Reverse-Anatomical Front and Back Reconstruction for Volar Carpal Instability Non-Dissociative: A Biomechanical Study

Sreetha Sidharthan, Viviana Serra Lopez, Kartik Inta Reddy, Rosie Mc Colgan, Kathleen Meyers, Scott W Wolfe

INTRODUCTION: Volar carpal instability non-dissociative (CIND-VISI) is characterized by abnormal motion between the proximal and distal carpal rows, leading to flexion of the lunate and a symptomatic midcarpal “clunk” during wrist motion. While limited midcarpal or four-corner fusions are commonly used to treat CIND-VISI, the associated loss of motion may be unacceptable to young, active patients. We describe a reverse anatomical front and back (RANAFAB) technique to reconstruct the critical volar and dorsal ligaments implicated in CIND-VISI. We hypothesize that RANAFAB will eliminate wrist clunking and restore normal wrist kinematics by reducing lunate flexion, capitate translation, and midcarpal shift in a cadaveric model of CIND-VISI.

METHODS:

A model of CIND-VISI was created in seven fresh-frozen cadaveric wrist specimens by sharply transecting the ulnar arm of the arcuate, scaphocapitate, scaphotrapeziotrapezoid, and the dorsal radiocarpal ligaments. RANAFAB was then performed on each specimen by weaving a synthetic tape through the carpus to reconstruct the affected ligaments. Each specimen was tested in three states: intact, after ligament sectioning (CIND-VISI), and post-reconstruction (RANAFAB). Testing was performed on a custom jig that applied a 40N palmar-directed force to the capitate during video-fluoroscopy. Radiolunate angle (RLA) and capitate translation were then measured on static lateral views under load application. A manual midcarpal shift test was also performed at baseline, after ligament sectioning, and after RANAFAB. Power analysis showed that seven specimens were required to detect a RLA change of 10 degrees with 80% power and 95% confidence. Statistical analysis included a two-way repeated measures analysis of variance with Bonferroni correction to compare RLA and capitate displacement across conditions. Cochran’s Q test was used to analyze differences in midcarpal shift test between the three states. An alpha value of 0.05 was used as the significance threshold.

RESULTS: In all seven specimens, ligament sectioning produced a positive midcarpal shift test and reconstruction with the RANAFAB technique eliminated wrist clunking ($p<0.001$). Mean RLA and capitate displacement differed significantly between the intact, CIND-VISI, and RANAFAB states (Figure 1). The CIND-VISI model led to an increase in absolute RLA by a mean of 18.6 degrees compared to the intact state ($p=0.001$) and an increase in capitate displacement of 4.8 mm ($p=0.001$). Following reconstruction with RANAFAB, we demonstrated a mean difference in absolute RLA of 33.8 degrees compared to the CIND-VISI state ($p=0.007$), restoring values below the VISI threshold of 20 degrees in all specimens. Similarly, capitate displacement was reduced by 7.8 mm after RANAFAB compared to the CIND-VISI state ($p=0.004$).

DISCUSSION AND CONCLUSION:

RANAFAB successfully eliminated midcarpal clunk and proximal row kinematic dysfunction in a cadaveric model of CIND-VISI. RANAFAB may offer a promising surgical option for the young, active patient with CIND-VISI and maintained cartilage who is reluctant to undergo arthrodesis.

Figure 1: Radiographic outcomes after ligament sectioning and reverse ANAFAB reconstruction. Radio lunate angle (A) and capitate displacement (B) measured under a 40N volarly directed load to the distal carpal row across three conditions: intact, CIND-VISI, and RANAFAB. Each line represents an individual specimen (n=7).