Changes at the Radiocarpal and Midcarpal Joints with Wrist Distraction

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INTRODUCTION:

Reducing the load on the articular cartilage in the carpus via wrist distraction is a potential treatment for wrist injuries, in particular intra-articular fractures [1]. However, the effect of wrist distraction on the conformation of the carpus is not well understood, and there have been reports of complications related to wrist distraction [2].

The effect of wrist distraction on carpal kinematics has been studied in vitro [3], but to date there have been no studies that have investigated changes associated with the application of a destructive load across the wrist in vivo. Understanding the influence of distraction on carpal spacing should improve our ability to predict when distraction might be appropriate or contraindicated.

Accordingly, this study was performed to evaluate changes in carpal bone spacing due to static wrist distraction. We hypothesized that during wrist distraction (with a relaxed forearm) the carpus would separate equally at the radiocarpal, midcarpal and carpal-metacarpal joints.

METHODS:

After IRB approval and informed consent, 7 healthy male and 7 healthy female (average age 24.9, range 21-31), right-hand dominant volunteers were enrolled in the study. Nylon finger traps (Instrument Specialists Inc., Boerne, Texas) were applied to the digits of each volunteer’s right hand such that a single distraction load directed along the outstretched middle finger would load the fingers and thumb equally.

Each volunteer was then positioned on the CT table in a prone position with their upper arm fully flexed and their hand extended along the CT table into the gantry of the CT machine. The traps were connected to a custom written software that allowed a static distraction load to be applied via dead weights. CT volume images were acquired of the unloaded wrist and after the application a 98 N (10kg) distraction load. CT scanning was performed at 80kVp and 80mA, with an in-plane image resolution of 0.3 mm x 0.3 mm and 0.6 mm slice interval. For the unloaded trial, the 98N distraction load was briefly applied to align the wrist in a clinical neutral posture and then removed for scanning. During the distraction trial the volunteers were instructed to relax their forearm muscles and allow the load to sublux their wrists.

Carpal posture and bone locations were calculated using an established CT-based markerless bone registration methodology [4]. In brief, Mimics 9.11 (Materialize, Leuven, Belgium) was used for segmentation, yielding closed 3-D surface models of each carpal bone, the radius and ulna, and the metacarpals. A combination of custom C++ and Matlab (The MathWorks, Natick, Massachusetts) code was then used to quantify changes in position as the bones were loaded. Wrist position was defined by the orientation of the long axis of the third metacarpal with respect to the radius. All of the analyses were performed with respect to a radius-based coordinate system whose origin was located at the center of the radiocarpal joint surface [5] and whose x-axis was oriented in the distal-to-proximal direction along the central axis of the radial diaphysis. The centroids of the carpal bones were calculated from the 3-D surface models assuming uniform bone density.

Changes in interbone distances were described along the distal-proximal coordinate axis (x-axis): radiocarpal (RC) distance was defined as the distance between the origin of the radial coordinate system and the centroid of the lunate; midcarpal (MC) distance was defined to be the distance between the centroid of the lunate and the centroid of the capitale; and carpal-3rd metacarpal (CMC) distance was defined to be the distance between the centroid of the capitale and a manually selected point on the third metacarpal head in the center of the capitale articulating surface.

The significance of the changes in the interbone distance at the RC, MC and CMC joints with distraction loading were determined using a two-way, repeated measures ANOVA with Tukey post-hoc test with alpha set to 0.05 a priori. Significance differences in the amount of distraction at each joint were determined using a one-way, repeated measures ANOVA with a Tukey post-hoc test and alpha set to 0.05 a priori.

RESULTS:

After distraction loading, the overall interbone distance (RC+MC+CMC) increased by 2.7 ± 3.7 mm, which was distributed largely between the RC and MC joints (Fig. 1). At the RC joint, distraction significantly (p=0.02) increased interbone distance by 1.0 ± 1.0 mm. The interbone distance between the lunate and the capitale (MC joint) also increased significantly (p < 0.01) after distraction, by 2.0 ± 2.2 mm. The change in interbone distance at the MC joint was significantly greater (p=0.03) then the change in interbone distance at the RC joint. There was no change in interbone distance at the CMC joint with distraction (p=0.49), which was significantly less then the change at the RC (p<0.01) and MC (p<0.01) joints (Fig. 2). After distraction loading, rotation of the wrist averaged 6 ± 4° and the average rotation of each carpal bone was less than 10°.

DISCUSSION:

This study was designed to determine how static distraction affects interbone spacing at the radiocarpal, midcarpal, and carpal-metacarpal joints. We disproved our original hypothesis of equal joint separation, finding instead that overall wrist distraction was dominated by increased interbone distances at the RC and MC joints, with no significant separation at the CMC joint (Fig. 2). Based on these findings, wrist distraction should decrease the cartilage loading at the radiolunate and lunocapitate joints but may not affect the joint loading at the capitale-third metacarpal joint. That distraction was greatest at the RC and MC is not necessarily unexpected, given the significant mobility of the scaphoid, lunate and capitale during normal wrist motion [6]. Similarly, limited CMC distraction is not unexpected given the tight ligamentous attachments and the constraints of the capitale third metacarpal during normal wrist motion [7].

Though our findings were significant, it is possible that our data actually under-represented what normally occurs during wrist distraction. While we asked our volunteers to relax during loading, and attempted to confirm this through palpation, it is possible that some volunteers partially resisted the loading via forearm muscle contraction. This study does provide some insight into the mechanical behavior of the ligamentous carpus, which to date is scant in the literature.

REFERENCES:


ACKNOWLEDGEMENTS: NIH AR0053648