

Research Article

Mid-term clinical and radiographic outcomes of perilunate injuries treated with open reduction and internal fixation

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ABSTRACT

Objective: This study aimed to present the mid-term clinical and radiographic outcomes of patients with perilunate injuries treated with open reduction and internal fixation (ORIF).**Methods:** Patients who underwent ORIF due to perilunate injuries from 2004 to 2015 were retrospectively reviewed. Surgery was mostly performed using a standard dorsal approach. Each injury was graded as per Mayfield staging. At the final follow-up, pain intensity was evaluated using a 10-cm visual analog scale (VAS). Wrist and elbow range of motion, handgrip and pinch strength, Modified Mayo Wrist Scores, and the disabilities of the arm, shoulder, and hand (DASH) scores were measured. On plain radiographic examination, the scapholunate (SL) angle, SL interval, carpal height, and continuity of Gilula arcs were evaluated. The presence of arthritis was also assessed using the Herzberg classification.**Results:** In total, 26 male patients (27 wrists) who met the inclusion criteria were included in the study. The mean age was 40 years (range: 20-58); the mean follow-up was 45 months (range: 16-96).

Most of the injuries were fracture-dislocations (n=20; 71.4%). According to Mayfield staging, 7 wrists were grade 3, and 20 wrists were grade 4. According to Herzberg staging, 11 (40.7%) patients were stage 2a. The mean VAS was 2.3 (range: 0-5) at rest and 3.3 (range: 0-7) during activity. The mean wrist flexion and extension were 50° (range: 21-80°; 73.5% of the unaffected side) and 45.1° (range: 20-74°; 70.9% of the unaffected side), respectively. The mean radial and ulnar deviation were 14.6° (range: 6-25°; 63.6% of the unaffected side) and 22.3° (range: 5-40°; 64.7% of the unaffected side), respectively. Grip and pinch strength were 57.6 kg (range: 15-106; 65.5% of the unaffected side) and 18.6 kg (range: 8-28; 78.2% of the unaffected side), respectively. The mean Mayo score was 63.3 (range: 20-90), and the DASH score was 24.1±25.2. The mean SL angle was 61.6° (range: 40-83). There was 1 wrist with a pathological SL interval, 11 wrists with dorsal intercalated segmental instability, and 3 wrists with fractures of the Gilula arcs. The mean carpal height was within the normal range.

Conclusion: In the treatment of perilunate injuries, satisfactory clinical and radiographic outcomes can be expected from ORIF at mid-term follow-up.**Level of Evidence:** Level IV, Therapeutic Study

Introduction

Perilunate injuries are rare injuries caused by high-energy trauma, such as motor vehicle accidents, sports injuries, or falling from a height. Perilunate injuries account for approximately 2% of all hand injuries and generally occur in young males. The injury mechanism is forced hyperextension of the wrist, ulnar deviation, and intercarpal supination. Depending on the severity and direction of the injury, it has been shown that there are a number of different injury types, ranging from perilunate fracture-dislocation to a full lunate dislocation (1-5). The direction of the perilunate dislocation is dorsal in 97% of the patients, with 10% being open injuries and 65% being accompanied by carpal and distal radial fractures (2).

In recent years, although closed treatment techniques have been suggested for these injuries, the current gold standard approach toward treatment is an anatomical reduction and repair of the ligamentous and osseous tissues. In literature, there are studies that

present successful treatment results for open reduction and internal fixation (ORIF), as well as new methods including arthroscopic and minimally invasive techniques that are reporting successful results (6-9).

The purpose of this study was to evaluate the clinical and functional treatment outcomes at mid-term follow-up, including pain, range of motion, disability, and pinch strength, along with functionality and disability during the activities of daily living, of patients treated within our clinic for perilunate dislocation and fracture-dislocation. In addition, the clinical and functional outcomes were compared with the radiological findings.

