Evaluation of Suture Technique for Biaxial Mechanical Testing of Soft Tissues

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Background

- In biomechanics, Biaxial testing is widely used to study tissue response and evaluate potential biomaterials[1].
- Problems with stress shielding (Fig 1) at ridged clamps when stretching square specimens in two directions[2]
- Cruciform shaped specimens are generally used to address stress shielding with clamps[3].
- However, sample tissues are often not large enough to cut a full cruciform specimen.
- Therefore sutures can be used to mitigate the effects of stress shielding with smaller specimen size[2].

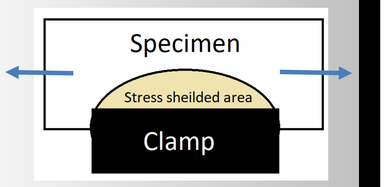

Figure 1: Illustration of clamp stress shielding

Design

- Barbed fishing hooks were tied to woven fishing line with a breaking strength of 50lbs

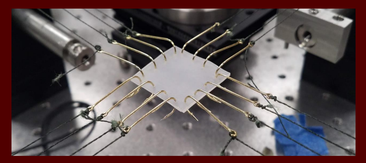

Figure 2: Suture design

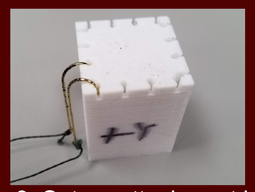

Figure 3: Suture attachment block

- Hooks inserted with a 3D printed stencil to ensure consistency of placement
- Sutures attached to linear actuators with pulleys to account for miniscule differences in suture length and ensure uniform loading

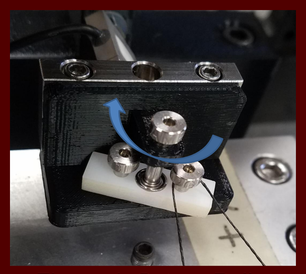

Figure 4: Suture Pulley

Figure 5: Specimen Floating in water

- Specimens were floated in water to reduce the impact of friction from the tissues sticking to the support surface

Objective

Develop a platform and procedure to utilize sutures in biaxial tensile testing.

Preliminary Testing and Evaluation

Tested on a Biaxial Testing Rig for Strain Control

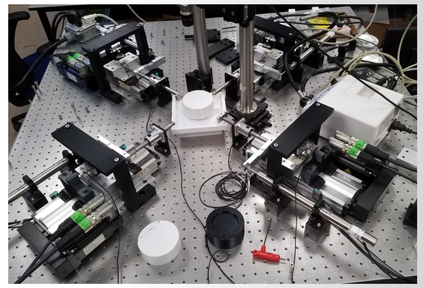

Figure 6: Biaxial Testing Machine

Test Parameters

Specimen Geometry

- Square specimens of side length 1.0',0.9', 0.8', and 0.7' were evaluated with the sutures
- Specimens were hooked closer to the center to create a smaller gauge area with more edge clearance.

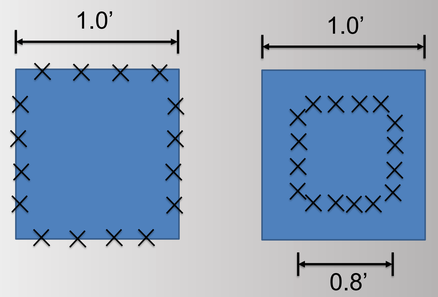

Figure 6: Example specimen geometry and suture placement (X)

Loading Conditions

- Specimens were loaded with equal strains from each axis

Preliminary Results

- Preliminary testing of the sutures showed a smooth transition of load in both directions. This means sutures will allow us to study materials behavior under various loading conditions that mimic en vivo loading.

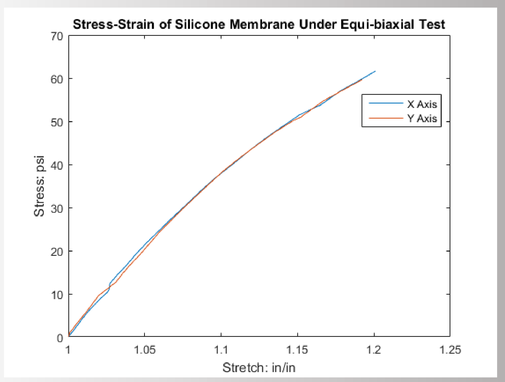

Figure 7: Graphical results of equiaxial testing

Discussion

- Hook knots and strings must aligned and untangled to prevent jumps in strain while testing
- Specimen must be pre-stretched properly from each axis or the test will result in an anisotropic strain response
- Smaller edge clearance is preferred, but the hooks could tear out if there is not enough space between the hook and the edge
- When specimens with larger edge clearances were stretched with the sutures, the edges of the specimen buckled up. This could effect the measured data.
- Specimens run the risk of submerging in the bath. This disrupts the focus on the finite element analysis camera

Future Work

- Improve the suture knots so that they are less likely to wrap around the hook end and cause jumps in strain
- Develop a floatation system to keep specimens afloat throughout the entire testing period
- Evaluate suture setup with organic tissue

References

[1] Sacks MS., Sun W., "Multiaxial Mechanical Behavior of Biological Materials". Annual Review of Biomedical Engineering 2003 5:1, 251-284

[2] Sacks M., Sun W., "Effects of Boundary Conditions on the Estimation of the planar Biaxial Properties of Soft Tissues". Journal of Biomedical Engineering 127(4), 7 09-715 2005

[3] Upadhyay M., Panzer T., Van Petegem S., Van Swygenhoven H., "Stresses and Strains in Cruciform Samples Deformed in Tension". Experimental Mechanics 2017 vol. 57, 905-920