LATTICE BOLTZMANN MODELLING APLLIED TO A BIOREACTOR FOR BONE TISSUE ENGINEERING

T. J. Spencer[*†], I. Halliday[†], C. M. Care[†], L. A. Hidalgo-Bastida[††], S. H. Cartmell[††]

[†]Materials & Engineering Research Institute, Sheffield Hallam University, Sheffield, UK.
e-mail: t.j.spencer@shu.ac.uk

[††]Institute for Science and Technology in Medicine, Keele University, Staffordshire, UK.
e-mail: I.a.hidalgo-bastida@istm.keele.ac.uk

ABSTRACT

Bone tissue engineering is an emerging therapy for treating patients undergoing orthopaedic trauma or disease. Bone tissue can be engineered in the laboratory using a bioreactor in which culture medium is perfused through a three dimensional (3D) scaffold. One important feature in bone tissue engineering is the configuration of placing the cells onto a porous 3D scaffold at the start of the culture period to create the tissue engineered construct. Mathematical modelling offers scientists assistance with regards to reducing the number of physical laboratory experiments needed for experimental characterisation and optimising cell seeding. We have used incompressible lattice Boltzmann (lB) modelling to investigate scaffold parameters and cell seeding.

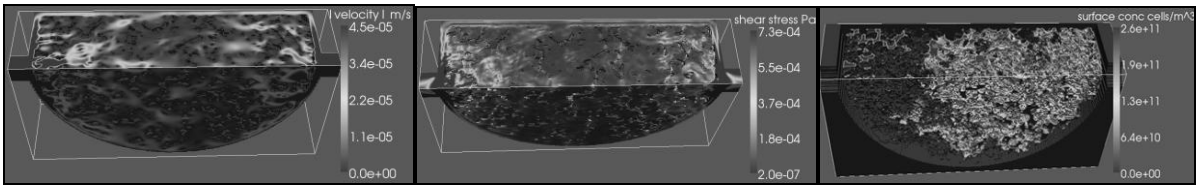
Our first approach was to use microCT images of PLA scaffolds to generate the 3D structure for the lB model. The first results model the hydrodynamics of the porous scaffold [1] without cells to measure typical flow velocities, wall shear stress, scaffold permeability and tortuosity. It is found flow is highly inhomogeneous and the PLA scaffolds are anisotropic. These findings highlight that Darcy flow models must be used with caution in a bioreactor environment [2].

The second approach couples advection diffusion reaction equations to the lattice Boltzmann method in order to model key components of the culture medium. Moreover, we consider dissolved oxygen (nutrient), carbon dioxide (waste) and Mesenchymal stem cell (bone forming cells) species together with a receptor ligand model of cell attachment. Simulations are done to reproduce experimental findings and begin the optimization process.

References

[1] F. Boschetti et al., Prediction of the micro-fluid dynamic environment imposed to three-dimensional engineered cell systems in bioreactors. *J.Biomech.* **39**(3) , pp. 418–425 (2006)

[2] R. Whittaker et al., Mathematical modelling of fibre-enhanced perfusion inside a tissue engineering bioreactor. *J. Theor. Biol*. **256**(4) , pp 533-546 (2009)



(a) (b) (c)

Figure 1. Plots over a one quarter segment of the bioreactor and scaffold showing the (a) culture medium velocity, (b) culture shear stress and (c) cell attachment concentration.