Kinematics of the wrist

EVIDENCE FOR TWO TYPES OF MOVEMENT

Barry D. Ferris, Jeremy Stanton, Javier Zamora

From Barnet General Hospital, Barnet, England

We enrolled 34 normal volunteers to test the hypothesis that there were two types of movement of the wrist. On lateral radiographs two distinct patterns of movement emerged. Some volunteers showed extensive rotation of the lunate with a mean range of dorsiflexion of 65°, while others had a mean range of 50°. The extensive rotators were associated with a greater excursion of the centre of articulation of the wrist. It is suggested that dynamic external fixation of a fracture of the distal radius carries with it the risk of stretching the ligaments or causing volar displacement at the site of the fracture.

**Subjects and Methods**

Radiographs were taken of the non-dominant wrists of 34 subjects in five standard projections with the shoulder abducted to 90° and the elbow flexed to 90°. Two posteroanterior views were taken with the wrist in full active radial and ulnar deviation and three lateral views with the wrist in full active dorsiflexion, neutral and in full active palmar flexion.

On the posteroanterior radiographs, measurement of the length of the scaphoid and the degree of scaphoid translation were made in both radial and ulnar deviation and the CR index and translation ratio calculated as described by Craig and Stanley.

Movement of the wrist during flexion and extension takes place at the radiolunate and lunate-capitate joints. Because of the complexity of its kinematics, many studies describe multiple readings on a few specimens or volunteers, although a few have reported more extensive series of subjects. There is debate as to whether the wrist functions as a row of carpal bones or as a column. Recently, Craig and Stanley suggested that there may be two types of wrist, one functioning as a row and one as a column. Their comparative study was based on measurements of lengthening and shortening of the scaphoid as seen on the posteroanterior view of the wrist. Our study is based on the senior author’s observation that, when the wrist is viewed from the lateral side during dorsal and palmar flexion, the lunate seems to rotate more in some wrists than others. If this observation is true there are implications for dynamic external fixation of the wrist. Our study was designed to investigate whether there are two types of wrist movement as seen on the lateral view, and to relate this observation to the study by Craig and Stanley of posteroanterior carpal kinematics.

**Subjects and Methods**

Radiographs were taken of the non-dominant wrists of 34 subjects in five standard projections with the shoulder abducted to 90° and the elbow flexed to 90°. Two posteroanterior views were taken with the wrist in full active radial and ulnar deviation and three lateral views with the wrist in full active dorsiflexion, neutral and in full active palmar flexion.

On the posteroanterior radiographs, measurement of the length of the scaphoid and the degree of scaphoid translation were made in both radial and ulnar deviation and the CR index and translation ratio calculated as described by Craig and Stanley. The CR index is the length of the scaphoid in radial deviation divided by its length in ulnar deviation. We measured the scapholunate gap in ulnar deviation on the radiographs to exclude occult scapholunate instability and the angle of volar inclination of the articular surface of the distal radius on the lateral films. The angles of dorsal and palmar flexion of the lunate and capitate in relation to the radius were also determined.

The range of flexion and extension of the capitate within the lunate fossa was calculated from these figures. The centre of the capitate was located and the distance which it moved during dorsal and palmar flexion was measured from a line projected from the volar surface of the radius. The proximal and distal movements of the centre of the capitate during dorsal and palmar flexion were measured from a fixed point on the distal radius. To eliminate error due to magnification, the result was expressed as a percentage of the length of the scaphoid in radial deviation. We used active movements of the wrist to eliminate non-physiological positions attributable to differences in tension of the ligaments in forced passive movements.

Statistical analysis was by the Student t-test and chi-squared test on a personal computer using analysis tools in Microsoft Excel version 7.0.
Results

We studied 34 subjects, 19 men and 15 women, with a mean age of 38.8 years (23 to 71). The mean volar inclination was 13.3 ± 3.3° (7 to 13). The range of movement of the wrists is shown in Table I. Each measurement had a considerable range, a finding common to previous studies. The mean total range of wrist movement was 124.5°. The mean range of wrist flexion was 59.3°. This was fairly evenly divided, with 55.1% of the movement at the radiolunate joint and 44.9% at the lunate-capitate joint. The mean wrist extension was 65.2° with 38% of the movement at the radiolunate joint and 62% at the lunate-capitate joint. These findings are slightly different from those of Sarrafian et al.

The scapholunate gap did not exceed 2 mm in any wrist.

Statistical analysis showed that total extension of the wrist was significantly greater than flexion (Student’s t-test, \( t = 2.21; 0.05 > p > 0.02 \)). This finding was observed by Sarrafian et al., although they made no statistical analysis.

