



# Perilunate fracture-dislocations: clinical and radiological results of 21 cases

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## Abstract

**Background** Perilunate dislocations and fracture-dislocations are a subcategory of the carpal instability complex. Herein, we report our university hospital experience with this complex injury. The goal of our study was to find predictive factors and quantify the development of arthritis and lunate necrosis. We tried to measure the impact of arthritis on hand function.

**Methods** Between January 2000 and December 2014, 21 patients underwent surgery for perilunate dislocations and perilunate fracture-dislocations of the wrist in our tertiary university center. Mean patient age was  $29.3 \pm 10.0$  years (range 18–49 years). All displacements were posterior. They were reviewed both clinically and radiologically.

**Results** Complications included misdiagnosed Essex-Lopresti-like lesion in one case, insufficient reposition of the carpus in two cases (LT in one case, SL in one case), and iatrogenic injury to the radial artery immediately sutured in one case. All 3 cases underwent a second procedure with satisfactory outcome. After a mean follow-up of  $112 \pm 60$  months (range 12–210 months), the average Cooney score was  $80 \pm 19$  (range 50–125). The mean PRWE score was  $10 \pm 8$  (range 0–25). The mean DASH score was  $40 \pm 13$  (range 30–75 months). Mean pain on load, measured with VAS was  $1.1 \pm 1.6$ ; Clinical examination assessed a mean wrist extension/flexion of  $42.4^\circ \pm 17.2^\circ/48.4^\circ \pm 15.2^\circ$ . Mean wrist ulnar/radial deviation was, respectively,  $22.9^\circ \pm 11.3^\circ/15.3^\circ \pm 7.0^\circ$ . Mean pro/supination was, respectively,  $75.2^\circ \pm 11.5^\circ/76.3^\circ \pm 8.1^\circ$ . Mean pinch strength was  $9.4 \pm 2.2$  kg ( $87.4 \pm 17.7\%$  of the contralateral side). Mean power strength was  $41.9 \pm 9.9$  kg ( $76.2 \pm 19.2\%$  of the contralateral side). Two patients had a scaphoid non-union identified on their most recent imaging. The mean carpal height ratio was  $0.53 \pm 0.05$  (range 0.44–0.65). All except one patient developed arthritis: Grade 1 in 11 patients, Grade 2 in 3 patients, and Grade 3 in the remaining 6 patients. Age, length of follow-up, and loss of reduction were significantly associated with wrist arthritis ( $p < 0.001$ ). Lunate avascular necrosis assessed by magnetic resonance imaging was present in 6 patients: Stage 2 in 4 patients, Stage 3a in 1 patient, and Stage 3b in the remaining patient. All these patients' intraoperative findings showed lesion of the cartilage of the radial side of the lunate. However, the small number of patients who developed lunate necrosis did not allow satisfactory statistical analysis.

**Conclusions** This retrospective study demonstrates good functional results despite the high rate of radiological wrist arthritis. Age, length of follow-up, and loss of reduction were significantly associated with wrist arthritis in our series.

**Keywords** Wrist · Perilunate dislocations · Fracture-dislocations · Herzberg classification

## Introduction

Perilunate dislocations and fracture-dislocations are a subcategory of the carpal instability complex. The impact of the trauma can propagate through ligaments (perilunate

dislocations) and/or bone (fracture dislocations), creating multiple variations of a basic injury pattern [1, 2]. Although closed treatment was historically advocated for these injuries, the trend has shifted toward anatomic reduction and repair of the ligamentous and osseous structures with early open reduction and internal fixation [3].

Many authors have suggested a dorsal approach as it offers the benefit of adequate exposure of the proximal carpal row and mid-carpal joint [4–8]. A complementary volar approach [9] allows access to distal scaphoid fractures and repair of the volar ligaments and capsular rent as well as the

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release of the carpal tunnel. The goal of the surgery is to stabilize the carpal bones and repair acute ligament lesions of the scapho-lunate or luno-triquetral or the dorsal intercarpal ligaments as well as the injured dorsal extrinsic avulsed ligaments to the radius.

There is usually a discrepancy between adequate stabilization and the radiological development of arthritis [10, 11]. In other words, according to Herzberg, post traumatic arthritis is very common in long-term outcomes despite adequate stabilization.

