Micromechanics of Electrospun Poly Ester Urethane Urea Scaffolds

Todd Courtney, Jun Liao, Michael Sacks, John Stankus, Jianjun Guan, William Wagner.
University of Pittsburgh, USA.

Introduction

Tissue engineered scaffolds for soft tissue applications should exhibit mechanical properties similar to the native tissue for at least the length of time it takes to develop an extracellular matrix (ECM). Tissue engineering typically utilizes bioreactors where mechanical training occurs under *in vivo* conditions. Deformation of the seeded cells within the scaffold under mechanical training, whether *in vivo* or *in vitro*, is largely unexplored. Such information is critical in developing truly engineered scaffolds. Previously, we developed isotropic and anisotropic elastomeric PEUU scaffolds and developed a structural constitutive model able to predict the fiber distribution and mechanical response of the scaffolds. For this study, we extended that work to measure the tortuosity of the fibers and to include the measure of tortuosity in the model so as to investigate the effect of scaffold strain on seeded cells and deposited extracellular matrix in future applications.

Materials and Methods

Electrospun scaffolds. The methods used to develop the PEUU scaffolds have previously been described [1]. The PEUU was synthesized and fed into a steel capillary suspended over the center of a cylindrical steel mesh focusing screen and aluminum rotating mandrel (11.4 cm). The mandrel speed was varied between 0.3 and 13.8 m/s.

Mechanical Testing. Biaxial testing was performed on the PEUUs to determine the mechanical response of the scaffolds [1]. The specimens were tested at equibiaxial forces (T11:T22) up to 90 N/m, with the last of ten cycles used for analysis.

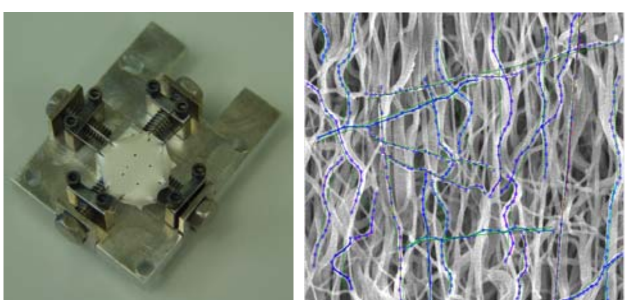

Figure 1 Left - Biaxial SEM stage with stretched PEUU Right – Measure of tortuosity of scaffold

SEM biaxial stage. A biaxial stretching device (Fig 1) was developed to determine the effects of stretch on fiber tortuosity (Fig 2). A non-stretched scaffold was sutured to the stage, imaged and used as a reference. The device was then removed from the SEM, stretched to a desired level and placed back within the SEM for imaging.

Structural Characterization & Tortuosity Measures. SEM images were obtained for the various mandrel speeds of PEUU synthesis and analyzed using image analysis software, which has been previously reported [1]. Fiber orientation of the non-stretched and stretched scaffolds utilized the same software. Tortuosity was measured using a custom program written in MATLAB. The end-to-end distance of the fibers, D, was measured along with the total length of the fiber, L. The tortuosity index was calculated as L/D.

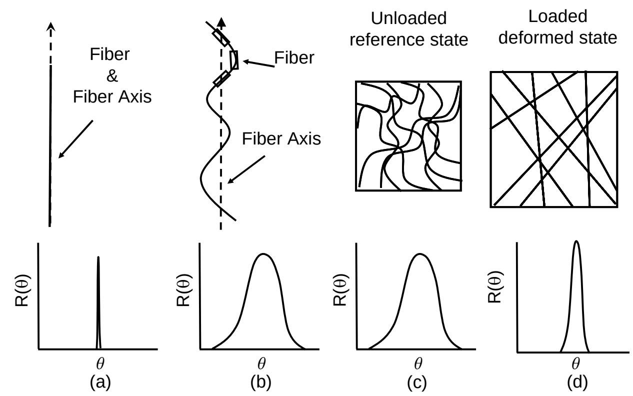

Figure 2 Effect of fiber tortuosity and straightening on fiber angular distribution

Results and Discussion

The PEUU scaffolds displayed higher orientation with increasing stretch as the degree of tortuosity is gradually lessened as depicted in figure 2. Tortuosity tended to be greater in the direction of spin of the mandrel. Thus, the scaffolds with the most amount of variation of tortuosity were those developed at higher mandrel velocities. Inclusion of the tortuosity effects into the constitutive model yielded a much more robust fit to the experimental data previously reported [1].

Conclusions

The development of a biaxial stretching device that fits within an SEM allowed for the measure of tortuosity of PEUU fibers. We demonstrated that 1) there is a gradual diminishing of that tortuosity with stretch, and 2) there exists directional variations in tortuosity. Future work will investigate the effect of stretch on cells integrated into the scaffold and compare this with cellular deformation within the ECM.

References

Sacks, MS et al., J Biomaterials, (Submitted)

Acknowledgements

Funded by NIH grants HL-069368 and HL-68816