Conformational Changes in the Carpus During Finger Trap Distraction

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Purpose Wrist distraction is a common treatment maneuver used clinically for the reduction of distal radial fractures and midcarpal dislocations. Wrist distraction is also required during wrist arthroscopy to access the radiocarpal joint and has been used as a test for scapholunate ligament injury. However, the effect of a distraction load on the normal wrist has not been well studied. The purpose of this study was to measure the three-dimensional conformational changes of the carpal bones in the normal wrist as a result of a static distractive load.

Methods Using computed tomography, the dominant wrists of 14 healthy volunteers were scanned at rest and during application of 98 N of distraction. Load was applied using finger traps, and volunteers were encouraged to relax their forearm muscles and to allow distraction of the wrist. The motions of the bones in the wrist were tracked between the unloaded and loaded trial using markerless bone registration. The average displacement vector of each bone relative to the radius was calculated, as were the interbone distances for 20 bone–bone interactions. Joint separation was estimated at the radiocarpal, midcarpal, and carpometacarpal joints in the direction of loading using the radius, lunate, capitate, and third metacarpal.

Results With loading, the distance between the radius and third metacarpal increased an average of 3.3 mm ± 3.1 in the direction of loading. This separation was primarily in the axial direction at the radiocarpal (1.0 mm ± 1.0) and midcarpal (2.0 mm ± 1.7) joints. There were minimal changes in the transverse direction within the distal row, although the proximal row narrowed by 0.98 mm ± 0.7. Distraction between the radius and scaphoid (2.5 mm ± 2.2) was 2.4 times greater than that between the radius and lunate (1.0 mm ± 1.0).

Conclusions Carpal distraction has a significant ($p < .01$) effect on the conformation of the carpus, especially at the radiocarpal and midcarpal joints. In the normal wrist, external traction causes twice as much distraction at the lunocapitate joint than at the radiolunate joint. *(J Hand Surg 2010;35A:237–244. © 2010 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)*

Key words Carpal, distraction, kinematics, lunate, scaphoid.

Wrist distraction is a common treatment maneuver with a variety of clinical uses. External traction on the wrist has been shown to assist in the reduction of intra-articular distal radius fractures, where the tension across the fracture by the soft tissues is used to help align the fracture fragments (ie, ligamentotaxis).[1] Wrist distraction is required during wrist arthroscopy to access the radiocarpal, mid-

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carpal, and radioulnar joints,[2,3] and it has been used as a test for scapholunate ligament injury.[4,5]

Much of what is currently known about the biomechanics of wrist distraction has been obtained from cadaver testing. Simple axial distraction studies have reported large variability in the load-deformation behavior of individual wrists,[6] and a subsequent investigation of three-dimensional carpal kinematics during wrist distraction has demonstrated that distraction alters carpal motion, specifically that it reduces radiocarpal motion during extension and increases radiocarpal motion during flexion.[7]

Accurate data on distraction-induced changes in the carpus has applications for both clinicians and basic scientists. A handful of studies have suggested that carpal distraction is associated with negative clinical outcomes.[8,9] For example, some authors have the opinion that distraction can cause neural damage[10,11]; however, at this point causation has not been definitively established. An understanding of the conformational changes in the carpus during distraction *in vivo* will be useful for the establishment of safe limits for distractive maneuvers used to diagnose wrist ligament injury. From a basic science perspective, data on bone motions during distraction can provide crucial input for computer models designed to estimate the mechanical properties of the carpal ligaments.

Accordingly, the purpose of this study was to quantify the three-dimensional changes in separation and rotation of the bones in the normal carpus induced by static distractive loading. In addition, given that carpal bone size[12] and ligamentous laxity vary with gender,[13–15] we investigated whether there were any gender-related differences in bone-to-bone separation with distraction.

MATERIALS AND METHODS

Volunteer recruitment and computed tomography scanning

After obtaining institutional review board approval, 14 healthy right-handed volunteers (7 men and 7 women; average age, 25 y; range, 21–30 y) were recruited into the study. Exclusion criteria included a history of wrist injury, wrist surgery, or systemic or metabolic disease that could alter the soft tissue structures in the wrist.

Computed tomography (CT) images were generated of each subject's dominant wrist (GE Lightspeed 16 CT scanner; GE Healthcare, Waukesha, WI). Scanning was performed with the wrist positioned in the center of the gantry, using a 14-cm scan field of view and tube settings of 80 kVp and 80 mA. This yielded images with an in-plane resolution of 0.3 mm × 0.3 mm. The slice interval was 0.6 mm.

Subjects were positioned prone on the scanning table, with their dominant arm extended above their head along the center of the CT table and their hand oriented in a pronated position (palm flat on the CT table). Scans were performed in both the loaded and unloaded states. An additional reference scan was performed with the wrist in neutral to yield images for the segmentation and registration algorithms. For scans in the unloaded state, the wrist was first briefly loaded and then unloaded. The scans were then performed immediately after the weight was removed. This sequence minimized wrist motion between the unloaded and loaded states. For scans in the loaded state, nylon finger traps and a dead weight were used to apply and distribute 98 N (10 kg) equally across all 5 digits. The dead weight was attached to the finger traps with a short cord that was routed over a pulley at the end of the scanning table. During scanning, the subjects were instructed to relax their forearm muscles and allow the load to distract their wrist. The 98 N load was comfortably tolerated by the study subjects and is consistent with loads used in previous studies.[16–19]

Carpal tracking

Changes in bone location and posture were determined to within 0.5 mm and 1° using established markerless registration methodologies.[20] In brief, the radius, ulna, carpals, and metacarpals for each volunteer were manually segmented from the reference neutral scan, yielding three-dimensional surface models (Mimics 9.11; Materialise, Leuven, Belgium). Bone centroids and inertial axes were calculated from the three-dimensional surface models of each fully imaged bone (assuming uniform density).[21,22] "Alternate centroids" were created for the partially imaged bones. For the radius and ulna, the alternate centroids were defined by the origins of their respective coordinate systems (described later), and for the metacarpal bones, alternate centroids were defined by points manually selected at the approximate center of the metacarpal heads.

To create a common reference frame for between-subject analysis, a radius-based coordinate system was defined for each subject using readily identifiable anatomic landmarks.[21] The x axis was defined by the long axis of the radius (positive proximal), the y axis was oriented in the radial direction (defined by a vector orthogonal to the x axis and passing through the radial styloid), and the z axis was oriented palmarly, orthogonal to both the x and y axes (calculated as the cross-product of the x and y axes). The origin of the coordinate system was located at the point on the radiocarpal surface of the radius model intersected by the x axis,