In this context, we have reviewed cases of perilunate dislocation and/or fracture injuries of this complex hand trauma in our university's hand center. The goal of our study was to define predictive factors and quantify the development of carpal arthritis and lunate necrosis. We tried to measure their impact on hand function. Our results were compared to those of the current literature.

## Materials and methods

### Patients

This retrospective study was performed following the ethical guidelines of the University of Bern (ethical board approval S2790). Inclusion criteria were: patients with

perilunate dislocations (PLD) and perilunate fracture-dislocations (PLFD), of all ages, both sexes, who underwent surgery in our department between January 2000 and December 2014. Exclusion criteria were the following: collagen disease, rheumatoid arthritis, and osteomalacia. Patient who received proximal row carpectomy were excluded from the series. The patients, of whom 21 were men, had a mean age of  $29.3 \pm 10.0$  years at the time of surgery (range 18–49 years). The dominant hand was injured in 13 of these patients and in 8 patients the non-dominant hand was involved (Table 1).

### Perilunate fractures

Injuries were classified according to the Herzberg classification (Table 2) [10, 11]. The degree of carpal instability after PLFD was classified according to the Mayfield classification [12]. On the anteroposterior view, there were 1 PLD and 20 PLFD (3 dislocations with associated radius styloid fracture, 17 transscaphoid perilunate fractures). On lateral views, assessing displacement of the capitate, all deformities involved posterior displacement. All the PLFDs were classified as stage 1 (lunate in place under the radius).

**Table 1** Patient demographics in our series (1/0 : yes/no)

N	Age (years)	Sex	Profession	Accident whilst working (1/0)	Etiology	Dominant/operated side
1	20	M	Construction worker	1	Fall from a Ladder	Dominant/left
2	34	M	Mechanic	0	Ice-hockey accident	Dominant/right
3	21	M	Unemployed	0	Fall from a motorbike	Non-dominant/right
4	25	M	Carpenter	0	Parachuting accident	Dominant/left
5	46	M	Photographer	0	Snowboarding accident	Dominant/left
6	41	M	Farmer	0	Fall from a bike	Adominant/left
7	22	M	Heating engineer	0	Fall from a train	Dominant/right
8	21	M	Plumber	0	Fall from a bike	Adominant/left
9	34	M	Farmer	1	Crane crushing injury	Dominant/right
10	18	M	Gardener	0	Ski accident	Adominant/left
11	23	M	Machine operator	1	Fall from a lorry	Adominant/right
12	49	M	Construction worker	0	Fall from a bike	Dominant/left
13	30	M	Unemployed	1	Cylinder crushing injury	Dominant/left
14	27	M	Farmer	0	Ice-hockey injury	Dominant/right
15	18	M	Surveyor	0	Parachuting accident	Adominant/left
16	18	M	Carpenter	0	Fall from a bike	Adominant/left
17	23	M	Construction worker	0	Fall from a motorbike	Adominant/right
18	37	M	Farmer	0	Ski accident	Dominant/left
19	47	M	Engineer	0	Ski accident	Dominant/right
20	34	M	Office worker	0	Parachuting accident	Dominant/right
21	27	M	Coachbuilder	0	Fall from a bike	Dominant/right

