ISB 2013 BRAZIL
24th CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS

CHANGES IN MECHANICAL STRENGTH OF ELECTROSPUN POLYMERIC SCAFFOLD DUE TO TISSUE INGROWTH IN A SUB-CUTANEOUS RAT MODEL

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INTRODUCTION

The design of regenerative medicine devices requires knowledge of the effects of tissue regeneration on the mechanical strength of the device material. [1, 2] Characterising constitutive material models from simplified experiments to capture these changes enables the use of finite element methods to model complex devices. [3]

This study investigated the changes in mechanical aspects using highly aligned electrospun polymeric scaffolds in a subcutaneous rat model. The data is to be used in a further study for the characterisation of constitutive computational material models to model reinforced vascular grafts.

METHODS

Scaffolds with a high degree of fibre alignment were electro-spun from bio-stable Pellethane onto a rotating cylindrical target. Rectangular samples were cut from the scaffold in both fibre and cross-fibre directions. Sample porosity was measured by means of a fluid displacement method. Individual sample dimensions were measured prior to sterilisation (70% Ethanol, 24 hours) and implantation in dorsal, subcutaneous pockets in a Wistar rat model. All animal experiments were approved by the institutional review board of the University of Cape Town and were performed in accordance with the National Institutes of Health (NIH, Bethesda, MD) guidelines.

Samples were explanted after 7, 14 and 28 days and subjected to uniaxial tensile tests (5 load cycles, strain $\varepsilon = 8$ to 12%; final extension to $\varepsilon = 25\%$) in the fibre and cross-fibre directions. Histological analysis of H&E stained sections were used to quantify tissue ingrowth by using VisioPharm to segment the image into two regions, tissue and not..

RESULTS AND DISCUSSION

Scaffold porosity was measured to be 85 ± 2%. Tissue ingrowth was 45 ± 9% at 7 days, 48 ± 6% at 14 days and 70 ± 1% at 28 days, as illustrated in Figure 1.

With the tissue ingrowth, the scaffolds showed non-linear behaviour, as opposed to the nearly linear behaviour of the bare samples. Similar results have been reported. [1]

In the fibre direction of the scaffold, stress at 25% strain and elastic modulus decreased by 48% and 57%, respectively, whereas cross fibre samples showed an increase in stress and elastic modulus of 1460% and 1600%, respectively, after 28 days of implantation. Figure 2 shows that the changes in the samples loaded along the fibre orientation were mainly observed between 14 and 28 days, while cross-fibre changes were more gradual across the time range.

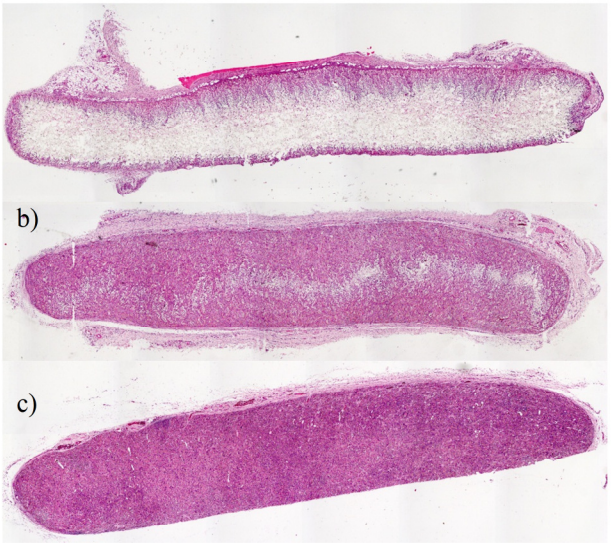

Figure 1: Histology images of cross sections through samples after a) 7 days; b) 14 days; and c) 28 days of implantation.

The drastic increase in the cross-fibre direction can be attributed to the very weak initial state of the highly aligned scaffold in this direction, where the tissue growth in the first 7 days already plays a major mechanical role. From 7 to 28 days this increase is remarkably slowed. In the fibre direction, changes during the first 14 days are statistically insignificant, after which there is a significant drop. The lack of significant change during the first 14 days could be due to the fact that the much stronger fibres are carrying the full load. The drop during the last 14 days could possibly be caused by the tissue altering the micro-geometry of the fibrous scaffold and thus changing the behaviour of the main load-bearing component.

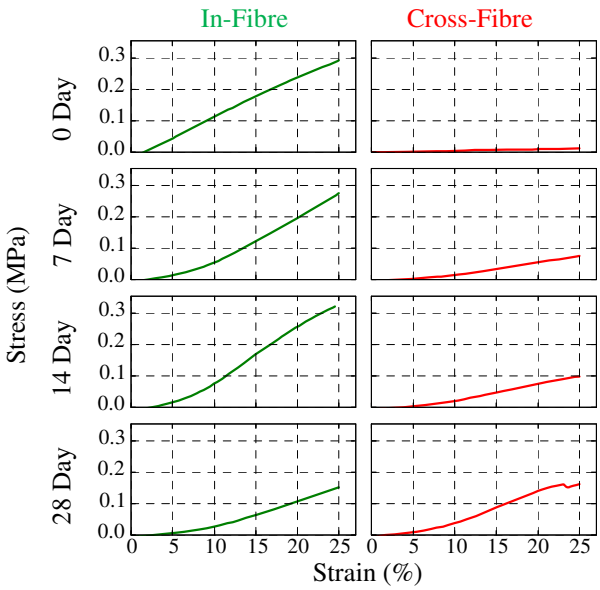

Figure 2: Averaged stress-strain data of the last loading cycle for in-fibre and cross-fibre uniaxial tensile tests at various stages.

CONCLUSION

The electrospun non-degradable scaffolds promoted rapid tissue ingrowth. The significant increase in strength of the scaffold in the weaker cross fibre direction demonstrates the mechanical contribution of the tissue. However, the considerable reduction in strength in fibre direction of the scaffold with tissue ingrowth requires further investigation. These data can be used to characterise constitutive material models in order to computationally model how the changes due to tissue ingrowth will affect and interact with a medical device design.

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ACKNOWLEDGEMENTS

This study was supported financially by the National Research Foundation (NRF) of South Africa. Any opinion, findings and conclusions or recommendations expressed in this publication are those of the authors and therefore the NRF does not accept any liability in regard thereto.

This study was supported partly by the International Society of Biomechanics (ISB) through a matching dissertation grant to HK.