Cellulose-Based Grafts for Bone Regeneration

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Introduction. Nowadays various bone grafting materials as autografts, allografts, xenografts and synthetic biomaterials are used for bone tissue regeneration. Autografts are the gold standard for this purpose, since they are osteogenic, osteoinductive and osteoconductive. However, transplantation of autograft tissue requires a second surgical site. This problem is avoided using allograft tissue, taken from another person or xenograft, taken from another species. However, these are generally associated with disease transmission. The synthetic bioceramic materials often agglomerate after implantation and blood vessels cannot grow in. Such constructs should be removed [1-3].

Three-dimensional (3D) scaffolds fabricated from polymers can be an alternative option for bone regeneration. Synthetic biodegradable polymers as poly(ε-caprolactone) (PCL), poly(glycolic acid) (PGA), poly(lactic acid) (PLA) and (poly(lactic-co-glycolic) acid (PLGA) are the most frequently used materials for the fabrication of 3D scaffolds [4]. In order to improve the mechanical stability of such constructs and enhance bioactivity, several materials, such as hydroxyapatite, β-tricalcium phosphate or bioactive glass are embedded in polymer-based frameworks [5-6].

The aim of this work was to prepare 3D natural polymer-based scaffolds with hydroxyapatite particles for bone tissue regeneration.

Materials and methods. Cellulose scaffolds with embedded hydroxyapatite (HA) particles were produced mechanically immobilizing HA during the formation of cellulose gel. The mean diameter and size distribution of HA particles which were used for the scaffolds were measured by *Beckman Coulter LS 200* analyser (Beckman Coulter, Inc., USA). The SEM equipped with the energy dispersive spectrometer (EDS) *Quanta 200* with a detector *XFlash 4030* (Bruker AXS Microanalysis Gmb, Germany) was used for the elemental analysis. The micro-computed tomography analysis was performed using a *μCT40* micro-CT system (Scanco Medical AG, Switzerland) in order to evaluate the morphology of the prepared scaffolds. The mechanical properties of the scaffolds were studied using the *H25KT* system (Tinus Olsen, UK). Scaffolds were loaded under compression using a crosshead speed of 1 mm/min with a 5000 N load cell.

Results. Scaffolds for bone tissue engineering were produced reinforcing cellulose with hydroxyapatite (HA) powder. The average size of HA particles was about 20 μm (Fig. 1).

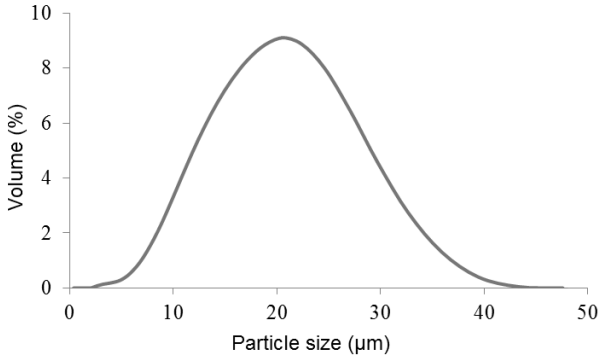

Fig. 1. Distribution of HA particles

The EDS spectra of cellulose matrix showed the presence of carbon (C) and oxygen (O) while spectra of composite scaffold showed additional peaks corresponding to calcium (Ca) and phosphorus (P) as the elements of HA (Fig. 2).

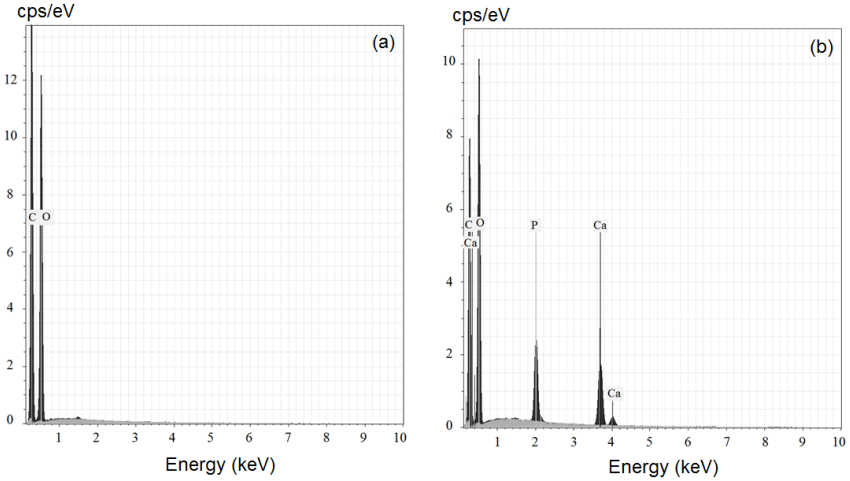

Fig. 2. EDS spectra of cellulose matrix (a) and composite scaffold (b)

