1. Introduction

There is a need to develop new scaffolds to repair large defects in load-bearing bones using materials that are biocompatible and durable during the patient’s lifetime [1]. Treatment methods based on the use of bone autographs and allografts are effective for the repair of contained defects in non-load-bearing bone which do not require a significant amount of graft material. However, they suffer from limitations (e.g. donor site morbidity; limited supply; possible transmission of diseases; high costs). Synthetic biocompatible scaffolds that replicate the structure and function of bone would be ideal bone substitutes, provided they have the requisite mechanical properties for reliable long-term cyclic loading during weight bearing.

Scaffolds should have a porous microstructure suitable for supporting tissue ingrowth, and mechanical properties comparable to those of the tissue to be replaced. An interconnected pore size (diameter or width of the openings between adjoining pores) of 100 μm is considered to be the minimum requirement to permit tissue ingrowth and function [2]. The repair of segmental defects in load-bearing bones, such as the long bones, often involves the substitution of defects larger than a few centimeters [3]. Therefore it is essential that processing methods provide control of the microstructure over the entire dimensions of the scaffold in order to achieve the requisite mechanical reliability of the scaffold.

The mechanical response of porous materials with an anisotropic microstructure is strongly dependent on the pore orientation [4–6]. Commonly, the mechanical response in the pore orientation direction is often far superior to that in the perpendicular direction, and superior to that for scaffolds with a random microstructure. For example, the compressive strength and elastic modulus of human cortical bone in the orientation direction are almost twice those in the perpendicular direction [7]. The formation of scaffolds with oriented pore architectures could provide an approach for creating porous and strong three-dimensional scaffolds for applications in the repair of loaded bone.

Unidirectional freezing of aqueous suspensions has been used recently to produce oriented scaffolds of bioeceramics and bioactive glass [8,9]. The process commonly results in the formation of porous constructs with a lamellar microstructure. However, the width of the slot-like pores (10–40 μm) is considered to be too small to support tissue ingrowth. A variety of techniques has been used to control the width and morphology of the pores, such as the freezing of aqueous systems.