Measuring the Local Strain During Tensile Testing of Electrospun Fibrous Mats for Tissue Engineering Applications

Meir Shimunov
Mentor: Julianne L. Holloway, Associate Professor of Chemical Engineering; Grace Schwarz, PhD Candidate
School of Engineering of Matter, Transport and Energy; Arizona State University

Research Question

What is the localized strain experienced by unaligned and aligned electrospun fibrous mat scaffolds at a 10% bulk tensile strain?

Motivation

Musculoskeletal injuries are a serious global medical issue. Surgery is currently one of the main ways to treat orthopedic injuries, yet it often carries significant risks and complications. However, tissue engineering is a field that offers an alternative approach by combining cells, signaling molecules, and scaffolds to create biological substitutes that can help repair or enhance the function of damaged or diseased tissues and organs. The goal of this research project is the mechanical characterization of electrospun fibrous mat scaffolds. This knowledge will enhance the field's understanding of how the mechanical properties of tissue engineered scaffolds impact stem cell development.

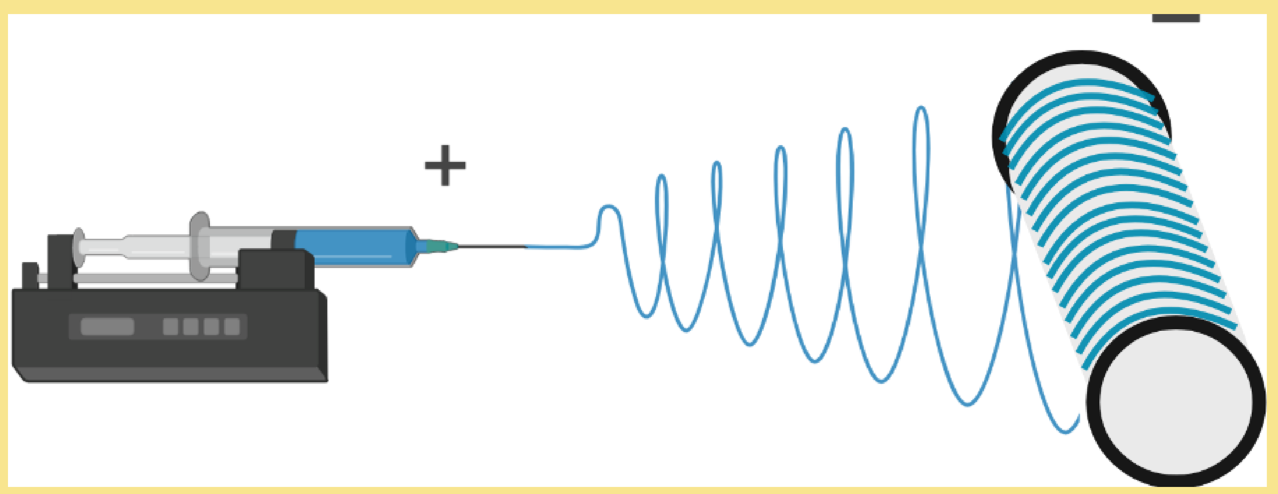

Figure 1. Electrospinning Schematic
Polycaprolactone (PCL) polymer solution is put in a syringe, a blunt needle is attached, and then the unit is placed in a syringe pump. The mandrel spins as the solution is extruded to form a fibrous mat.

Results

Ultimate tensile strength and elastic modulus were calculated for each scaffold. The average elastic modulus was 9277.4 kPa and 24722.2 kPa for the unaligned and aligned scaffolds, respectively. The average ultimate tensile strength was 4101.2 kPa and 16720.0 kPa for the unaligned and aligned scaffolds, respectively. Digital image correlation (DIC) results of the aligned scaffold indicate a unidirectional vertical displacement of up to 3 cm prior to failure. Strain data was missing likely due to software issues, limiting the reliability of the strain analysis.

