Project Statement

3-Point Bending Device to Measure Transmural Strains for Multilayer Soft Tissue Composite

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Statement of Need

The client has requested a 3-point bending device that is capable of measuring transmural strains of native and engineered tissues. The device must use computer-controlled stepper motors, a calibrated bending bar, a high resolution CCD camera, and a PC with frame grabber and a time code generator to measure flexure properties as well as tissue transmural strain. Measuring the flexure properties requires that the tissue be submerged in a phosphate-buffered saline solution at normal body temperature (37°C ± 1°C). Tissues being tested for flexure properties will also be marked with small (~0.3 mm) black graphite markers and tested using a calibrated bending bar. Transmural strains will be determined by spraying microdots on tissue specimens and subjecting them to the 3-point bending. Random microdots must be captured and followed by the CCD camera to determine the extent of tissue deformation.

Introduction and Overview

Dr. Wei Sun, the client, and his research team deal heavily with the biomechanics of various soft tissues, especially heart valves. Biaxial testing is currently used in Dr. Sun’s lab to determine the stress and strain of responses of the soft tissues. This type of testing is very limited and assumes the test specimen is a homogenous material. Most tissues are heterogeneous and consist of multiple different layers. In these types of tissues, bending is a significant form of deformation. At this time, Dr. Sun’s biomechanics lab has no effective method of evaluating this type of deformation.

To aid our client’s research, he has requesting the construction of a three-point bending device. The primary purposes of this device are to perform flexure testing and compute the
flexure rigidity, bending stiffness, transmural strain, and transverse shear stiffness of soft tissue composites. The device will consist of a calibrated bending bar submerged in phosphate-buffered saline solution at body temperature. The tissue will be sprayed with microdot markers. These markers will be followed by a high resolution CCD camera. The camera will follow the deformation of the tissue. The data collected will be read into a computer program, specifically designed for this device, to calculate the flexure rigidity, bending stiffness, transmural strain, and transverse shear stiffness. The successful completion of this project will allow Dr. Sun to more accurately predict the mechanical properties of tissues where bending is a significant form of deformation. This understanding will especially aid in Dr. Sun’s research of heart valves.

**Realistic Constraints**

When designing and building the 3-point bending device, there are many constraints and potentials for error that may affect the project. The following are a list of constraints to keep in mind throughout the entire process.

- **Economic** – A budget for the project has not been set in stone yet. The client has told the group that materials necessary for successful completion of the device will be provided. It is still pertinent to attempt to be as cost effective as possible when purchasing materials for the project.

- **Environmental** – The environment of the 3-point bending device is extremely important. By having a phosphate-buffered saline solution at normal body temperature the tissues are tested under similar temperature and pH conditions as the human body. If the
temperature and pH falls out of the acceptable bodily ranges then 3-point bending tests will create impractical data.

- **Sustainability** – Parts susceptible to corrosion will have to be replaced during the testing process. Proper lubrication must be maintained on the mounting poles and other places where friction occurs.

- **Manufacturability** – Whenever possibly, parts that can be manufactured at University of Connecticut machine shop will be used.

- **Imaging** – While the tissue is being deformed the camera must be able to move with the specimen. The CCD camera will have to zoom in on a tissue strip painted with microdots and be able to follow the microdots deformation throughout the whole bending process.

- **Ethical** – What types of tissues will be used?

- **Safety** – There are many electronic parts that will be used in the final product. Because of this, extra precautions must be made to prevent electrical fires or electrical shock. Also, various tissues will be tested on the device. Proper sterilization must be performed after each test to prevent bacterial growth.

**Other Data**

The client, Dr. Wei Sun, is currently an Associate Professor in the BME and ME department at the University of Connecticut. Dr. Sun’s research pertains to tissue biomechanics, computational biomechanics and medical device design. Specifically, he has worked on the experimental study and constitutive modeling of cardiovascular biomaterials, and the study of tissue and organ function using computational biomechanics tools. In the past, Dr. Sun has worked on research projects including new heart valve and annuloplasty prosthesis design,
modeling of biomimetic fibre scaffold materials for artery substitutes, and biomechanics of heart valve biomaterials.

Dr. Sun’s proposed design of a 3-point bending device to measure transmural strains in multilayer composite tissue was attempted two years ago by another Biomedical Engineering Senior Design Team. Dr. Sun has requested that we improve their previous design. The major improvement he wants to the device is a CCD camera mount that moves with the tissue as deformation takes place.

Questions

- What will the budget be?
- Is it necessary for the tissue to be in a phosphate buffer solution at 37°C?
- Are tissues marked with black graphite along one edge going to be tested or solely tissues with painted microdots?
- What program should be used for image acquisition?
- What is the calibration process for the bending bar?
- What formulas will be needed to calculate transmural strain, flexure rigidity and bending stiffness?
- What kind of programming will be necessary? What computer languages?
- What parts of the previous project does Dr. Sun want to be included?