The Association Between the Volar Aspect of the Distal Radial Diaphysis and the Lunate Rotation Center on Lateral View X-ray of the Wrist

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Purpose: For the treatment of severe distal radius fracture dislocations or malunions, especially those accompanied by intra-articular fractures, radiographic indexes based on the relationship between the carpus and radius are occasionally needed to achieve the ideal radiocarpal reconstruction. This study defined a reference point on the lunate and examined whether this point was located on a line extending along the volar aspect of the distal radial diaphysis on lateral radiographs of the wrist.

Methods: Two hundred one lateral wrist radiographs of adults were obtained, and the center of a circle passing through 3 selected points on the proximal articular surface of the lunate was defined as the lunate rotation center. Thereafter, the distance between the rotation center and a line extending along the volar aspect of the distal radial diaphysis was measured. Additionally, the distance between the rotation center and the midpoint of the distal articular surface of the lunate was measured.

Results: The mean distance between the lunate rotation center and the line extending along the volar aspect of the distal radial diaphysis was \( 0.01 \pm 0.09 \) mm. The difference in this distance between both wrists in the same patient was \( 0.3 \pm 0.12 \) mm. The distance between the rotation center and the midpoint of the distal articular surface of the lunate was \( 0.3 \pm 0.05 \) mm.

Conclusions: This study demonstrated that the lunate rotation center was located on a line extending along the volar aspect of the distal radial diaphysis and at the midpoint of the distal articular surface of the lunate.

Clinical relevance: This study demonstrates that this association could become an important index for preoperative planning of corrective osteotomy for complicated intra-articular distal radial fracture malunions. Additionally, it may aid in confirming the reduced position during or after surgery for wrist fracture dislocations.

Changes in radiocarpal alignment are known to occur after severe distal radial fracture dislocations or malunions.1,2 This occasionally results in a decreased range of motion, grip power, or pain in the wrist.3 Restoration of normal radiocarpal alignment is one of the treatment objectives in these cases. Carpal instability adaptive is a postural adaptation of the proximal and distal carpal rows to conform to an abnormal inclination of the malunited distal radius.4 Corrective osteotomy is usually performed with reference to volar tilt. However, it is occasionally difficult to plan reconstruction of the deformed distal radius in cases of accompanying intra-articular fracture malunions.5 In volar marginal articular fractures of the distal radius with radiocarpal subluxation, small fracture fragments or fixation devices sometimes make it difficult to confirm the reduced position. However, some radiographic indexes have been advocated for the evaluation of intra-articular distal radial fractures.

Declaration of interests: No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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https://doi.org/10.1016/j.jhsg.2022.07.006
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fractures. Other radiographic indexes based on the relationship between the carpus and radius are preferable to those based on deformed shape of the distal radius.

Medoff showed that a line extending along the volar aspect of the radial shaft nearly bisected the radial articular surface and the lunate on lateral wrist radiographs. However, no study has described these detailed measurements. A possible reason for this is the lack of a detailed definition of a fixed reference point on the lunate.

The purpose of this study was to define a reference point on the lunate and investigate whether this point is located on a line extending along the volar aspect of the distal radial diaphysis. The hypothesis was that this reference point will become a useful index for the treatment of severe distal radial fracture dislocations and fracture malunions.

Materials and Methods

We analyzed medical records between 2010 and 2019 from our hospital and extracted 201 lateral wrist radiographs of adult patients (aged 18–92 years). Radiographs showing fractures, static wrist instability, osteoarthritis, wrist tumors, and rheumatoid arthritis were excluded. The mean age of the patients was 56.9 ± 1.3 years, and the study included 78 men and 123 women. The right wrist was involved in 98 patients, and the left wrist was involved in 103 patients. A lateral wrist radiograph was taken in the zero position and defined based on the pisoscaphocapitate relationship, where the palmar cortex of the pisiform should lie between the anterior surface of the distal pole of the scaphoid and capitate. Three points on the proximal articular surface of the lunate (dorsal, volar, and proximal) were selected, and the center of a circle passing through the 3 points was identified as the lunate rotation center (Fig. 1A, B). The dorsal and volar points of the proximal articular surface of the lunate were defined as an increased point of curvature on both sides. The proximal point was defined as the point most proximal on the proximal articular surface of the lunate. A line parallel to the central long axis of the distal radius was then drawn along the volar aspect of the distal one-third of the radial diaphysis (yellow dotted line). The distance between the lunate rotation center (white dot) and the line extending along the volar aspect of the radius was measured (Fig. 2B). If the lunate center was posterior to this line, it was expressed as a negative value, and if it was anterior, it was expressed as a positive value. The distance between the middle of the distal articular surface of the lunate and the lunate rotation center was also measured (Fig. 1C). If the lunate rotation center was distal to the distal articular surface of the lunate, it was expressed as a positive value, and if it was proximal, it was expressed as a negative value. All the measurements were performed from digital radiographs using the Centricity PACS software (GE Healthcare). The measurements were performed by 2 examiners (S.O and Y.K) who were blinded to the clinical data and reperformed by the same team after 3 weeks. Data are expressed as mean ± standard error and were analyzed using the intraclass correlation coefficient to assess the intraobserver and interobserver reliability. Statistical analyses were performed using statistical package R (R Foundation for Statistical Computing).
The mean distance between the lunate rotation center and the line extending along the volar aspect of the distal radial diaphysis was $-0.01 \pm 0.09$ mm (range, $-2.5$ to $2.88$ mm; 95% confidence interval [CI], $-0.2$ to $0.18$). Of the 201 radiographs evaluated in this study, 76 were evaluated for both wrists in the same patient. When both wrists in the same patient were evaluated, the mean difference in the distance between both wrists was $0.3 \pm 0.12$ mm (range, $-0.81$ to $1.58$ mm; 95% CI, $0.04$–$0.56$). The mean distance between the center of the distal articular surface of the lunate and the lunate rotation center was $0.3 \pm 0.05$ mm (range, $-2.25$ to $2.84$ mm; 95% CI, $0.2$–$0.48$).

