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# Fabrication, mechanical and in vivo performance of polycaprolactone/tricalcium phosphate composite scaffolds

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ABSTRACT

This paper explores the use of selective laser sintering (SLS) for the generation of bone tissue engineering scaffolds from polycaprolactone (PCL) and PCL/tricalcium phosphate (TCP). Different scaffold designs are generated, and assessed from the point of view of manufacturability, porosity and mechanical performance. Large scaffold specimens are produced, with a preferred design, and are assessed through an in vivo study of the critical size bone defect in sheep tibia with subsequent microscopic, histological and mechanical evaluation. Further explorations are performed to generate scaffolds with increasing TCP content. Scaffold fabrication from PCL and PCL/TCP mixtures with up to 50 mass% TCP is shown to be possible. With increasing macroporosity the stiffness of the scaffolds is seen to drop; however, the stiffness can be increased by minor geometrical changes, such as the addition of a cage around the scaffold. In the animal study the selected scaffold for implantation did not perform as well as the TCP control in terms of new bone formation and the resulting mechanical performance of the defect area. A possible cause for this is presented.

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## 1. Introduction

Interest in tissue engineering has grown over the last decade since it offers an alternative approach with great potential for reconstruction or replacement of damaged bone tissues [1–5]. Three of the main elements required to engineer tissue are (i) a scaffold, (ii) cells and (iii) a dynamic environment in which the cell–scaffold construct can be conditioned [6–8]. In bone tissue engineering, current techniques employ porous, 3-D, biodegradable, biocompatible and bioresorbable scaffolds, which act as temporary platforms for initial cell attachment and subsequent tissue formation. Biomimetic scaffolds with similar microarchitectures, and mechanical and biological properties as native tissue are of significant interest. Some groups have established libraries for scaffold or unit cell designs which can be used to build scaffolds with particular mechanical and physical properties to satisfy the needs of the implantation site [2,9–12]. Limitations of conventional fabrication techniques in producing the desired scaffold design can be overcome by rapid manufacturing (RM) techniques, which allow the manufacturing of complex 3-D shapes with various pore designs from CAD files [13–16]. One RM technique is selective laser sintering (SLS), which employs a $CO_2$ laser to melt polymeric powders and form scaffold geometries without the use of any toxic chemicals, blowing agents or support structures [17]. The SLS process has been utilized in combination with above-mentioned design libraries to produce scaffolds for cardiac tissue engineering that fulfil certain mechanical needs, and efforts have been made to reduce the amount of powder needed even when only small parts are being manufactured [18] for those machines that can produce large models and therefore normally use large amounts of powder.

Only a limited number of materials, including composites, have successfully been evaluated thus far using SLS; however, from recent results laser sintering of selected biocompatible materials for tissue engineering has proven promising. Biomaterials considered for tissue engineering scaffold fabricated via SLS include poly-ε-caprolactone (PCL) [12,19–24], polyetheretherketone (PEEK) [17], polylactide acid [25] and poly(lactic-co-glycolide) [26]. As these materials may not stimulate sufficient bone ingrowth on their own, bioactive components can be added to enhance bone ingrowth, cell attachment, etc. Furthermore, the stiffness of the scaffold may be enhanced with second-phase particles, in particular when the scaffold is likely to be loaded after implantation. Hence, scaffolds with optimal properties for bone tissue engineering may

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