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

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Research question

What forces are experienced by unaligned and aligned electrospun fibrous mat scaffolds under a 10% strain rate?

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.

Methods

First, the PCL solution was synthesized using 1:1 ratio of tetrahydrofuran (THF) and dimethyl formamide (DMF). 14.3% by weight of polycaprolactone (PCL) was added. For unaligned fibrous mats, the mandrel was spinning at a rate of 1.5 m/s. For aligned fibrous mats it was spinning at a rate of 10 m/s. Tensile testing was performed on both types of scaffolds until 10% strain. Stress vs. strain data results were collected and elastic modulus of each type of scaffold was calculated. The obtained data allows for better representation of the forces each scaffold would undergo in the MCT6 bioreactor under 10% strain.

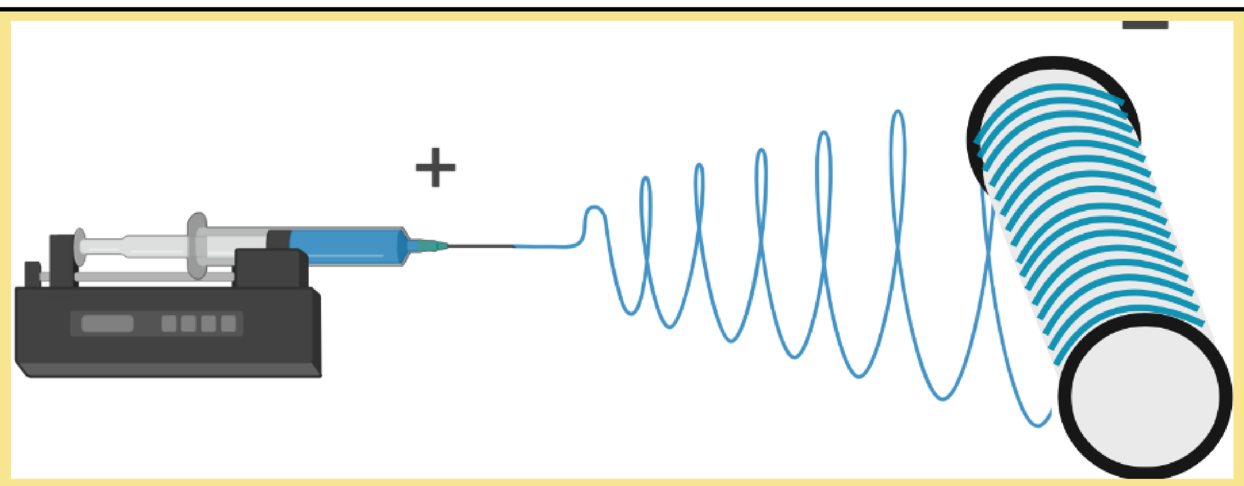

Figure 1. Electrospinning Schematic
Polycaprolactone polymer solution is put in a syringe, a blunt needle is attached, and then the unit is placed in a syringe pump. The mandrel spins as the solution is extruded to form a fibrous mat.

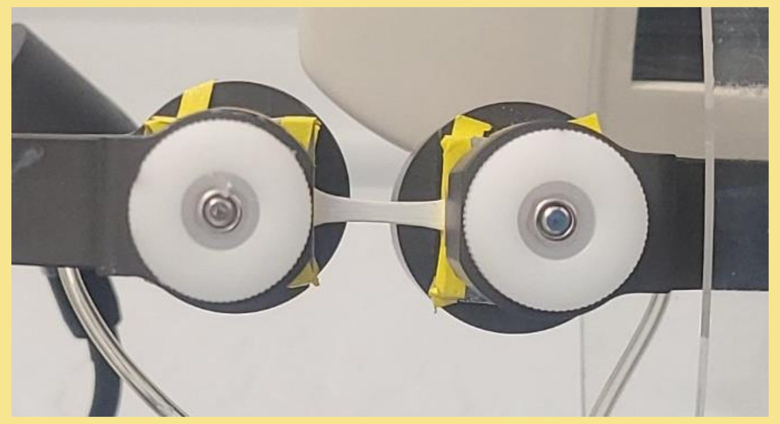

Figure 2. Image of Stretched Scaffold
Macro image of an aligned scaffold undergoing a tensile test, showing the deformation of a scaffold.

Results

Four tensile testing trials of each type of scaffold were graphed to show the stress vs. strain relationship. Ultimate tensile strength (maximum stress) and elastic modulus (slope in the linear region of the curve) 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.

