Constitutive Model of PLG 10-90 for Anterior Cruciate Ligament Reconstruction

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Purpose

Determine the viability of PLG 10-90 (L-lactide-co-glycolide) for Anterior Cruciate Ligament (ACL) reconstruction and method for further innovation.

Background

- ❑ Approximately 100,000 cases of torn Anterior Cruciate Ligaments (ACL) in the United States each year
- ❑ Current procedures (Autografts & Allografts) are expensive, labor intensive, cause donor site morbidity, & require a lengthy patient recovery process
- ❑ Synthetic implants eliminate the harvesting procedure and have great biocompatibility

Objectives

- ❑ Construct custom apparatus for tensile testing in Instron 3360
- ❑ Determine basic material properties and accuracy of method
- ❑ Perform stress relaxation tests at varying strain rates and levels of degradation in PBS pH 7.4
- ❑ Build Standard Linear Solid Model with properties in terms of the degradation of the material
- ❑ Simulate life cycle fatigue in ANSYS Software package

Background

- ❑ PLG 10-90 (L-lactide -co-glycolide) is a GMP grade copolymer in a 10/90 molar ratio used for orthopedic reconstruction
  - ❑ Nominal Diameter = 0.0148”
- ❑ Optical microscope and ImageJ used to calculate actual diameter
  - ❑ Measured (actual) Diameter = 0.0153” ± 0.0002”
- ❑ Future diametric measurements will be made with a Keyence 7030 Laser Micrometer
  - ❑ 80 millionths of an inch of resolution

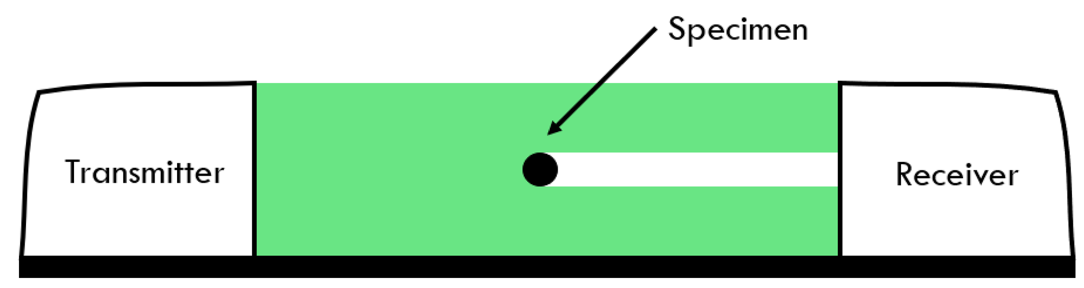
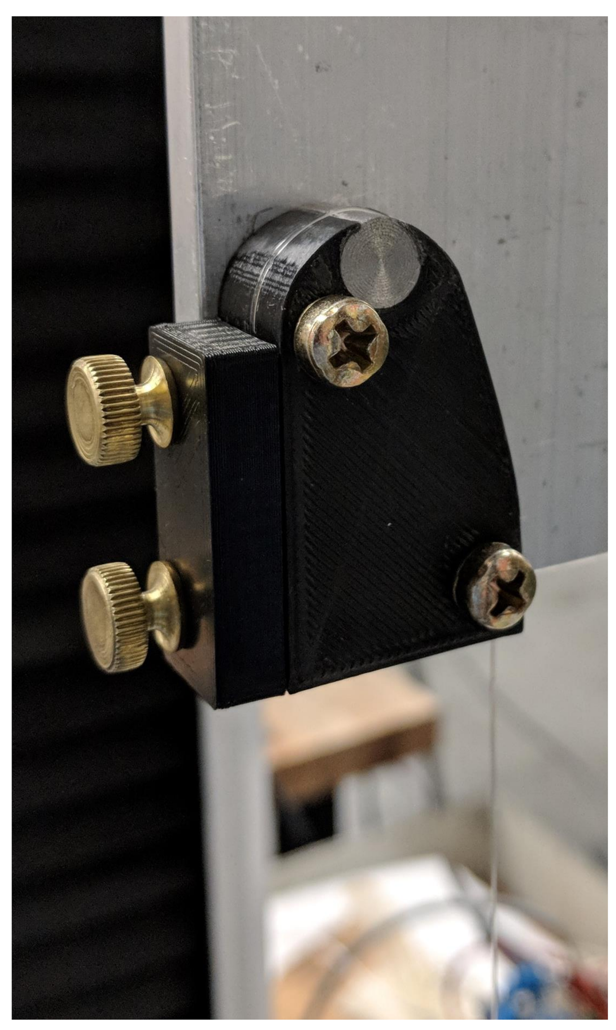
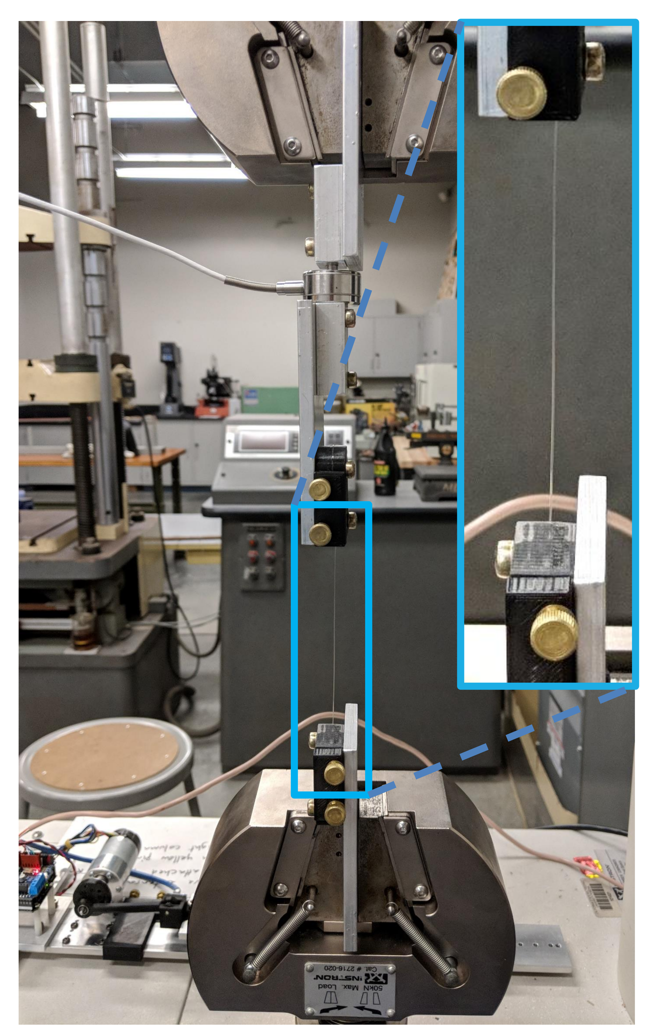


