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A PILOT STUDY TO DETERMINE THE TENSILE PROPERTIES OF THE TRANSVERSE CARPAL LIGAMENT

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SUMMARY

The transverse carpal ligament (TCL) is important in the stability of the carpus. Studies have shown the TCL plays a biomechanical role in promoting grip and pinch strength during the performance of hand functional activities of daily living. Previous studies have investigated the biomechanical properties of the TCL intact using indentation methods [1,2] as well as manipulation and load bearing techniques [3,4]. Despite the valuable contribution these investigations have provided, the literature still lacks an efficient method designed to specifically evaluate the tensile properties of the intact TCL.

Due to the complexity of the hand and wrist, the need has arisen to develop a sophisticated method to determine the tensile properties of the intact TCL.

INTRODUCTION

Anatomically, the carpal tunnel complex comprises bones, ligaments, muscles, tendons, and nerves all enveloped within the skin. Within the carpal tunnel complex the TCL forms the volar boundary of the carpal tunnel. In vivo, the tendons and median nerve wrap around the TCL to form a pulley system. During finger and hand movements the median nerve and tendons become compressed as they move in a volar and dorsal direction towards the TCL [5].

Biomechanically, the TCL plays two main roles in wrist function: carpal arch stability and retention of the extrinsic digital flexor tendons within the carpal tunnel. A study by Xiu *et al* (2010) investigated the structural mechanics of the carpal arch and the TCL [6]. They applied paired forces to the attachment sites of the TCL (two forces applied to the pisiform and hook of hamate on the ulnar side and two forces applied to the scaphoid and trapezium on the radial side). With the TCL intact, the inwardly and outwardly applied loads at the carpal tunnel and carpal arch resulted in deformation. They report that under 10N of inwardly applied load with the TCL intact, carpal arch width decreased by 10.8% at the distal portion and by 37.5% at the proximal portion. When an outwardly applied load of 10N was placed with the TCL intact, carpal arch width increased by 3.7% distally and 18.8% proximally. The authors concluded that the TCL plays an important role in the stabilisation of the carpal tunnel under outwardly applied loads and that the proximal portion of the carpal arch is more compliant than the distal portion.

With respect to our pilot study, only a few studies have isolated the TCL to determine its intrinsic properties [3, 7]. Although majority of the studies have investigated the intrinsic mechanical properties of the TCL and addressed only tensile properties from a radial / ulnar direction [6, 7, 8], the need has arisen to test the tensile properties of the TCL in the volar / dorsal direction. Thus, an experiment testing method has been developed to determine the tensile properties of the TCL in the volar / dorsal direction.

METHODS

Prior to commencing tests, approval for the study was obtained from the Laboratory of Human Anatomy, University of Glasgow and from the Department of Biomedical Engineering, University of Strathclyde, Departmental Ethics Committees. One embalmed left handed cadaveric specimen amputated at the mid forearm was tested. The specimen was free from any musculoskeletal or neurological disorders. The tensile properties of the TCL were determined using a D'Shackle fastened to a steel work piece (Figure 1).

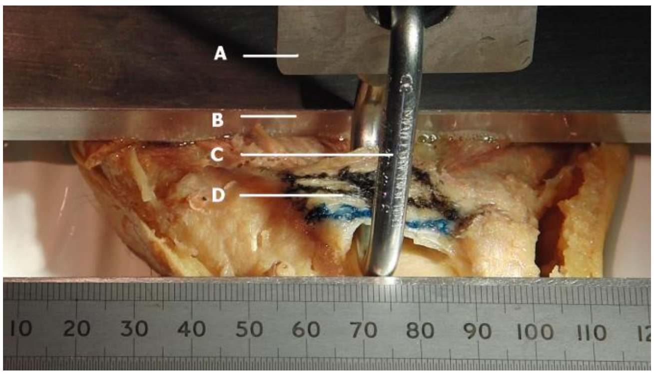

Figure 1: Illustration of specimen setup on Instron E10000 (Instron, Bucks, UK) Materials Testing Machine. (A) Steel

work piece, (B) Rectangular aluminium bar for securing specimen, (C) D'Shackle, (D) Transverse Carpal Ligament.

