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Original Article

월상골의 형태는 원위 요골 골절의 수술적 치료 결과에 영향을 미치는가?

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Does the Morphological Type of the Lunate Affect Surgical Outcomes in Patients with Distal Radius Fractures?

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Purpose: We sought to compare the surgical results of distal radius fractures treated with volar locking plate (VLP) between two types of lunate. The hypothesis was that wrists with type II lunate might have worse surgical outcomes of distal radius fracture.

Methods: Seventy patients with surgically treated distal radius fracture were included in this study. Morphology of the lunate was analyzed with computed tomography scans and simple radiographs. Patients with type I lunate were defined as having no articulation with the hamate. Patients with type II lunate were defined as having accessory articulation with the hamate. Surgical outcomes were assessed. Range-of-motion (ROM) and grip strength were measured at the final follow-up. All subjects were divided into two groups based on the lunate type and compared. Multiple logistic regression analysis was performed to find predictors for worse surgical outcome.

Results: Mean age of the subjects was 53.66 years (17 to 74 years). Mean follow-up was 14.54 months (12 to 52 months). The mean flexion of the wrist joint was significantly lower in the group with type II lunate. The multiple logistic regression analysis demonstrated that the predictors for worse flexion of the wrist joint were patients with type II lunate, and insufficient restoration of normal volar tilt angle at final follow-up.

Conclusion: Type II lunate wrist joints had significantly lower ROM, compared with type I lunate wrist joints after surgical treatment of distal radius fracture using VLP.

Key Words: Distal radius fracture, Lunate type, Surgical outcome, Wrist range of motion

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INTRODUCTION

Painless full range-of-motion (ROM) of the wrist joint is an important goal in treatment of patients with distal radius fractures. The wrist joint consists of the radiocarpal and midcarpal joints, and previous authors described a substantial amount of motion in the midcarpal joint during wrist motion[1]. Recently, the association between the morphology of the lunate and extent of the midcarpal joint stiffness have been described in the literature[2-5]. The lunate morphology can be classified by the presence of accessory articulation between the lunate and hamate; type I lunates have a single lunocapitate articulation and type II lunates have an additional lunatohamate articulation[6-8]. Previous studies have described that wrist joints with different lunate types show different wrist joint kinematics[2,3,9,10]. In addition, joints with type II lunate have a relatively stiffer midcarpal joint than those with type I lunate.

We postulated that different inherent kinematics of the wrist joint caused by different lunate types might affect ROM of the wrist joint after surgical treatment of the distal radius fracture, and also might affect its surgical outcome. We sought to determine the effect of lunate morphology on surgical outcomes of distal radius fractures treated with a volar locking plate (VLP). The hypothesis was that type II lunate wrists might have worse surgical outcome of the distal radius fracture.

MATERIALS AND METHODS

The institutional review board of our institute approved the current study. We reviewed the medical records of 86 consecutive patients who were surgically treated for unstable fractures of the distal radius at our institute between May 2012 and February 2014. The inclusion criteria were unstable fractures of the distal radius that were surgically treated with a VLP. Exclusion criteria were a history of ipsilateral hand, wrist injury, an accompanying metaphyseal or diaphyseal ulnar fracture, or absence of preoperative computed tomography (CT) scans. Of the 86 patients, six had a history of ipsilateral hand and wrist injury, five had an accompanying metaphyseal or diaphyseal ulnar fracture, three had no preoperative CT scans, and two were lost to follow-up. In total, 70 patients were included in the final study.

Distal radius fractures were surgically fixated with VLP systems (VA-LCP; Synthes, Paoli, USA or Acumed, Oregon, USA) in all patients. A short arm splint was applied postoperatively. ROM exercises of all five fingers were instructed to be done on the day of surgery. The splint was changed to wrist brace at two weeks following surgery, and wrist joint ROM exercises were started, and then increased as tolerated.

Classification of the lunate type was performed using both simple radiographs and CT scans by two independent observers. Type I is defined as the lunate with no articulation with the hamate, and type II is defined as the lunate with accessory articulation with the hamate. The lunate with vague morphology classification was defined as a vague type and included only in the measurement reliability and agreement between CT and simple radiographs when evaluating lunate type. All measurements were performed by a single observer and followed by a second independent observer who was unaware of the initial measurements to assess measurement reliability.