**Table 2** Operative approach for each patients of our series

N	Type of lesion	Associated fracture and chip fractures	Herzberg stage	Neuro-logical deficit (1/0)	Surgical approach	Fixation	OP-duration (min)	Complications	Tourni-quet duration (min)
1	PLFD	RSF + TTF	1	1	Palmar and dorsal	Screw (RSF), KW (SL,LT, CL)	120		90
2	PLFD	TSF + TTF	1	1	Palmar and dorsal	Herbert (S), Screw (T), KW (LT)	180		135
3	PLFD	TSF + TCF + TTF	1	1	Palmar and dorsal	KW (S,C,LT)	240	LT-Dissociation	150
4	PLFD	RSF	1	0	Palmar and dorsal	KW (SL, LT)	170		130
5	PLFD	TSF + TTF	1	0	Dorsal	Herbert (S), KW (LT)	180		140
6	PLFD	TSF + TTF	1	1	Palmar and dorsal	Herbert (S), KW (LT, SC)	150		120
7	PLFD	RSF + TSF	1	1	Palmar and dorsal	Herbert (S), Screw (RS)	105		90
8	PLFD	TSF	1	0	Palmar and dorsal	Herbert (S), KW (LT)	240	Essex-Lopresti Fracture	190
9	PLFD	TSF + USF	1	1	Palmar and dorsal	Herbert (S), KW (US,SL,LC, LT)	180		120
10	PLFD	TSF + TCF	1	0	Dorsal	Herbert (S,C), KD (LT)	180		160
11	PLFD	RSF	1	0	Palmar and dorsal	KW (RS,SL,LT)	240		180
12	PLFD	RSF + TSF + TTF	1	0	Palmar and dorsal	Herbert (S), Screw (RS), KW (LT)	170		130
13	PLFD	RSF	1	1	Palmar and dorsal	KW (RS,SL,LT)	140		120
14	PLFD	TSF	1	1	Palmar and dorsal	Herbert (S), KW (SC,LT)	210		210
15	PLFD	TSF	1	1	Palmar and dorsal	Herbert (S), KW (LT)	135		120
16	PLFD	TSF + TCF + USF	1	0	Palmar and dorsal	KW (S,LT,US)	150		120
17	PLFD	TTF	1	0	Dorsal	KW (SL,LT,T)	170		130
18	PLFD	RSF + TCF + TTF	1	0	Dorsal	Herbert (T), Screw (RS), KW (SL,SC,LT)	210		140
19	PLFD	TSF + USF	1	0	Palmar and dorsal	Herbert (S), KW (LT)	160		130
20	PLD	None	Mayfield 4	0	Palmar and dorsal	KW (SL, LT, SC)	165	SL-Dissociation	120
21	PLFD	RSF + TSF + TTF	1	0	Palmar and dorsal	Herbert (S), Screw (RS), KW (LT)	150		130

*PLFD* perilunate fracture-dislocation, *PLD* perilunate dislocations, *RSF* radial styloid fracture, *TTF* trans-triquetral fracture, *TSF* trans-scaphoid fracture, *TCF* trans-capitate fracture, *USF* ulnar styloid fracture, *KW* kirschner wire, *SL* scapho-lunate, *LT* luno-triquetral, *CL* luno-capitate, *S* scaphoid, *T* triquetrum, *RS* radial styloid, *US* ulnar styloid

## Surgical technique

A combined dorsal and volar approach is the rule. However, in case of low velocity trauma with moderate swelling and

no neurological deficit, only a dorsal approach may be performed. On the dorsal approach, the lunate is reduced and temporarily fixed to the radius in a neutral position. Scaphoid fractures are treated by compression screws [13–16] or

k-wires usually from a dorsal approach depending on the comminution, the fracture location, and the need for bone graft. The state of the lunotriquetral joint and the existence of osteochondral damage are noted. Lunotriquetral fixation by ulnar transfixation with 1.4 or 1.6 mm k-wires are performed as well as triquetro-capitate k-wire fixation. Additional fractures including bony avulsions of intrinsic ligaments are fixed by screws, k-wires or micro-anchors. Fresh ligament lesions of the scapholunate or lunotriquetral or the dorsal intercarpal ligaments are readapted or reattached by micro-anchors, as well as injured dorsal extrinsic avulsed ligaments to the radius.

On the volar site, carpal tunnel release is performed and the radio-lunate ligaments checked, reattached or readapted by (non)-resorbable sutures.

### Post-operative protocol

The wrist is immobilized in a scaphoid splint for at least 6 weeks, the splint is closed circumferentially after removal of the stitches. After 6 weeks, a removable splint is used for another 3–4 weeks with compliant patients before the removal of k-wires is performed. Initial swelling of the hand and fingers can be considerable, and regular hand therapy for finger and interphalangeal thumb joint mobilization is performed. Pro-Supination in the plaster is allowed. Regular non-steroidal anti-inflammatory drugs are given. In case of massive swelling, a short-course of corticosteroids is used for 3 days (Dexamethasone 8 mg the first day then dropped to 4 mg). We use k-wires of 1.4 mm thickness since we experienced mid carpal breakage with smaller k-wires (1.25 mm). It can be technically challenging to remove broken k-wires. The use of thicker k-wires permits movement of the radiocarpal joint without load-bearing after 6 weeks. Removal of the k-wires after 10 weeks is done under fluoroscopy followed by mobilisation of the wrist under fluoroscopy. Depending on the radiographic appearances, progressive mobilisation and strength training can be started after 10 weeks and removal of k-wires.

