Three Dimensional Carpal Kinematics After Carpal Tunnel Release

INTRODUCTION

Nearly five hundred thousand carpal tunnel releases (CTR) are performed yearly in the United States. Though the majority of patients enjoy symptomatic relief, up to 25% complain of ulnar sided wrist problems such as pillar pain and loss of grip strength. Previous research has demonstrated CTR alters carpal arch morphology. However, the effect of CTR on the three-dimensional kinematics of the carpal bones has not been demonstrated. In this study we explored whether release of the transverse carpal ligament (TCL) in a cadaveric wrist model would alter the three-dimensional kinematics of the bony attachments of the TCL, with special attention to the ulnar side of the wrist.

METHODS

Based on two hundred hands from seven studies analyzing carpal arch width (CAW) in the literature, a power analysis was performed using a power of 0.8 and an α value of 0.05, determined five specimens were needed to demonstrate a significant change in the in vitro kinematics of the carpus. Five fresh frozen cadaveric wrists were studied before and after a mini-open CTR using serial three-dimensional computerized tomography (CT scan, GE HiSpeed Advantage; GE Medical, Milwaukee, WI) and markerless bone registration techniques. The specimens were postmortem in cadaveric wrists after defrosting 8 hours and radiographs demonstrated no carpal pathology. The flexor (flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus) and extensor (extensor carpi radialis longus and brevis, and extensor carpi ulnaris) tendons were isolated and loaded with 5 pounds to maintain balanced finger position. Specimens were evaluated pre- CTR in three positions neutral, 60° flexion, and 60° extension. Without removing the specimen from the custom design jig, the finger flexor and extensor tendons were unloaded and a mini-open CTR was performed. The finger flexor and extensor tendons were then cycled 10 times. The finger flexor and extensor tendons were reloaded with 5 pounds and the specimens were evaluated post CTR in three positions neutral, 60° flexion, and 60° extension. Post scan wrist dissections were done on each specimen to confirm complete release of the TCL.

CT scans of the carpus both pre- and post CTR were segmented. Bone contours were mapped (Analyze-5, Mayo Foundation, Rochester, MN; Geomagic; Raindrop, Durham, NC) and bone volume, inertial axis, and bone centroid (geometrical center of a solid object) were calculated (Matlab; Mathworks, Natick, MA). Pre- and post CTR comparisons of centroid diastasis and rotation of the hamate and trapezium were made using Student t tests. P-values <.05 were considered statistically significant.

RESULTS

Effect of CTR on Carpal Arch Width

After CTR, the data indicates carpal arch width (CAW) increased significantly between pre- and post CTR in neutral (avg. 1.81 mm; p < .02), 60° flexion (avg. 0.81 mm; p < .003), and 60° extension (avg. 1.25 mm; p < .003). No significant difference in CAW was demonstrated between 60° flexion and neutral, neutral and 60° extension, or 60° flexion and 60° extension.

Effect of CTR on centroid spacing and rotation

Centroid spacing between the trapezium and the hamate increased significantly between pre- and post CTR (average of 0.4 mm) in neutral (p < .035), 60° flexion (p < .02), and 60° extension (p < .03). No significant differences were found in centroid spacing between pre- and post release in the scaphoid and pisiform. Centroid rotation of the hamate and trapezium relative to a fixed capitate, increased significantly from pre-release neutral to post release neutral (p < .05). The hamate rotated approximately 4.5° while the trapezium rotated 2.25°. No significant rotation between pre and post release was evident in the scaphoid, lunate, triquetrum, pisiform, or trapezium relative to the capitate in any of the positions.

Effect of CTR on ulnar side carpal posture

After CTR, the pisiform rotated outwardly relative to the triquetrum by 3.83° (p < .001) from 60° flexion to 60° extension. No significant rotational changes were evident in the hamate-pisiform, or hamate-triquetral relationship from 60° flexion to 60° extension. The pisiform centroid displayed a trend toward displacement away from the triquetrum by 0.13 mm, though this was not significant (p > .0995).

DISCUSSION

This study was performed to determine if CTR would alter the three-dimensional kinematics of the carpus, specifically on the ulnar side of the wrist. Results demonstrated carpal kinematics was significantly altered after a CTR. This confirmed previous work in the literature stating CAW increases after CTR. However, previous work was performed using only radiographs, CT scans, and MRI.

This is the first study to date demonstrating three-dimensional conformational changes in the carpal attachments of the transverse carpal ligament after CTR, particularly on the ulnar side of the wrist. The ulnar sided changes in the carpus were exemplified by increased rotation of the hamate relative to a fixed capitate when compared to the trapezium. Additionally, significant outward rotation of the pisiform, as measured bone volume, away from the triquetrum occurred, though the outward rotation of the pisiform centroid did not reach statistical significance. This suggests the increased CAW and ulnar sided changes in the carpus after CTR maintain a rotational and translational component.

Though the significant kinematic changes observed in the bony attachments of the transverse carpal ligament after CTR are small, they may be clinically relevant and contribute to transient ulnar sided wrist complaints after CTR such as pillar pain or loss of grip strength.

REFERENCES


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