Materials and Methods

Patients treated for perilunate injuries and fracture-dislocations in our department between 2004 and 2015 were included in this study. Informed consent was obtained from all the patients involved in this retrospective study. The study was approved by

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Two standard posteroanterior and lateral views of the injury were taken at the time of diagnosis. Preoperative radiographs were evaluated by the first author. The perilunate injuries were classified according to the Herzberg classification (1). Mostly, surgery was started using a standard dorsal approach (Table 1). A palmar approach was also used if there were median nerve symptoms or an irreducible dislocation. Direct sutures were used to repair or reattach the scapholunate (SL), lunotriquetral, or the dorsal intercarpal ligaments. K-wires with 1.4-1.6 mm width were used in the stabilization of the reduction, and scaphoid fractures were stabilized using headless compression screws. Additional fractures and bony avulsions were repaired using screws or K-wires. The wrist was immobilized in a scaphoid splint and closed circumferentially after removal of the sutures. At the end of the 6-week postoperative period, the scaphoid splint was removed, and a removable splint was used for 2-4 weeks after which the K-wires were removed and physiotherapy was started (7-11).

Age, trauma setting, injury type, Mayfield classification (4), fractures, treatment time, surgical approach, and the clinical and radiological measurements were recorded on the patient assessment forms prepared by the authors. At the last follow-up assessment, the patient's pain was evaluated using a 10-cm visual analog scale (VAS), where 0 represented no pain and 10 represented unbearable pain (12). Wrist and elbow active joint range of motion (extension/flexion, radial/ulnar abduction, and pronation/supination) was assessed using a universal goniometer. Grip strength was assessed with a dynamometer (Jamar *Hand Grip Dynamometer*; Biometrics Ltd., Gwent, UK), and pinch strength was assessed with a pinch meter (Hydraulic Pinch Gauge; Saehan, Masan, Korea) (13). Range of motion and grip and pinch strength values of the affected side were compared with those of the contralateral side. Functionality was assessed using the Modified Mayo Wrist Score and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire (14, 15). The measurements were assessed twice weekly by an independent assessor (a physiotherapist qualified in hand injuries). The average of the measurements was used for clinical analysis.

Radiological measurements were obtained on posteroanterior, lateral, and anteriorposterior X-rays that were taken at the last follow-up. All the radiographic alignment measurements were taken twice with an interval of 1 week by an independent assessor, and the average of the scores was recorded for analysis. The SL angle, dorsal intercalated segmental instability (DISI) or volar intercalated segmental instability (VISI) configuration, SL interval, carpal height, and the shape of the Gilula arcs were assessed (10, 11). The presence of arthritis was assessed according to the Herzberg classification (1).

Statistical analysis

Analysis of the study results was performed using the Statistical Package for Social Sciences version 16.0 program (SPSS Inc., Chicago, IL, USA) statistical software. A two-tailed value of $p < 0.05$ was considered statistically significant. Descriptive statistics were used

to determine the mean, percentage distribution, and standard deviation values. Outcome measurements were compared using the Mann-Whitney U and Kruskal-Wallis H tests according to the age, treatment time, incision site, type of injury, and scaphoid fracture.

Results

We identified 43 patients who were treated in our department for perilunate injuries and fracture-dislocations; 14 patients did not wish to participate in the study and 3 patients were treated with conservative treatment. Consequently, only 26 patients, 27 wrists, (all men; average age: 39.96 ± 11.1 years; range: 20-58; average follow-up: 45.2 months; range: 16-96) were included in the study. Most of the injuries were fracture-dislocations ($n=20$; 71.4%; Table 1). Moreover, 51.9% ($n=14$) of the injuries were work-related. According to Mayfield staging, 7 wrists were grade 3, and 20 wrists were grade 4. According to Herzberg staging, 11 (40.7%) patients were stage 2a. Perilunate injuries were most commonly associated with radial styloid (51.85%) and scaphoid (44.44%) fractures of the same wrist. Distal radial fractures (7.4%) in the opposite extremity and acetabulum fractures (11.11%) were the most common concomitant injuries. The affected side was dominant in 10 patients, with 1 patient having a bilateral injury. Furthermore, 6 patients had median nerve symptoms; 1 injury was open. In addition, 10 patients received surgical treatment within 1 week, initial diagnosis was missed in 8 patients, and 2 were in the intensive care unit; 6 wrists were treated using only a palmar approach, and 3 wrists were treated using dorsal and volar approach. Average time for return to work was 5.3 ± 2.83 (3-12) months, with 3 patients being unable to return to work.