The CR index and translation ratio, as previously described, are shown in Table II along with the movement of the capitate during flexion and extension of the wrist. The centre of the capitate describes an arc during flexion and extension. Displacement in the dorsipalmar direction was about 43% of the length of the scaphoid. There was proximal to distal movement of about 10% of the length of the scaphoid. This may be an underestimate of the true movement since it was not always possible to obtain a lateral radiograph with the lunate precisely in the neutral position. In contrast with the previous study of Craigen and Stanley, we were unable to find any correlation between the CR index and the translation ratio despite regression analysis (\( r = 0.202 \)). The correlation previously reported was weak (\( r = 0.498 \)), but there were more subjects in that study. Therefore, although we could not detect a correlation we cannot exclude the possibility that there may be one.

There was no correlation between the CR index or the translation ratio with age or gender, particularly with the range of midcarpal or wrist movement. There were some gender differences. Women had significantly greater mean wrist flexion than men (65.1 ± 11.9° v 54.7 ± 14.2°; Student’s t-test, \( t = 2.26, 0.05 > p > 0.02 \)) but there was no gender difference in extension of the wrist. Those subjects with a volar angle greater than 13° had significantly greater radiolunate flexion (\( t = 1.746; p > 0.0098 \)). The angle of volar inclination of the distal radius was significantly greater in women than in men (\( t = 2.62; p > 0.01 \)). This would suggest that the increased wrist flexion noted in women may be due to the result of increased volar angulation, either genetic or developmental, rather than ligamentous laxity. The total movement between the lunate and the capitate was also greater in women (\( t = 2.51; 0.05 > p > 0.02 \)). There was significantly greater movement of the capitate in the dorsipalmar direction in men than in women (\( t = 4.77; p > 0.001 \)).

Plotting of the amount of lunate rotation on a frequency histogram (Fig. 1) tested the hypothesis that there were two types of lunate movement. This showed a bimodal distribution, suggesting that two groups were present. The mode was 57°. The range of movement of each group, above and below this value, was compared. We noted a significant difference between the means (50 ± 5.7° v 64.6 ± 4.5°; \( t = 2.04, 0.02 > p > 0.05 \)) suggesting that there is one group.

Table I. Range of movement (degrees) of the various components of the wrists of 34 volunteers

<table>
<thead>
<tr>
<th>Range of movement</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total movement</td>
<td>124.5 ± 18.4</td>
<td>79 to 159</td>
</tr>
<tr>
<td>Total flexion</td>
<td>59.3 ± 14.1</td>
<td>28 to 88</td>
</tr>
<tr>
<td>Total extension</td>
<td>65.2 ± 9.4</td>
<td>35 to 86</td>
</tr>
<tr>
<td>Radiolunate flexion</td>
<td>32.7 ± 9.3</td>
<td>6 to 57</td>
</tr>
<tr>
<td>Radiolunate extension</td>
<td>24.8 ± 5.7</td>
<td>14 to 37</td>
</tr>
<tr>
<td>Total radiolunate movement</td>
<td>57.7 ± 8.9</td>
<td>39 to 75</td>
</tr>
<tr>
<td>Lunate-capitate flexion</td>
<td>26.6 ± 14.1</td>
<td>-7 to +52</td>
</tr>
<tr>
<td>Lunate-capitate extension</td>
<td>40.4 ± 8.3</td>
<td>21 to 57</td>
</tr>
<tr>
<td>Total lunate-capitate movement</td>
<td>66.7 ± 17.1</td>
<td>39 to 99</td>
</tr>
</tbody>
</table>

Table II. Details of the CR index, translation ratio and capitate movement (percentage of the length of the scaphoid) for 34 volunteers

<table>
<thead>
<tr>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR index</td>
<td>0.79 ± 0.072</td>
</tr>
<tr>
<td>Translation ratio</td>
<td>0.27 ± 0.087</td>
</tr>
<tr>
<td>Capitate movement (%)</td>
<td></td>
</tr>
<tr>
<td>Proximal/distal</td>
<td>10.62 ± 7.02</td>
</tr>
<tr>
<td>Dorsal/palmar</td>
<td>43.20 ± 14.78</td>
</tr>
</tbody>
</table>
of ‘small’ or modest range lunate rotators, mean 50°, and another of ‘large’ rotators of greater range, mean 65°.