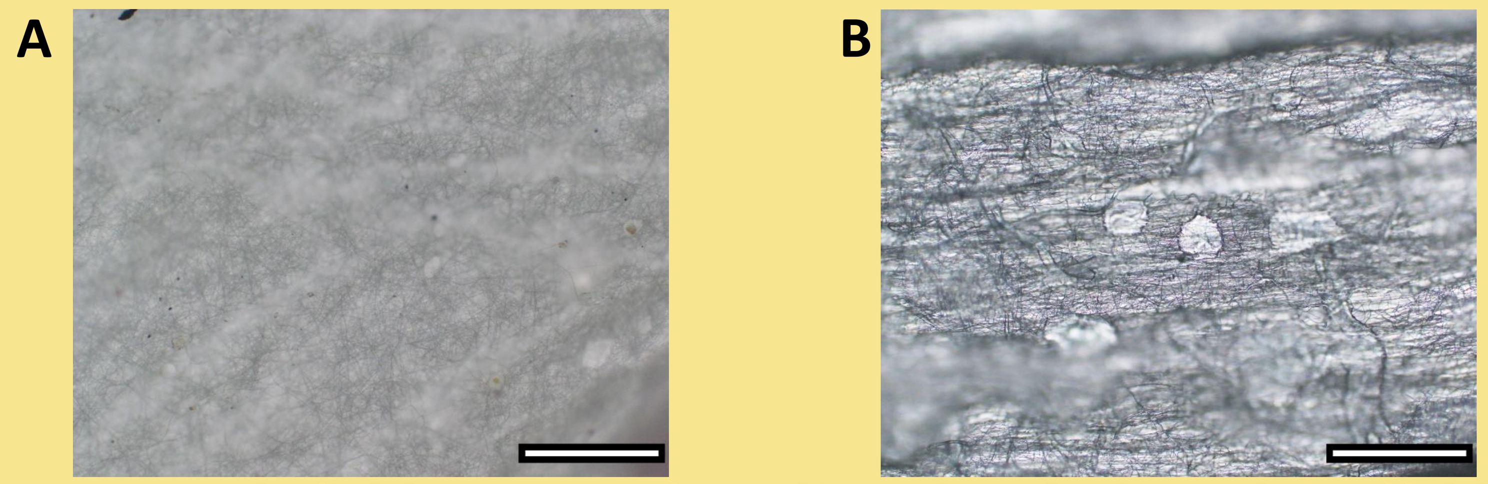

Figure 3. Brightfield Images of Unaligned and Aligned Scaffold
A) Unaligned fibrous mat scaffold brightfield image. B) Aligned fibrous mat scaffold brightfield image. Scale bars are 300 µm in length.

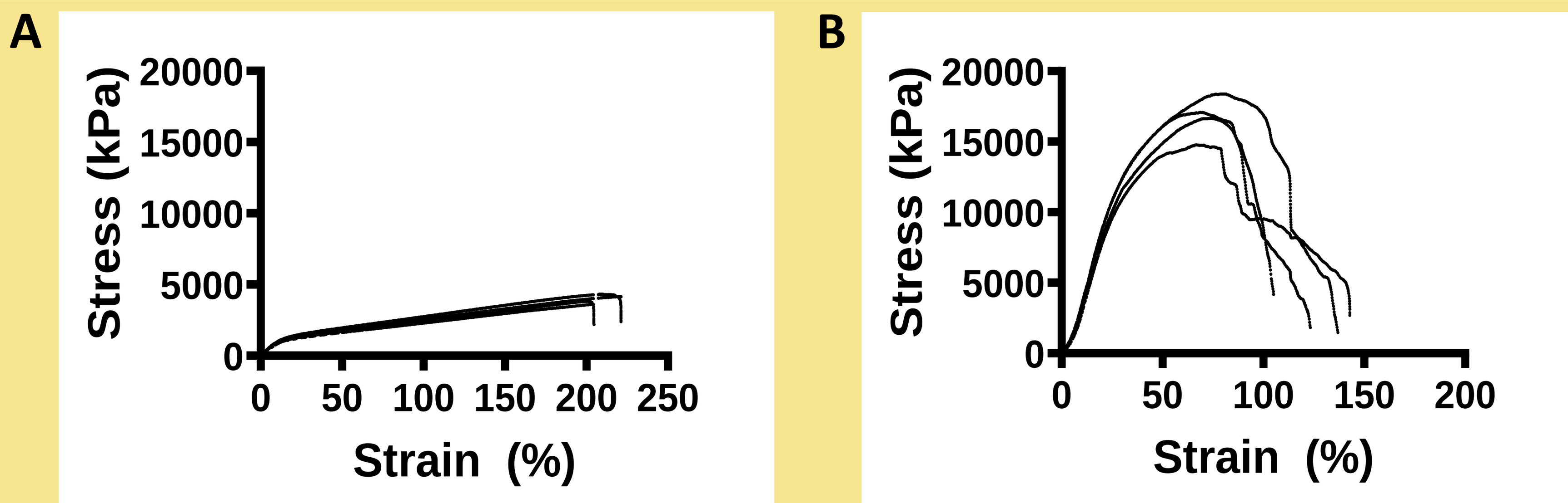

Figure 4. Stress Vs. Strain Curves of Fibrous Mat Scaffolds
A) 4 curves describing the stress vs. strain of unaligned scaffolds. B) 4 curves describing stress vs. strain of aligned scaffolds.

