THE SCAPHOTRAPEZIO-TRAPEZOIDAL (STT) JOINT:
AN ANALYSIS OF IN-VIVO STT MOTION IN FLEXION, EXTENSION, AND ULNAR DEVIATION

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INTRODUCTION
Current theories describing the mechanics of the STT joint are based on a cadaveric study (n=3) by Moritomo et al. [1]. These include two hypotheses about how the trapezoid and trapezium move with respect to the scaphoid that may have important clinical significance, if accurate. First, the trapezoid and trapezium are rigidly linked and travel as a unit. Second, the STT is a single degree of freedom joint, i.e. the trapezoid and trapezium follow a single path of rotation (between ulnolateral and radial deviation) during all directions of wrist motion. We interpret this, also to mean that the amount of trapezoid and trapezium motion depends only on the magnitude of wrist orientation and is independent of direction. The purpose of this study is to test these hypotheses with in-vivo data and to describe the motion of the STT joint.

METHODS
An IRB approval and informed consent was obtained from each of 10 healthy volunteers (5 male, 5 female, avg. age: 26 [range: 21-47]). Computed tomography scans were performed simultaneously on both wrists of each volunteer in neutral, 30° and 60° of flexion and extension, and 20° and 40° of ulnar deviation. Carpal bone kinematics were calculated using a markerless bone registration algorithm [2]. Wrist position was defined by the magnitude and direction of capitate orientation relative to the radius. Trapezoid and trapezium kinematics were determined relative to the scaphoid.

In order to determine whether the trapezoid and trapezium move as a rigid unit, we measured the centroid spacing, or the distance between the centroids of the trapezoid and trapezium in neutral and maximum flexion, extension, and ulnar deviation. Paired Student’s t tests were used to determine if the spacing in the maximum wrist positions was significantly different from neutral spacing.

To determine whether the STT is a single degree of freedom joint, we evaluated two kinematic parameters: centroid displacement and trapezoid-trapezium centroid pair orientation. Neither should vary with the direction of wrist position if the STT is a single degree of freedom joint. We first measured how far the trapezoid and trapezium centroids displaced with respect to their locations in the neutral position. For rotation about a single axis, the relationship between trapezoid and trapezium displacements should not change with direction of wrist position. Paired Student’s t tests were used to determine if the differences between the trapezoid and trapezium centroid displacements at each wrist position were significant. For each investigated position of wrist motion, we then measured the angle between the two line segments connecting the trapezoid and trapezium centroids in a given wrist position and in the neutral position. If the amount of trapezoid and trapezium rotation is dependent only on the magnitude of wrist position, then all of the orientation angles should fall on a single path.

RESULTS
In response to the question of whether the trapezoid and trapezium move as a unit, our data confirmed that the spacing between the trapezoid and trapezium remained relatively constant during ulnar deviation and extension, but increased slightly at maximum flexion (mean diff = -0.37mm, p<0.01, Table 1).

Table 1: Trapezoid-Trapezium Centroid Spacing (mm, µ±σ)

<table>
<thead>
<tr>
<th></th>
<th>Neutral</th>
<th>Max Ext</th>
<th>Max Flx</th>
<th>Max Uln Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5 ± 1.0</td>
<td>12.5 ± 0.9</td>
<td>*12.9 ± 1.0</td>
<td>12.6 ± 1.0</td>
<td></td>
</tr>
</tbody>
</table>

In response to the question of whether the STT is a single degree of freedom joint, the kinematic data demonstrated that the STT joint articulates with more than one degree of freedom because movement of the trapezoid and trapezium centroids differed with direction of wrist position. A comparison of the centroid displacements showed that the trapezoid’s displacements were significantly greater than the trapezium’s in flexion (p<0.01), but less than the trapezium’s in extension (p<0.001, Table 2). Furthermore, in ulnar deviation, there are no significant differences between the two bones’ centroid displacements, implying that the two bones do not rotate the same amount about the same axis in each direction of motion. The trapezoid-trapezium centroid pair orientation angles indicated that the magnitude of STT joint motion depends both on direction and magnitude of wrist position. The orientation angles differed greatly in extension and ulnar deviation (Figure 1). Additionally, the orientation angles changed at different rates with respect to magnitude of wrist position in flexion (0.23), extension (0.14), and ulnar deviation (0.56).

Table 2: Trapezoid & Trapezium Centroid Displacements (mm, µ±σ)

<table>
<thead>
<tr>
<th></th>
<th>**Extension</th>
<th>*Flexion</th>
<th>Uln Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezoid</td>
<td>2.2±1.0</td>
<td>2.7±1.9</td>
<td>8.1±2.8</td>
</tr>
<tr>
<td>Trapezium</td>
<td>3.2±1.5</td>
<td>2.4±1.7</td>
<td>8.1±3.0</td>
</tr>
</tbody>
</table>

Figure 1: Graph of the angle (Orientation Angle) between the line segments that connect the trapezoid and trapezium centroids in a given wrist position and in the neutral position. Magnitude of wrist position was defined by capitate orientation angle. Orientation of the trapezoid-trapezium centroid pair varied with direction of wrist position such that ulnar deviation exhibited the greatest angles for a given capitate motion while extension exhibited the smallest angles.

DISCUSSION
Based on our study of in vivo kinematics, the trapezoid and trapezium centroids appear to be rigidly linked during extension and ulnar deviation but not at the extremes of flexion. During maximum flexion, our subjects’ bones diverged, though only by 0.37mm. Analysis of centroid data with respect to the scaphoid suggests that the STT joint is not a one-degree of freedom joint. There are two possible explanations for the trapezoid moving more than the trapezium in flexion, but less than the trapezium in extension: either the axis of rotation must change, or the trapezoid and trapezium must rotate different amounts about a single axis. The differences in trapezoid-trapezium centroid pair orientation imply that the amount of trapezoid and trapezium motion depends on the direction of wrist position as well as the magnitude.

Our results indicate that the trapezoid and trapezium centroids are rigidly linked in most wrist positions and that the STT motion occurs with more than one degree of freedom. Further analysis of the rotational data in combination with the centroid data above, and data from an increased range of wrist positions will lead to a more comprehensive understanding of the motion of the STT joint.

REFERENCES:

ACKNOWLEDGEMENTS
Funded in part by NIH AR44005 and OREF Grant # 02-008.

49th Annual Meeting of the Orthopaedic Research Society
Poster #1201