The average rest pain score according to VAS was 2.3 ± 1.6 (range: 0-5), and the activity pain score was 3.3 ± 1.9 (range: 0-7). The mean active range of motion values were reduced in all the planes. The average wrist flexion was $50^\circ \pm 17.6^\circ$ (21-80°; 73.5% of the unaffected side), extension was $45.1^\circ \pm 15.3^\circ$ (20-74°; 70.9% of the unaffected side), the mean radial deviation was $14.6^\circ \pm 6.2^\circ$ (6-25°; 63.6% of the unaffected side), and ulnar deviation was $22.3^\circ \pm 10.2^\circ$ (5-40°; 64.7% of the unaffected side). The values for pronation and supination range of motion were normal in all the patients, with the exception of 1 patient. Grip strength was 57.6 ± 21.5 (15-106) kg (65.5% of the unaffected side), and pinch strength was 18.6 ± 4.5 (8-28) kg (78.2% of the unaffected side).

Radiological abnormalities according to the Herzberg classification were 3 patients with type A+ and 12 with type B+ (Table 1). At the point of last follow-up, X-ray examinations showed scaphoid non-union in 2 patients; however, they refused further surgical treatment. The average SL angle was 61.6° . There was 1 wrist with a pathologic SL interval. The mean carpal height was within normal range (Table 2). There were 11 wrists with DISI and 3 with fractures of the Gilula arcs.

The average Modified Mayo Wrist Score was 63.3 ± 18.4 (range: 20-90) with good-excellent results in 5, satisfactory results in 14, and poor results in 8 patients. The average DASH score was 24.1 ± 25.2 . A total of 17 wrists had excellent (< 20) DASH scores and 10 wrists had poor (> 50) scores (Table 3).

There were only statistically significant differences in the resting pain scores when the patients were grouped under the age of 30 and older according to their age ($p=0.027$). The mean resting VAS scores were 1.5 in patients under 30 years of age and 2.7 in patients over 30 years of age.

When the outcome measurements were compared according to the incision site, only wrist flexion ($36^\circ \pm 19.8^\circ$) and ulnar deviation ($11.8^\circ \pm 5.7^\circ$) range of motion were significantly lower in patients who

HIGHLIGHTS

- It is possible to achieve optimal functional treatment results in perilunate injuries with accurate diagnosis and timely treatment.
- The current gold standard approach toward treatment is an anatomical reduction and repair of the ligamentous and osseous tissues.
- Age, early treatment, and accompanying scaphoid fractures are associated with better outcome measurements.

Table 1. Clinical features of injuries and surgical approach

N (wrists)	Type of lesion	Associated fractures	Herzberg stage	Neurological deficit	Surgical approach	Fixation	Radiologic abnormalities according to Herzberg
1	PLFDa	TSFb	2B		Dorsal	KWc (Sd), KW (SLe, Lcf, LTg)	B+
2	PLFD	TSF	2A		Dorsal	KW (S), KW (SL, LC)	B+
3	PLDh	RSFi	2B		Dorsal	KW (SL, LC)	B
4	PLFD	RSF+TSF+TTFj	2B		Dorsal	Herbert (S), Screw (Tk, RSI), KW (SL, RLm)	B+
5	PLFD	TSF	2B		Volar	KW (S)	B+
6	PLFD	RSF	2A	+	Dorsal	KW (SL, LT)	B+
7	PLFD	RSF + TTF	2A		Dorsal	Screw (RS), KW (SL,LT)	B+
8	PLFD	TSF+USFn	1		Dorsal	Herbert (S)	A
9	PLFD	RSF+USF	2B		Dorsal	Screw (RS), KW (SL,RL)	A
10	PLFD	RSF+TTF	2B		Volar	KW (SL,RL)	B+
11	PLFD	RSF+TSF	1		Volar	KW (S, RS), KW (SL, LC)	A+
12	PLFD	TSF	2A	+	Combine	Herbert (S), KW (LC, LT)	B+
13	PLFD	RSF	2A		Dorsal	KW (SL,SC,LT)	B+
14	PLFD	RSF	2A		Combine	KW (RS), KW (SL)	A
15	PLD	USF	2A	+	Combine	KW (SL,RS)	B+
16	PLD	TTF	2B		Volar	KW (RC)	B+
17	PLFD	RSF+TTF	2A	+	Dorsal	KW (RS) KW (SL, RL)	A
18	PLFD	RSF+TTF	2A	+	Dorsal	KW (SL)	A
19	PLD	RSF	2B		Dorsal	KW (SL)	A
20	PLFD	TSF	1	+	Dorsal	Herbert (S)	B
21	PLFD	TSF	1		Dorsal	Herbert (S)	A+
22	PLFD	TSF	1		Volar	Herbert (S) KW (LC)	A+
23	PLFD	RSF+TSF+USF	1		Volar	Herbert (S), KW (RS)	B+
24	PLD	USF	2A		Dorsal	KW (SL)	A
25	PLD	RSF+TTF+USF	2A		Dorsal	KW (SL)	A
26	PLD	None	2B		Dorsal	KW (SL)	B
27	PLFD	TSF	1		Dorsal	Herbert (S)	A

