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BIOFABRICATION AND MICROCT VALIDATION OF TPMS-BASED SCAFFOLDS FOR TISSUE ENGINEERING APPLICATIONS

J. E. Santos[1], L. Krishnan[2], P. R. Fernandes[1], A. P. G. Castro[1,3], S. J. Hollister[4]

[1] IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal

[2] Parker H. Petit Institute for Bioengineering and Bioscience, Georgia Institute of Technology, USA

[3] ESTSetúbal, Instituto Politécnico de Setúbal, Portugal

[4] Center for 3D Medical Fabrication, Dep. of Biomedical Eng., Georgia Institute of Technology, USA

jorge.e.santos@tecnico.ulisboa.pt; lkrishnan6@gatech.edu; paulo.rui.fernandes@tecnico.ulisboa.pt; andre.castro@tecnico.ulisboa.pt; scott.hollister@bme.gatech.edu

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1 INTRODUCTION

TPMS (triply periodic minimal surfaces)-based scaffolds have gained attention in tissue engineering because they offer high surface area to volume ratios, reduced stress concentration, and increased permeability, promoting better cell adhesion, migration, and proliferation and the resulting structures are appropriate to be manufactured using 3D printing technology. However, when manufacturing biomedical devices for clinical practice, it is essential to monitor the production protocols to assess how much the produced device is similar, or different, from the idealised one. Quantitative assessment of macrostructural characteristics like geometry, microstructural features like density/porosity, and connectivity may improve the ability to estimate the device performance and is crucial to ensure structural integrity and corresponding desired behaviour. This work presents a MicroCT image segmentation methodology that aims to access the production validation of TPMS-based scaffolds produced by Selective Laser Sintering (SLS) using a PCL + HA (polycaprolactone + hydroxyapatite) powder [1], [2]. Apart from geometrical and macroscopic characterisation, the method aims to quantitively access the presence of residuals that may compromise the scaffold's performance.

2 MATERIALS AND METHODS

Hollow cylinders of 9 x 11.5 mm (outer D x H) and 6 mm inner D were designed to be used as a validation phantom. TPMS-based scaffolds were developed using a homemade Python code with a cylindrical configuration of 10 x 7 (D x H) mm (figure 1).

a) b)

Figure 1 – Different lattices of a Gyroid with 80% porosity and 3mm cell size: a) Sheet, b) Network.

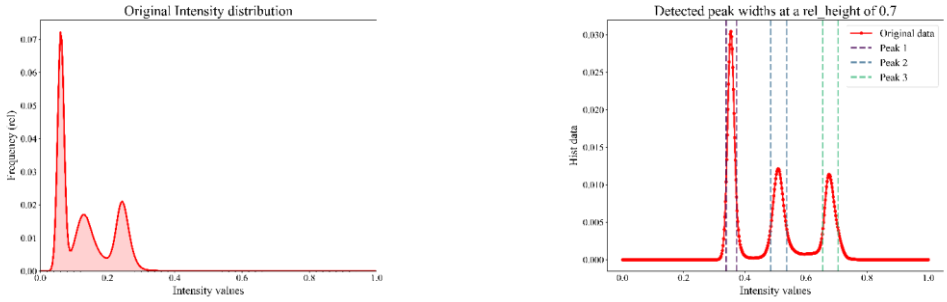
Sheet and Network TPMS-based scaffolds with 50, 60, 70, and 80% porosity values and 2.75 and 3.0 mm cell sizes were also designed. Then the structures were manufactured with a PCL powder marketed under the brand name CAPA® 6501 (Solvay Caprolactones, Warrington, UK) plus 4% HA, using a sinterstation 2000™ machine (3D Systems, Valencia, CA). Scaffolds were built

layer-by-layer using a powder layer thickness of 100 µm. Excess powder surrounding the scaffolds was brushed off and the scaffolds were finally cleaned by blowing compressed air and physically removing unsintered powder from the scaffold.

All samples were scanned using a SCANCO µCT 50 cabinet microCT scanner with a 20-100 kVp (45, 55, 70, 90 kVp preset and calibrated), 5-30 µm spot size (4 - 18W) X-ray source, into 3400 x 1200 elements, 20 µm pitch detector. Samples were stored as DICOM collections with a pixel resolution of 20 µm. All DICOM collections were imported and processed as 3D NumPy arrays. The proposed method is fully Python-based and consists of a spatial-domain transformation based on a smoothing step, a contrast enhancement step, and an edge-enhancing step.

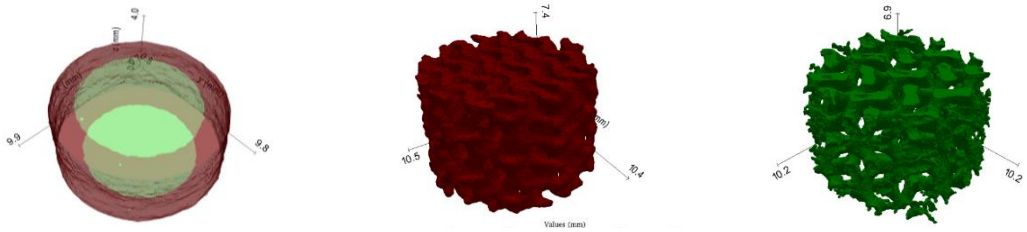
3 RESULTS AND DISCUSSION

The applied methodology enhances the contrast and the edges of the original image improving foreground object identification and thresholding. Validation was performed over the scanned cylindrical phantoms, filled with unsintered powder. The algorithm efficiently spreads the peaks of the gray levels histogram (figure 2) and identifies the different regions corresponding to sintered and unsintered powder. Figure 3a shows the phase decomposition over a cross-section of the cylinders filled with unsintered powder. The same methodology was applied to the mentioned TPMS-based scaffolds. Figures 3b and 3c show the segmentation result applied to a Gyroid structure with 50% porosity and 2.75 mm cell size.



a) b)

Figure 2 – a) Original gray level histogram, b) Segmented histogram and peaks, and thresholds detected.



a) b) c)

Figure 3 – Segmentation outputs: a) for the hollow cylinder (red) filled with powder (green); b) produced scaffold, c) trapped unsintered powder inside its pores.

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