INTRODUCTION
Currently, carpal tunnel syndrome (CTS) affects 1% of America’s population. CTS is classified as a compression neuropathy of the median nerve which, in turn, causes pain. To treat CTS, surgeons transect the transverse carpal ligament to release pressure off the median nerve.

The transverse carpal ligament (TCL) is located at the palmar roof of the carpal tunnel. Gross observation shows that the ligament appears to be a dense collagenous matrix with fibers roughly oriented along the transverse direction [1]. However, an anatomical investigation on the configuration of the TCL shows that there are fibers orienting in the oblique (unlar/radial oblique) and the transverse directions [2]. The mechanical properties of the ligament could be largely affected by the fiber orientation within the matrix. Thus, knowledge of the TCL’s fiber orientation is needed to better understand its mechanical properties and its role in regulating carpal tunnel biomechanics.

Therefore, the purpose of this study was to quantify collagen fiber orientation within the TCL using the small angle light scattering (SALS) technique which has shown to be effective in quantifying fiber structure in connective tissue [3].

METHODS
Eight TCL samples, removed from human cadaver hands (53±13 years), were used in this study. The TCL tissue was fixed in 10% formalin solution for 24 hours. Two tiny holes were drilled along the connection line between the midpoints of the distal and proximal edges of the TCL. These two holes were used as the reference for quantifying fiber orientation. The TCL’s thickness was measured with calipers. Individual 20µm sections were cut evenly along the thickness of the TCL in a cryostat (Microm®). Sections of three thickness levels (25%, 50% and 75%) were collected from each TCL referenced at its dorsal face. SALS was used to scan the fiber orientation for each section [3].

The orientation index (OI) and the preferred fiber direction were used to describe the fiber distribution on each scanned area [3]. The OI is a value that measures the sparsity of fibers over the area while the preferred fiber direction is the average measurement for fiber orientation. Fiber areas were included in locations where their OIs were less than 45º [4]. Fibers were grouped in the following orientation ranges: Radial-Oblique [23º, 67º], Transverse [0º, 22º] & [158º, 180º], Ulnar-Oblique [113º, 157º], and Longitudinal [68º, 112º] (Fig. 1). In the left hand, the oblique ranges are switched to match with the anatomical descriptors for the right side.

The Watson-Williams test on the angular dispersion was used to investigate the differences of the fiber orientation with respect to the tissue slice depth. In addition, a two-way ANOVA was used to analyze differences along the slice depth and the fiber orientation type. Thereafter, Bonferroni post-hoc analyses were run for each factor and the interaction term between
factors to if significant differences were found ($\alpha=0.05$).

RESULTS
The fiber percentages in each orientation range along the 25%, 50% and 75% thickness of the TCL are shown in Fig. 2 that the transverse fibers increased as the depth increased. The predominance of the transverse fibers seemed to increase as the depth increased. In contrast, the radial-oblique and longitudinal fiber areas seemed to stay relatively constant while the ulnar-oblique fiber areas decreased as the slice depth increased. Although there appears to be an increasing amount of transverse fibers as the depth increases, the Watson-William test revealed this change to be insignificant ($P > 0.05$).

In contrast, the two-way repeated measures ANOVA found that the fiber percentages in individual orientation types were significantly different ($P < 0.05$). Post-hoc testing for the fiber percentages indicated that the transverse fibers are the predominant orientation type, followed by oblique and longitudinal fibers (Fig. 2).

DISCUSSION
The predominant fiber within the TCL was found to be transverse followed by oblique and longitudinal fibers. It was also found that this arrangement of fibers doesn’t significantly change from the surface to the deeper portion of the TCL. The data are in contrast with those in the past [2]. But, we believe that the current technique is more quantitative.

Also the TCL was found to have a preferred degree of fiber alignment suggesting material anisotropy, namely transverse isotropy because the predominant, fiber direction is transverse while there are marginal, orthogonal fibers. These findings are validated by our laboratory; tensile testing of the TCL showed that the tangent modulus of the transverse direction was 38 times respectively higher than those in the longitudinal direction.

REFERENCES

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Figure 1: Displays fiber ranges that were considered (palmar view of right hand).

Figure 2: Shows the fiber percentages throughout the depth of the TCL.