Biomechanical Role of the Transverse Carpal Ligament in the Deformability of the Carpal Tunnel

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INTRODUCTION:
The carpal tunnel at the wrist is formed by the interconnected carpal bones at its medial, lateral and dorsal borders, and the transverse carpal ligament (TCL) at its volar border. Carpal tunnel syndrome (CTS) results from compression on the median nerve in the tunnel. Previous research indicated that the carpal tunnel can be mechanically expanded (e.g. myofascial manipulation) to reduce the carpal tunnel pressure (Sucher BM, 1993). The effectiveness of such a procedure is predominantly determined by the deformable characteristics of the carpal tunnel. In addition, the role played by the TCL in stabilizing the tunnel structure is limited (Garcia-Elias, 1989). The goal of this study was to examine the deformability of the carpal tunnel in response to the application of inward and outward forces to the TCL insertion sites. In particular, the effect of TCL transection on the deformability of the carpal tunnel was studied.

METHODS:
Six fresh-frozen cadaver arms (one male and five females) with no prior history of injury or disease involved in the hands were used in the study. The mean age was 58 ± 17 years. For dissection preparation, a large skin flap was made by two longitudinal and two horizontal cuts at volar surface to expose the subcutaneous tissue. Then dissection was carried out to the TCL, exposing its proximal and distal edges and four insertion sites. The carpal tunnel was evacuated all of its contents. A piece of custom designed plywood with a 20 degree inclination was fixed onto a metal plate. Inclination of the plywood was to provide a functional neutral position for the wrist. The specimen was then mounted onto the plywood with a pin through the middle of the third metacarpal, and with a Velcro strip around the forearm. After the fixation, the four insertion sites of TCL to the carpus were marked and individual holes were drilled. Cortex screws (Synthes Inc, West Chester, PA) with a 2.0 mm diameter and 10–12 mm in length were inserted into these drilled holes. Individual wires were attached to the screws. Four pulleys were constructed for force application by weight suspension. Each pulley can be adjusted in horizontal and vertical directions for force alignment. Two pairs of forces were applied, one aligned with the connection line between the hamate and trapezium (HT) and proximal distance between the pisiform and scaphoid (PS) calculated for each trial. Statistical differences between conditions with TCL and with TCL transection and respective. TCL transection didn’t significantly affect the changes of the HT (p = 0.212) or PS (p = 0.887) distances. For outward force at 10 N, the HT distance increased by 0.9 ± 0.4 mm and 2.2 ± 0.9 mm for the TCL-intact and TCL-transected conditions, respectively. The increases for the PS distance were 5.6 ± 1.6 mm and 9.4 ± 2.7 mm for the TCL-intact and TCL-transected conditions, respectively. TCL transection had a significant effect on the changes of the HT (p = 0.003) and PS (p < 0.001) distances.

RESULTS:
For inward force at 10 N, the HT distances decreased by 2.6 ± 1.1 mm and 2.5 ± 1.1 mm for the TCL-intact and TCL-transected conditions, respectively. The decreases for the PS distance were 10.5 ± 1.6 mm and 10.5 ± 2.2 mm for the TCL-intact and TCL-transected conditions, respectively. TCL transection didn’t significantly affect the changes of the HT (p = 0.212) or PS (p = 0.887) distances. For outward force at 10 N, the HT distance increased by 0.9 ± 0.4 mm and 2.2 ± 0.9 mm for the TCL-intact and TCL-transected conditions, respectively. The increases for the PS distance were 5.6 ± 1.6 mm and 9.4 ± 2.7 mm for the TCL-intact and TCL-transected conditions, respectively. TCL transection had a significant effect on the changes of the HT (p = 0.003) and PS (p < 0.001) distances.

DISCUSSION:
In this study, we found that the proximal level of the carpal tunnel was more flexible than the distal level. This flexibility was evidenced by the larger amount of changes in PS distance in the inward or outward force direction, whether the TCL was intact or transected. Mobility of the carpal tunnel at the proximal level may help explain the post-operative “pillar pain” possibly associated with the pisiform-triquetral joint. Our results also showed that the TCL played an important role in stabilizing the carpal tunnel as indicated by the increases of the distance changes or compliance in the outward direction after TCL transection. As such, carpal tunnel release may cause biomechanical instability of the tunnel. However, TCL transection did not influence the inward deformability of the carpal tunnel, which is expected because the ligament does not resist compression forces.

REFERENCES:

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Figure 1. Two pairs of forces applied to the carpal tunnel in the inward (A) and outward (B) directions

Figure 2. Force-distance change curves for the HT with TCL and without TCL during inward (A) and outward (B) forces