BME 315 Biomechanics Experiment 4. Fall 2006.

Deformation of tendon

Pre-lab assignment

Review concepts as suggested in class. Also, you will need to bring a 3.5" floppy disk to record your data from a digital oscilloscope.

Dissection of rat tail tendon

Obtain a rat tail and check to make sure the rat tail is thawed. Be sure to wear gloves as this is biological tissue that is not prepped in cross linking agents such as formalin, which destroy possible disease causing agents but also change tissue properties. Rat tails will have the skin attached; skin must be removed before the tendons can be dissected out. Measure the tail length before dissecting.

Before making any incision, note the following: the tendons of interest are just below the skin but spaced evenly around the outer circumference of the tail. Therefore they can be easily damaged by even the most superficial cuts. To remove the skin, make an incision longitudinally from the superior aspect of the tail inferiorly towards, but not all the way to, the tip. Tendons appear white in color and can be easily avoided when making the longitudinal incision simply by analyzing the cross section of the tail where it was chopped off and determining tendon location. The skin may then be peeled off similarly to a sock, while using the scalpel to cut any connective tissue still attached. Multiple similar incisions may be necessary. After removing the skin dissect out one of the six or seven tendons by carefully cutting between the tendon and the tail bones. Start at the superior end of the tendon and continue inferiorly until the very tip of the tail. Tendons are continuous longitudinally for the entire length of the tail. Angle the cutting edge of the blade away from the tendon so it scrapes on the tail bones rather than damaging the tendon tissue.

Measure the diameter of the tendon at several points along its length using calipers provided in the laboratory. Measure the length of the tendon. Determine the tendon area using the following formula which is an ellipse approximation. Area = (Width x Height x Pi) / 4. Make sure to measure the two orthogonal thicknesses in order to perform this calculation.

Do not pull, stretch or manipulate the tendon because small injuries to the fibrous structure will affect the experimental data. Do not let the tendon dry; this would change the mechanical properties of the tendon. Keep the tendon moist with water via a cotton swab or paper towel.

Testing (for specifics see below)

The small tensile test frames on the right in the first room entered in 1313 EH will be used.

Calibrate the frame using the 500 g weight. Connect the scope channel 1 to the frame using a BNC cable. Set the vertical to 100 mV / division and horizontal to 10 sec / division. Clamp the weight in the upper grip. Write down the change in the voltage. Also record reading in frame's upper left load meter.

Clamp the tendon into the pull test mounts: hang the tendon from the inferior end (the skinny side) over the top mounting clamps so the superior (wide) end of the tendon hangs to a level at least in the middle of the bottom mounting clamps. This will ensure that an optimal region of the tendon is tested. Keep the grips centered in both directions or they may fall out.

Perform a stretch to failure test at constant deformation rate. Capture load versus time. If the tendon slips out of the grips, you may use a cardboard or paper insert to distribute the gripping force.

If several tendons are studied, test each one at a very different rate. Share data, compare.

Plot force versus displacement. Calculate and plot stress versus strain. Compare your results with results from the literature. Some results for ligament are provided in the class web resource.

Extra Credit: Relaxation test. Stretch the tendon to 3% strain, then hold it at constant extension. Monitor the force vs. time for 10 minutes. Do not let the tendon dry out. Plot force vs. log time. Use the fastest stretch speed to go from zero to 3% strain. The reason is that relaxation is strictly defined as the load response to step function stretch. Calculate the time first. You will have to hit "stop" quickly.

Questions

What do you think is the biological benefit of the shape of the stress strain curve?

Compare the stiffness, strength, and strain to failure with those of other tissues.

Instructions for Operation of the Instron Model 1000 tester for Tendon Tensile Test

There are several test frames with different load capacity. Noise is about 1 kg force on the 500 kg force machine and around 0.1 kg force on the 50 kg force machine. The larger capacity test frames are therefore not sensitive enough (signal to noise ratio is inadequate) unless you want to do some digital post-processing or electronically filter the signal. A passive filter will be provided.

