Original Article
Clinics in Orthopedic Surgery 2016;8:175-180 • http://dx.doi.org/10.4055/cios.2016.8.2.175

The Role of Lunate Morphology on Scapholunate Instability and Fracture Location in Patients Treated for Scaphoid Nonunion

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Background: To determine the association between lunate morphology and the scapholunate instability using radiographic images, and investigate the association between lunate morphology and scaphoid fracture location.

Methods: Between January 2003 and December 2011, we retrospectively evaluated the plain radiographs and computed tomography (CT) images of 70 patients who underwent surgical intervention for a scaphoid nonunion, in order to determine the association between lunate type (I or II) and scapholunate instability or scaphoid fracture location. We determined the scaphoid fracture location using the fragment ratio and measured the radiolunate angle and capitate-triquetrum (C-T) distance.

Results: A type II lunate was present in 68.6% (48 of 70 cases). Mean fragment ratio of fracture location was 50.6% in the type II lunate group and 56.2% in the type I lunate group ($p = 0.032$). Sixteen of the 70 patients had dorsal intercalated segmental instability (DISI) deformities. Nine of 22 cases showed DISI deformity in type I lunate and 7 of 48 cases showed DISI deformity in type II lunate ($p = 0.029$). However, there were no significant differences between the presence of DISI deformity and fracture location ($p = 0.15$). Morphologic comparisons by both plain radiography and CT indicated a mean C-T distance in the type I lunate group (22 cases) of 2.3 mm and 5.0 mm in the type II lunate group (48 cases). The C-T distances were significantly correlated with lunate morphology ($p = 0.001$).

Conclusions: A type II lunate was associated with low incidence of DISI deformity and proximal location of fracture in patients presenting with a scaphoid nonunion.

Keywords: *Lunate morphology, Scaphoid nonunion, Dorsal intercalated segmental instability*

The lunate is a carpal bone that has often been described as the keystone of the wrist.[1,2] It is uniquely positioned at the middle of both the transverse and coronal arches of the carpus, and intercalated between the radius and distal carpal row.[3] Furthermore, critical ligamentous attachments between the lunate, the scaphoid, and the triquetrum stabilize the proximal carpal row.

Viegas[4] classified lunate type based on midcarpal articulation. According to this description, a type I lunate has a single distal facet for the capitate, and does not articulate with the hamate. In contrast, a type II lunate has two distal facets; the radial facet articulates with the capitate and the ulnar facet with the hamate. However, the reported incidence of an ulnar lunate facet appears to differ between radiography, magnetic resonance imaging, and anatomic cadaver interpretations, which are reportedly associated with variations in ligament composition and distribution,[5-8] carpal kinematics,[9,10] and various carpal pathologies.[4-6,11-13] Despite this, Haase et al.[3] reported that

Received September 14, 2015; Accepted January 7, 2016
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a type II lunate morphology is associated with a significantly lower incidence of dorsal intercalated segmental instability (DISI) deformity in cases of established scaphoid nonunion.

The purpose of this study was to evaluate the plain radiographs and computed tomography (CT) images in a series of patients with a scaphoid nonunion, in order to determine the association between lunate morphology type (i.e., type I vs. type II) and scapholunate instability or scaphoid fracture location.

METHODS

A retrospective cohort study involving a tertiary referral center was approved by the Chonnam National University Hospital Institutional Review Board to evaluate 70 patients who underwent open reduction and internal fixation with bone graft for established scaphoid nonunion between January 2003 and December 2011.

Preoperative two-dimensional radiographic films and CT of the wrist were reviewed for each patient to assess the lunate morphology, define the radiolunate angle and scaphoid fracture location, as well as to measure the capitate-triquetrum (C-T) distance. Only radiographs showing adequate distal radioulnar overlap and a radius-third metacarpal angle of < 20° from neutral were accepted. An orthopedic surgeon, who had not been involved in treatment, conducted the radiological assessment.