### Clinical assessment

The postoperative complications were identified through the electronic patient chart. An additional clinical and radiological assessment was performed for all patients. This included a review of the median nerve function, wrist extension/flexion, wrist radial/ulnar deviation, pro/supination, grip strength, and power strength. Grip strength and power strength were measured using the Jamar dynamometer. The whole clinical evaluation was scored using the Cooney score [5].

### Subjective assessment

Patients were asked to quantify pain on load using a visual analogue scale (VAS) from 0 (no pain) to 10. Median nerve compression symptoms were also recorded at each assessment. A complementary subjective evaluation of the upper limb was also performed with disability of arm-shoulder-hand score (DASH) [17] and patient-rated wrist evaluation (PRWE) [18].

### Radiological assessment

Radiographs of the wrist including anteroposterior view, lateral view, ulnar-deviation view, radial deviation view and clenched fist view were performed regularly after the surgery and at the final follow-up visit. The scapho-lunate angle was systematically measured on the lateral view. A scapho-lunate angle greater than 60° or lower than 30° was used to define the presence of dorsal intercalated segmental instability (DISI) or volar intercalated segmental instability (VISI) configuration, respectively. The scapholunate interval was systematically measured on the anteroposterior view. A scapholunate interval greater than 3 mm was considered as scapholunate dissociation (SLD). The carpal height was used to diagnose and assess the severity of carpal collapse. It is defined as the distance between the base

**Table 3** Subjective results following surgery in our series

N	Follow-up (months)	DASH (points)	COONEY (points)	PWRE (points)	VAS (0–10)
1	138	58	55	25	1
2	78	36	90	19	0
3	12	36	75	3	1
4	12	41	50	4	2
5	90	30	100	11	0
6	78	46	85	16	3
7	210	43	70	13	0
8	66	50	80	22	2
9	126	75	50	24	2
10	174	36	75	5	1
11	186	30	80	0	0
12	190	32	75	5	0
13	126	31	75	5	1
14	80	33	85	9	2
15	76	30	125	0	0
16	126	30	125	0	0
17	126	72	65	21	7
18	48	30	80	8	0
19	174	34	75	4	1
20	186	34	80	5	0
21	48	30	90	7	0

of third metacarpal and the subchondral bony cortex of the distal radius on the anteroposterior view. But due to variations between individuals, it is more appropriate to calculate the carpal height ratio. It is calculated by dividing the carpal height by the length of the third metacarpal [19]. Its normal range is between 0.51 and 0.57.

Radiographic evidence of arthritis was assessed according to the Watson staging [20]: osteoarthritis of the articulation between the radial styloid and the scaphoid (Grade I), osteoarthritis involving the whole radioscaphoid articulation (Grade II), osteoarthritis of the radioscaphoid and capitolunate articulations (Grade III), osteoarthritis of the radiocarpal and intercarpal articulations +/- distal radioulnar joint (DRUJ) (Grade IV). Avascular necrosis of the lunate was graded according to the Lichtman classification [21].

### Measured parameters

In this retrospective study, 21 patients underwent surgery in our university hospital hand center for perilunate dislocations and fracture-dislocations of the wrist. Data are presented as mean  $\pm$  standard error of the mean (SEM). Statistical analysis was performed using the SPSS program (SPSS, Chicago, IL, USA). Where applicable, Fisher's exact test and Student's *t* test (2 samples) were used to calculate the *p*

values, and a *p* value lower than 0.05 was considered to be statistically significant. When the heterogeneity of the injury mechanisms and subsequent deformity patterns did not allow satisfactory statistical analysis, data were presented in a descriptive manner.

### Results

The delay between the injury and the surgical procedure was less than 6 h in all but two cases. In the remaining two patients it was less than 24 h. The mean surgical time was  $136.0 \pm 29.2$  min. Complications included misdiagnosed Essex-Lopresti-like lesion in one case, insufficient reposition of the carpus in two cases (LT in one case, SL in one case), and iatrogenic injury to the radial artery immediately sutured in one case. All 3 cases underwent a second procedure with satisfactory reposition. There were no infections or development of a complex regional pain syndrome.