Turn on the power to the Instron tester. Set the "Load Amp" switch is set to "Metric/SI" (assuming the machine is calibrated in kg). Next, make the effective load range 5 kg—at station #1 turn the "Range" dial to 50 kg (5 kg max. load), at station #4 turn the "Range" dial to 5 kg (50 kg max. load). The values are different because the dial values are actually percentages of the max. load. On the 50 kg capacity frame, 5 kg corresponds to 1 volt on the scope. Verify by a dead weight calibration. Set the scope at a slow speed, and grip the 500 g mass in the grips, using the wrench. Measure the voltage. The remaining instructions apply to both stations.

Hit the "Decimal" button until the force readout has the decimal point between the first and second digit (e.g., 1.20). The displacement readout is in millimeters. Can you verify that? Make sure the "Variable Speed" dial is set to max. Next, move the top clamp apparatus down to a height for optimal tendon testing by pressing the "Down" button. NEVER PRESS "Return" since the resulting motion is dangerously fast. Press "Stop" when optimal height has been achieved. Control speed of the apparatus by the "Crosshead Control" dial. The dial can be manipulated during operation but ordinarily the speed should be constant during a test.

Oscilloscope for Data Acquisition (This is the preferred method)

Connect the oscilloscope via a BNC cable into the back of the Instron tester; use a BNC to dual banana adapter. Clamp in the tendon as indicated in the "Testing Section." Use the coarse and fine adjustment knobs on the Instron tester to zero the digital load readout (be sure tendon is lax after clamping). Set "time/div" to a reasonable value with consideration of deformation rate. Set voltage range to 1 Volt (When you set the effective load range on the Instron it outputs 1 volt at max. load).

For stress relaxation, the slowest scale on the scope is 10 sec / div or 100 sec full scale. Results for longer periods of time may be captured manually. Activate the cursor, and write down the digital output at 100 sec, 200 sec, 400 sec, etc.

Insert disk into oscilloscope for data capture of force vs. time. To save digital data, hit "save" button on center, upper right cluster. Press "Save waveform Ch 1" at center, bottom of scope screen. Use spreadsheet file format. Hit Save Ch 1 to selected file, at lower right of screen. Saving takes a while. Only the waveform on the screen will be saved, therefore hit "stop" button on upper right to stop the trace before saving it. Eject disk when done. To relate displacement to time, use the setting on the speed control. Plot the data as load vs. displacement on your computer using graphics software.

Pen plotter for Data Acquisition Turn plotter power on. Press the "Input" button so it is set at "Zero". Press "time/prop" button to set to prop. Uncap and insert pen into plotter and lower onto paper in the "Pen Down" position. Insert the tendon into the clamps as indicated in the "Testing" section. Use the coarse and fine adjustment knobs on the Instron tester to zero the digital load readout (be sure tendon is lax after clamping). Now, on the plotter, depress the "Input" button so it is set at "Measure". Use the "Position" knob to move the pen to the line at the farthest right of the paper. Press the "Start" button. Set the Chart Magnification at 2. The plotter is ready to record data.

The plotter is set up to move in the direction of paper feeding proportional to the amount of displacement of the Instron tester. By setting the Chart Magnification at 2, the chart moves twice the amount of displacement of the machine (1 inch of tendon deformation = 2 inches of travel on the paper). The paper scaling factor is 1 inch/ two large division, or each small division = 1/10 of an inch. The force scale range is determined by the effective load range, which was previously set at 5 kg. This scale is orthogonal to the direction of paper feeding.

To get the data into your computer, mark data points on the paper, pick off horizontal and vertical coordinates, create a table of values, then type into your graphics software. Alternately, scan the pen plot and digitize the data points from that. Software for this varies across platforms.

Performing Tensile Test

Set the "Crosshead Control" dial to 20 mm/min. or desired deformation rate. Push reset under the "Extension" digital readout to zero the extension. Push "Up" to start the test. Push "Stop" once the tendon has completely torn.