# Project report: Tensile Test Instrument for Soft Biological Tissues

Hannah Streat

## Introduction

The aim of my project was to continue development of a novel tensile test instrument for soft biological tissues. The conceptual design had been proposed by my supervisor and aspects of the design had been created by previous students.

Soft tissue is the term used to describe the structures that bind, support and protect organs and does not include mineralized structures such as bone. Examples of soft tissue include tendon, muscle, fat, blood vessels and skin. There are many medical problems whose solutions require a detailed knowledge of the mechanical properties of the tissues involved, for example, the Young's Modulus. The Young's Modulus of both traditional engineering materials and soft tissues can be obtained from a uniaxial tensile test. Tensile testing of traditional engineering materials, like metals, is relatively easy and can be performed on commercially available test rigs. Currently available test rigs have several drawbacks when it comes to testing soft tissue including:

- Poor reliability: attaching the specimen to the test rig causes deterioration of the tissue and untrackable stress concentrations
- Use of large specimens meaning multiple orientations of tissue cannot be investigated
- Testing environment: tests are often performed in air, however, to accurately determine what the mechanical properties of the tissue are when in the body, the in vivo environment should be recreated as much as possible.

In order to overcome these limitations a novel tensile test device has been proposed and developed. Figure 1 shows a diagram of the current prototype. The specimen is attached to

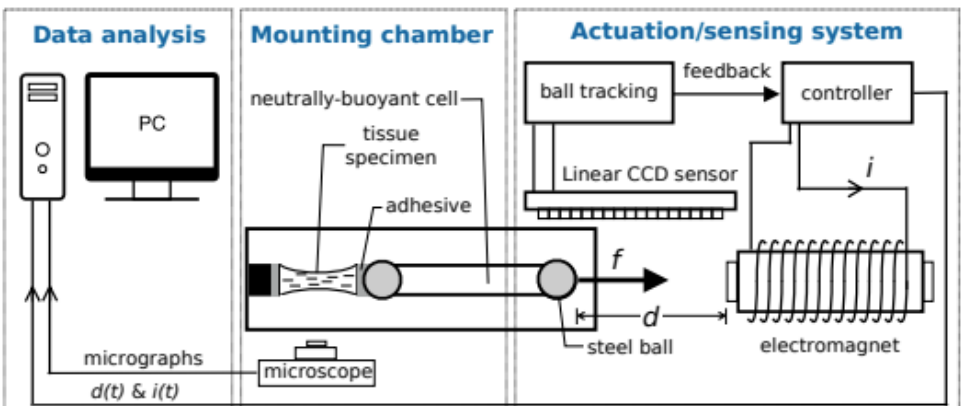


*Figure 1 Diagram of tensile test rig*

the chamber lid at one end and a neutrally buoyant cell at the other. The end of the cell

contains a magnetic steel bead. This bead is attracted to an electromagnet, exerting a tensile force on the specimen. The extension of the specimen can be calculated by tracking the position of the steel bead. This is done by using a CCD to track the position of a shadow cast by the bead. If the dimensions of the specimen are measured before the test, then the Young's modulus can be calculated. The mounting chamber of the device is made from transparent plastic and can be filled with Phosphate Buffered Saline in order to mimic the in vivo environment.