### Subjective assessment

Complete evaluation was obtained in all patients. The subjective findings are reported in Table 3. After a mean follow-up of  $112 \pm 60$  months (range 12–210 months), the

**Table 4** Functional post-operative results in our series

N	WristR/U (°)	Wrist F/E (°)	Wrist P/S (°)	Grip strength (ABSOL/REL)	Pinch strength (ABSOL/REL)
1	30/10	60/24	74/74	40/74	10/100
2	6/24	40/30	90/85	50/119	9/112
3	10/26	40/26	80/80	50/80	10/66
4	15/30	70/40	80/70	44/75	7/70
5	30/10	50/60	70/70	49/80	7/77
6	15/30	62/60	80/80	42/77	8/66
7	6/16	30/40	80/80	36/78	12/100
8	10/10	48/12	36/70	40/80	10/100
9	6/8	30/20	66/50	40/57	13/81
10	10/25	30/30	70/70	42/77	8/100
11	20/35	50/40	90/90	38/65	8/88
12	16/0	44/56	80/80	40/60	10/90
13	15/30	20/30	80/80	32/48	10/100
14	8/30	60/24	74/74	68/89	11/100
15	20/16	44/52	80/80	48/93	9/90
16	10/25	60/45	80/80	44/75	9/90
17	20/24	54/54	60/70	12/28	3/33
18	15/30	30/70	80/80	40/74	11/84
19	20/20	60/65	80/80	40/72	12/100
20	15/25	54/42	70/80	42/86	10/77
21	20/30	80/70	80/80	42/100	9/90

R/U wrist radial/ulnar deviation, F/E wrist flexion/extension, P/S, wrist pronation/supination, ABSOL/REL absolute/relative

average Cooney score was  $80 \pm 19$  (range 50–125). The mean PRWE score was  $10 \pm 8$  (range 0–25). The mean DASH score was  $40 \pm 13$  (range 30–75 months). There was a discrepancy between the DASH score and PRWE score ( $p < 0.001$ ). Patient 9 and 17 with DASH score of 75 and 72 refused complementary treatment because they did not want to stop working during secondary surgery. Mean pain on load, measured with VAS was  $1.1 \pm 1.6$ . None of the patients had median nerve symptoms.