a*PLFD: perilunate fracture-dislocation. bTSF: trans-scaphoidfracture. cKW: Kirschner wire. dS: scaphoid. eSL: scapho-lunate. fCL: luno-capitate. gLT: luno-triquetral. hPLD: perilunate dislocations. iRSF: radial styloid fracture. jTTF: trans-triquetral fracture. kT: triquetrum. lRS: radial styloid. mRL: radio-lunate. nUSF: ulnar styloid fracture. oUS: ulnar styloid

Table 2. Radiologic measurements

Measurements (n=27 wrists)	Mean±SD (min-max)/N (%)
SL angle (°)	61.6±12.3 (40-83)
SL interval (mm)	1.27±0.9 (0-5)
Carpal height	0.50±0.04 (0-1)
DISI	11 wrists (40.7%)
Gilula arcs	3 fractures (11.1%)
Herzberg score	A → 12 wrists (44.4%) B → 11 wrists (40.7%) B+ → 4 wrists (14.8%)

*SL: scapholunate
*DISI: dorsal intercalated segmental instability

underwent volar incision than those who underwent dorsal and dorsal plus volar incisions (p=0.037; p=0.013).

The SL interval was significantly higher (p=0.038) in the patients who had suffered their injury at work. Additionally, wrist flexion range of motion was less (p=0.048) and activity pain scores (p=0.043) were higher in this group.

When the outcome measurements were compared according to treatment, time groups had similar results; however, the mean ulnar deviation range of motion was found to be significantly (p=0.023) lower in the patients who had undergone surgical treatment later than the first week.

The time taken to return to work was significantly longer in patients with trans-scaphoid perilunate fractures than those with perilunate dislocations and other carpal fractures (radial styloid, triquetrum, capitat, ulnar styloid; p=0.004).

Table 3. Follow-up time, Modified Mayo Wrist score, and DASH score of patients

N (wrists)	Follow-up Time (months)	Modified Mayo Wrist Score	Grading for Modified Mayo Wrist Score	DASH* Score
2	68	35	Poor	61.4
3	16	40	Poor	56.8
4	47	80	Good	16.2
5	24	70	Satisfactory	31.2
6	27	50	Poor	42.6
7	35	40	Poor	62
8	24	70	Satisfactory	22.4
9	83	70	Satisfactory	11.8
10	25	25	Poor	80
11	25	25	Poor	80
12	64	50	Poor	17.5
13	55	75	Satisfactory	5
14	65	65	Satisfactory	5.8
15	17	65	Satisfactory	10
16	96	55	Poor	12.5
17	64	80	Good	0.8
18	36	70	Satisfactory	14.2
19	51	75	Satisfactory	11
20	31	45	Poor	32
21	28	75	Satisfactory	3.3
22	92	80	Good	5
23	75	65	Satisfactory	11.2
24	64	70	Satisfactory	14
25	19	80	Good	4.2
26	70	90	Excellent	3.2
27	17	65	Satisfactory	10

*DASH: Disabilities of the Arm, Shoulder and Hand.

There was no significant relationship between the measured variables and the presence of arthritis. When the development of arthritis in patients with scaphoid fractures or without scaphoid fractures was compared, the value was close to significance ($p=0.056$). The Mayo ($p=0.032$) and DASH ($p=0.041$) scores were significantly worse in patients who had arthritis. In addition, resting VAS scores ($p=0.025$), grip strength ($p=0.005$), flexion ($p=0.041$), and ulnar deviation ($p=0.001$) range of motion values were significantly lower in patients with arthritis.

