	8	8	RM×8	25	28.3 ± 4
25RM+						
25MIX-	4 thin layers	4	8	RM×2+UD×4+ RM×2	25	27.8 ± 2
25MIX+						
25UD-	1 thick layer	N/A	12	UD×1	25	23.3 ± 4
25UD+						
35UD-	2 thick layers	N/A	11	UD×2	35	34.7 ± 1
35UD+						
45UD-	3 thick layers	N/A	10	UD×3	45	47.7 ± 3

Table 1: Sample codes with numbers of fibre and polymer layers used. Theoretical and actual Vf is also included. The + and – signs indicate with and without screw-holes respectively.

3 RESULTS AND DISCUSSION

The flexural modulus values for the composites produced increased with increasing fibre Vf. Similar profiles were seen for the flexural strength profiles also. The mass change profiles were very similar for the samples with and without screw-holes, where a mass increase with time was seen during the initial part of the study, after which a decrease was seen at the 7 day interval. After that no major mass change was observed with the exception of sample 45UD. The mechanism for mass change was suggested to be wicking of the media along the fibres disrupting the fibre matrix interface.

Fracture surfaces of the composites were investigated by SEM analysis. A clear difference could be observed from the fracture surfaces between the 25UD8 (Fig 1a) sample and 25UD (Fig 1b). The fracture surface of sample 25UD8 revealed much shorter fibre pull-out lengths as compared to 25UD. Accordingly, voids were seen around the surface edge for the degraded 25UD sample whereas none were seen for the degraded 25UD8 sample. In addition, increasing fibre volume fraction was clearly observed (Fig 1c), whereas pores and/or channels were seen within the matrix as the fibres had degraded for 45% Vf samples (Fig 1d).

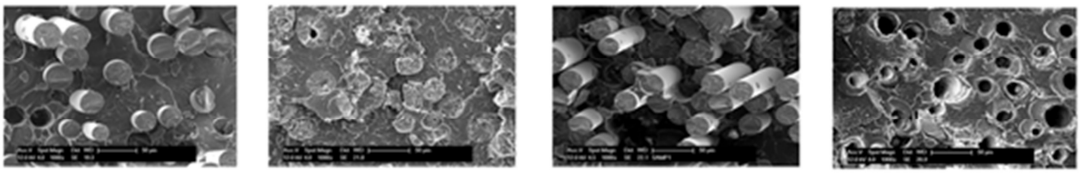

Figure 1a-1d. Representative SEM images of samples before after immersion in PBS at 37°C.

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