Mechanical Response of Joint Cartilage Under Biomechanical Loading

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Introduction

- Microindentation is a mechanical testing technique by which the mechanical properties of biological sample are acquired.
- A narrow tip is displaced into the sample, and the sample's resistive force is measured via an attached load cell.
- Relationships between displacement, force, and time are collected, allowing for the calculation of several properties through curve fitting.

Aim 1: Refurbish a custom-built microindentation device.

- Computer utilizes LabVIEW code to specify actuator motion, data collection rate, and other test parameters.
- Voltage amplifier and low pass filter update computer with current force readings, piezo servo controller implements actuator instructions sent from computer.

Aim 2: Use refurbished microindenter for testing of articular cartilage samples to determine their Young's Modulus, Poisson's ratio, and permeability.

Methods

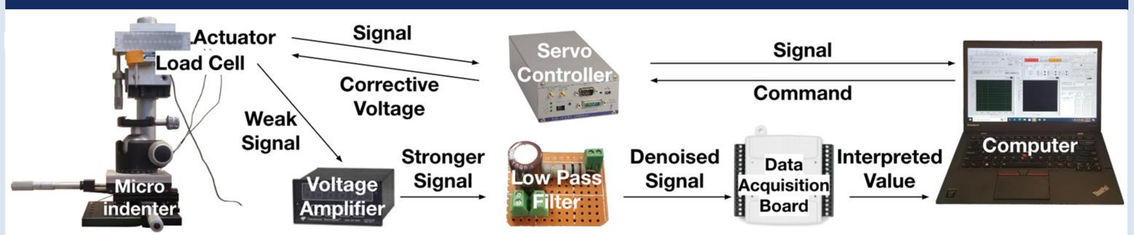

Fig. 1 Hardware Setup: Hardware elements (load cell and signal amplifier) were replaced with versions capable of the high precision required in cartilage testing. A low pass filter was implemented to remove noise from the load cell output, and an adapter to connect indenter tip holder and load cell was designed and machined.

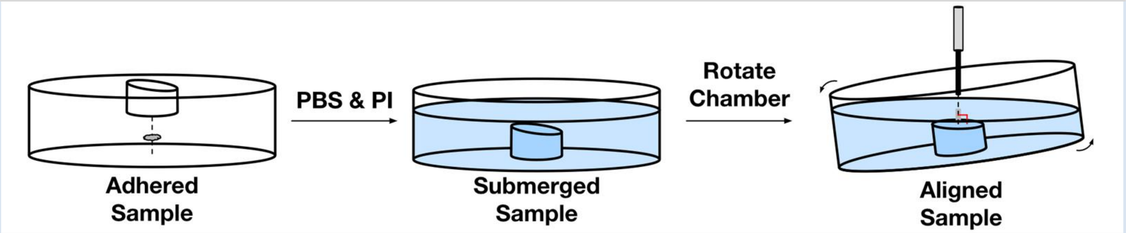

Fig. 2 Cartilage Testing Protocol: Samples were adhered to the test platform, submerged in PBS, and supplemented with a protease inhibitor cocktail to maintain hydration of the tissue and prevent degradation. A tare load of 0.5 g was applied to the sample and held for 5 minutes. The creep test was then conducted by applying a constant deformation of 0.3 μm at 5 Hz. This is applied for 30 minutes until a 2.5 g load is achieved. Output data was then opened in MATLAB and curve-fitted using a custom program to determine values of mechanical properties.

Results

Completed Microindentation Device

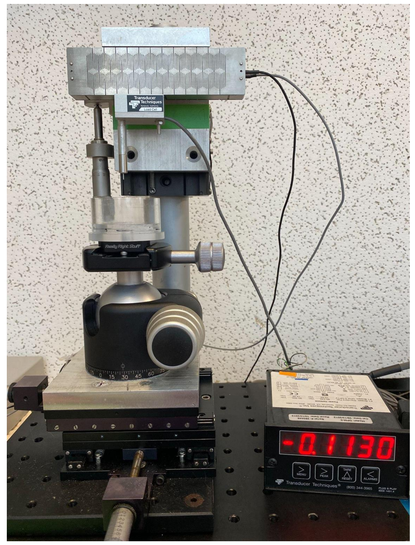

Fig. 3: Microindentation device after refurbishment. All hardware devices have been fixed and work properly. Software and code have been updated in a new computer, and successfully records all the data received, as seen to the right in Fig. 4.

Microindentation Data Plot

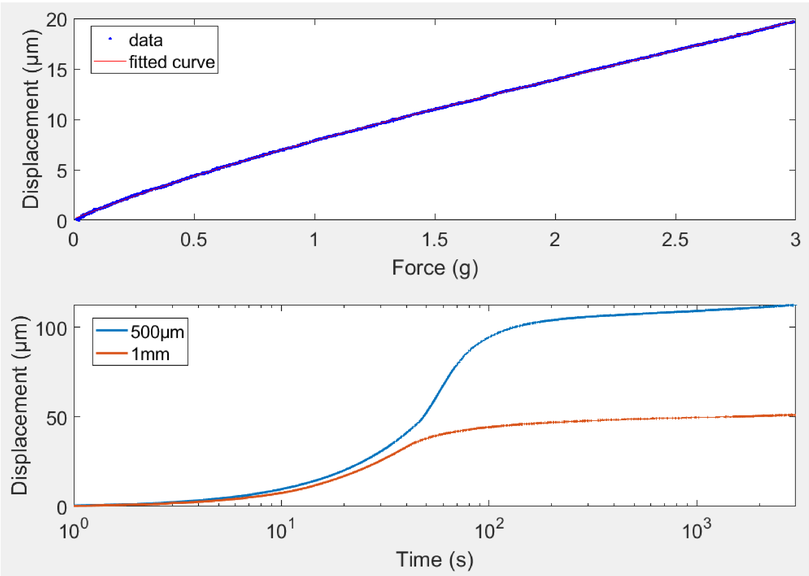

Fig. 4: Example of results received from microindentation test, which would be used in a curve-fitting program to find mechanical properties of the sample. System stiffness was accounted for by substituting force readings into an exponential curve fit to chamber compression test data (top). Sample displacement was then obtained by subtracting system displacement from absolute displacement (Bottom). Two results can be seen in the bottom plot of sample displacement, blue line being the 500μm indenter tip, red line being the 1mm indenter tip.

Path Forward

Microindenter:

- Add integral and derivative controls to reduce overshoot and stutter
- Improve readability of the program
- Create detailed protocol

Testing:

- Utilize MATLAB curve fitting program to extract mechanical properties from microindentation test results
- Use microindenter to study effects of resveratrol on osteoarthritis in rats
- Test temporomandibular joint

Acknowledgements

We would like to thank the Undergraduate Research Office's Summer Scholars program at University of Delaware.

Conclusions

- Microindenter successfully records accurate data
- Able to record all parameters required for the curve fitting program

References

[1] X. L. Lu, D. D. N. Sun, X. E. Guo, F. H. Chen, W. M. Lai, and V. C. Mow, "Indentation Determined Mechanoelectrochemical Properties and Fixed Charge Density of Articular Cartilage," 370–379, Mar. 2004.