The intraobserver and interobserver reliabilities of the distance between the lunate rotation center and the line extending along the volar aspect of the distal radial diaphysis were $0.87$ (95% CI, $0.84$–$0.91$) and $0.83$ (95% CI, $0.79$–$0.87$), respectively. The intraobserver and interobserver reliabilities of the distance between the rotation center and the midpoint of the distal articular surface of the lunate were $0.90$ (95% CI, $0.87$–$0.93$) and $0.88$ (95% CI, $0.85$–$0.91$), respectively. The intraobserver and interobserver correlations were excellent (intraclass correlation coefficient $> 0.8$) for all data.

Discussion

In our study, the lateral wrist radiographs showed that the center of the circle passing through the proximal articular surface of the lunate was located on the line extending along the volar aspect of the distal radial diaphysis. This center was located in the middle of the distal articular surface of the lunate.

Distal radius fracture malunions are usually reduced by referring to radiographic sagittal plane indices, such as volar tilt, although the extent of reduction has not been strictly determined. Wada et al13 reported good results in a study concerning corrective closed wedge osteotomy for extra-articular distal radius fracture malunions. They reduced the dorsal angulation within a normal range of $1^\circ$–$21^\circ$ with reference to that of the contralateral intact wrist. On the other hand, in cases of distal radius intra-articular fracture malunions, including malunited volar marginal fragments, Orbay et al5 suggested that the goal of corrective osteotomy in the sagittal plane was to achieve neutral or slight dorsal tilting of the residual lunate fossa surface. The elongated volar edge of the lunate fossa makes it difficult to apply a normal value of volar tilt. Other radiographic indices concerning an association between the carpus and radius in the sagittal plane would be helpful in such malunited distal radius articular surfaces. Thivaios and McKee4 reported corrective osteotomy for volarly displaced distal radius fracture malunions. They used the central long axis of the radius as a reference line for correction of volar translation of the hand and carpus. The distal fragments were repositioned to the extent that a line collinear with the middle of the lunate and capitate was identical to the central long axis of the radius. The reference line and goal of the reconstruction surgery varied in the study. However, the fact that the lunate rotation center is located on an extended line along the palmar cortex of the radial diaphysis is important for preoperative planning of reconstruction or intraoperative confirmation of reduction for the treatment of complicated fracture dislocations or fracture malunions. Figure 3 shows representative radiographs of a distal radius fracture malunion. A type C volar shearing fracture malunion showed a 5.5-mm anterior displacement of the lunate rotation center (Fig. 3A, B). A dorsally angulated distal radius fracture malunion showed a 11.5-mm posterior displacement of the lunate rotation center (Fig. 3C).

On lateral wrist radiographs, the neutral position of the lunate is ideal for the evaluation of wrist alignment. However, a somewhat dorsally or volarly rotated position of the lunate is usually seen on routine lateral wrist radiographs, although a uniform procedure for radiography was performed. Therefore, it is necessary to define a steady reference point on the lunate despite different lunate inclinations. The lunate motion during flexion and extension of the wrist is $34^\circ$ in flexion and $26^\circ$ in extension.13 Therefore, in this study, the proximal articular surface of the lunate was considered to be located on the same circle, and the center of this circle was defined as the lunate rotation center. Further, our study demonstrated that the mean position of the lunate rotation center was $0.2$ mm distal to the middle of the distal articular surface of the lunate on the lateral

Figure 3. Displacement of the lunate rotation center in A and B type C volar shearing fracture malunions and C dorsally angulated distal radius fracture malunions.
wrist radiographs. Consequently, for convenient use, it would be better to define the midpoint of the distal articular surface of the lunate as a steady reference point on the lunate.

The volar aspect of the distal radius curves anteriorly along the transition of the diaphysis to the metaphysis, although the boundary between these 2 regions is unclear. Because even a small difference in the inclination line may result in inaccurate and dispersed data, we defined the inclination of the anterior surface line of the radius to be the same as that of the central long axis of the distal radial diaphysis. A line parallel to the central long axis of the distal radial diaphysis was then drawn along the volar aspect of the distal one-third of the radial diaphysis.

A small amount of variation (−2.9 to 3.0 mm) was found in the distance between the line along the volar aspect of the radial diaphysis and the lunate rotation center. Our study also showed that this difference was within 1 mm for both wrists of the same person. Therefore, the use of the distance of the contralateral side as a reference value would make preoperative planning more precise. One of the possible limitations of this study is incomplete medical history of the wrist. The patients may have excluded conservatively treated wrist trauma from their medical history. It is also possible that some patients with minor posttraumatic deformities of the wrist were included in this study. Another limitation is that the subjects in this report were exclusively Japanese, and caution should be exercised while applying these findings to non-Japanese patients.

The lunate rotation center was located on the line extending along the volar aspect of the distal radial diaphysis. This association has the potential to become an important index for preoperative planning of corrective osteotomy for complicated intra-articular distal radial fractures, malunions, or the confirmation of reduction during or after surgery for wrist fracture dislocations. Further investigations in diverse populations are needed to demonstrate the utility of this association in the treatment of distal radius fracture dislocations or fracture malunions.

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