Lunate morphology was determined by examining standard posteroanterior (PA) wrist radiographs and CT. If a medial lunate facet could be identified on one of the radiographs and CT, the lunate was classified as type II (Fig. 1).[14] The radiolunate angle was evaluated on the lateral wrist radiograph using the tangential method.[15] DISI deformity was deemed present when the radiolunate angle was greater than 15°.[16] Scaphoid fracture locations were determined using fragment ratio using ulnar-deviated and PA semi-pronated oblique views. Long axis of the scaphoid and the fracture are best visualized in both views.[17] Using the ulnar-deviated and PA semi-pronated oblique views, horizontal lines were drawn at the ends of each fragment to define the length of the fragment. Its middle was then identified and a line was drawn between these points to connect the horizontal lines. The length of this line represented the fragment size. The fragment ratio was then calculated by dividing the proximal fragment size by the sum of the sizes of proximal and distal fragments (Fig. 2).[18] The C-T distance was measured with the wrist in neutral radioulnar deviation, maintaining the straight alignment of the middle finger metacarpal, capitate, and radius. Na-

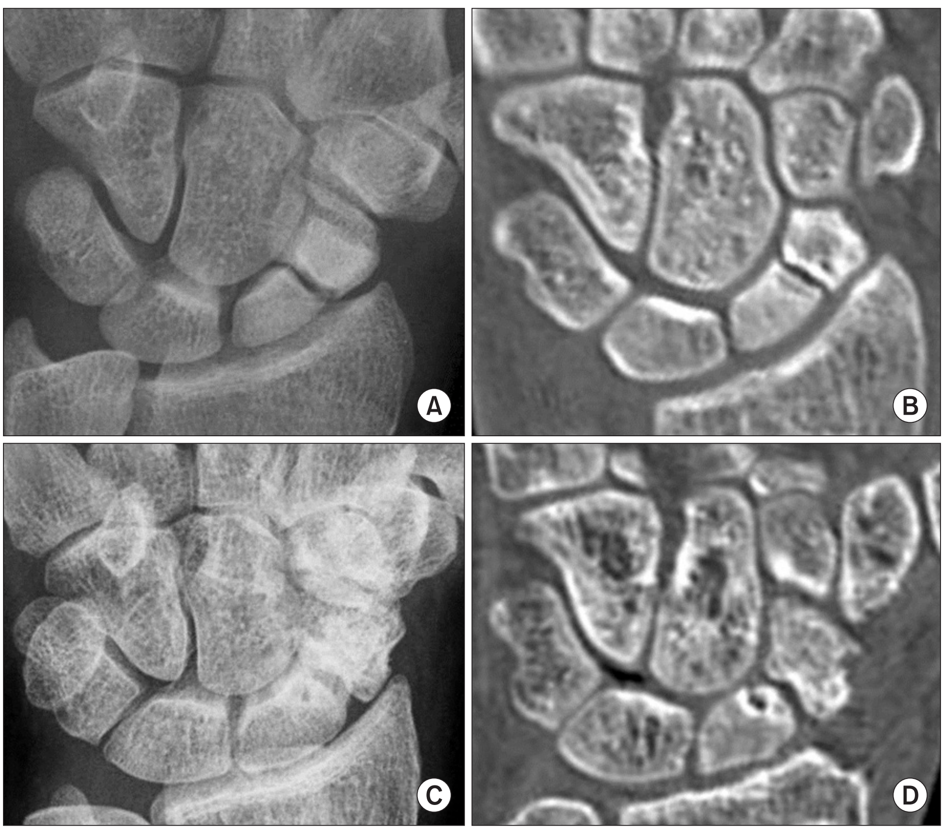

Fig. 1. Type I lunate with a single midcarpal articulating facet with the capitate (A, B) and type II lunate with two midcarpal articulating facets, one with the capitate and the other with the hamate (C, D).

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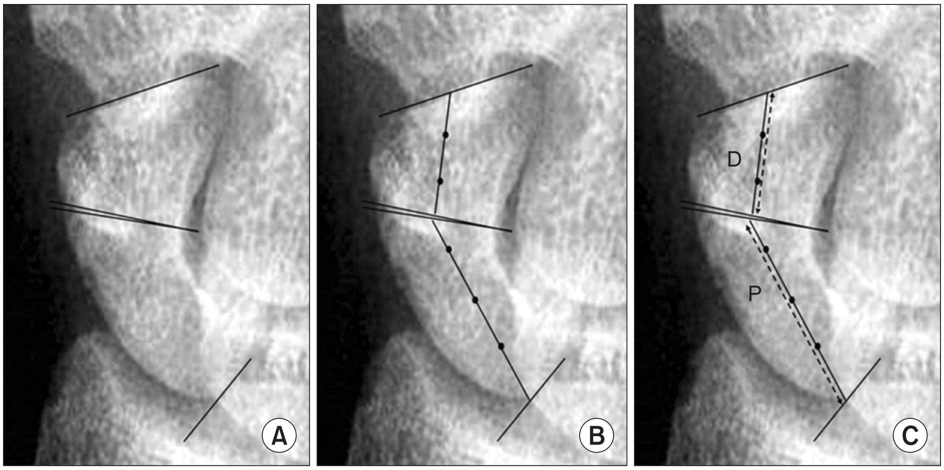

