Assessment and modeling of oxygen tension in porous structures and engineered tissue constructs

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Introduction

Tissue Engineering holds the promise to repair damaged human tissues and organs by engineering tissues in the laboratory. Usually, cells are seeded in porous scaffolds and subjected to a bioreactor for the regeneration of tissues. Unfortunately, the regenerated tissues commonly suffer from inadequate thickness and cell density. They are usually non-homogenous, thicker near the periphery but less dense near the bottom [1]. These problems make the tissue grown this way unsuitable for clinical applications. It is believed that this is due to limited diffusion of essential nutrients (most importantly oxygen) into the scaffold, which hampers tissue growth. We hypothesized that the scaffold's structural properties, such as void fraction, pore size distribution, degree of cross-linking influence the ability of oxygen diffusion in the scaffold. Thus, it is necessary to study oxygen diffusion profiles in scaffolds in order to design better scaffolds to enhance cellular activities and tissue quality.

Objectives

- To study how different scaffold parameters (structural properties) influence oxygen diffusion
- To develop a mathematical model correlating scaffold's parameters with oxygen diffusion profile
- To determine optimum scaffold parameters needed to promote and sustain cellular activities and tissue regeneration

Materials and Methods

- Characterizing scaffold structural and physical properties [2]

Image Analysis: Scanning Electron Microscope (SEM)

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Porosity/Void Fraction/Pore Size Distribution

- Measurement of oxygen profile (Figure 1)

Scaffold Loaded on Petri Dish and Immersed in Water

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Vacuum Oven

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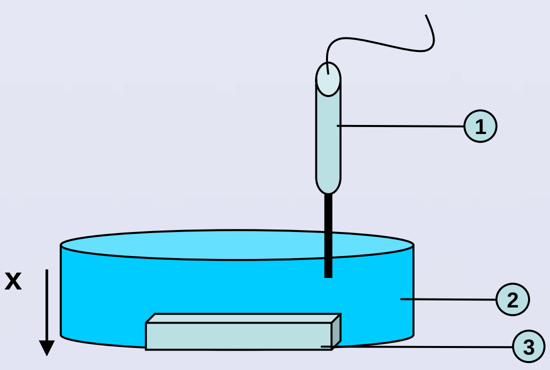
Oxygen Measurement Using Fiber Optic Oxygen Sensor (Precision Sensing, GmbH, Germany)



<u>Fiber-optic sensor with static set-up.</u>
1. Fiber-optic sensor syring
2. Petri dish with water
3. Scaffold

Figure 1. Schematics for the Measurement of Oxygen Profile in Scaffold.