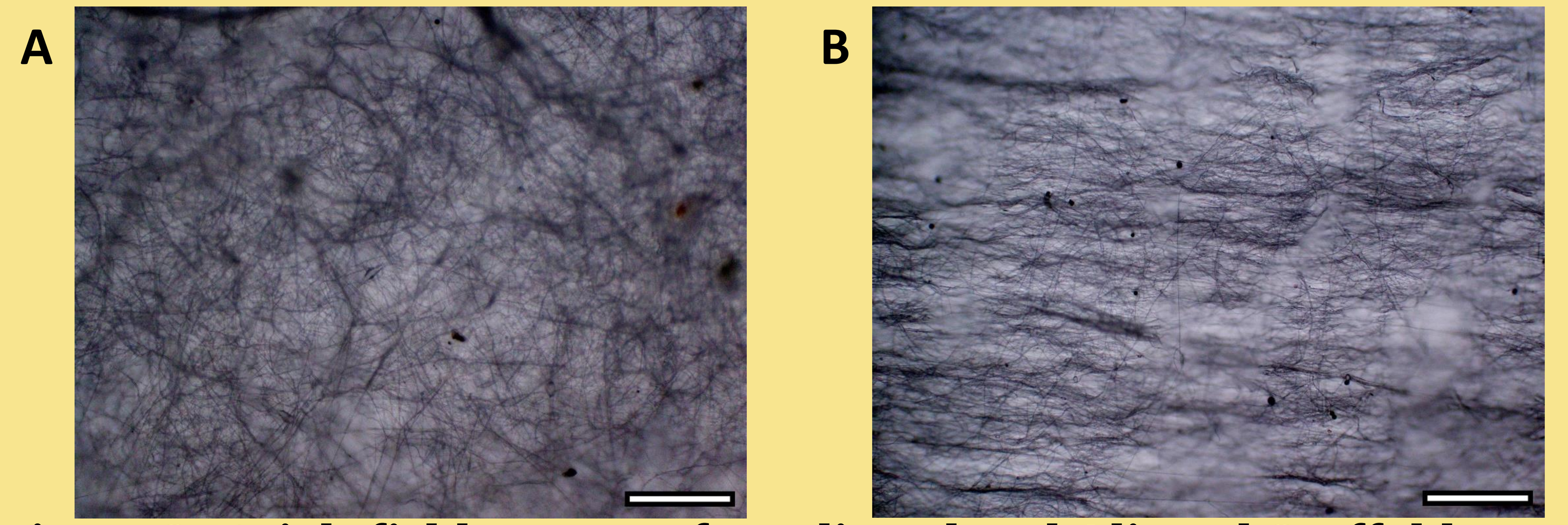

Figure 3. Brightfield Images of Unaligned and Aligned Scaffolds
A) Unaligned fibrous mat scaffold brightfield image. B) Aligned fibrous mat scaffold brightfield image. Scale bars are 100 µm in length.