The surgical outcome of the distal radius fracture was assessed with the disabilities of the arm, shoulder, and hand (DASH) score and the modified Mayo wrist score (MMWS) at the final follow-up. The DASH score is a patient-rating outcome scoring system developed by the Institute for Work and Health in Ontario and the American Academy of Orthopedic Surgeons[11]. It evaluates the symptoms and physical function of the arm, shoulder, and wrist. The total score of 100 point indicates maximum disability, and of 0 point indicates a normal wrist. The MMWS is a physician-rating scoring system. It is comprised of four, 25-point sections[12].

ROM of the wrist joint and grip strength were also measured at the final follow-up and recorded as the proportion to the contra-lateral side. Measurement of the ROM was performed by an orthopedic surgeon who was blinded to the type of the lunate of the patients. The measurement procedures were performed with standardized

protocol as below. Patients were sitting on chairs, and elbow joints were kept in 90˚ of flexion. The axis of the goniometer was centered over the center of the capitate. The center of the capitate was defined as the midpoint between the radial and ulnar styloid process in the coronal plane. Distal arm of the goniometer was positioned so that it was aligned with the third metacarpal, and the proximal arm was positioned centrally to the forearm. For flexion, radial deviation, and ulnar deviation of the wrist joint, the goniometer was placed on the dorsal surface of the wrist, and for extension, it was placed on the volar surface. Grip strength was also measured at final follow-up and also recorded as a percentage of the contralateral.

1. Statistical analysis

To assess measurement reliability between two independent observers, and measurement agreement between CT images and simple radiographs, we calculated Cohen's kappa values. All the subjects were divided into two groups according to lunate type, and the two groups were compared. Multiple logistic regression analysis was performed to find predictors for the worse surgical outcomes of the distal radius fracture. The variables that might affect final ROM of the wrist joint, such as age, initial fracture classifications, final radiographic reduction index, follow-up duration, and the lunate type, were included as independent variables, and backward conditional analysis was performed. Dependent variables were flexion and extension of the wrist joint. Decreased flexion or extension of the wrist joint was defined as flexion or extension ROM of less than 85% compared with that on normal side, to perform multiple logistic regression analyses.

During our pilot study, the mean wrist flexion compared to that of the contra-lateral side of group I was 94.2, and the group II was 83.9. The standard deviation of group I and group II was 11.85 and 13.92, respectively. Using the two-tailed Student t-test, a level of significance of 0.05, and power of current study of 80%, the calculated number of subjects was 26 in each group.

Table 1. Baseline data of the subjects

Variable	Value	95% CI of proportion
Patient no.	70	
Age (yr)	53.66±12.72 (17-74)	
Sex (men:women)	19:51	
Follow-up duration (mo)	14.54±7.72 (12-52)	
Fracture type (AO/OTA)		
A:B:C	26:12:32	
Lunate morphology (evaluated with CT)		
Type I	38 (54.3)	42.9-65.7
Type II	29 (41.4)	30.0-52.9
Vague type	3 (4.3)	0-10.0

Values are presented as number, mean±SD (range), or n (%).
CI: confidence interval, CT: computed tomography.

RESULTS

Baseline patient demographic data are described in Table 1. Mean age of the subjects was 53.66 years (range, 17 to 74 years). Mean follow-up duration was 14.54 months (12 to 52 months). The proportion of subjects with type II lunate was 41.4% (95% confidence interval=30.0 to 52.9). Measurement reliabilities of both CT and simple radiographs to evaluate lunate type were listed in Table 2. Measurement reliabilities of CT scan showed nearly perfect agreement (kappa=0.946), and those of simple radiographs showed substantial agreement (kappa=0.738)[13]. Measurement agreement of the classification result obtained by using CT scans and simple radiographs showed substantial agreement (kappa=0.739)[13]. The incidence of the vague lunate type was greater when simple radiographs were used for evaluation than when CT scans

Table 2. Inter-observer measurement reliability

Variable	Value
Lunate type measured with CT	
Observer I (type I:type II:vague)	38:29:3
Observer II (type I:type II:vague)	37:31:2
Cohen's kappa	0.946
Lunate type measured with simple X-ray	
Observer I (type I:type II:vague)	37:25:8
Observer II (type I:type II:vague)	33:26:11
Cohen's kappa	0.738

CT: computed tomography.