Results and Discussion

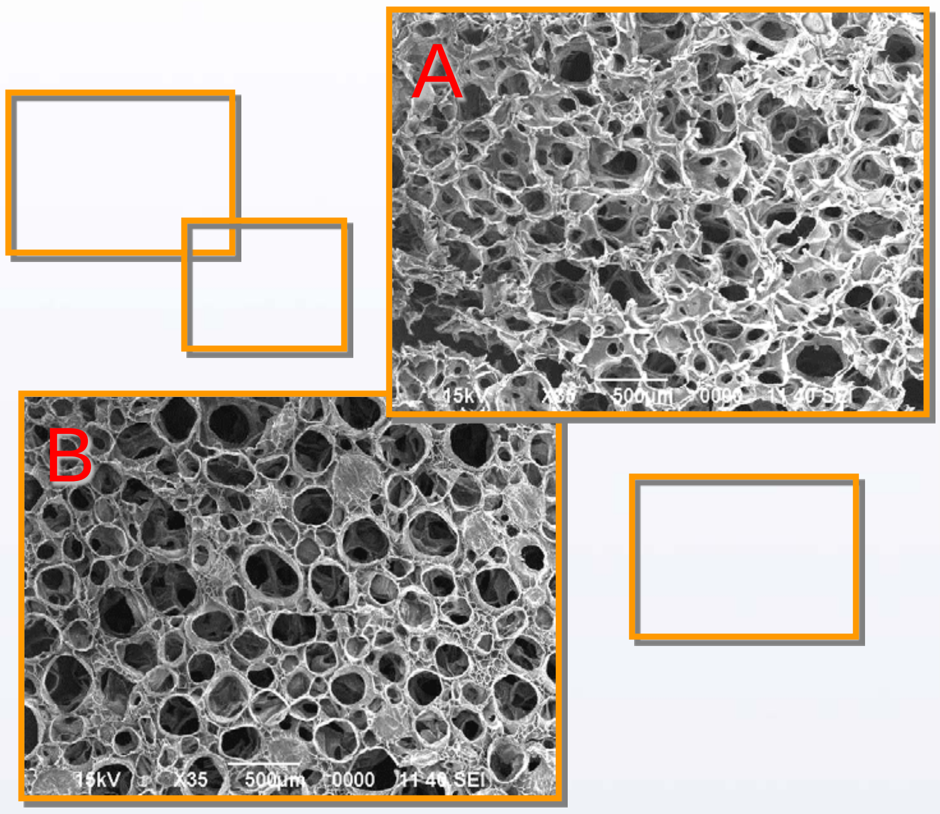


Figure 2. SEM micrographs of gelatin scaffolds with different structural properties (porosity, void fraction).

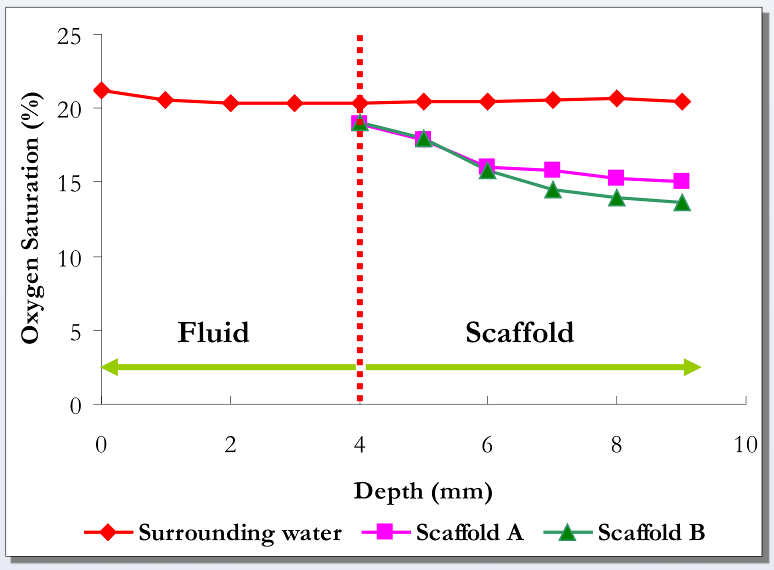


Figure 3. Oxygen profile measured in fluid medium and within scaffolds of the structures shown in Figure 2.

- Uniform oxygen concentration in surrounding fluid
- Oxygen gradient is established within the porous scaffold
- Oxygen gradient is influenced by the structural properties of scaffold

Future Plan

- Quantification of the porous structure, porosity, and void fraction of scaffold using SEM image analysis and porosimetry
- Measurement of oxygen profiles in scaffolds of different structures under dynamic flow
- Development of a mathematical equation to relate scaffold parameters with oxygen diffusion
- Cell culture studies to test further hypothesis that the quality of regenerated depends on effective oxygen diffusion in the tissue construct

References

[1] M.C. Lewis, et. al. *Heterogenous Proliferation Within Engineered Cartilagous Tissue: the Role of Oxygen Tension.* Willey InterScience E-journal (2005).

[2] P.V. Grant, et. al. *Physical Characterization of a Polycaprolactone Tissue Scaffold.* Surface Chemistry in Biomedical & Envionmental Science, 215-228, (2006).

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