Load-dependent shear wave elastography of the transverse carpal ligament

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INTRODUCTION: The transverse carpal ligament (TCL) forms the volar boundary of the carpal tunnel and is relevant to carpal tunnel syndrome due to its volar restriction of the median nerve. Compression of the median nerve is closely tied to mechanical factors including the stiffening and thickening of the TCL [1]. Determining the tissue properties of the TCL would improve the understanding of the ligament's role in carpal tunnel mechanics and its interactions with other carpal tunnel components, including the median nerve. Shear wave elastography imaging allows us to examine real-time mechanical properties of the TCL and has previously been used to measure carpal tunnel pressure [2] and determine TCL stiffness with and without compression [3]. However, it has not yet been used to determine the effect of axial load on shear wave velocity in the TCL. Therefore, the purpose of this study was to evaluate the effect of axial load on the shear wave velocities of an excised cadaver TCL.

METHODS: Six strips/samples were obtained from a single TCL of cadaveric arm. The samples were cut into six sections of equal length and width as shown in Figure 1A. Each sample was clamped into a custom-built uniaxial tensile testing system, which consists of a 3D-printed water bath, a 5 kg Degraw load cell and an HX711 amplifier connected to an Arduino Uno board. One clamped edge of the sample was attached to the load cell while the other to a translation stage. The shear-wave elastography was performed on an Aixplorer Mach 30 Ultrasound System using the SuperLinear SLH20-6 probe. The probe was submerged in saline along the axis of motion of the clamped sample. The experimental setup is shown in Figure 1B. Using the manual translation stage, the sample was loaded to 0.5 kg of axial load in 0.1 kg increments. At each increment, the shear wave velocities were measured and recorded. The mean shear-wave velocity from each strip was averaged at each load increment to evaluate the effect of the axial load.

RESULTS SECTION: The shear-wave velocities of each TCL section were measured by tracing the relevant cross-sectional area and determining the mean velocities in that traced area. Qualitatively, the shear-wave velocities increased with axial load. The mean representative shear-wave velocities for each TCL section were plotted against the axial loads and are shown in Figure 2. The velocities at each axial load were averaged across all TCL sections and plotted in Figure 3. Each section showed that the shear-wave velocities increased in an asymptotic way approaching a value. The velocities qualitatively did not increase beyond 0.1 kg axial load.

DISCUSSION: We found that shear wave velocity increased in the TCL with increasing axial load, but did not increase when the load was greater than 0.1 kg. This suggests that the TCL may stiffen as strain is applied, but only up to a certain point. This may be explained by properties of the tissue that limit deformation, preventing an increase in strain, even at higher axial loads. Shear wave velocity did vary between sample locations, but there did not seem to be a direct relationship between shear wave velocity and how distal or proximal the section was. This could be due to variation in tissue thickness or fiber orientation at different locations in the TCL. Overall, this study demonstrates the unique regional material properties as a function of axial load. Future studies could increase the sample size or examine how shear wave velocities differ between radial and ulnar sections of the TCL.

SIGNIFICANCE/CLINICAL RELEVANCE: The tissue mechanical properties of the TCL could shed more light on the role of the TCL in carpal tunnel pathologies.

REFERENCES: [1] Li et al. *Journal of wrist surgery 3(4)*, 2014. [2] Kubo et al. *J Orthop Res 36(1)*, 2018. [3] Shen et al. *PLOS ONE 8(7)*, 2013.

IMAGES AND TABLES:

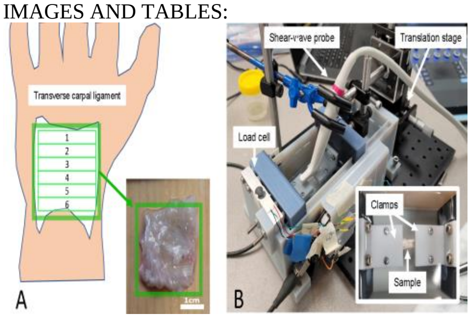

Figure 1. A sample form the TCL (A) under experimental testing (B).

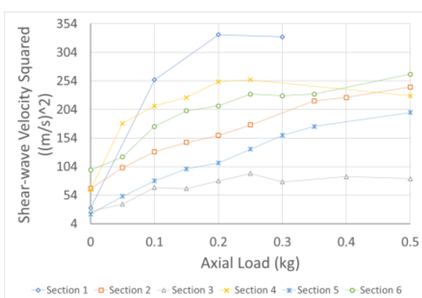

Figure 2. Shear-wave velocities of individual TCL sample sections against axial loads

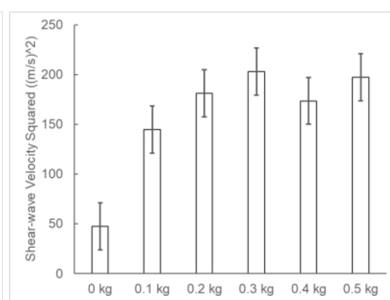

Figure 3. Shear-wave velocities for all TCL strips at various axial loads. Error bar indicates standard deviation.