BI-DIRECTIONAL MECHANICAL PROPERTIES OF THE AXILLARY POUCH OF THE GLENOHUMERAL CAPSULE: IMPLICATIONS FOR SURGICAL REPAIR

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INTRODUCTION
Traumatic anterior dislocation of the glenohumeral joint accounts for 80% of shoulder dislocations.[2] The inferior glenohumeral ligament (IGHL) complex has been shown to be the primary restraint for anterior-inferior stability [7], and is composed of two bands (anterior and posterior) separated by its axillary pouch. While experimental and analytical models have focused on the uniaxial tensile properties of these bands [1], surgical repair techniques shift this study is to determine the mechanical properties of the axillary pouch in both directions perpendicular (transverse) and parallel (longitudinal) to the long axis of the AB-IGHL. Based on its force transmission characteristics, we hypothesize that the mechanical properties of the axillary pouch are similar in both directions.

MATERIALS AND METHODS
Fifteen longitudinal and nine transverse dog-bone (Figure 1) samples were obtained from the capsule of six fresh frozen cadaveric shoulders (average age: 58.0 ± 11.1 years). Eight dog-bone samples were taken from the AB-IGHL in the longitudinal direction for comparison. Each shoulder was dissected and placed in a cold room (5°C) until tested within 36 hours of thawing. Throughout the entire testing protocol, samples were kept moist with physiological 0.9% saline solution. The cross-sectional area of the midsubstance of each sample was then determined using a laser micrometer system while the specimens were fixed within customized clamps. A circular punch was used to obtain low-reflective black plastic markers (1.6 mm diameter, 318 μm thick) from shim stock for non-contact video strain analysis. Two markers were fixed to the midsubstance of each sample using cyanocrylate, centered approximately 7 mm apart, and analyzed with a Motion Analysis system.

The samples were subsequently mounted in a preheated saline bath (37°C) on a uniaxial material testing machine (Instron Model 4502). The load cell had a range of 0-44.8 N with an accuracy of ±0.07 N. A 0.1 N preload was applied to each sample and the tissue was preconditioned via cyclic elongation for 10 cycles (<55% of failure load). A load-to-failure test was then performed at a crosshead displacement rate of 10 mm/min. From the stress vs. strain curve, the tangent modulus and the ultimate stress were obtained. An unpaired t-test was used to compare the parameters from the longitudinal and transverse directions with statistical significance set at p<0.05.

RESULTS
The dog-bone thickness for the axillary pouch was 1.9±0.7 mm (mean±SD) and 2.4±0.9 mm for the AB-IGHL. The traditional “toe region” followed by a linear region prior to failure were found for each sample as shown in the typical stress-strain curves for the axillary pouch (Figure 2). The data is reported as the mean of the average property values for each specimen in the specified direction (Table 1). Samples failed in the midsubstance (n=21) or by slippage out of the clamps (n=2). Additionally, 5 samples were damaged during handling, one exceeded the limits of the load cell, and 4 were not reported due to noise near the markers during strain analysis. The tangent modulus of the transverse samples (1.7±1.1 MPa) was found to be significantly different (p<0.05) from the tangent modulus of the longitudinal samples (3.0±2.5 MPa). A significant difference (p<0.05) was also demonstrated between the ultimate stress of the transverse (1.4±1.2 MPa) and longitudinal (5.3±2.5 MPa) samples. However, the modulus and ultimate stress of the AB-IGHL were not found to be significantly different from either the transverse or the longitudinal samples.

DISCUSSION
The mechanical properties of the axillary pouch of the IGHL were determined in the longitudinal and transverse directions with respect to the AB-IGHL. The data did not support our hypothesis that the mechanical properties are similar in each direction. However, based on the ratio of the moduli (14.3±11.5) in each direction, the properties of the axillary pouch in the transverse direction should be considered more important as compared to other ligaments such as the medial collateral ligament (MCL) (30.1) of the knee and interosseous ligament of the forearm (384.8). [4, 5] Our results for tangent modulus of the axillary pouch in the longitudinal direction are similar compared to values reported in the literature (30.3 ± 10.6 MPa [1]). Previously, the primary focus of clinicians has been on restoring the AB and the axillary pouch in the longitudinal direction only. Based on the data reported in this study, failing to consider pouch fixation in the transverse direction may disrupt the pouch’s ability to distribute loads. Therefore, surgical repair and future models should consider the AB-IGHL and the axillary pouch in both the medial-to-lateral and superior-to-inferior directions.

Table 1. The mechanical properties in the transverse and longitudinal directions of the axillary pouch as well as the AB-IGHL.

<table>
<thead>
<tr>
<th></th>
<th>Trans. (n=9)</th>
<th>Long. (n=15)</th>
<th>Long. AB-IGHL (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus (MPa)</td>
<td>1.7±1.1 (n=5)*</td>
<td>15.4±12.2 (n=11)*</td>
<td>6.0±5.9 (n=5)*</td>
</tr>
<tr>
<td>Ultimate Stress (MPa)</td>
<td>1.4±1.2 (n=5)*</td>
<td>5.3±2.5 (n=10)*</td>
<td>3.5±3.0 (n=5)*</td>
</tr>
</tbody>
</table>

*significance (p<0.05)

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REFERENCES