GRADIENT SCAFFOLDS FOR THE REGENERATION OF OSTEOCHONDRAL DEFECTS OBTAINED USING 3D PRINTING TECHNOLOGY

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Introduction

Recovery of osteochondral defects is still a challenging task for surgeons across the world. Osteochondral tissue consists of bone, cartilage and bone-cartilage interface, and therefore is characterized by gradient of mechanical and biological properties. When designing scaffolds, it is important to properly design a porosity gradient. The porosity of the scaffold is influenced by the pore size, pore size distribution and geometry. The pore structure plays an essential role in cell adhesion, migration, proliferation and tissue formation as well as nutrient diffusion [1]. 3D printing technology is a very promising tool for osteochondral defects regeneration applications, as it allows for the creation of precisely designed, personalized implants.

The aim of the work was to design scaffolds with different porosity gradients based on the literature data. As the structural design plays a critical role in improving the mechanical properties of porous biomaterials. The second goal of this work was the selection of a scaffold that meets the requirements for porosity and mechanical properties.

Materials and Methods

Scaffolds were made of polycaprolactone (PCL, Sigma-Aldrich, Mw 80 kDa) using 3D printing in fused deposition modelling (FDM) technology. Samples were first designed using Autodesk Inventor and converted into FDM-printable files using Prusa Slicer software. Six different scaffolds 20 x 20 mm with different porosity gradient were designed and produced using Prusa i3 MK3 printer. SEM and µCT investigation of the scaffolds were performed in order to evaluate the porosity gradient along the printed scaffold. Scanning electron microscope (Nova NanoSEM 200, FEI, AGH) equipped with EDS analysis was used to evaluate scaffold microstructure. The samples were coated with carbon before observation. The architecture of the scaffolds was analyzed by micro-computed tomography (µCT) using a SkyScan 1172 Bruker® scanner.

Tensile tests have been performed using computerized universal testing machine (Zwick/Roell, Germany), according to EN ISO 527-2:1996. Samples with dimensions given in the standard were printed on a printer.

Results and Discussion

Size of the osteoblasts is in the range of 10-50 µm, however preferred scaffold pore size for osteoblasts proliferation is in the range of 100 – 200 µm [2].

6 scaffolds with different pore size, geometry and shape were designed. Among others, scaffold with a pore size of 100-200 µm in the chondral layer and a pore size of 300-450 µm in the osseous layer [3] were prepared.

An example of designed scaffold used in the research is shown in FIG. 1.

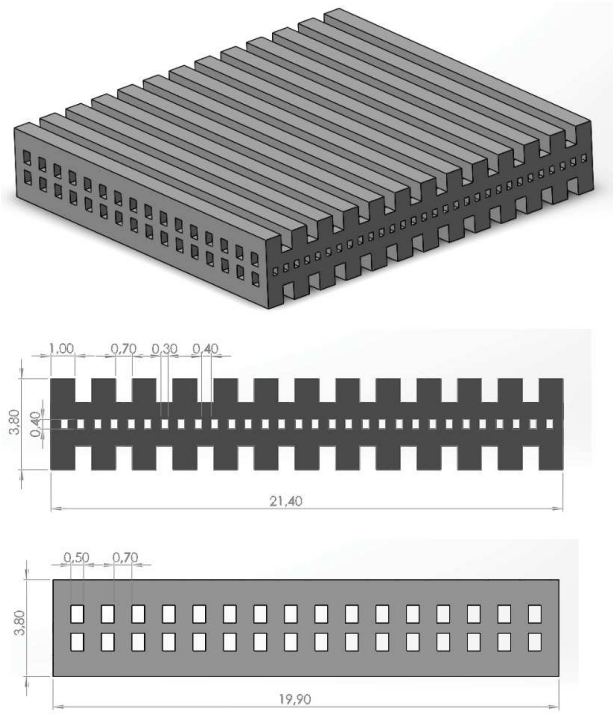

FIG. 2. Example of gradient scaffold structure used in the research.

All designed scaffold were printed and tested. The microscopic observation confirmed the presence of pores with different geometries along the scaffold. The scaffolds varied in mechanical properties.

Conclusions

Preparation of biocompatible gradient scaffold for osteochondral face defect treatment should facilitate implantation, increase recovery rate and improve the final appearance of the patient.

Further studies will focus on designing more advanced, perhaps multi-material gradient scaffolds and implementation of the 4D printing technology into implant preparation process.

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References

[1] J. M. Sobral *et al*., Acta Biomaterialia 7 (2011) 1009–1018.

[2] N. Abbasi, S. Hamlet, R. M. Love, N. T. Nguyen. Journal of Science: Advanced Materials and Devices 5 (2020) 1-9.

[3] P. Duan *et al.,* Journal of Orthopaedic Translation 19 (2019) 68-80.