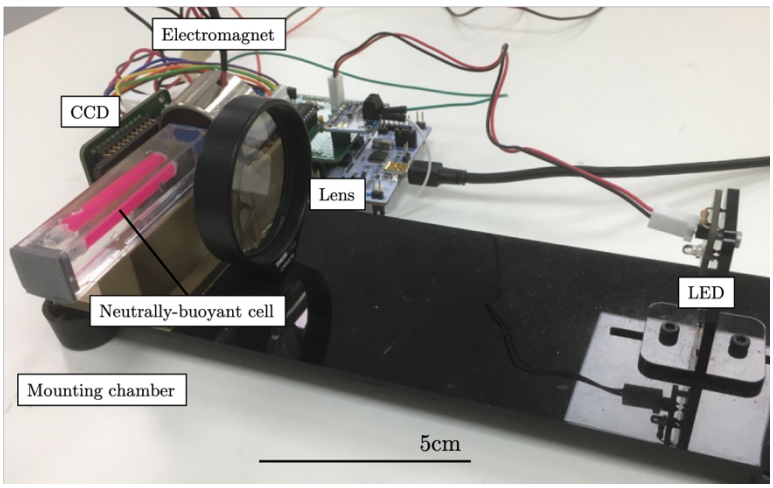


*Figure 2 Photograph of tensile test rig*

## Specimen preparation and attachment

Following the development of the test rig, the next challenge was to devise a way to attach millimeter scale specimens of soft tissue to the device without damaging them. Previously used attachment methods include clamping and tethering. Due to the slippery nature of soft tissue the clamps have to be lined with sandpaper or other abrasive material to increase the friction on the clamp surface. This causes damage to the delicate specimens, eventually leading to premature failure of the specimen. Tethering involves piercing the specimen with small hooks around its edges, which introduces stress concentrations.

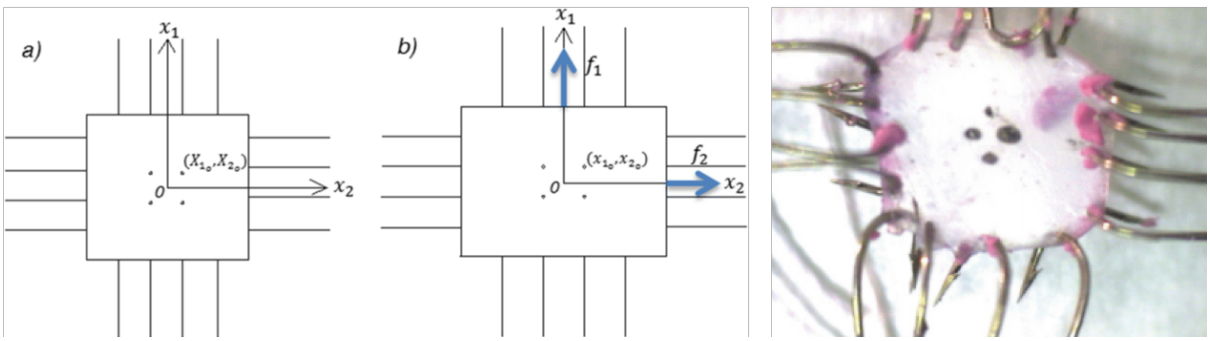


*Figure 3 Biaxial tensile test using tethering attachment*

Use of superglue as a method of attachment was therefore investigated. Superglue is commonly used in surgery as a method of wound closure therefore it has been shown to be

effective at adhering tissue with minimal damage. In order for superglue to be an effective attachment method the depth of penetration of glue into the tissue had to be controlled. In order to do this the level of hydration of the tissue had to be regulated before the glue was applied. It was found that if the tissue specimens were placed on a strip of absorbent material saturated with PBS the absorbent material would remove excess liquid from the tissue whilst preventing excessive dehydration that would change the material properties.

Experiments were performed to investigate the difference in penetration depth caused by the method of superglue application. It was found that applying the glue as a droplet caused a non-uniform penetration profile, which was undesirable. Applying the glue as a uniform layer by saturating tissue with the glue was successful at limiting penetration to 1% of the specimen length.

