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BIOMECHANICAL PROPERTIES OF THE TRANSVERSE CARPAL LIGAMENT AND OVERLYING SOFT TISSUE LAYERS

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SUMMARY

This study investigates the biomechanical properties of the transverse carpal ligament in relation to the carpal tunnel contents and overlying soft tissue layers.

INTRODUCTION

Carpal Tunnel Syndrome (CTS) is regarded as the most common peripheral compression neuropathy affecting the hand. CTS is characterised by pain, tingling, numbness and burning sensation of the lateral three and a half fingers, and palm of the hand; muscular atrophy of the thenar and hypothenar muscles, leading to decreased grip and pinch strength, and decreased hand function [1, 2]. Indeed, it is a painful and debilitating condition affecting approximately 4 to 12 people per 10000 of the UK population each year and is more prevalent in females than in males, with females accounting for approximately two thirds of total CTS cases, and more common in the over 40 age groups [3].

There are several possible causes of CTS including: tendonitis, tenosynovitis, bursitis, lesions and inflammation of the transverse carpal ligament (TCL). The effect of these is an increased pressure within the carpal tunnel leading to compression and impingement of the median nerve. Anatomically, the carpal tunnel complex comprises bones, ligaments, muscles, tendons, and nerves all enveloped within the skin. Within the carpal tunnel complex the TCL which is attached distally to the hook of hamate and trapezium and proximally to pisiform and scaphoid encapsulates muscles, tendons and the median nerve. While the mechanics of the carpal tunnel complex has been studied by various researchers [4, 5, 6], it still remains unclear what the biomechanical properties of the TCL is in relation to the carpal tunnel contents and overlying soft tissues.

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. All specimens were free from any musculoskeletal or neurological disorders. Six embalmed cadaveric specimens amputated at the mid forearm and aged 82 ± 6.29 years were tested. The six hands were from four individuals (two pairs and two individual hands), three males (four hands) and one female (two hands). The biomechanical properties of the TCL and the overlying soft tissue layers were tested by indentation using a BOSE Electroforce 3200 materials testing machine. The indenter was attached to the BOSE 450N dry load cell (Model: 10-32 THD) and fitted to the upper actuator of the machine. The testing machine was operated by a personal computer running the Wintest 4.1 Digital Control System Software package. Prior to testing hand anthropometric measurements of the specimens were obtained. The cadaveric hands were placed on a custom made aluminium specimen platform and adjusted until the indenter was aligned and perpendicular to a defined central location on the palmar surface directly above the TCL. The cadaveric hands were secured in a custom made aluminium specimen platform fastened to the base of the Electroforce 3200 materials testing machine. The specimens were secured in place via three rectangular aluminium bars that were tightened using two M8 threaded bolts and wing nuts per bar.

The experimental procedure entailed performing four indentation trials for each specimen at the following different levels of dissection: (a) Intact hand, (b) Skin removed – epidermis, dermis, subcutaneous adipose and palmar aponeurosis removed, (c) Removal of one muscle group – Thenar or Hypothenar muscle, (d) TCL exposed with carpal tunnel contents intact. The test protocol started with a preconditioning cycle where indenter was lowered to 0.5N preload with the specimen. Ten sine wave preconditioning cycles of -4.5mm displacement at a rate of 2Hz were performed. The specimen was allowed a 10s recovery period before performing a displacement ramp of -4.5mm at 2mm/s and held at constant displacement (constant strain) for 1800s. Each specimen was allowed a one hour recovery period between the different indentation trials. Ligament strain was calculated and the stiffness of the TCL and overlying soft tissues were determined. Stiffness was calculated as slope of the linear portion of the Load-Displacement graph and minimum R^2 value was set at $R^2 = 0.95$ for all trials [5]. Descriptive statistics and t-tests were performed to compare the difference between the dissection levels. P value was set to 0.05.

RESULTS AND DISCUSSION

All specimens exhibited similar viscoelastic properties (Figure 1). The thenar muscle group provided more load absorption compared to the hypothenar muscle group. With respect to the different levels of dissection all specimens showed a similar trend at specific time points during the load relaxation test. The muscle layer (particularly the thenar muscle) showed the fastest relaxation (Figure 1).

Peak loads and stiffness increased as each dissection level was removed. The 'Hypothenar Removed' condition (Mean (SE) = 115.7 (37.5) N) reported a lower peak load when compared to the 'Thenar Removed' condition (Mean (SE) = 228.2 (58.4) N), though not significantly lower, P = 0.204. The Mean (SD) peak loads recorded for the 'Intact' and TCL exposed' conditions in this study were 68.02 (42.87) N and 179.64 (56.84) N respectively, compared to 27.1 N and 80.5 N respectively reported by Chaise *et al* (2003). Though our recorded peak loads may be higher, the percentage increase in loads between the two conditions for both studies are very similar (62% and 66.3 % increases in peak load for the TCL exposed conditions of our study and that for Chaise *et al,* 2003, respectively). A possible explanation for the greater peak loads in our study could be attributed to the use of embalmed specimens as opposed to the fresh frozen specimen used by Chaise *et al* (2003).