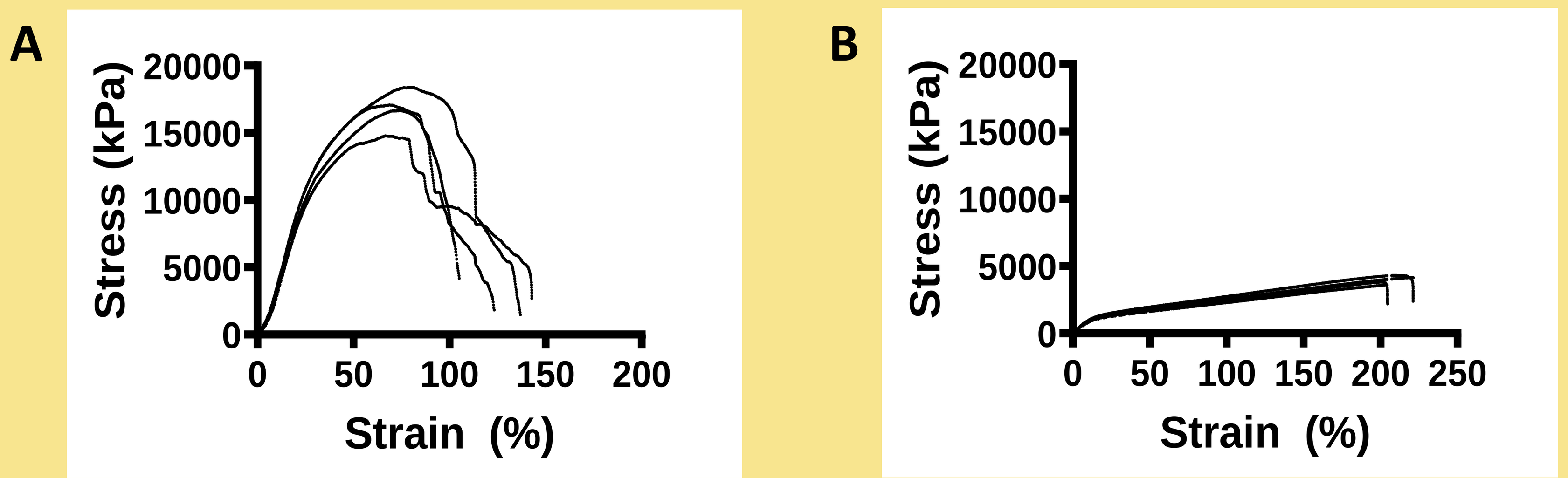

Figure 4. Stress Vs. Strain Curves of Fibrous Mat Scaffolds
A) Tensile stress vs. strain curves for unaligned scaffolds (n=4). B) Tensile stress vs. strain curves for aligned scaffolds (n=4).

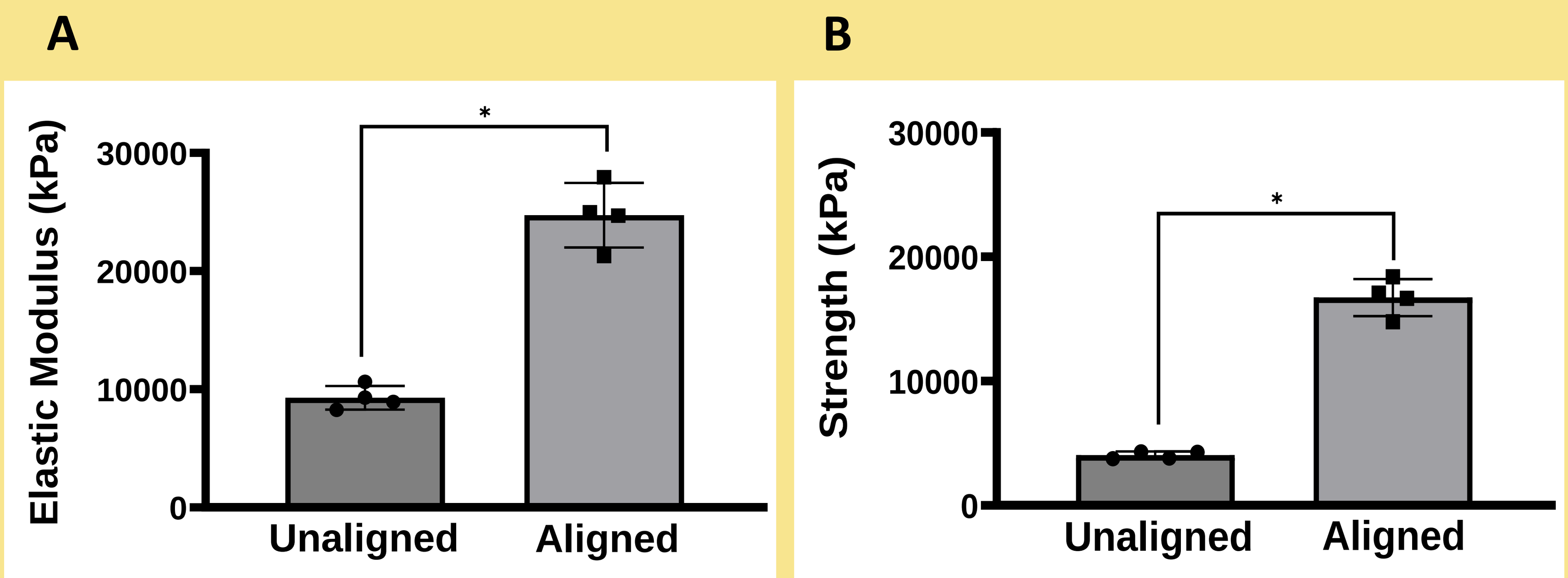

Figure 5. Comparison of Elastic Modulus and Ultimate Tensile Strength of Each Scaffold
A) Elastic modulus of unaligned and aligned scaffolds. B) Ultimate tensile strength of unaligned and aligned scaffolds.

