COMPARISON OF SHEAR WAVE ELASTOGRAPHY AND MECHANICAL TESTING

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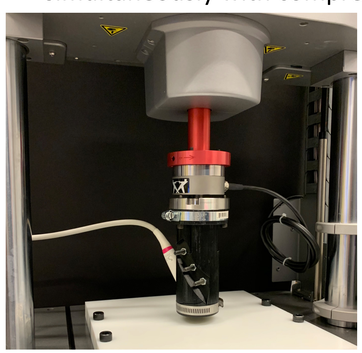
BACKGROUND

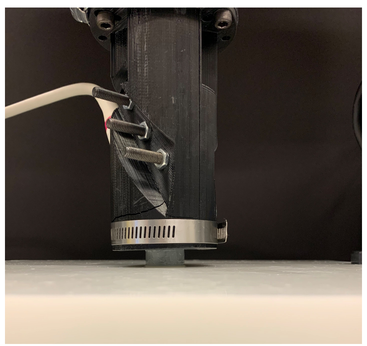
- In 2015 10% of Americans had diabetes and the prevalence is expected to grow to 33% of the population by 2050.[1]
- Pedal ulceration can occur resultant to diabetes, often preceding lower extremity amputation.[2]
- Changes in plantar soft tissue properties of diabetic patients may indicate increased ulcer risk.
- Shear wave elastography (SWE) uses ultrasound to provide a measurement of modulus but has only been validated in low-stiffness/low-compression environments.[3]

Can SWE be used in high-stiffness/high-compression applications to determine modulus?

METHODS

- Agar-gelatin phantoms were developed to mimic plantar soft tissue properties. A subset of these phantoms included oil to more closely mimic plantar soft tissue properties.
- A compression platen was 3D printed to hold the ultrasound transducer so that ultrasound images could be acquired simultaneously with compression.





Mechanical testing set up for compression experiments.

- First, phantoms underwent compression testing with cycles of triangle waves to 40% strain to compare to prior mechanical testing of plantar soft tissue.
- Second, phantoms were subjected to a series of 14 compression steps (45-65% final strain per sample) and three SWE images were taken at each step.

RESULTS

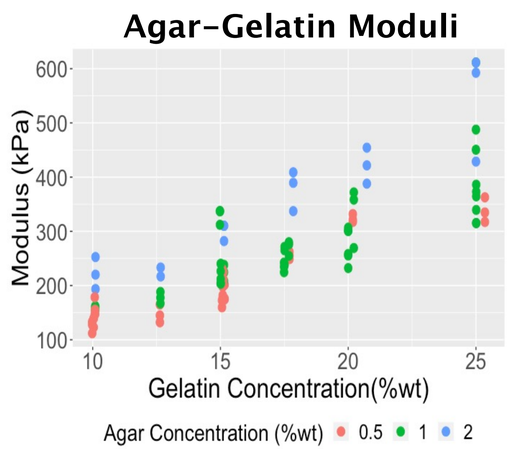


Figure 1. Mechanical moduli from triangle wave testing for each agar-gelatin concentration. Higher gelatin-agar concentrations had moduli in the range of plantar soft tissue moduli (~600kpa).

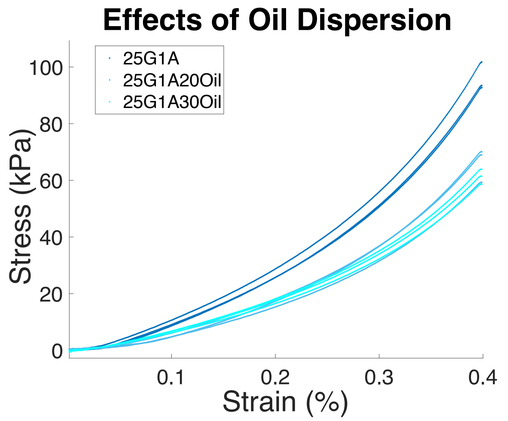


Figure 2. Triangle wave compression data for 25% Gelatin 1% agar with and without oil dispersion. Phantoms with oil have an elongated region of low stress.

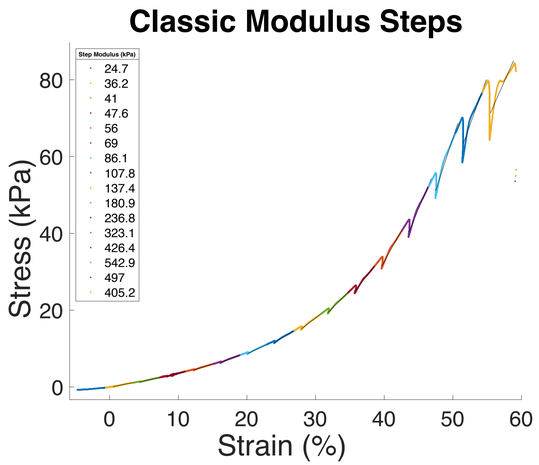


Figure 3. Stress/strain curve for the shear wave step-down testing. Moduli were calculated for each step. Viscoelastic relaxation is seen at higher strain.

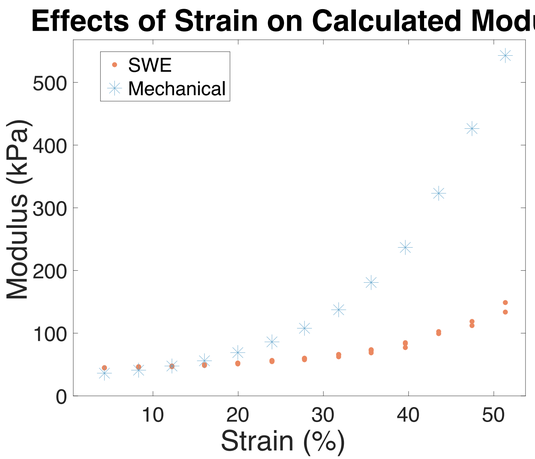


Figure 4. SWE moduli plotted alongside the mechanical moduli as strain increases. As the strain increased SWE and mechanical moduli diverge.

DISCUSSION

Figure 1
Agar-gelatin phantoms demonstrated moduli consistent with plantar soft tissue at high strain.

Figure 2
The elongated low-modulus region along with an unchanged final modulus in the oil dispersion phantoms more closely aligns with plantar soft tissue mechanics. Higher oil concentrations may further elongate the low-modulus region, more closely mimicking plantar soft tissue.

Figure 3-4
The approximations used to calculate Shear wave modulus may not hold as the strain increases. Future work is needed to characterize this divergence since the functional range of plantar soft tissue encompasses the higher strain region.

CONCLUSIONS

- Agar-gelatin phantoms can mimic mechanical properties of plantar soft tissue.
- There may be potential to further modify phantom properties to more closely resemble characteristics of plantar soft tissue.
- SWE displays some nonlinearity but diverges from the expected modulus at high strain.

REFERENCES

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