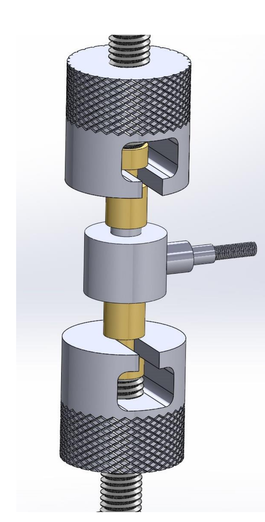
Diagram of Keyence LS-7030 Laser Micrometer

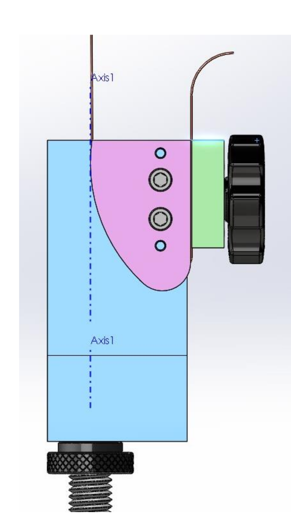
Method

- ❑ Five Specimen per Batch
  - ❑ Batch 1: Dry
  - ❑ Batch 2: 7 days immersed
    - ❑ Immersed in Phosphate Buffer Saline (PBS) pH 7.4
- ❑ Monotonic tensile test in Instron 3360 until failure
  - ❑ Deformation rate set to 12 in/min