Comparing the two groups, the difference was attributable to increased extension of the wrist at both the radiolunate and lunate-capitate joints (t = 2.042; p > 0.05 and t = 2.048, 0.05 > p > 0.02, respectively). There was no difference in the ranges of flexion at these joints. As might be expected, wrists showing greater extension also had significantly greater displacement of the centre of the capitate in the dorsipalmar and proximodistal planes (t = 2.045 and t = 2.042, 0.05 > p > 0.02, respectively). There was no age or gender difference between the two groups, and therefore greater stiffness of the wrist in the older individuals does not account for this observation.

The CR index and translation ratio in the large rotator group were greater than those in the small rotator group (t = 2.042; p > 0.05 and t = 2.05, p > 0.05, respectively). An example of this group is shown in Figure 2. Craigen and Stanley would have described these as ‘row’ wrists. They found this to be more common in men, but in our study we found no difference in the gender distribution. Interestingly, in an early study of the wrists of 20 cadavers, Cyriax recorded the range of lunate rotation to be 55.5% of the total. This fits most closely with a large rotating wrist, 51.6% of total wrist movement in our series (Fig. 3).

Discussion

Craigen and Stanley found two types of function in their study of anteroposterior views of the wrist. They proposed that there was a spectrum which ranged from ‘row’ wrists to ‘column’ wrists. We were unable to confirm this, although we studied slightly fewer subjects. Our study of lateral views of the wrist has confirmed the impression that there are two types of movement of the dorsal wrist, those which have an increased angle of dorsiflexion at the lunate and those which do not. Wrists with greater rotation tend to have a high CR index and translation ratio. These function as a row as opposed to a column as described by Craigen and Stanley.

Compared with previous studies our mean value for total range of wrist movement, 124.5°, was greater than that observed by Youm et al (95°) and Ruby et al (112°), and similar to that of Sarrafian et al (121.9°), but less than that of Linscheid (150°). We have also shown that in the lateral plane there is no single centre of articulation. Dorsal and palmar flexion of the wrist is a composite of radiolunate and lunate-capitate movement (Figs 4a and 4b). In a study of six cadavers and six volunteers, Youm et al found the centre of flexion and extension to be located in the head of the capitate near the lunate. They found a total range of wrist movement of 95°, which is less than in most other studies. They also noted that the proximal and distal rows moved, but made no attempt to quantify by how much. Linscheid also observed that the instant centres of rotation of the lunate and capitate were separate. He suggested that one was located near the concavity of the lunate, and the other near the centre of the capitate.

We have shown that the centre of articulation of the wrist changes during dorsal and palmar flexion, particularly in dorsiflexion. Dynamic external fixators applied to the wrist provide only one centre of rotation. Thus, when a fixator applied for a distal radial fracture is dynamised it is possible for movement to occur at the site of the fracture (Fig. 4c) because the centre of rotation translates dorsally in the capitate during dorsiflexion. The fixed hinge of a dynamic fixator will prevent this movement and move the centre of articulation of the wrist to the centre of movement of the fixator. The effect is either to stretch the ligaments, which is unlikely since they are already taught because of ligamentotaxis, or to cause volar displacement of the distal radial fragment (Fig. 4c). The reverse pertains to palmar flexion. Cooney, Dobyns and Linscheid observed that distraction across the wrist, because of ligamentotaxis results in loss of movement. In a prospective study of static and dynamic external fixation of distal radial fractures, McQueen, Hajducka and Court-Brown and Sommerkamp

---

Fig. 2
Lateral radiograph of a small rotating lunate with dorsiflexion of 21°. The total wrist dorsiflexion is similar to that in Figure 3.

Fig. 3
Lateral radiograph of a large rotating lunate with dorsiflexion of 37°. There is apparent mild subluxation of the inferior part of the lunate.
et al. found no improvement in the range of movement. The latter found, however, that patients treated with static external fixation achieved greater wrist flexion at an earlier stage than the dynamised group. In the same study the dynamic external fixator group lost significantly more radial length; moreover, their cadaver study showed that movement is detectable at the site of the fracture with the use of a dynamic external fixator. This is explained by movement of the centre of articulation. It follows that dynamisation of externally fixed fractures of the distal radius should be considered carefully.

We have not analysed the movement of the opposite wrist and are therefore unable to say whether or not these features are symmetrical.

We have confirmed that dorsal and palmar flexion of the carpus is a composite movement of the radiolunate and lunate-capitate joints. We have found that there are two types of wrist movement, in some of which the lunate rotates more than in others. This finding did not correlate with a previous observation of movement at the wrist. With the observed movement of the centre of rotation there is a strong case for not using dynamic external fixators in the treatment of fractures of the distal radius. If such a fixator needs to be used it should be restricted to those wrists which are 'small' rotators of the lunate, assuming of course that it is possible to identify them before surgery.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References