Table 3. Comparison results between two groups*

Variable	Group I (Lunate type I)	Group II (Lunate type II)	p-value
No.	38	29	-
Age (yr)	51.8±13.30	56.0±11.72	0.183
Sex (men:women)	11:27	8:21	0.903
Fracture type (AO/OTA)			
A:B:C	11:7:20	13:4:12	0.238
Follow-up (mo)	14.71±8.50	14.31±6.69	0.835
Within normal range:Abnormal			
Radial inclination at final	34:4	26:3	0.981
Radial height at final	33:5	25:4	0.940
Ulnar variance at final	31:7	24:5	0.901
Volar tilt at final	30:8	21:8	0.534
DASH	17.58±20.44 (0-91)	18.27±21.45 (0-82)	0.815
MMWS	76.61±16.94 (20-100)	76.38±17.47 (15-100)	0.944
Flexion	96.4±10.67 (50.0-112.5)	86.7±15.63 (53.3-100.0)	0.002
Extension	94.8±12.0 (35.3-118.2)	88.9±12.70 (60.0-110.0)	0.028
Radial deviation	92.7±23.2 (33.3-121.3)	88.2±16.83 (50.0-100.0)	0.457
Ulnar deviation	98.0±18.76 (50.0-150.0)	88.7±19.18 (33.3-116.7)	0.063
Supination	96.9±8.56 (60.0-100.0)	96.6±9.66 (58.8-100.0)	0.993
Pronation	97.1±11.09 (33.3-100.0)	98.3±2.61 (93.8-100.0)	0.248
Grip strength	79.1±21.86 (26.8-123.8)	79.8±18.61 (28.6-100.0)	0.652

Values are presented as number, mean± SD, or mean±SD (range).
DASH: disabilities of the arm, shoulder, and hand, MMWS: modified Mayo wrist score.
*Cases with vague type lunate were excluded in analysis.

were used for evaluation (11.4% vs. 4.3%, p=0.033).

Comparison of results between the two groups divided by the lunate type is listed in Table 3. The mean flexion of the wrist joint was significantly lower in the group with type II lunate (96.4% vs. 86.7%, p=0.002). The mean extension of the wrist joint was also significantly lower in the group with type II lunate (94.8% vs. 88.9%, p=0.028).

The result of multiple logistic regression analyses are listed in Table 4. For worse extension ROM, we could not find significant predictors in multiple logistic regression analysis. For worse flexion ROM, significant predictors were found to be the type II lunate (odds ratio=6.156, p=0.010), and abnormal volar tilt angle at final follow-up (odds ratio=5.494, p=0.027).

Table 4. Odds ratio of the several variables predicting worse flexion of wrist joint controlled with other confounders

Variable	Odds ratio (95% CI)	p-value
Lunate type II	6.156 (1.558-24.313)	0.010
Age	0.978 (0.925-1.034)	0.434
Fracture type (AO/OTA)		
A (reference value)	-	-
B	3.634 (0.457-28.876)	0.222
C	2.330 (0.523-10.387)	0.267
Follow-up	0.886 (0.886-0.750)	0.434
Abnormal radial inclination at final	3.332 (0.376-29.539)	0.280
Abnormal radial height at final	1.079 (0.121-9.599)	0.946
Abnormal ulnar variance at final	2.575 (0.434-15.273)	0.298
Abnormal volar tilt at final	5.494 (1.216-24.820)	0.027

CI: confidence interval.

DISCUSSION

The current study revealed that wrists with type II lunate show less ROM of the wrist joint after surgical fixation of the distal radius fracture. Furthermore, type II lunate was shown to be a predictor of worse flexion ROM after surgical fixation of the distal radius fracture. Our results might reveal one of the reasons for why some patients with surgically treated distal radius fracture showed

less ROM despite good surgical fixation and standardized rehabilitation protocol.