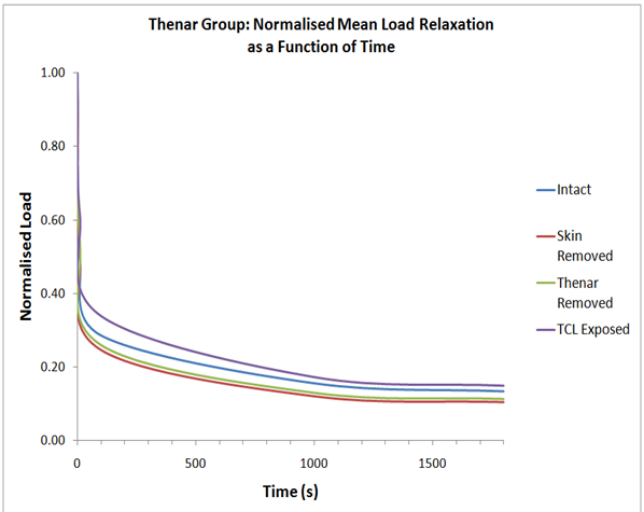

Figure 1: Normalised mean load relaxation graph for the Thenar Group.

Table 1: Ligament Strain Results.

Specimen Number	Thenar (T) or Hypo (H) – thenar Group	TCL Width (mm)	Instantaneous Ligament Width (mm)	Strain
1	H	25.22	27.68	0.10
2	T	27.97	30.09	0.08
3	T	22.03	25.03	0.14
4	H	22.93	25.76	0.12
5	T	26.21	28.54	0.09
6	H	27.2	29.41	0.08
Mean		25.26	27.75	0.10
SD		2.36	2.01	0.02

There were no significant differences between the hypothenar and thenar muscle groups (P = 0.808). The Mean (SD) ligament strain for the hypothenar muscle group and thenar muscle group were 0.01 (0.02) and 0.103 (0.032) respectively (Table 1).

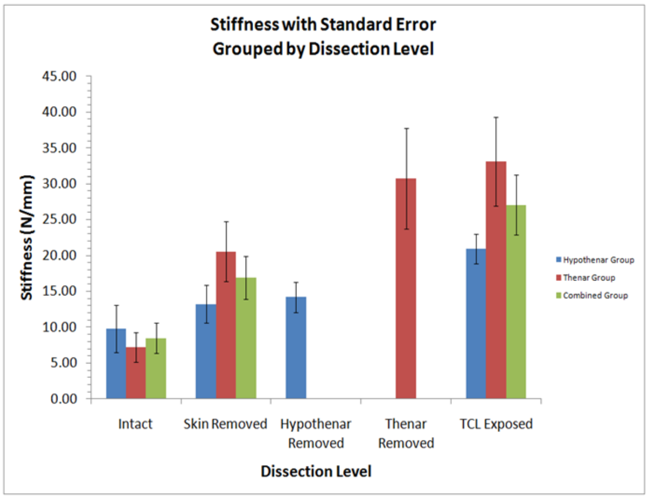

Figure 2: Mean stiffness with standard error across all dissection levels.

Within the combined group, the 'TCL Exposed' condition (Mean (SE) = 27.05(4.94) N/mm), recorded the greatest stiffness. The 'TCL Exposed' condition was significantly higher than the 'Intact' condition (Mean (SE) = 8.50 (2.52) N/mm), P = 0.026, and greater but not significantly, than the 'Skin Removed' condition (Mean (SE) = 16.90 (3.50) N/mm), P = 0.074.

There were no significant differences between the 'Thenar Removed' and 'Hypothenar Removed' conditions, P = 0.251. Stiffness was greater for the 'Thenar Removed' condition (Mean (SE) = 30.7 (9.90) N/mm), compared to the 'Hypothenar Removed' condition (Mean (SE) = 14.19 (3.00) N/mm). As with peak load, the stiffness increased with each level of additional dissection, with the exception of the removal of the hypothenar muscles which showed no increase in stiffness compared to the 'Skin Removed' level of dissection.

CONCLUSIONS

The authors acknowledge that as a result of the small sample size, the power of any statistical analysis performed is compromised. As a consequence of maintained loading of the carpal tunnel region, our results provide useful information of what potential biomechanical changes could occur at the different levels of dissection.

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