For the morphological characterisation of the prepared scaffolds, micro-computed tomography was performed. As can be seen from 2D images, the scaffolds comprised non-symmetrical interconnected pores (Fig. 3). Such arrangement of the pores is essential for cellular activity, in-growth of blood vessels and formation of bone tissue.

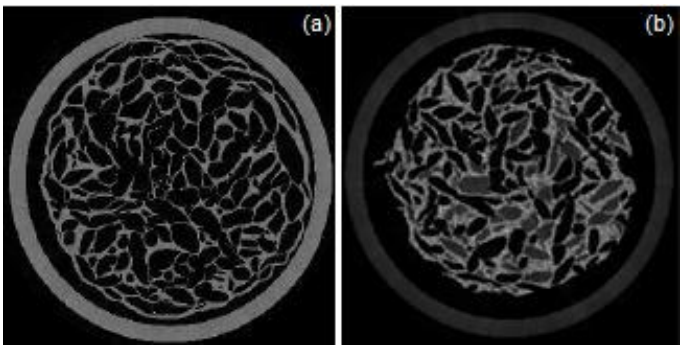

Fig. 3. 2D images of: cellulose framework (a); cellulose reinforced with HA particles (b)

The microcomputer tomography data showed that the porosity of reinforced scaffold was reduced by 9% compared with the control cellulose matrix and reached the value of 66%. The smaller pores appeared within composite scaffold. The mean diameter of the pores was of 540 μm, while cellulose matrix contained larger pores - 750 μm.

It can be concluded that the size of pores of composite scaffold is still in the range of needed as pores from 100 μm up to 1000 μm are required [7].

Composite scaffolds with embedded HA particles also demonstrated differences in mechanical properties, compared with cellulose framework (control) (Fig. 4).

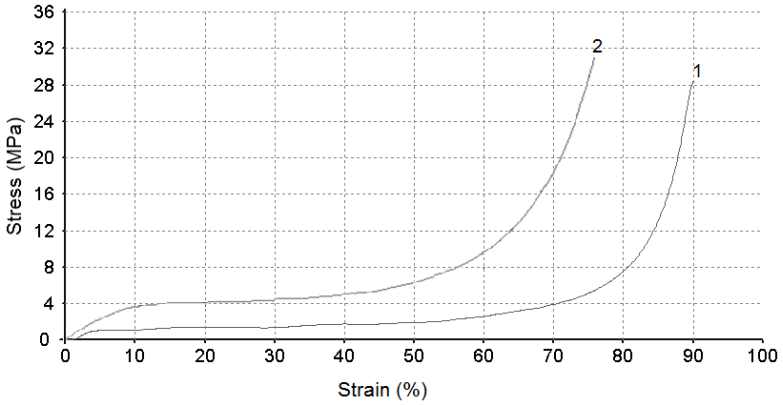

Fig. 4. Compression stress-strain curves of cellulose scaffolds before (1) and after (2) reinforcing with HA particles

It was found that the addition of HA improve the mechanical properties of the scaffold. The Young's modulus of the reinforced scaffold increased up to 9 MPa.

Conclusions. Cellulose-based scaffolds were prepared by mechanically immobilizing hydroxyapatite particles during the regeneration of cellulose. The

morphological parameters of prepared scaffolds were in the range of required. Moreover, reinforced cellulose scaffolds, compared to control, have demonstrated improved mechanical properties.

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In this work cellulose scaffolds with embedded hydroxyapatite particles were prepared. The results obtained in this work revealed that the morphology of composite scaffolds is suitable for bone tissue regeneration. The highly porous scaffolds comprised non-symmetrical interconnected pores. Such arrangement of the pores is essential for cellular activity, in-growth of blood vessels and formation of bone tissue. Moreover, reinforced cellulose scaffolds have demonstrated improved mechanical properties.