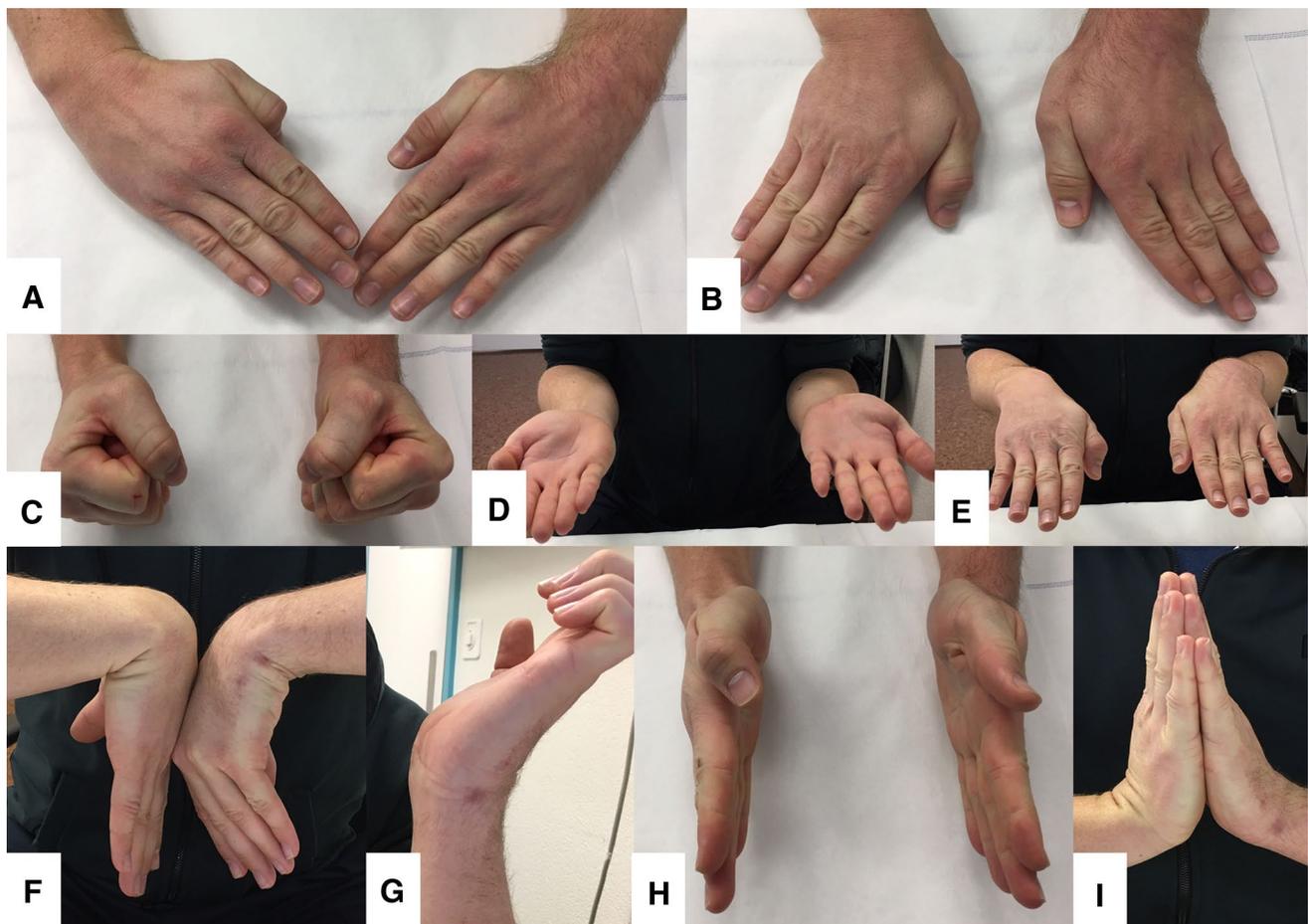
### Objective assessment

The functional results at post-operative check-up are reported in Table 4. Clinical examination assessed a mean wrist extension/flexion of  $42^\circ \pm 17^\circ/48^\circ \pm 15^\circ$  (Fig. 1). Mean wrist ulnar/radial deviation was  $23^\circ \pm 11^\circ/15^\circ \pm 7^\circ$ . Mean pro/supination was  $75^\circ \pm 11^\circ/76^\circ \pm 8^\circ$ . Mean pinch strength was  $9 \pm 2$  kg ( $87 \pm 18\%$  of the contralateral side).

Mean power strength was  $42 \pm 10$  kg ( $76 \pm 19\%$  of the unaffected contralateral side).

### Radiological assessment

The radiological results at the postoperative check-up are reported in Table 5 (Fig. 2,3). At the last X-ray examination, two patients had scaphoid non-union but refused further surgery. The mean carpal height ratio was  $0.53 \pm 0.05$  (range 0.44–0.65). Radiographic evidence of arthritis was present in all but one patient: 11 were classified as stage 1, 3 were stage 2, and 6 were stage 3. Age and length of follow-up were significantly associated with wrist arthritis ( $p = 0.001$  and  $p < 0.001$ ). Comparison between patients without arthritis or arthritis grade I and patients with arthritis grade II to IV showed no significant difference regarding wrist range of motion, pain, grip and power strength, DASH or PRWE score ( $p > 0.05$ ). Development of arthritis was correlated to the increase of the



**Fig. 1** Functional results 78 months after perilunate fracture-dislocation (Patient 6 of the series). **a, b** Wrist radial/ulnar deviation  $20^\circ/24^\circ$ ; **c** complete fist; **d, e** wrist pronation/supination  $90^\circ/90^\circ$ ; **f–i** wrist flexion/extension  $54^\circ/54^\circ$

scapho-lunate angle between the immediate follow-up and long-term radiological assessment ( $p < 0.01$ ).

Avascular necrosis of the lunate was diagnosed by magnetic resonance imaging in 6 patients after suspicion in the x-ray: stage 2 in 4 patients PLFD with radial styloid fracture (patient 4) associated with trans-triquetral fracture and trans-scaphoid fracture (patient 1 and 21), and PLFD with trans-scaphoid fracture, trans-capitate and ulnar styloid fracture (patient 16), stage 3a in 1 patient with trans-scaphoid PLFD associated with ulnar styloid fracture (patient 9) and stage 3b in the remaining patient with PLD Mayfield IV (patient 20).

All these patients' intraoperative findings showed lesion of the cartilage of the radial side of the lunatum. However, the small number of patients who developed lunate necrosis did not allow satisfactory statistical analysis.