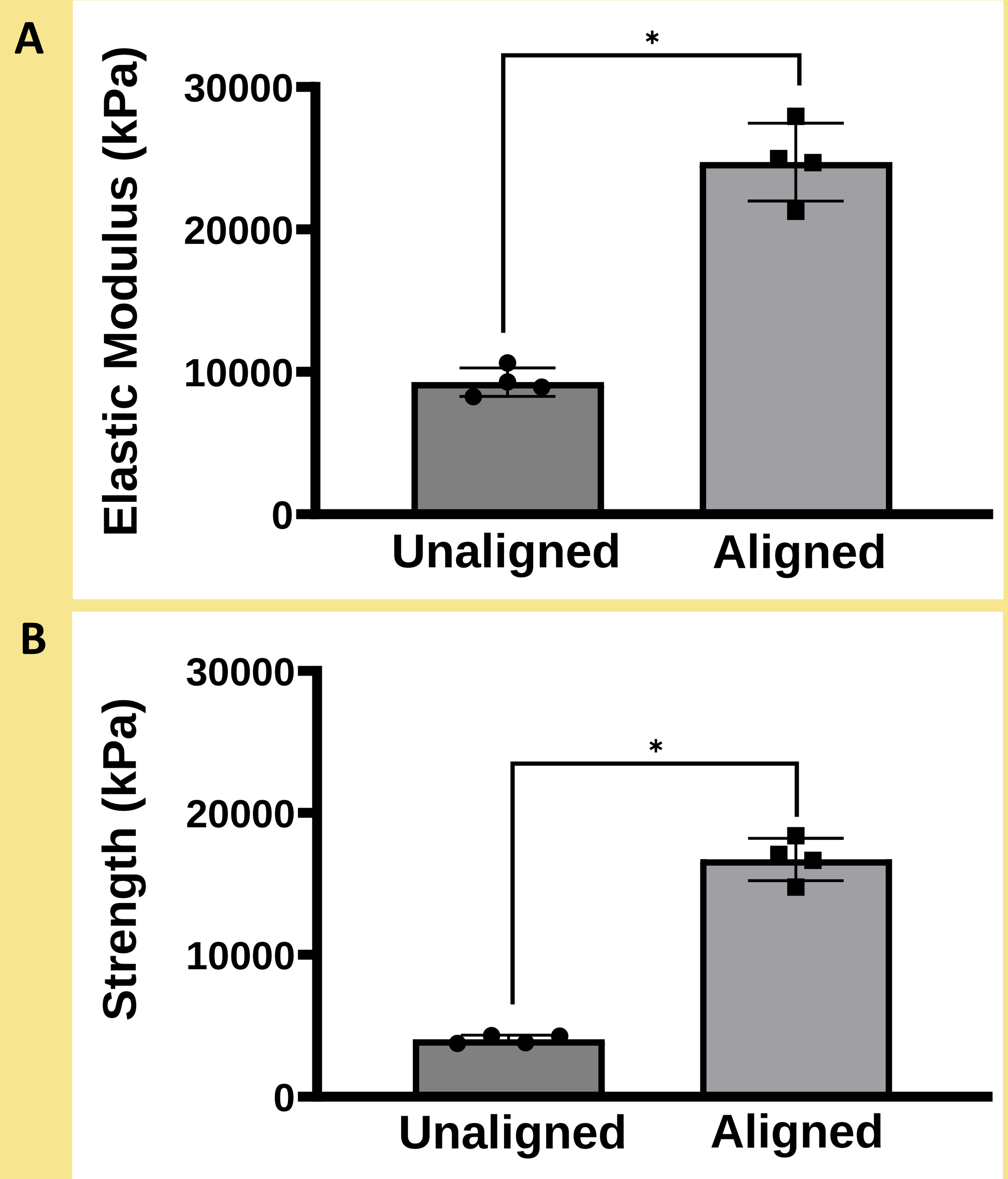

Figure 5. Comparison of Elastic Modulus and Ultimate Tensile Strength of Each Scaffold
A) Elastic modulus of unaligned and aligned scaffolds. B) Ultimate tensile strength of unaligned and aligned scaffolds.

Conclusions and Future Work

The elastic modulus and the ultimate tensile strength of the aligned scaffolds were higher than that of the unaligned scaffolds. Aligned fibers can resist tension in the direction of alignment, while unaligned fibers have no alignment and resist tension equally in all directions. Future work will include an interpretation of the forces experienced by each scaffold using digital image correlation (DIC), which will allow for a better visualization of the spatial dispersion of forces throughout the scaffold under tension.

Acknowledgements

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