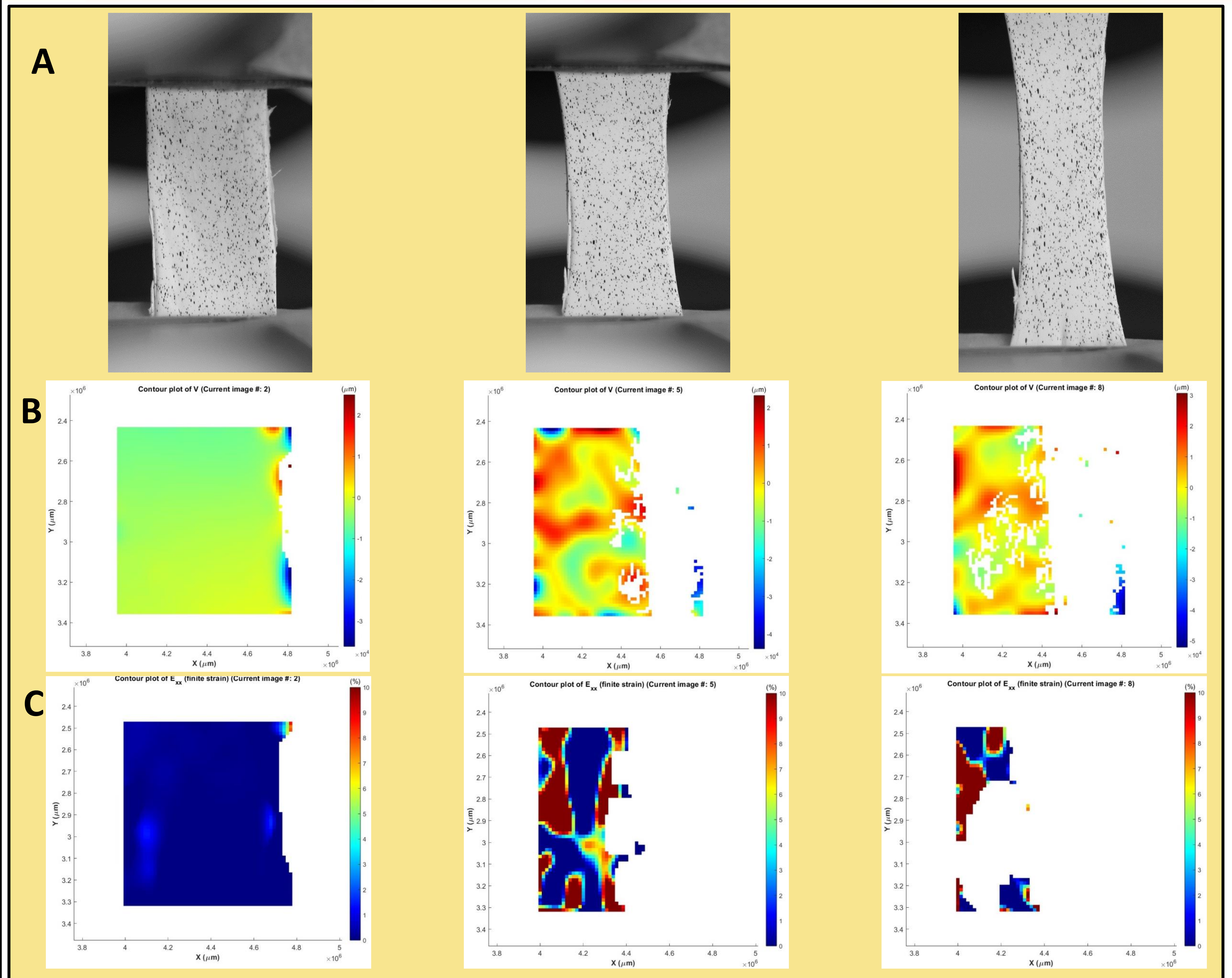

Figure 6. DIC Displacement and Strain Data of Aligned Scaffold
A) Stretching of speckled aligned scaffold during tensile testing on Instron. B) Displacement pattern at the beginning, in the middle, and at the end of the test. C) Localized strain experienced by the scaffold at the same points in time.

Conclusions and Future Work

Elastic modulus and tensile strength were greater for the aligned scaffold compared to the unaligned scaffold. Aligned fibers can resist tension in the direction of alignment, while unaligned fibers resist tension equally in all directions. Future work should analyze unaligned scaffolds and attempt to obtain displacement and strain data using a different DIC code to evaluate the results and explain the abnormal data loss.

Acknowledgements

We would like to thank the Arizona Biomedical Research Centre (ABRC) and Flinn Foundation for funding.

FURI

ASU Ira A. Fulton Schools of Engineering
Arizona State University