Achieving painless full ROM of the wrist joint, as well as the union of fracture, is an important factor for the treatment of patients with distal radius fractures. During wrist flexion and extension, substantial motion occurs in the midcarpal joint. Kaufmann et al.[1] performed in vitro analysis of the wrist joint motion and described that overall wrist flexion was 68°±12° and extension was 50°±12°, and the lunocapitate joint shows 15°±11° of extension and 22°±19° of flexion. The substantial contribution of the midcarpal joint for wrist motion has also been described by Werner et al.[14] They noted that the capitate movement on the lunate contributes 50% of the total wrist motion. To maximize ROM of the wrist joint after injuries, achieving motions in both joints of the midcarpal and the radiocarpal are important.

Numerous previous studies have described that type II lunate wrists have an inherently stiffer midcarpal joint compared to wrists with type I lunate. Haase et al.[3] noted that the wrist with type II lunate is associated with significantly lower incidences of dorsal intercalated segment instability (DISI) deformity in scaphoid nonunion. They postulated that accessory lunatohamate articulation might lend additional stability that resists abnormal extension force. Similarly, Rhee et al.[4] described a lower incidence of DISI deformity in cases of scapholunate dissociation with the wrist joints with type II lunate. They also theorized that this might be caused by the stabilizing effect of accessory lunatohamate articulation on the lunate. McLean et al.[15] compared the incidence of type II lunate in two groups divided by the presence of scaphoid-trapezium-trapezoid (STT) arthritis. They noted significantly greater incidences of type II lunates in STT arthritis group. They postulated that the lunate morphology causes changes in scaphoid motion and it may contribute to the development of STT arthritis. Increased incidence of proximal hamate arthrosis is also described with type II lunate in the literature[16-18]. Bain et al.[2] performed ex vivo analysis of three-dimensional wrist kinetics with eight cadaveric wrists. In their study, the wrist with type I lunate showed significantly greater ROM at both the radioscaphoid and the lunocapitate joint, and significantly lesser ROM at the radiolunate joint, compared to the wrist with type II lunate, during flexion of the wrist joint. In other words, the wrist with type II lunate depends more on the radiolunate joint than on the lunocapitate joint regarding wrist flexion ROM.

Based on these data, we postulated that the possible joint stiffness on the radiocarpal joint after treatment of the distal radius fracture might cause more restriction of the all overall joint motion in the wrist with type II lunate, compared with type I lunate wrists. It may be because the type II lunate wrist, that has inherently less mobile lunocapitate joint, may depend more on the radiocarpal joint regarding the ROM of the wrist joint, compared to the wrist with type I lunate. Furthermore, decreased ROM of the radiocarpal joint after distal radius fracture might be less compensated by the lunocapitate joint in the wrist with type II lunate, compared to the wrist with type I lunate with more inherently mobile lunocapitate joint.

On evaluating lunate type with simple radiographs, we found that a substantial number of wrists showed lunate with vague morphology to classification. Dyankova and Marinov[19] also noted that lunatohamate articulation less than 3 mm seems to be impossible to detect using simple radiographs. Sagerman et al.[17] specifically examined 81 cadaver dissections to evaluate the predictability of simple radiographs for identifying type II lunate. Their result showed that 74% of type I lunates and 66% of type II lunates could be identified on simple radiographs.

The results of the current study might have important clinical implications in the treatment of distal radius fractures. In cases of type II lunate wrist, prevention of radiocarpal joint stiffness seems to be more important than that in the wrist with type I lunate. Since the wrists with type II lunate have inherently stiffer midcarpal joint, loss of motion in the radiocarpal joint might result in more restriction of the wrist overall. Patients with definite lunatohamate articulation on their preoperative images should be counseled regarding the possibility of joint stiffness after surgical treatment of the distal radius fracture, and careful postoperative rehabilitation should be performed to prevent radiocarpal joint stiffness.

