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ABSTRACT BOOK

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STUDY OF THE FLUID BEHAVIOUR IN 3D PRINTED MACROSCAFFOLDS USING CFD ANALYSIS AND PIV

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Introduction

Damages affecting bone structures are frequent in modern societies, caused by trauma, diseases or prolonged physical activities. Bones can heal by itself as long as the defects are small [1]. In case of more severe bone damage, scaffolds can be used to provide a template that supports seeded cells to get an optimal environment for their proliferation [2] to re-build the structure. The geometry of the pore network of the scaffold has to provide an appropriate pore size, sufficient permeability and suitable mechanical properties [2,3]. The evaluation of biocompatible properties, such as permeability and wall shear stress (WSS), is challenging because of their influence on cell bioactivity within scaffolds and the micro-size of the scaffold [4]. Therefore, in this work, computational fluid dynamics (CFD) simulations were used to investigate the WSS and to analyse the flow field at different velocities along the scaffold model surface. The numerical results were experimentally validated with µ-particle image velocimetry (PIV) measurements.

Methods

Scaffold geometries, which have a 6 mm long sinusoidal channel with a characteristic length of 0.5 mm, an amplitude of 0.1 mm and different frequencies (f=3.5 mm^{-1}, f=7 mm^{-1}), were designed using CATIA®. The CFD simulations were performed using the software OpenFOAM®. The scaffolds were meshed using snappyHexMesh. A steady laminar fluid flow was simulated using the solver icoFoam with different inlet velocities, zero pressure outlet and non-slip wall condition. An incompressible Newtonian fluid with a viscosity of 0.000001 m^2/s was assumed. The fluid flow is described by the three-dimensional Navier-Stokes equation. For the µ-PIV experiments, scaffolds were printed by using the Two-Photon polymerisation technique (2PP) based on cross-linking of photosensitive polymers induced by femtosecond laser pulses. The scaffolds were composed of ethoylated trimethylolpropane triacrylate, trimethylolpropane triacrylate (ETA:TTA) and 5 mM of M2CMK photoinitiator.

Results

Two meshes were used to evaluate the mesh dependence of the solution. The surface cell size was reduced by a factor of four in the finer mesh compared to the coarser one. The comparison of the meshes shows a difference in the transition of the velocity profile as depicted in Fig. 1. Changing the frequency also changes the flow field as shown in Fig. 2. The printed 2PP scaffold was used for the µ-PIV experiments to validate the results of the CFD simulations as shown in Fig. 3. A backflow on the top of the cavity with a higher velocity than in the numerical result (Fig. 2b) was observed.

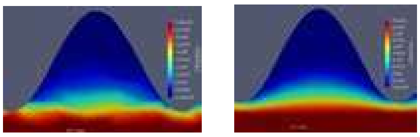

Figure 1: Result of (a) coarse and (b) fine mesh.

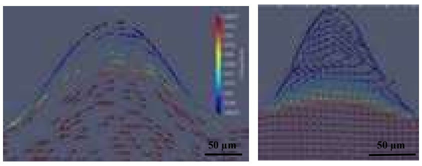

Figure 2: Velocity vector field for an inlet flow of 5 mm/s with a frequency of (a) f=3.5 mm^{-1} *(b f=7* mm^{-1}.

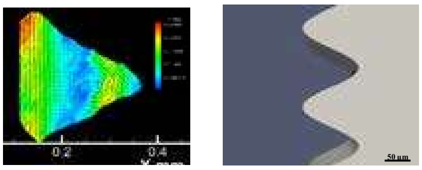

Figure 3: Result of (a) µ-PIV measurement (b) scaffold model surface.

Discussion

The results illustrate the use of CFD to characterise scaffold design and get valuable information on the fluid dynamics for different geometric variations. This is important because changes in the flow field, especially in the regions near the wall, can directly affect the cell behaviour [5].

References

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