Discussion

In this study, it was found that perilunate injuries were mainly in the form of fracture-dislocations in young, actively working men, and the most common concomitant injuries were radial styloid and scaphoid fractures of the same extremity. Furthermore, in the mid-term follow-up, the wrist active joint range of motion and grip strength were lower compared with the uninjured extremity. Modified Mayo Wrist Scores of 65.3% of the patients were satisfactory. Young patients had less resting pain and the time duration until their return to work was longer in those with scaphoid fractures.

It is possible to achieve optimal functional treatment results in perilunate injuries affecting hand function and activities of daily living with accurate diagnosis and timely treatment. Although closed reduction treatment has been used in previous years, ORIF is now used as the gold standard approach to treatment (8). Additionally, one study has reported that similar results were obtained between ORIFs and proximal row carpectomies (16), and more recently, minimally invasive methods have started to be used (9, 17). In this study, we evaluated the clinical and radiological outcomes of the patients treated by ORIF in our clinic because of perilunate injuries. Outcome measurements were compared according to age, incision site, occupational accident, treatment time, and scaphoid fracture.

The patients included in the study were men between the age of 20 and 58 years, and other literature has also reported that injuries were usually seen in a similar age range (1, 17, 18). Additionally, all or most of the cases included in the previous studies were males (1, 17, 18). In this study, 51.9% of the injuries occurred at the workplace, and the patients were manual workers. Kremer et al. reported that 67% of injuries occurred in blue-collar workers, and 41% of them were work-related (7). Krief et al. reported that 43.3% of the patients were heavy manual workers (19). In most of our patients, the injury type was a fracture-dislocation (71%). Similarly, previous studies also reported that fracture-dislocation type injuries were more common (7, 19, 20).

In this study, 74% of the injuries were stage 4 according to the Mayfield staging. A previous study reported that 33% of the injuries were stage 3, as well as 41% being unknown due to missing or poor quality of X-rays (7). The degree of sagittal displacement in the lateral view was 2a in most of the injured wrist (40.7%) according to Herzberg staging. In a study including 27 wrists, Herzberg et al. reported that the most common injury stage was 1 followed by type 2a injury (33%) (9). In this study, the most common injuries associated with the perilunate injury were radial styloid and scaphoid fractures. In previous case series, scaphoid fractures had been reported as the most common concomitant injury (7, 17, 21). We believe that the radial styloid fracture was the most common concomitant injury in our study because high-energy injuries were more common in our patients.

Preoperative evaluation revealed median nerve injuries in 6 wrists (22%), and follow-up evaluation revealed a permanent medial nerve deficit in only 1 wrist (3.7%). However, Dunn et al. reported acute

medial nerve deficits in 50% of their patients, and 17.5% had persistent median nerve paresthesia after reduction (22). In addition, functional impairment in the two-point discrimination of median and ulnar nerve sensory areas after reduction has been reported in the literature (7, 20).

Surgical treatment was performed within 1 week in 10 wrists, and in the other wrists, treatment was delayed owing to the additional trauma and missing diagnosis. Many previous authors have reported that perilunate injuries can be missed, and early treatment is important for good functional outcomes (1, 22-24).

Although the group treated in the first week had better outcome measurements, there was no statistically significant difference between the patients who underwent a reduction in the first week as compared with those who were treated in a later period. Only the ulnar deviation ranges were superior in patients operated on in the early period. Yu et al. showed that ORIF can be used to achieve good results and prognoses in patients with both acute and delayed perilunate dislocations (24). Similarly, Dunn (22) reported that patients treated after the first week up to 45 days had similar outcomes to the patients treated in the first week.

A total of 88.5% of the patients included in this study returned to work, and the average time taken to return to work was 5.3 months. Data analysis showed that patients with accompanying scaphoid fractures returned to work over longer periods. Similarly, Kremer et al. showed that patients with scaphoid fractures had poorer functional outcomes, although they were not statistically significant (7). In a study by Griffin et al., 88% of patients returned to work, and the average time taken to return to work was 6 months (20). When perilunate injuries were examined in the US military, 7.5% of the patients had left the military because of disability due to the injury and 75% were able to return to recreational sports (22).

