Scaphoid Morphology and Alternate Pin Configuration in the Treatment of Scaphoid Nonunion

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DISCLOSURES: Francis E. Sharpe (N); Erika Hookasian (N); Jenna M. Wahbeh (N); Saeed Mohammad (N); Sumant S. Iyer (N); Milan Stevanovic (N); Sang-Hyun Park (N); Sophia N. Sangiorgio (N); Edward Ebramzadeh (N)

INTRODUCTION: Scaphoid fractures account for 60% of all carpal fractures. These fractures are notorious for their propensity to display a delayed union or non-union. Various surgical approaches can be utilized to securely fix a scaphoid fracture. Immobilization or casting can be considered a viable option for stable, non-displaced fractures. However, surgical stabilization has been championed for the treatment of scaphoid fractures. K-Wire fixations are typically used when the scaphoid fragments are too small to accommodate a screw and as an aggressive approach to non-displaced fractures to decrease the risk of nonunion and time required for external immobilization. K-wire fixation has long been the preferred method of fixation when there is minimal remaining bone, especially in the proximal pole fragments. These wires can be spaced to provide broader stabilization at the fracture site and are more flexible during insertion, resulting in decreased stress shielding. There are limited biomechanical studies regarding the method of K-wire configurations for scaphoid fixation. Divergent configurations were found to be more stable in a finite-element model, however parallel K-wires may not be as ideal as they cannot sustain loads applied in the direction of their axis. Therefore, the aim of the present study is to investigate the strength and stiffness of convergent and parallel K-wire configurations with a biomechanical model using a simulated non-union with a 3-mm gap.

METHODS: Nine matched paired cadaveric scaphoids were harvested from will-bodied donors by an experienced orthopaedic surgeon and relevant geometric measurements were obtained. A simulated nonunion fracture was created in each specimen. Mid-points of each specimen were identified to ensure reproducibility of each configuration. A 3-mm gap was created in each specimen to replicate the degree of gaping that typically occurs due to scaphoid nonunion. Two K-Wire fixation orientations were performed: either parallel or convergent pin placements. Following successful fixation, radiographic images were taken to confirm the screw placements. Biomechanical testing was conducted using a six-degree-of-freedom materials testing system under 1-mm of cantilever bending. The proximal end was potted at 45° to the horizontal axis. Motion tracker flags were rigidly attached to the proximal fragment of the scaphoid and to the distal potted fragment. A dorsal to volar cantilever load was continuously applied at a rate of 0.5mm/s for 10 cycles until the maximum actuator deflection of 1 mm. Interfragmentary motions and the load applied for each cycle were continuously measured throughout the duration of the test. Relative motions of the proximal and distal fragments were filtered and calculated by a custom MATLAB program to calculate the average cyclic motion and the stiffness of each construct. Paired t-tests were done to calculate significance between pairs.

RESULTS: Seventeen cadaveric scaphoids were successfully tested under 1mm loading. One specimen was not tested as, prior to testing, the specimen was unstable and the pins fell out. Relative motions between the distal and proximal ends of the bone, along with the force required, were continuously measured during testing. The maximum interfragmentary motion under 1 mm cantilever bending for convergent was 0.83 ± 0.83 mm and 0.65 ± 0.19 mm for parallel (p = 0.57). Stiffness values were then extracted from force vs. displacement graphs for each specimen. The average stiffness of the convergent pin configurations in 1mm testing was 77.6 ± 53.7 and the stiffness values for parallel were 86.3 ± 83.4 Pa (p = 0.75). The average of the relevant geometries for the scaphoid specimen are shown in Table and Figure 1.

DISCUSSION: Parallel and convergent K-Wire configurations are both common methods of fracture fixation in the scaphoid. However, the optimum configuration of K-wires is still unknown, and few biomechanical studies have compared scaphoid fracture fixation configurations in a cadaveric model. In a cadaveric model of the scaphoid, the large variability in specimen size as seen in their coefficients of variation ultimately seemed to outweigh the potential benefits that may be gained with utilizing alternate pin configurations for scaphoid fixation.

SIGNIFICANCE/CLINICAL RELEVANCE: The present study provides biomechanical data comparing the stability of a parallel and convergent fixation configuration in a scaphoid cadaveric model, as well as average geometric data for eighteen scaphoid specimens. There is no clear evidence demonstrating a stiffer construct with either pin configuration, as both seem to have comparable stiffness values. Further clinical studies are indicated to assess the outcomes of patients with parallel or convergent fixation configurations.

Table 1: Scaphoid Specimen Geometry

<table>
<thead>
<tr>
<th></th>
<th>Length (mm)</th>
<th>Distal Width (mm)</th>
<th>Waist Width (mm)</th>
<th>Proximal Width (mm)</th>
<th>Distal Thickness (mm)</th>
<th>Waist Thickness (mm)</th>
<th>Proximal Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergent</td>
<td>28.8 ± 2.6</td>
<td>13.3 ± 2.4</td>
<td>12.1 ± 2.3</td>
<td>13.4 ± 3.8</td>
<td>12.7 ± 3.4</td>
<td>12.2 ± 2.3</td>
<td>15.1 ± 2.9</td>
</tr>
<tr>
<td>Parallel</td>
<td>28.8 ± 2.9</td>
<td>13.6 ± 2.2</td>
<td>12.1 ± 1.4</td>
<td>12.5 ± 3.4</td>
<td>13 ± 2.6</td>
<td>12.4 ± 1.6</td>
<td>15 ± 2.7</td>
</tr>
<tr>
<td>Both</td>
<td>28.9 ± 2.6</td>
<td>13.4 ± 2.2</td>
<td>12.1 ± 1.8</td>
<td>13 ± 3.4</td>
<td>12.8 ± 2.8</td>
<td>12.3 ± 1.8</td>
<td>15.1 ± 2.7</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>9.0</td>
<td>16.4</td>
<td>14.9</td>
<td>26.2</td>
<td>21.9</td>
<td>14.6</td>
<td>17.9</td>
</tr>
</tbody>
</table>

Figure 1: Geometric lengths measured for all cadaveric scaphoid specimens.

Figure 2: X-ray image of two match paired specimen with fixed scaphoid fracture. Specimen 1 has parallel pin configuration and Specimen 2 has convergent configuration.