INTRODUCTION:
The carpal bones within the wrist are arranged in two rows, proximal and distal. The distal row consists of the trapezium, trapezoid, capitate, and hamate with the carpal arch width (CAW) defined from the transverse carpal ligament attachments on the trapezium and hamate. The distal carpal row is considered to be tightly bound with little or no intercarpal motion. However, evidence of intercarpal mobility of the distal row has been reported in different cases. Studies have investigated manipulating the CAW, widening or narrowing, to alter the carpal tunnel area. Additional evidence of mobility of the distal carpal bones can be seen as CAW varies during flexion and extension of the wrist. This suggests that a change in CAW may be a result of mobility of the hamate-capitate (H-C) joint as literature states that the trapeziun-trapezoid (Tm-Td) and trapezoid-capitate (Td-C) joints are immobile. An additional study has shown that carpal tunnel release leads to an increase in CAW; and the trapezium and trapezoid bones exhibited external rotations. This suggests that the Td-C joint might not be as immobile as previously stated. The aim of the study was to investigate the relative contributions of the distal carpal joints during carpal arch widening and narrowing. We hypothesized that the movement of the H-C and the Td-C joints are greater than the movement of the Tm-Td joint.

METHODS:
Specimen Preparation: 8 fresh frozen cadaver specimens were thawed overnight. The specimens were dissected volarly to expose and remove the transverse carpal ligament. The carpal contents, including the median nerve and nine flexor tendons, were left intact. The specimens were then dissected dorsally removing skin, fat, and extensor tendons to expose the carpal bones taking special care not to damage any intercarpal ligaments. Holes were drilled into the attachment sites of the transverse carpal ligament on the hamate and trapezium. Screws were then inserted into the holes within the hamate and trapezium. Additional holes were drilled, dorsally, into the hamate, capitate, trapezoid and trapezium under the guidance of radiographic imaging. Clusters of 3 reflective markers were inserted and glued into the dorsal holes of each bone (Figure 1, left). Three additional markers were glued to the skin at the dorsal aspect of the radius for defining the forearm coordinate system.

Experimental Setup: A custom apparatus was used to narrow and widen the CAW via the volar screws on the hamate and trapezium (Figure 1, right). The apparatus consisted of a rigid frame, two height adjustable pulleys, and a fingertrap. The specimen’s elbow was placed on the base of the apparatus and the finger trap, attached to the third digit, was then used to hold the forearm in a vertical position. Wires, which were attached to the hamate and trapezium screws, were looped around the pulleys and attached to a turnbuckle. Based on the initial measurement of CAW, a total of 5 conditions were performed consisting of changes in CAW: +4, +2, 0, -2, and -4 mm; where negative changes reflected narrowing of CAW and positive changes reflected widening of the CAW. CAW was measured with a caliper, as the distance between the 2 screws, and adjusted with the turnbuckle until the desired ∆CAW was reached. The 5 conditions were performed in a randomized order within a trial. A total of 3 trials were performed with each specimen.

Kinematics: To investigate the kinematics of the carpal bones, we used a motion capture system (Vicon MX, Oxford, UK) to record the movement of the marker clusters during widening and narrowing of the CAW. The motion of the bones was described using pronation/supination (Y), flexion/extension (Z), and ulnar/radial deviation (X) rotation axes of the wrist following recommendations of International Society of Biomechanics.

RESULTS:
From a ∆CAW of -4 mm to +4 mm, movement was observed within the joints among the distal carpal bones. The hamate fractured in one specimen; therefore, data from the remaining 7 specimens was used for statistical analysis. The hamate significantly pronated (6.5 ± 2.2°), extended (2.5 ± 1.9°), and ulnarily deviated (6.0 ± 2.4°) relative to the capitate (p<0.05). The trapezoid significantly supinated (5.6 ± 1.6°) and flexed (4.0 ± 2.0°) relative to the capitate (p<0.05) with no significant ulnar/radial deviation. The trapezium significantly supinated (5.1 ± 2.7°) and ulnarily deviated (1.9 ± 4.3°) relative to the trapezoid (p<0.05) with no significant flexion/extension.

For all joints, rotations were the greatest about the pronation/supination axis. However, comparison of interjoint mobility showed that the joints were not statistically different except for movement of the H-C joint about the ulnar/radial deviation axis; which was significantly larger than the Td-C and Tm-Td joints (p<0.05). Joint movement in the transverse plane (about the pronation/supination axis) during narrowing and widening of CAW is represented in Figure 2.

DISCUSSION:
The largest motion observed for each joint occurred in the pronation/supination axis. This mobility about the pronation/supination axis was expected as it directly corresponds with variation of the CAW. H-C joint was the most mobile joint with rotation about the ulnar/radial deviation axis, which is also true for rotation about the pronation/supination axis although it was not significant. Our results report mobility of the Td-C and Tm-Td joints which differs from previously reported during normal wrist motion. However, the mobility of the Td-C and Tm-Td joints observed in this study coincides with the observed external rotations of the trapezoid and trapezium following carpal tunnel release. Furthermore, we demonstrated that even though the H-C joint exhibited the greatest mobility, all three joints of the distal carpal row contribute to narrowing/widening of the CAW. This study has also shown that narrowing/widening of the CAW is not strictly limited to rotations about the pronation/supination axis, but a complex combination of rotations about all three axes.

SIGNIFICANCE:
This study provides information on the relative movement of the distal carpal joints. This gives insight into the biomechanics of the wrist relevant for both surgery and therapeutic manipulation.

REFERENCES:

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