At the last follow-up assessment (mean: 42 months), patients were experiencing ongoing rest (2.3) and activity (3.3) pain. Similarly, resting pain was reported to be less than activity pain at 24 months follow-up (20). In another study, patients were followed up for as long a time as 112 months, and the authors found that patients had a 1.1 pain score with loading (18). In another study, with a mean of 47.8 months follow-up, authors stated that 78% of the patients had pain with activity (22).

In our study population, the range of motion of the wrist joint was reduced in 4 directions and the grip, and pinch grip strengths were reduced relative to the unaffected side, similar to the results of the previous studies. We found that radial deviation (63% of unaffected hands) was the most limited motion. The flexion-extension range of motion was 70.0%-73.5%, and grip strength was 65.5% of the unaffected side. In previous studies, results showed that the flexion-extension range of motion was 57%-80% of the unaffected side, and grip strength ranged between 71%-87% of the unaffected side (19). Wrist flexion range was significantly lower in patients with work-related injuries. It has been reported that the range of motion, grip strength, and functionality outcomes were affected more in work-related perilunate injuries (7, 17, 18, 24). Muller et al. suggested that the mean pain score was lower in the group treated with proximal row carpectomy than the group treated using ORIF, and the mean grip strength value was higher in proximal row carpectomy group (16). Oh et al. showed that the range of movement (ROM) values of patients undergoing arthroscopic reduction were superior to the patients having undergone ORIF (21). In this study, supination and pronation ROM values were within the normal range, similar to the results presented in previous studies (7, 25).

The SL angle was assessed on a lateral view, and an angle greater than 60° or lower than 30° is used to define the presence of DISI (dorsiflexion instability) or VISI (volarflexion instability) configuration, respectively. If the SL interval measured on an anteriorposterior view was greater than 3 mm, SL dissociation was considered. The carpal height was used to diagnose and assess the severity of carpal collapse. The average SL angle of our patients was 61.6°, and 11 had DISI. There was 1 wrist with a pathologic SL interval, and the mean carpal height was within the normal range. Similar to the results of this study, Griffin et al. (20) measured the average SL angle as 66° and 4.38 mm SL diastasis for lesser arc injuries in the follow-up evaluation. Kremer et al. (7) specified that the average SL angle was 44°, but 46% of the patients had a pathological SL angle and only 13% (5) of the patients had a normal carpal height in their follow-up assessment.

The mean Mayo (63) and DASH (24.1) scores were found to be similar to those of the previous studies (7, 20, 24). In the literature, 14 studies included case series with perilunate dislocations and perilunate fracture-dislocations; the Mayo scores were reported to be between 63 and 81. In a study by Muller et al., the mean quick DASH score was estimated as 27 of 16 patients treated with ORIF (16). In a study of 7 patients by Yu et al. (24), the authors suggested that patients who had early treatment achieved better Mayo scores. Another study also reported that patients younger than 30 years had better Mayo and DASH scores, but the difference between the patients younger than 30 years and older was not statistically significant (7). In this study, when the results were analyzed according to age, it was found that patients younger than 30 years had better functional outcomes. However, there was no statistically significant difference between the mean values. The small sample size may be the reason for not obtaining a significant difference between the age groups.

It has been reported that patients treated by ORIF had better functional results than those treated with conservative treatment, and patients treated with arthroscopic surgery or proximal row carpectomy had better functional results than those treated by ORIF (7, 15, 16, 21). The treatment methods of chronic perilunate injuries vary in literature and involve ORIF, proximal row carpectomy, partial wrists fusions, wrist arthrodesis, and lunate excision (11).

In conclusion, although new methods of treatment have been defined in the literature, ORIF can still be used to achieve good results and prognoses in cases of perilunate injury. Age, early treatment, and accompanying scaphoid fractures are associated with better outcome measurements.

Ethics Committee Approval: Ethics committee approval was received for this study from the Regional Scientific Ethics Committee of Kartal Dr. Lütfi Kırdar Training and Research Hospital (2019/514/167/3).

Informed Consent: Informed consent was obtained from all the patients involved in this retrospective study.

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