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COLLAGEN/HYDROXYAPATITE BONE GRAFTS MANUFACTURED BY HOMOGENEOUS/HETEROGENEOUS 3D PRINTING

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Abstract

This paper presents a new way to obtain collagen/hydroxyapatite (COLL/HA) composite materials by 3D printing. Because of high tendency of segregation of COLL/HA composite materials, printing was done using COLL/Ca^{2+} gel (even COLL/$Ca(OH)_2$) followed by precipitation of HA and crosslinking of COLL. The HA precipitation occurs simultaneously with crosslinking of COLL molecules, these processes being assured by the presence of glutaraldehyde supplemented PBS solution. By printing with COLL/Ca^{2+} at acidic pH homogeneity was increased. FTIR spectroscopy and microscopy reveal HA formation as the main inorganic phase these nanoparticles being homogeneously dispersed in the volume. In vitro biocompatibility assays were performed on Vero cells (ISO10993-5/2009). Results show that the extract of the developed biomaterial in cell culture medium elicited a similar cellular response to standard culture medium demonstrating its potential for biomedical applications. The described procedure and proposed ink can be used for developing 3D bone scaffolds and open new perspectives for COLL/Ca^{2+} homogeneous inks.

Keywords: Biomaterials; Composite materials; Functional; FTIR; 3D-printing; collagen-hydroxyapatite

1. Introduction

Collagen/hydroxyapatite (COLL/HA) composite materials (CM) are extremely attractive for bone tissue engineering (TE) due to the high bone similitude [1]. An important issue in developing materials for (TE) is related to the material's morphology, therefore extensive studies are conducted in this direction. In bones (TE), porosity and pore size are essential in obtaining high quality grafts. Pore size should be in the range of 50–150μm because osteoblasts are in the range of 20–30μm and thus, can penetrate inside the graft and induce cell adhesion and bone ingrowth meaning a faster osteointegration. Higher pore sizes aren't recommended because they induce loss of mechanical performances [2-4].

Amorphous HA can be easily synthesized by precipitation method, the method being suitable for the synthesis of COLL/HA directly in presence of collagen gel, with limited risk of degradation. Different calcium precursors for HA (hydroxide, nitrate, sulphate, chloride) can be used and various phosphate precursors (H_3PO_4, $NaH_2PO_4 \cdot xH_2O$, $(NH_4)_2HPO_4$) at appropriate pH [5, 6].

Printability depends on ink composition but also on printing parameters (especially needle diameter). Based on literature data different additives, especially poly(ethylene glycol), are used to modify the rheology of gels. The aim of this study is to develop an alternative ink with limited or no agglomeration and to avoid segregation of composite gels over time. These gels are intended as ink for 3D printing. For this purpose, we tested the use of COLL/Ca^{2+}