TRUE STRAIN CHARACTERIZATION FOR TMJ DISC TENSILE TESTING

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INTRODUCTION
The temporomandibular joint (TMJ) is a bilateral synovial joint that is formed by the condyle of the mandible and the glenoid fossa of the temporal bone. In between these two bones is a fibrocartilagenous structure called the TMJ disc. Deterioration or displacement of the TMJ disc can lead to temporomandibular joint disorders (TMDs), which can cause symptoms such as pain, discomfort, joint dysfunction, and malocclusion. It is estimated that over 10 million Americans are affected by TMDs [1]. In addition, research estimates that 25% of the population will experience symptoms relating to TMDs at some point in their lives. [2]. Attempts to relieve pain associated with TMDs include medications, injection therapies, and/or surgical intervention. The current clinical treatment for patients with irreparable TMJ disc damage is to perform a discectomy. This can be done without graft replacements, which will lead to joint surfaces remodeling over time, or it can be done with autogenous tissue sources, which tend to resorb over time, making them ineffective for long-term treatment.

Extracellular matrix (ECM) derived scaffolds have shown significant potential for local regeneration of damaged tissues in multiple biological applications. These scaffolds are derived from the matrix of natural tissues and are currently studied as an alternative to TMJ disc replacements. The ultimate goal is that these ECM scaffolds will remodel into a tissue that closely resembles the mechanical and biochemical properties of the TMJ disc. The hope is for these ECM scaffolds to become a long-term solution for TMDs and disc replacement therapies.

Currently, our lab is investigating the use of ECM as a template for constructive remodeling in a porcine model. In order to determine the efficacy of the remodeled ECM, it must be characterized mechanically and compared to native discs. Current published tensile testing protocols, however, produce failure strain that is higher than those found in other cartilages. This suggests that the samples might be slipping during testing. For this reason, a novel method of assessing true strain needs to be established. Strain values are obtained by subjecting the native discs to elongation and forces, using a tensile testing machine. This testing apparatus records the maximum strain value immediately before the breaking point for the disc. We have developed a novel protocol for assessing true strain, in an attempt to determine if the samples are slipping and to also determine their true failure strain value.

HYPOTHESIS
We hypothesized that the true strain values of native discs would be lower than both those previously reported in literature, and the clamp-to-clamp tissue strain determined by the testing in the present study. In order to test this hypothesis, we utilized an independent samples T-test to determine whether the two sets (native true & native measured) of data are significantly different from each other. Providing that, if the calculated p-value fell below 0.05, we would be able to conclude that the hypothesis is valid and that there is a significant difference between these two tested parameters.

METHOD
This study was designed to add strain trackers to 55 different native TMJ discs to allow tracking of elongation for accurate strain values. Strain trackers (poppy seeds) were glued to every native disc sample. We obtained these native disc samples from pigs from a local abattoir. As seen in Figure 1, the discs with trackers were inserted, one at a time, into the clamps of the Instron 5566 tensile testing apparatus, to undergo tensile testing. The clamp-to-clamp measured strain from the testing machine was calculated for every native disc tested. As the machine applied tension, which resulted in the discs being pulled vertically, a camcorder recorded the movement of the disc and the trackers. These video files were obtained for every disc studied for this experiment.

Figure 1. Placement of the native disc with strain trackers into the tensile testing machine.

For each individual video file uploaded into Mathematica code, the strain trackers for that particular disc were manually identified on the program. The program outputted the values needed to determine the maximum strain for that particular disc. After processing, a figure similar to Figure 2, was outputted, illustrating the disc’s true strain values at different frames. The last frame before each disc snapped was identified manually and the strain values at this frame were averaged together. This averaged value was the TMJ native disc’s maximum true strain, which was recorded manually. This
process was repeated for the next native disc.

Figure 2. Example of Mathematica output for true strain for a simple sample.

RESULTS

The true and measured maximum strain values for the 55 native discs were recorded for analysis. On average, the maximum measured strain in the native discs was found to be 24%. By contrast, the average maximum true strain obtained by the video tracking for the native disc was found to be 14%. After performing statistical analysis, it was determined that the true strain was statistically lower in native discs than the measured strains indicated. The two data sets (true and measured) were statistically different with $p = 0.000020$.

Figure 3. Measured percent strain and true percent strain for native TMJ discs.

DISCUSSION

The results of this study did support the hypothesis that the native TMJ discs were slipping in the tensile testing apparatus. Values calculated from the clamp-to-clamp measurements, in fact, overestimate the strain value for the native discs. The true strain values were statistically lower in native discs than measured strains indicated. In addition, future studies involving native discs and ECM scaffolds for regenerated discs should use video strain tracking. Using video strain tracking will allow for much more accurate tensile property measurements to compare regenerated tissues to normal or diseased tissues.

This research study was limited by a couple of factors. The sample size of native discs was a little small. By analyzing more native discs, a clearer grasp of the difference between the true and measured values can be obtained.

Looking to the future, the regenerated scaffolds’ true strain values can be compared to measured strains. Additionally, a biomechanical comparison between native and regenerated discs can be conducted to gauge the feasibility of this medical technology.

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REFERENCES