Fig. 2. (A) Fragment ratio. Horizontal lines were drawn to define the extent of the fragment. (B) The middle of the fragment was identified and a midline was drawn connecting the two horizontal lines. (C) The lengths of these lines (P: proximal fragment, D: distal fragment) were measured to determine the fragment size. Fragment ratio = P / (P + D).

kamura et al.[19] reported that the shortest distance between the capitate and triquetrum (i.e., C-T distance) was the best determinant of lunate type, and that C-T distance increased as the width of the lunate ulnar facet increased.

The significance of the relationship between lunate morphology and DISI deformity was analyzed using a chi-square test, while the relationship between lunate morphology and nonunion site, and C-T distance were analyzed using the independent *t*-test for normally distributed data. Statistical significance was accepted for a p-value < 0.05.

RESULTS

Type II lunate was identified in 48 of 70 patients using CT imaging. The demographics for the 2 groups were shown in Table 1. There was no significant difference between the 2 groups for age (p = 0.120), gender (p = 0.529) or dominant hand (p = 0.597), manual labor (p = 0.316), and union at final follow-up (p = 0.597).

Sixteen of 70 patients (22.8%) had DISI deformity. Nine of 22 patients had DISI deformity in type I lunate group, and 7 of 48 patients had DISI deformity in type II lunate group. Type I lunate group showed higher incidence of DISI deformity than type II lunate group in statistical evaluation (p = 0.029). Mean fragment ratio of fracture location was 50.6% (range, 29.2% to 65.2%) for a type II lunate and 56.2% (range, 34.4% to 69.2%) for a type I lunate morphology determined. We found a relationship between a type II lunate and a proximally located fracture (p = 0.032) (Table 2). The mean fragment ratio in patients with DISI deformity was 55.6% and 51.5% in patients without DISI deformity. Fracture location was not dependent on the presence of DISI deformity (p = 0.15).

The mean C-T distance in type I lunate was 2.3 mm (range, 1.2 to 4.7 mm), while the mean C-T distance in type II lunate was 5.0 mm (range, 2.3 to 9.2 mm). The C-T distances were significantly correlated with lunate morphology (p = 0.001) (Table 2).

Table 1. Demographic Data of Patients with Type I and II Lunate

Variable	Type I lunate (n = 22)	Type II lunate (n = 48)	*p*-value
Age (yr), mean (range)	32.4 (17–49)	28.0 (14–55)	0.120
Gender			0.529
Male	17	40	
Female	5	8	
Dominant hand			0.597
Yes	13	32	
No	9	16	
Manual labor			0.316
Yes	19	42	
No	3	2	
Union at final follow-up			0.597
Yes	13	32	
No	9	16	

DISCUSSION

The reported incidence of a type II lunate ranges from 46% to 73% (Table 3).[3,4,6,11,12,20-23]

Sagerman et al.[12] examined whether lunate morphology could be accurately predicted using radiographs

Table 2. DISI Deformity, Fragment Ratio, and C-T Distance of Type I or II Lunate Morphology

Variable	Type I lunate	Type II lunate	*p*-value
DISI deformity	9/22	7/48	0.029
Fragment ratio (%), mean (range)	56.2 (34.4–69.2)	50.6 (29.2–65.2)	0.032
C-T distance (mm), mean (range)	2.3 (1.2–4.7)	5.0 (2.3–9.2)	0.001

DISI: dorsal intercalated segmental instability, C-T: capitate-triquetrum.

Table 3. Reported Incidences of Type II Lunate

Study	Year	Method	Case	Type II lunate (%)
Viegas[4]	1990	Midcarpal arthroscopy (cadaver)	61	60.7
Burgess[21]	1990	Cadaver dissection	28	46.4
Viegas et al.[6]	1993	Cadaver dissection	393	72.8
Sagerman et al.[12]	1995	Cadaver dissection	81	56.8
Malik et al.[22]	1999	Magnetic resonance imaging	186	57.5
Aufauvre et al.[23]	1999	Plain radiography	100	56.0
Nakamura et al.[11]	2001	Cadaver dissection	170	71.2
Haase et al.[3]	2007	Plain radiography	45	53.3
McLean et al.[20]	2009	Cadaver dissection	13	63.0
Present study		Computed tomography	70	68.6

and concluded that only 74% of type I lunates and 66% of type II lunates could be accurately identified on plain radiography. Cadaveric dissection and arthroscopy studies have reported incidence rates of 63% to 73% for a type II lunate, which are higher than those obtained by plain radiography. In this study, we used plain radiography and CT to evaluate the lunate morphology. Our findings of 68.6% on radiographic evaluation compare favorably with these reports. Thus, lunate morphology could be accurately identified using CT image.

