Tensile Material Properties of Human Costal Cartilage Perichondrium

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Introduction

Rib and costal cartilage fractures are the most commonly observed thoracic injuries due to blunt thoracic loading. Costal cartilage connects the anterior portion of the ribs to the sternum and makes up a notable portion of the thorax, contributing to the overall structural response and injury tolerance of the thorax. While there is a large body of work focused on the material and structural properties of the ribs, few studies have focused on quantifying the biomechanical properties of the costal cartilage, which consists of an interstitial matrix surrounded by the perichondrium. The perichondrium has two layers: a chondrogenic layer responsible for the generation of new cartilage tissue, and a fiber layer surrounding the chondrogenic layer. Previous research has focused on the tensile material properties of the interstitial matrix, but tension studies on isolated perichondrium samples are scarce. This study aims to quantify the effects of loading rate, age, and sex on the tensile material properties of human costal cartilage perichondrium.

Methodology

To date, twenty-five (n=25) samples from fifteen (n=15) donors have been successfully fabricated and tested. The donors ranged from 11 to 69 years of age (8 M, 6 F). The perichondrium samples were fabricated by first removing the extraneous soft tissue and interstitial matrix. For seven (n=7) samples, the fiber layer was removed to explore the role of the fiber on the perichondrium tensile strength. Next, a custom-made stamping jig was used to stamp out a dog bone-shaped coupon. The coupons were finally sanded in a custom-made sanding jig to a thickness of~1.3mm. Black India ink was used to mark dots on the samples that will be tracked to quantify the strain in the gauge length during the tensile tests. The samples were loaded to failure at either as low loading rate (0.005 strain/s) or a fast loading rate (0.5 strain/s) using a material testing system.

Results

Although the study is still ongoing, the data obtained to date illustrate several notable potential trends. The fast loading rate resulted in higher ultimate stresses than the slow loading rate. Samples that did not include the fiber layer had much lower failure stresses than samples with the fiber layer attached. The failure stresses for perichondrium samples with and without the fiber layer attached were considerably larger than those reported for interstitial matrix samples in previous studies. The perichondrium from older subjects was more brittle than that of younger subjects. In older subjects, the chondrogenic layer tended to fail before the fiber layer. Conversely, the chondrogenic layer tended to fail after the fiber layer in younger subjects.

Conclusions

Overall, the material response of the perichondrium appears to be both rate dependent and stronger than the underlying interstitial matrix. Further testing is being conducted to increase sample size to thirty (n=30) tests per loading rate. Statistical analyses will then be performed to evaluate the effects of loading rate, age, and sex on the tensile material properties of the perichondrium.