INTERFRAGMENTARY MOTION IN PATIENTS WITH SCAPHOID NONUNIONS

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INTRODUCTION:
Nonunion of the carpal scaphoid bone of the wrist is common and disabling. If left untreated non-union leads to degenerative changes and carpal collapse. Of the 35,000 scaphoid fractures in the US each year, as many as 12 percent fail to unite, regardless of treatment [1]. There are two theories for the high rate of scaphoid nonunion: tenuous vascularization at the fracture site and excessive interfragmentary motion. Interfragmentary motion and altered carpal kinematics have been investigated in cadavers [2], but the findings have never been confirmed in vivo. This study was performed to quantify the three-dimensional (3-D) motion of the proximal and distal fragments of the scaphoid and lunate at various wrist positions in patients with scaphoid nonunions.

METHODS:
After IRB approval, informed consent was obtained from six patients with clinically confirmed unilateral scaphoid nonunions (3 male, 3 female; avg. age 31, range 18-38). Computed tomography (CT) scans were performed on both wrists in static positions of neutral and eight positions of circumduction. Established segmentation and registration methods were used to calculate 3-D carpal kinematics from the sequence of CT volume images [3]. Carpal bone motion was described relative to the fixed radius using helical axis of motion variables. The proximal and distal scaphoid fragments were tracked as separate carpal bones. All left wrists were mathematically converted into right wrists to facilitate comparisons between uninjured and injured wrists.

The motion of the distal and proximal scaphoid fragments were described as a function of wrist position (defined by capitate position). Interfragmentary motion was quantified by calculating the rotation of the distal fragment with respect to the proximal fragment, as well as by the change in distance between points on the volar, radial, ulnar, and dorsal margin of the proximal fragment and points nearest on the distal fragment (Fig. 1).

Linear regression was used to evaluate correlations between carpal bone rotation and wrist position. Changes in scaphoid and lunate kinematics with injury were examined by comparing radioscpaphoid (and distal and proximal fragment) and radiolunate flexion/extension rotation as a percentage of wrist position (radiocapitate rotation). Change in distances between fragments was examined by averaging the maximum change in distance across subjects at each of the four points.

RESULTS:
In uninjured wrists, the scaphoid closely tracked the capitate in wrist extension, but rotated only 54% (R²=0.60) as much as the capitate rotated in wrist flexion (Figure 2). In the injured wrists, the distal fragment rotated similar to the intact scaphoid, while the proximal fragment lagged behind. We found that the distal scaphoid fragment extended 93% (R²=0.84) as much as the capitate during wrist extension (compared to 101% for the intact scaphoid), while in flexion it rotated 58% (R²=0.61) as much as the capitate (compared to 54% for the intact scaphoid). In contrast, the proximal fragment rotated only 61% (R²=0.37) as much as the capitate during wrist extension, and only 39% (R²=0.41) as much during wrist flexion.

The differences in proximal and distal fragment rotation resulted in substantial interfragmentary motion that significantly increased with increasing wrist motion (P<0.01). Rotation of the distal fragment relative to the proximal fragment was 34% of overall wrist flexion (R²=0.24) and 35% of wrist extension (R²=0.30). Across all subjects and wrist positions, the average maximum change in distance between the two fragments was 1.35mm at the volar point, 1.17mm at the ulnar point, 1.31mm at the dorsal point and, 1.31mm at the radial point (Fig. 1).

DISCUSSION:
This study was performed to evaluate interfragmentary motion in vivo in patients with clinically documented scaphoid nonunion. We found significant motion between the two scaphoid fragments, as well as altered kinematics of the lunate bone in the injured wrists. The magnitude of the motion was on the order of 1 mm at the fracture, which is more than enough to inhibit bone healing. Our finding of increased lunocapitate motion in the injured wrists also is consistent the supposition that the scaphoid functionally links the distal and proximal carpal rows in normal wrists. With scaphoid fracture, the proximal and distal carpal rows are unlinked and lunocapitate motion increases.

The limitations of our study include a relatively low sample number and the limitations inherent in calculating kinematics from static postures. Despite the low R² values, the data generated in this study from the uninjured wrists is consistent with prior studies, and decreased motion of the lunate and proximal scaphoid in the injured wrist is consistent with cadaver models. The advantages of the approach we used are that the 3-D kinematics are acquired in vivo and without the use of invasive markers.


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Figure 1. Volar view of the fractured scaphoid (distal fragment on top). Blue bars are the average maximum change in distance between the two fragments at the given locations.

Figure 2. Regression lines (R² values) of carpal bone motion in injured (n = 6) and contralateral uninjured wrists (n = 6). The distal fragment of the scaphoid rotated similar to the capitate and to the uninjured scaphoid, while the proximal fragment lagged in both flexion and extension (% of wrist position listed).

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