Scaphoid nonunion is a well-known predisposing condition for carpal instability, and specifically DISI deformity. In a recent radiographic study, Haase at al.[3] reported a significantly lower incidence of DISI deformity among patients with type II lunate. They inferred that in patients with a scaphoid nonunion, the "extension moment" of the triquetrum caused by force transmitted through its screw-like articulation with the hamate, is halted by the lunatohamate articulation present in type II midcarpal joints. However, no additional studies have been performed to confirm this finding; thus, we assessed lunate morphology using plain radiography and coronal CT images to identify correlations between DISI and lunate morphology.

Our present work demonstrates a significantly lower incidence of DISI deformity in patients with a scaphoid nonunion and a type II lunate. In a study on the effect of lunate morphology on the three-dimensional kinematics of the carpus, Bain at al.[24] reported a significantly greater motion in the radiocarpal joint during flexion-extension of type I wrist than a type II wrist. As reported by Haase et al.,[3] this may be related to the additional stability of the lunatohamate articulation in the proximal carpal row and variations in scaphoid motion. It is possible that additional articulation of lunatohamate may protect from the scapholunate instability after scaphoid fracture.

Moritomo et al.[25] reported that carpal instability following scaphoid nonunion appears to be related to the location of the fracture line and whether it passes distal or proximal to the scaphoid apex, where the dorsal scapholunate interosseous ligament and the dorsal intercarpal ligament attach. Similarly, Haase et al.[3] demonstrated that 5 of 24 (20.8%) proximal pole fracture patients and 14 of 28 (50%) patients with a scaphoid waist fracture developed DISI deformity. They concluded that a significant association exists between fracture location and the development of DISI deformity. In the present study, a type II lunate was also correlated with proximal fracture location, but fracture location was not a predictor of DISI deformity. Further biomechanical studies are required to determine the effect of a type II lunate on carpal instability.

Nakamura et al.[19] reported that C-T distance, measured on plain anteroposterior radiographs or on coronal CT scans, is the best determinant of lunate type, and that C-T distance increases with increasing width of the ulnar facet. Nakamura et al.[19] defined a type I lunate as having a C-T distance of 2 mm, and a type II lunate as having a C-T distance of 4 mm. In the present study, C-T distance was related to lunate morphology and a type II lunate was found to have a larger C-T distance than a type I lunate. McLean et al.[20] reported an average C-T distance for a type I lunate of 2.50 mm (range, 0.70 to 3.65 mm), which was similar to our average C-T distance for a type I lunate of 2.33 mm (range, 1.2 to 4.68 mm). Both values are larger than those reported by Nakamura et al.[9] Thus, C-T distance may not discriminate between a type I and type II lunate to routinely allow for differentiation of lunate morphology.

This study has several limitations. First, this was a retrospective case series study, and thus, the level of evidence is low. Second, this study included a small series of patients. Based on the effect size in this study, a power calculation for a trial (effect size, 0.5; α [type I error], 0.05; power, 0.8) suggested that 64 patients would be needed in each group. Given the group-wise differences of incidence in this study (type I lunate, 31.4%; type II lunate, 68.6%), each group would need 48, and 96 patients, respectively. Further study on a large series of patients is needed. Third, the correlation between lunate morphology and clinical outcome was not evaluated. So, further research is required to investigate the relationship between lunate morphology and clinical outcomes. Fourth, this study was the radiological assessment by only one observer. Fifth, other factors affecting the DISI deformity such as duration of nonunion, scapholunate ligament injury, humpback deformity were not evaluated; hence, further research is required to investigate the relationship between other factors and DISI deformity. Our study could contribute to the prediction of DISI deformity on scaphoid nonunion and the decision making regarding the treatment plan for patients such as selection of approach technique and need of bone graft.

In conclusion, a type II lunate was associated with decreased DISI deformity and a more proximally located fracture in patients presenting with a scaphoid nonunion. Future studies are required for designing biomechanical methods to determine the effect of type II lunate on carpal stability and correlation between lunate morphology and clinical outcome.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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