Our final results described that the scores of DASH and MMWS in both groups showed statistically insignificant differences. However, severe ceiling effect of DASH in an evaluation of the clinical outcome of the distal radius fracture was noted in a previous study[20]. Researchers have recently published data that many clinical scores currently used for clinical research have bias of the ceiling effect[20,21]. If the results of clinical outcome scores have the ceiling effect, it is known that content validity and reliability of the score are reduced, because it is not possible to distinguish the true difference between two different groups, that is, the likelihood of type II error might be increased[20]. Furthermore, although overall mean of outcome score showed relatively good result, there were some patients with severe restriction of wrist function in the current study. Although our study could not reveal any significant differences in DASH and MMWS, it might have some difference when evaluating with a more detailed new score system in evaluation of the distal radius fracture outcomes. In addition, if patients with distal radius fracture have jobs or recreational activities related to dacing, musical instrument playing, or push-up, small decrease of the wrist joint ROM might have some effect on patients' subjective satisfaction.

The current study has a few limitations. First, this is a retrospective observational study. A prospective design with more numbers of subjects might be needed for more definitive result. Second, we could not observe the actual motion of the radiolunate and lunocapitate joints after surgical treatment of the distal radius fracture. The wrist motion analysis after surgical treatment of distal radius fracture and the differences between the wrist with type I and II lunate could be attributed to the result of the current study. Third, we could not detect subradiological additional injuries on the midcarpal joint that can occur in fractures of the distal radius. This might affect surgical outcomes after distal radius fracture. In fact, we first hypothesized that the inherent midcarpal stiffness caused by type II lunate could cause more injuries in the midcarpal joint with distal radius fractures. Subradiological midcarpal injuries can only be detected with magnetic resonance imaging (MRI). However, performing MRI routinely in cases with distal radius fractures might not be justified. Fourth, we did not include preoperative anxiety and catastrophic pain ideation of patients as possible prognostic factors. Previous research found significant relation between these factors and surgical outcomes of the distal radius fracture[22]. If these factors were included in current study, the eivdence of the result might be more strong. In spite of this limitation, high statistical significance ($p=0.002$) of the relation between type II lunate and decreased wrist flexion angle might have some significance.

CONCLUSION

The wrist joint with the type II lunate shows significantly lower wrist joint ROM compared to the wrist with the type I lunate after surgical treatment of the distal radius fracture using VLP. Patients with the type II lunate on their preoperative images should be concerned about their postoperative ROM of the wrist joint.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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월상골의 형태는 원위 요골 골절의 수술적 치료 결과에 영향을 미치는가?

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목적: 본 연구의 목적은 원위 요골 골절에서 수장측 잠김 금속판을 이용하여 수술한 후의 월상골의 형태에 따른 치료 결과의 차이를 비교하는 것이다. 가설은 제2형 월상골을 가진 수근관절의 경우 원위 요골의 수술적 치료 결과가 더 불량하다는 것이다.

방법: 원위 요골 골절에 대하여 수술적 치료를 시행한 70명의 환자가 포함되었다. 월상골의 형태는 컴퓨터 단층촬영 스캔과 방사선 검사를 이용하여 분석하였다. 월상골 및 유구골 사이의 관절면이 존재하는 경우를 제1형 월상골로, 존재하지 않는 경우를 제2형 월상골로 정의하였다. 임상적 결과와 수근관절의 관절 운동각 및 악력을 최종 추시시에 측정하였다. 두 군으로 비교 분석하였으며 다중 회귀 분석법을 이용하여 불량한 수술 결과를 보이는 예측 인자를 분석하였다.

결과: 평균 연령은 53.66세(17-74세)였다. 평균 추시 기간은 14.54개월(12-52개월)이었다. 평균 수근관절 굴곡각은 제2형 월상골을 가진 군에서 의미 있게 불량한 결과를 보였다. 불량한 수근 굴곡각에 대한 예측 인자로 제2형 월상골과 비정상적인 요골 장측 경사로 분석되었다.

결론: 제2형 월상골을 가진 수근관절의 경우 수장측 잠김 금속판을 이용한 원위 요골 골절의 수술적 치료에서 불량한 최종 수근관절 운동각을 보이는 것으로 평가되었다.

색인단어: 원위 요골 골절, 월상골의 형태, 수술 결과, 수근 관절의 관절 운동각도

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