Developing a Soft Tissue surrogate for use in Photoelastic Testing

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Abstract

Current research on the deflections of needles through soft tissue is limited due to ethical issues raised from animal testing or testing human tissue reactions *ex vivo*, therefore tissue substitutes must be created which closely replicate the complex properties of soft tissue. Many materials have been developed to replicate the properties of tissue, such as ballistic gel, yet they are commonly used for large scale testing and therefore can neglect the small scale properties of tissue, such as its resistance to tearing.

Carrageenan is a potential tissue phantom; it is a food thickening agent often found in everyday food products [1]. A variety of concentrations have been assessed and compared with the published mechanical properties of skin tissue; which has an elastic modulus between 0.1MPa – 0.27MPa *in vivo* [2]. When carrageenan is mixed with water it creates a clear jelly which exhibits temporary birefringence. This allows it to be used for photoelastic testing to assess the deflections involved in needle insertion.

Introduction

When a needle is inserted deep into tissue it often misses its intended target due to uneven load distributions across the length of the needle. The aim of this research is to investigate the forces that both needle and tissue experience during biopsy, and how these forces alter the needle's trajectory. A slight deviation from the needles intended path can cause problems in procedures requiring high accuracy; which can potentially lead to misdiagnosis, or having to repeat a procedure and thus causing otherwise unnecessary trauma to a patient [3].

Current skin tissue substitutes neglect the small scale properties of tissue. One main property is the materials resistance to tearing. When a needle enters skin tissue it does not tear, whereas when a needle enters ballistic gelatine tearing is observed; as seen in Figure 1b.

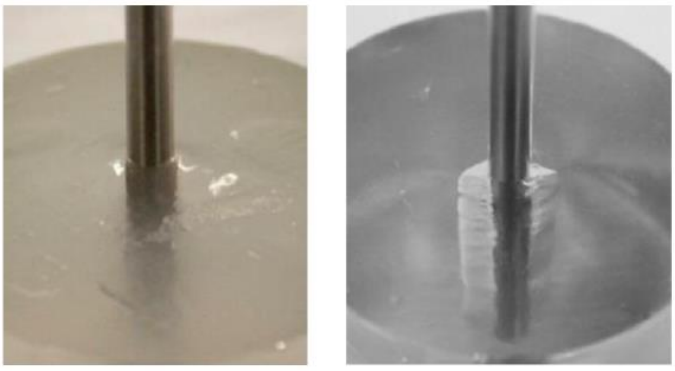

Figure 1: Image of needle inserted into gel phantom which a) does not exhibit tearing b) tears [4].

Carrageenan produces a clear jelly that can be used as a potential tissue phantom. Preliminary work shows that it does exhibit a greater resistance to tearing than gelatine, but this needs to be investigated further. A variety of concentrations have been assessed and compared with the published mechanical properties of skin tissue.

Methodology

Small samples of carrageenan jelly with concentrations between 1% and 3% carrageenan to water were subject to compression experiments at varying strain rates in order to gather information on their viscoelastic and mechanical properties.

The samples were also observed through a polariscope in order to determine their suitability for future photoelastic testing by assessing their birefringent properties. Future analysis will involve inserting needles into the carrageenan jelly at varying strain rates. The sample's mechanical response can be recorded with use of the photoelastic apparatus, and any deflection of the needle can also be recorded visually as the jelly is transparent.

Sugar was also added to two thirds of the samples as previous experiments suggest sugar addition could cause the materials resistance to tearing [5]

Results

Figure 2 displays the elastic modulus for various concentrations of carrageenan jelly. As shown, the samples with a concentration of 3% Carrageenan to water produced an elastic modulus of 0.1062, which lies within the published range of mechanical properties for skin tissue. It also exhibited viscoelastic behaviour much like skin tissue. The addition of sugar appears to lower the elastic modulus of the gel; more detailed experimentation is required before the link between sugar addition and resistance to tearing can be fully understood.

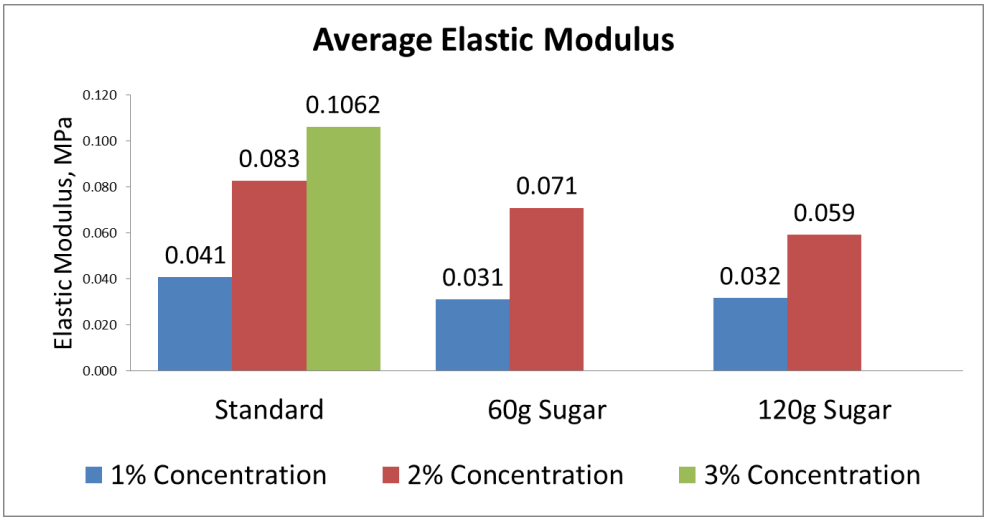

Figure 2: Image depicting the calculated elastic modulus for various concentrations of carrageenan

Conclusion

Carrageenan is a potential skin tissue substitute but further development is required to confirm its reliability and repeatability. Future work will involve developing and running tensile tests for soft gel samples so their resistance to tearing can be measured. The effect of sugar addition will be tested to assess whether it improves the materials resistance to tearing.

References

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