## Discussion

In this study, 21 patients underwent surgery in our tertiary hand center for perilunate dislocations and fracture-dislocations of the wrist. The displacement of all these lesions was posterior. A combined volar and dorsal approach was performed in all but 4 patients. Complications included misdiagnosed Essex-Lopresti-like lesion in one case, insufficient

reposition of the carpus in two cases (LT in one case, SL in one case), and iatrogenic injury to the radial artery immediately sutured in one case. The other three cases underwent a second procedure with satisfactory repositioning and outcome. After a mean follow-up of 112 months, despite good functional long-term results, radiologic evidence of arthritis was present in all but one case and avascular necrosis of the lunate was present in 6 patients. Age, length of follow-up, and loss of reduction were significant factors associated with wrist arthritis.

As reported in the "Introduction" section, the combined surgical approach presents the following advantages: (1) The volar approach suggested by Herbert and Fisher [9] allows access to distal scaphoid fractures and allows repair of the volar ligaments and capsular rent as well as the release of the carpal tunnel. In our opinion, this injury is usually caused by a high velocity trauma and release of the carpal tunnel is mandatory to prevent possible median nerve compression due to post-operative swelling. In other words, the volar approach can be spared in case of low velocity trauma with moderate swelling and no neurological deficit. In our series, carpal tunnel symptoms were present in 9 out of 21 patients (43%). For all but 4 patients, the palmar approach was performed to combine carpal tunnel release and repair of important ligament tears or distal scaphoid fractures. After a mean follow-up of 112 months, no patients complained of carpal

**Table 5** Radiological outcomes in our series

N	Herzberg (Grade)	Carpal height ratio	Arthritis (Grade)	DISI 1/0	VISI 1/0	Lichtman
1	1	0.49	1	No	No	2
2	1	0.52	0	No	No	–
3	1	0.60	1	No	No	–
4	1	0.53	1	No	No	2
5	1	0.49	2	Yes	No	–
6	1	0.52	3	yes	No	–
7	1	0.50	1	No	No	–
8	1	0.53	1	No	No	–
9	1	0.44	3	No	No	3a
10	1	0.50	1	No	No	–
11	1	0.65	2	yes	No	–
12	1	0.65	3	Yes	No	–
13	1	0.55	3	Yes	No	–
14	1	0.50	1	No	No	–
15	1	0.53	1	No	No	–
16	1	0.47	1	No	No	2
17	1	0.55	2	yes	No	–
18	1	0.55	1	No	No	–
19	1	0.52	3	yes	No	–
20	Mayfield 4	0.46	3	yes	No	3b
21	1	0.49	1	No	No	2

1/0 yes/no



**Fig. 2** Patient 2 of the series: **a, b** radiological findings at the time of the accident showing perilunate fracture-dislocation Herzberg I with trans-scaphoid fracture and trans-triquetral fracture; **c, d** scaphoid osteosynthesis with Herbert screw, Triquetral osteosynthesis with mini screw, and LT reposition with kirschner wires. The Herbert screw is protruding proximally; **e, f** radiological findings 80 months after trauma showing good position of the lunate, no arthritis, but bone resorption around the protruding part of the screw

tunnel symptoms, supporting the benefit of this approach. (2) The dorsal approach offers adequate exposure of the proximal carpal row and the mid-carpal joint [4–6]. The space produced by the luxation allows easy Kirschner wire placement in both the scaphoid for scapho-lunate transfixation and the triquetrum for triquetro-lunate fixation. These are the main reasons for avoiding closed reduction during preoperative management. However, when these injuries arrive at night and there is no OR capacity, we start with closed reduction and proceed with the surgical reduction described above within the next 24 h. Whatever the variation and complexity of the injury, the primary goal of surgery is to stabilize the carpal bones and repair ligaments to reconstruct the carpal integrity in both sagittal and anteroposterior views and obtain stability during movement. In our series, the length of follow-up was correlated to a loss of reduction, which may explain its statistically significant association with arthritis. The two patients with scaphoid non-union refused further surgery and developed a dorsal intercalated segmental instability with subsequent Grade III arthritis.

