CARPAL BONE POSTURES AND MOTIONS ARE ABNORMAL IN BOTH WRISTS OF PATIENTS WITH UNILATERAL SCAPHOLUNATE INTEROSSEOUS LIGAMENT TEARS

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INTRODUCTION

Motion of the human wrist is accomplished through complex kinematic patterns of the eight carpal bones, radius and ulna. Due to their small size, measuring the three-dimensional (3-D) kinematics of the carpal bones is a challenge, and has been achieved only in a small number of cadaveric (in vitro) studies. Kinematic analysis based on bone features and markerless registration is a potentially valuable tool for in vivo studies and clinical use, as it can accurately track joint motion without invasive markers [1,2].

Using one such markerless bone registration (MBR) method, we have studied normal healthy carpal motion in four directions of wrist motion. The purpose of this study was to determine if and how 3-D kinematics are altered in vivo when the scapholunate interosseous ligament (SLIL) is torn.

METHODS

Using computed tomography (CT)-based MBR, carpal bone postures and kinematics were determined for both wrists (defined as Injured and Uninjured) of 8 subjects with unilateral SLIL injuries (7 males, 1 female, avg. age: 38 [range: 20-54]). These values were compared to data from 20 healthy wrists defined as Normal (5 male, 5 female, avg. age: 26 [range: 21-47]).

Image Acquisition. After IRB approval and informed consent, both wrists were scanned simultaneously (voxel size: (0.2 to 0.9) x 1 mm³) as patients held plastic grips aligned by protractors in neutral, 30º and 60º of flexion and extension, 20º and 40º of ulnar deviation, and 20º of radial deviation.

Bone Segmentation & Registration. Cortical surfaces of the carpal bones, radius, and ulna were segmented from the CT images. Left wrists were mathematically reflected into right wrists to simplify analyses. Bone postures and kinematics were calculated relative to the neutral position [2].

Data Analysis. Flexion(+)/extension(-) posture of a bone was defined as the angle between the sagittal plane projection of its principal inertia axis (I₁) and the long axis of the radius. Carpal bone motions were described using helical axis of motion (HAM) variables, consisting of a rotation about and translation along a unique axis, with respect to a coordinate system fixed in the distal radius. Bone rotations were plotted as a function of capitate rotation and fit with regression lines, for wrist flexion and extension. Capitate rotation was used as a measure of wrist rotation.

Statistics. A one-way ANOVA and Dunnett multiple comparison post-tests were used to compare postures of the bones in the neutral wrist position. Slopes of rotation regression lines for Injured and Uninjured wrists (n = 8), and Normal wrists (n = 20), were compared using Student's t-tests with a Bonferonni correction factor for multiple comparisons.

RESULTS AND DISCUSSION

Carpal Bone Neutral Postures. There were no significant differences between the neutral postures of the capitate bones in Injured (-50º ± 19), Uninjured (-46º ± 23), and Normal subjects (-45º ± 9). This is important because all bone rotations were examined with respect to rotations of the capitate from its neutral posture.
Both the Injured (56° ± 13) and Uninjured (53° ± 7) lunates, however, were significantly less flexed (p < 0.01) than the lunate in Normal wrists (83° ± 8) in the neutral position (Figure 1). Both the Injured (34° ± 16) and Uninjured (27° ± 20) scaphoids were also significantly less flexed (p < 0.05) than Normal (49° ± 11).

Carpal Bone Rotations. In extension, Injured and Uninjured lunates rotated 35% and 26% as much as the capitate, respectively, each rotating significantly less (p < 0.01) than the Normal lunate, which rotated 69% as much as the capitate. They extended a similar amount to one another, however (p = 0.77). In flexion, the Injured and Uninjured scaphoids rotated 80% and 89% as much as the capitate, respectively, each rotating significantly more (p < 0.01) than the Normal scaphoid, which rotated 73% as much as the capitate. Again, their flexion was similar to one another (p = 0.53).

Varying bone rotations may be attributable to varying bone postures, though the specific relation could not be proven in this study. For example, neutral Injured and Uninjured lunates were more extended than those of Normal subjects, leaving less range for further extension.

Remarkably, Feipel and Rooze have also recently reported abnormal bilateral kinematics in subjects with a variety of unilateral soft and hard tissue injuries, however they did not describe neutral posture differences [3]. Arkless, too, described a case for which a patient had post-traumatic unilateral wrist pain, but roentgenograms showed bilateral widening of the scapholunate joint [4]. The mechanism responsible for these bilateral differences has not yet been identified. In our study it is possible that aging affected wrist bone posture; mean injured subject age was 12 years greater than that of Normal subjects.

Figure 1: 3-D ulnar view of the neutral postures (I1) of Injured, Uninjured, and Normal lunates. The capitate and radius are also rendered in dark grey. To the right are lunate posture angular histograms. Injured and Uninjured lunate postures were initially significantly less flexed than Normal, but similar to one another.

SUMMARY
Neutral postures of the scaphoid and lunate in wrists with SLIL tears were different from those of Normal subjects, though capitate postures, which were used as a measure of wrist position, were the same. Contralateral uninjured wrists were similar to the injured wrist and different from Normal. These postural differences may explain the abnormal bone rotations. Further research is needed to understand and confirm bilaterally abnormal wrist bone posture and kinematics in subjects with unilateral SLIL injuries.

REFERENCES

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