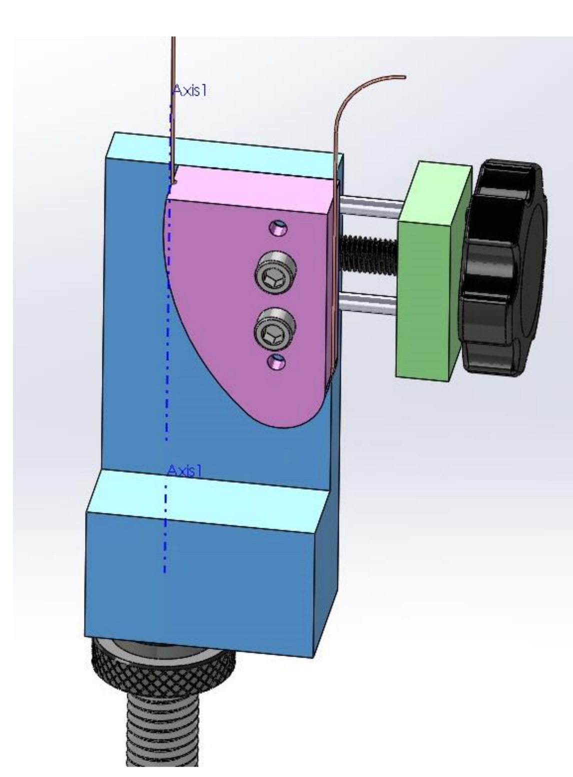


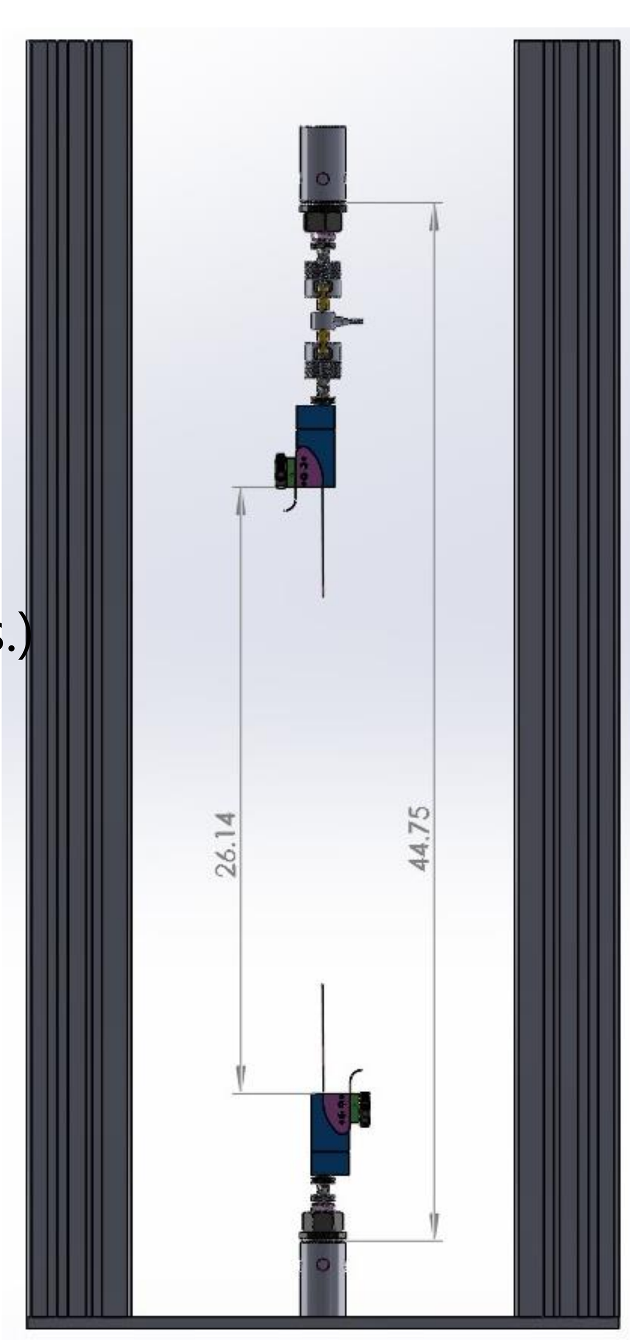






↖ 50 lbs. Load Cell ± 0.15% (0.001 lbs.)





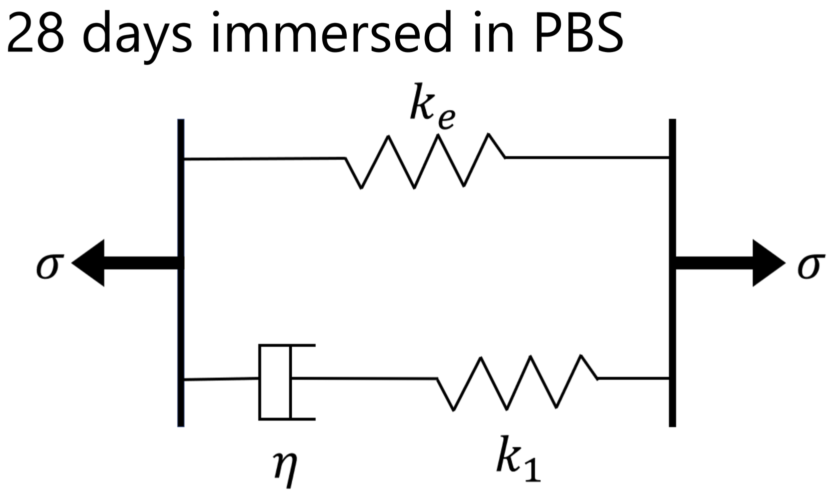
Updated Full Assembly

Results & Discussion

- ❑ Reduction in yield strength due to deterioration of polymer chain, however increased ultimate tensile strength due to absorption of the PBS
- ❑ Strain rate increased from 0.0167 $^1/_s$ to 0.0181 $^1/_s$ (expected to be the same at equivalent deformation rates)
  - ❑ Material is strain rate dependent
  - ❑ Increased strain rate may have artificially increased the yield and ultimate tensile strength for the 7-days immersion results
- ❑ Jump test to determine strain rate sensitivity failed when increasing deformation rate from 1.2 in/min to 12 in/min
  - ❑ Cause determined to be excessive rotational inertia of Instron motor

Future Work

- ❑ Perform stress relaxation test at different deformation lengths at 0 (dry), 7, 14, 21 & 28 days immersed in PBS



$$\sigma(t) = \varepsilon_0 \left(k_e + k_1 e^{-t/\tau}\right) \qquad \tau = \frac{\eta}{k_1}$$

- ❑ Build Standard Linear Solid Model where η, k_e & k_1 are in terms of degradation of the material
- ❑ Validate model with strain rate sensitivity determined by increasing strain rates during monotonic tensile testing
- ❑ Build system in ANSYS, simulate life cycle fatigue, and compare to clinical results of ACL fatigue data

Acknowledgements

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