The patients in our case series are heterogenous and hence difficult to compare. Furthermore, the small sample number does not allow for satisfactory statistical analysis. The highly variable presentation of this injury means that a much larger case series would be required to obtain statistically significant results. The relative rarity of this injury means that such a study would be highly challenging to achieve in practice. However, the functional results obtained with our series of 21 patients appear adequate after 112 months mean follow-up. The average Cooney score of 80 is similar to other series with a shorter follow-up: Martinage et al. [22], Inoue and Imaeda [23], Inoue and Kuwahata [24], and Sotereanos et al. [25] reported a Cooney score (follow-up) of 70 pts (27 months), 72 pts (25 months), 84 pts (26 months), 65 pts (26 months), respectively. Series of Herzberg and Forissier [11], Herzberg et al. [10], Cooney et al. [5], and Hildebrand et al. [26] with a longer follow-up but smaller patient numbers than our series, reported a Cooney score (follow-up) of 79 pts (103 months), 63–86 pts (75 months), 65–75 pts (50 months), and 66 pts (37 months), respectively.

Moreover, the wrist extension/flexion range of motion in our series (Table 4) is quite similar to the previous cited series that described a ROM from 76° [5] to 112° [21]. Relative grip strength of 76% in our series is also comparable to other published series. Herzberg and Forissier [21], Trumble

et al. [27], Hildebrand et al. [26], Sotereanos et al. [25], Inoue and Kuwahata [24], Inoue and Imaeda [23], and Martinage et al. [22] published a relative grip strength of 79, 77, 73, 77, 88, 77, and 77%, respectively. However, once again the mean follow-up was shorter in all these series.

There is an inconsistency between the good functional outcome of this series and the radiological development of arthritis in all but one patient. According to Herzberg [10, 11], post traumatic radiological arthritis is very common in long term outcomes despite adequate stabilization. However, results have shown that radiographic demonstration of arthritis is not significantly associated with reduced function. Considering the good functional results and the lack of pain, patients with radiological arthritis refused further surgery at long-term follow-up. Patient 9 and 17 with a DASH score of 75 and 72 refused further treatment because they did not want to stop working during secondary surgery. Before concluding, we should like to stress on the discrepancy in our series between the DASH and PRWE scores, which emphasizes the subjectivity of the results. Recently, Sorensen et al. [28] pointed out the subjective interpretation of these scores and designed a study to define the minimal clinically important differences (MCIDs) of the DASH, QuickDASH (subset of DASH), and PRWE. They have concluded that longitudinal changes on the DASH of 10 points, on the QuickDASH of 14 points, and on the PRWE of 14 points represent minimal clinically important changes. In our study, the discrepancy between the DASH and PRWE scores remains difficult to interpret because the preoperative scores were not recorded. This makes the longitudinal changes of both scores impossible to calculate. The rate of avascular necrosis is heterogenous among published series [22–26]. In our series, despite the high rate of 29%, the small number of patients that developed lunate necrosis did not allow satisfactory statistical analysis. However, we noticed that all patients' intraoperative findings showed cartilaginous lesions of the radial side of the lunate. In high grade avascular necrosis without major damage to the articular surface of the radius or to the dome of the capitate, a proximal row carpectomy would have been our therapy of choice. However, in our series, surgery was not performed because the patient concerned was asymptomatic.

Despite the long-term outcomes, our series present both methodological and technical limits: (1) First, this is a retrospective study. (2) Second, the diversity of surgeons makes the series inconsistent, although this is counterbalanced by the standardization of the technique within the same surgical department. (3) Third, with the small number of cases in this series and the heterogeneity of the cases, only age, length of follow-up, and loss of reduction were pointed out as factor of post-traumatic development of wrist arthritis. (4) Finally, the absence of a control group did not allow us



**Fig. 3** Patient 14 of the series: **a** radiological findings (antero-posterior view) after closed reduction showing perilunate fracture-dislocation Herzberg 1 with trans-scaphoid fracture; **b** Scaphoidosteo-synthesis with Herbert screw and scapho-capitate kirschner wire, and LT

reposition with kirschner wires; **c** radiological findings 78 months after trauma showing Scaphoid fracture consolidation, good position of the lunate, but osteoarthritis of the articulation between the radial styloid and the scaphoid; **d–f** lateral views

to compare the long-term outcomes of our technique with other surgical approaches.

## Conclusion

This retrospective study demonstrates good functional results despite the high rate of radiological wrist arthritis. Age, length of follow-up, and loss of reduction were significantly associated with wrist arthritis in our series.

## Compliance with ethical standards

**Conflict of interest** The author(s) declare that they have no competing interests.

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