

COMPUTATIONAL FLUID DYNAMICS ANALYSIS TO QUANTIFY THE VARIABILITY OF RAPID-PROTOTYPING SCAFFOLDS

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Introduction

Tissue engineering aims to restore functional tissue with the development of synthetic or natural materials that can act as a scaffold or template for cells to attach, proliferate and differentiate. One of the industrial and scientific challenges of tissue engineering is to create a consistent and reproducible tissue structure for many different kinds of clinical applications. Scaffold biomaterial structure is one of the most critical parameters to control. Rapid prototyping techniques have been used recently to fabricate scaffolds with regular internal microstructure. However, a remaining problem with this fabrication method is that CAD scaffold models can differ significantly from the fabricated scaffolds [Ryan et al. 2009]. In this study, the difference between an ideal scaffold and a fabricated one is analysed in terms of local structural and fluid flow changes.

Methods

Commercial scaffolds made of PCL from 3D Biotek (New Jersey, USA) were used. The fibre diameter and the spacing between the fibres are both 300 μm , and the diameter and height of the scaffold are 5 mm and 1.5 mm respectively. A CAD geometry with these structural parameters was created in Ansys Design Modeler (Pennsylvania, USA). A fluid volume mesh was created with a total number of 4,931,153 elements.

The manufactured samples were scanned using micro-CT with a resolution of $6 \times 6 \times 6 \mu\text{m}^3$ and reconstructed using Simpleware (Exeter, UK). The interconnected pore volume was meshed with a total number of 4,957,306 elements and exported in Ansys Fluent.

CFD simulations were performed in both geometries using Fluent Ansys with the following settings: steady state and laminar fluid flow, incompressible Newtonian fluid with a viscosity of 1.45×10^{-3} Pa.s, no-slip boundary conditions on walls, velocity inlet of 1 mm/s, and zero-pressure outlet.

Results

Structural differences are clearly observed in Fig. 1. There is a lack of pore repeatability compared to the CAD drawing. The structural changes affect significantly the fluid flow pattern within the scaffold (Fig. 1). Important differences of fluid velocity values are observed within the reconstructed scaffold. Fig. 1a shows values of fluid flow from 0.5 to 2.5 mm/s while in Fig. 1b, values are from 1 to 1.5 mm/s. Results also indicate regional differences in the reconstructed scaffold due to imperfect pore size distribution.

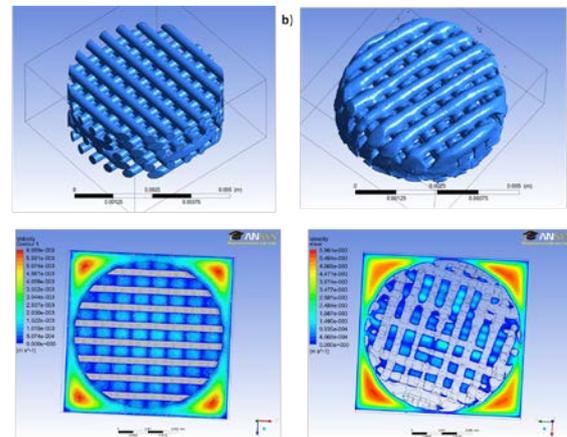


Figure 1: Velocity contours on plane cutting the centre of the scaffold for, a) idealized CAD geometry, b) Reconstructed scaffold.

Discussion

Significant differences were found between the ideal scaffold and the real fabricated scaffold. Moreover, it is expected that intersample variability will affect *in vitro* results by increasing the noise already present in experimental results. This study shows that the physical scaffolds used *in vitro* need to be thoroughly analysed to better predict the effect of local architecture and local mechanical stimuli on the cell response.

References

G. Ryan *et al*, J Biomech Eng, 90:894-906, 2009.

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