The D'Shackle and steel work piece unit were attached to the upper hydraulic tensile grips connected to the 1000 N load cell (Model: Instron E10000 (Instron, Bucks, UK)), of the Instron Materials Testing Machine. The testing machine was operated by a personal computer running the High Load Materials Testing Machine Instron E10000 Bluehill Software package.

Prior to testing the specimen was prepared by exposing the TCL with carpal tunnel contents removed. Hand anthropometric measurements of the specimens were obtained. The lower hydraulic tensile grip was disconnected and removed to provide room for the custom made aluminium specimen platform. The custom made aluminium specimen platform was fastened to the base of the Instron E10000 Materials Testing Machine. The specimen was placed on the aluminium platform. The D'Shackle was fastened on to the TCL and then attached to the upper hydraulic tensile grips connected to the 1000 N load cell. The specimen was adjusted until the TCL was aligned and perpendicular to the D'Shackle. Once the specimen was aligned, it was secured in position via three rectangular aluminium bars that were tightened using two M8 threaded bolts and wing nuts per bar.

The experimental procedure entailed raising the D'Shackle and steel work piece unit until contact was made with the inside surface of the TCL and a load of 0.5 N was recorded. The load cell was subsequently tared and a deformation rate of 20 mm/s was used to deform the TCL until a drop off load was detected. Load-displacement curves were recorded and converted to stress-strain curves. Stiffness of the TCL was determined and was calculated as slope of the linear portion of the Load-Displacement graph with minimum R^2 value set at $R^2 = 0.95$.

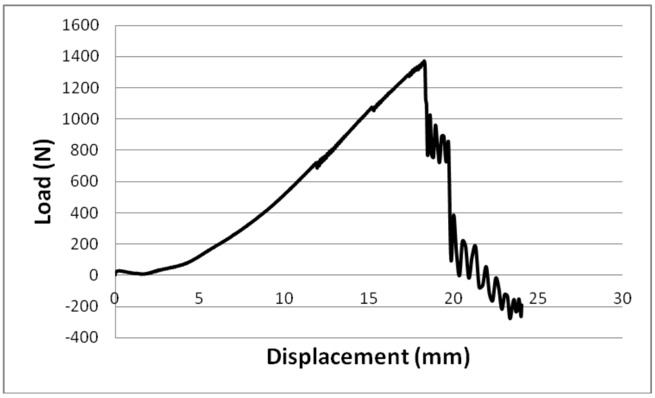

Figure 2: Load-displacement curve for TCL tensile test.

RESULTS AND DISCUSSION

The pilot experiment provides a unique method of determining the tensile properties of the TCL in conjunction with a gold standard Material Testing Machine, Instron E10000 (Instron, Bucks, UK). This preliminary data is useful and provides an insight into the tensile properties of the TCL from a volar / dorsal direction. At maximum deformation the peak load and maximum TCL displacement were 1369.66 N and 18.27 mm respectively. The initial TCL length was 27.20 mm and final TCL length at maximum deformation was 46.39 mm. The TCL stiffness was 64.59 N/mm. The TCL cross-sectional area was 31.09 mm^2 and initial and final D'Shackle contact area was 0.07 mm^2 and 86.30 mm^2 respectively.

In comparison to previous studies, our preliminary study is in line with earlier research performed by Zong-Ming Li and colleagues where they investigated the expansion of carpal tunnel by stretching the TCL palmarly [3]. Though their methodology is different, their study reported the TCL arch height (mean (SD)) as 2.8 (0.30) mm at 10 N and 5.4 (0.4) at 200N compared to 0.01 mm at 10 N and 6.22 mm at 200 N generated from our study.

CONCLUSIONS

A unique approach to determining the expansion of the TCL in the palmar direction has been developed. Although, this pilot study is limited to only one embalmed specimen, the experimental procedure and execution has been satisfactory. As a methodology we believe this technique potentially could be used to investigate the tensile properties of other TCL specimens in situ in fresh specimens. Efforts are currently underway to further develop this methodology.

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