Iranian Polymer Journal (2020) 29:219–224
https://doi.org/10.1007/s13726-020-00789-6

ORIGINAL RESEARCH

Mechanical modeling of silk fibroin/TiO_2 and silk fibroin/fluoridated TiO_2 nanocomposite scaffolds for bone tissue engineering

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Received: 21 May 2019 / Accepted: 25 January 2020 / Published online: 7 February 2020

Abstract

Biocompatible and biodegradable three-dimensional scaffolds are commonly porous which serve to provide suitable micro-environments for mechanical supporting and optimal cell growth. Silk fibroin (SF) is a natural and biomedical polymer with appropriate and improvable mechanical properties. Making a composite with a bioceramicas reinforcement is a general strategy to prepare a scaffold for hard tissue engineering applications. In the present study, SF was separately combined with titanium dioxide (TiO_2) and fluoridated titanium dioxide nanoparticles (TiO_2-F) as bioceramic reinforcements for bone tissue engineering purposes. At the first step, SF was extracted from *Bombyx mori* cocoons. Then, TiO_2 nanoparticles were fluoridated by hydrofluoric acid. Afterward, SF/TiO_2 and SF/TiO_2-F nanocomposite scaffolds were prepared by freeze-drying method to obtain a porous microstructure. Both SF/TiO_2 and SF/TiO_2-F scaffolds contained 0, 5, 10, 15 and 20 wt% nanoparticles. To evaluate the efficacy of nanoparticles addition on the mechanical properties of the prepared scaffolds, their compressive properties were assayed. Likewise, the pores morphology and microstructure of the scaffolds were investigated using scanning electron microscopy. In addition, the porosity and density of the scaffolds were measured according to the Archimedes' principle. Afterward, compressive modulus and microstructure of the prepared scaffolds were evaluated and modeled by Gibson–Ashby's mechanical models. The results revealed that the compressive modulus predicted by the mechanical model exactly corresponds to the experimental one. The modeling approved the honeycomb structure of the prepared scaffolds which possess interconnected pores.

Keywords Silk fibroin · Titanium dioxide nanoparticles · Fluoridated titanium dioxide nanoparticles · Gibson–Ashby's mechanical models · Bone tissue engineering

Introduction

Three-dimensional (3D) scaffolds are applied for tissue engineering, drug delivery and the evaluation of cell behavior [1, 2]. The porosity and pore size of 3D scaffolds are the most important parameters which have direct efficacy on their biofunctionality. Indeed, open porous and interconnected networks are essential for cell nutrition, proliferation, migration, vascularization and formation of new tissues [3–5]. Open and interconnected pores provide good nutrient exchange and effective release of proteins, genes, or cells. In addition, a porous structure assists mechanical interlocking between the scaffold and the surrounding tissue that promotes the mechanical stability of the implant [5, 6].

The mechanical properties of tissue engineering scaffolds considerably affect their functionality. The microstructure of the scaffold is a key parameter which dictates the mechanical behavior [7]. In compressive stress–strain

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