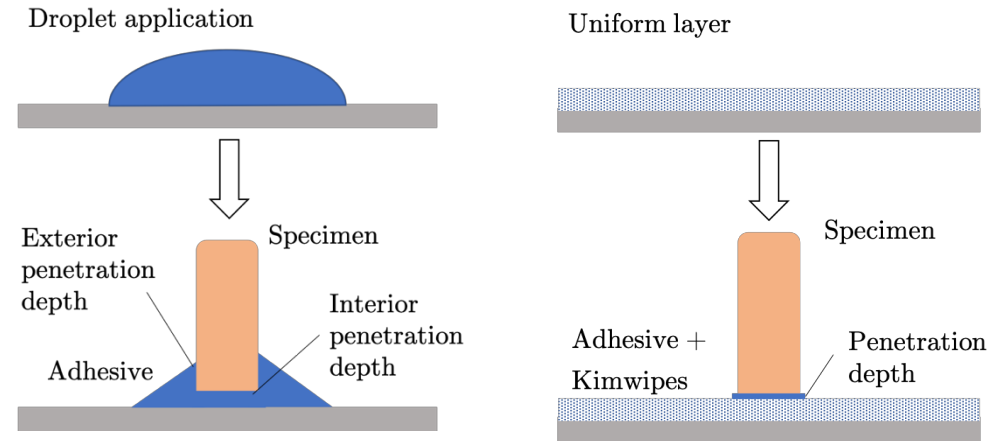


*Figure 4 Adhesive application methods*

## Results from testing of oesophagus

The device was successfully used to characterize the mechanical properties of mouse oesophagus. The oesophagus is the tube that connects the mouth to the stomach and is comprised of three main layers: muscle stroma and epithelium. These layers were tested both independently and as intact oesophagus. The device was sensitive enough to characterize the differences in the properties of the different layers, and the error bars are significantly smaller than those obtained using previously existing methods

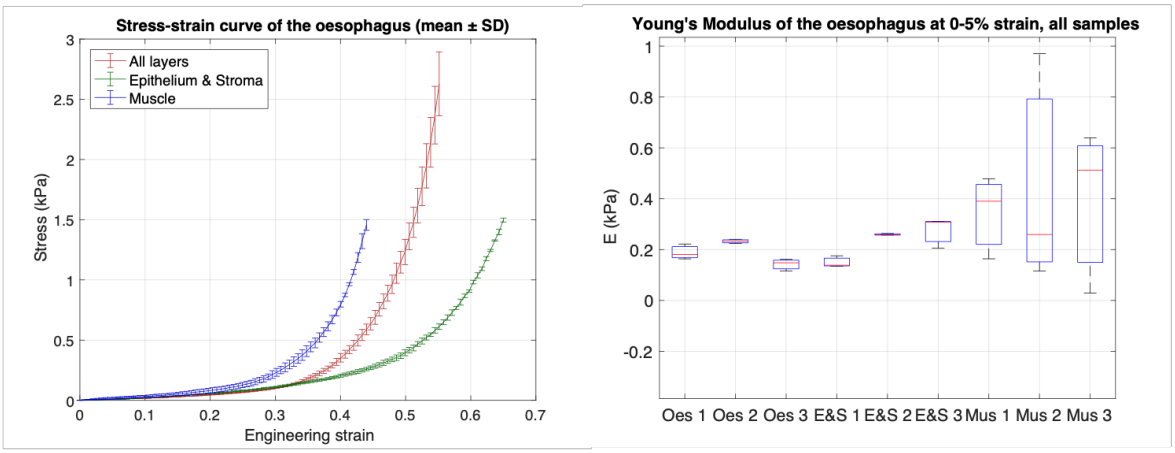


*Figure 5 Example of results from tensile test device*

The shape of the stress strain curve is different to those obtained for traditional engineering materials. This is due to the structure of tissue. Tissues can be thought of as complex fiber reinforced composites, comprised of constituents such as collagen, elastin and a hydrated matrix. Collagen is the main load carrying element in a large proportion of soft tissues. There is a strong correlation between the orientation of the collagen fibres and the functional requirement of the tissue, for example in tendons collage appears as parallel oriented fibres to withstand uniaxial loading.

The stress strain curve for soft tissues is initially linear as the stiffness is controlled by the elastin fibres while the collagen fibres remain coiled. As the strain is increased the collagen fibres uncrimp and reorient to align with the loading direction. The stress strain curve undergoes a nonlinear transition associated with the uncrimped collagen becoming the primary load bearing element. This can be clearly seen in the results from the oesophagus testing.

## Conclusions

Overall the new tensile test device has shown an improvement in performance when compared to existing commercial devices. A specimen preparation and attachment protocol were developed to be minimally invasive to the specimen's properties whilst ensuring secure attachment to the device. Future work will be centered on adapting the device to enable real time microscopy of the specimen and thermal control of the mounting chamber to better replicate the physiological environment.