Perilunate Dislocations and Perilunate Fracture Dislocations in the U.S. Military

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Abstract

Background Perilunate dislocations and perilunate fracture dislocations (PLDs/PLFDs) are rare and often associated with poor outcomes. Heretofore, these outcomes have not been evaluated in a high-demand military population.

Questions/Purpose The purpose of this study was to evaluate the outcomes in a young, active population after sustaining PLD/PLFD injuries.

Patients and Methods We retrospectively reviewed the U.S. military service members who underwent surgical treatment for a PLD/PLFD (Current Procedural Terminology codes 25695 and 25685) between June 1, 2010, and June 1, 2014 through the Military Health System Management Analysis and Reporting Tool (M2) database, capturing patients with a minimum 2-year follow-up. Patient characteristics and outcomes were gathered; however, radiographic analysis was not possible.

Results In this study, 40 patients (40 wrists) were included with an average follow-up of 47.8 months. The average age was 28.8 years. Twenty-two injuries (55%) were PLFD and 22 (55%) cases involved the nondominant extremity. On initial presentation, 11 (27.5%) were missed and 50% of patients were presented with acute carpal tunnel syndrome. Range of motion (ROM) was 74% and grip strength was 65% compared with the contralateral wrist; 78% reported pain with activity and only 55% remained on active duty status at final follow-up. Injuries to the nondominant extremity were significantly more likely to experience a good to excellent outcome and regained a more ROM. Patients with ligamentous PLD had less pain at rest and were more likely to return to sport.

Keywords

- ▶ perilunate dislocation
- ▶ greater arc
- ▶ lesser arc
- ▶ wrist

Conclusion Worse outcomes can be expected for PLD/PLFD of the dominant extremity, transscaphoid PLFD, greater arc injuries, and those undergoing pinning alone. A high-demand patient may expect worse functional results with a higher degree of limitation postoperatively.

Level of Evidence The level of evidence is therapeutic IV.

Perilunate dislocations and perilunate fracture dislocations (PLDs/PLFDs) are uncommon injuries caused by an axially loaded, hyperextended wrist and often have poor postinjury

functional outcomes.^{1–3} PLFDs include greater arc injuries, those that include ligamentous and carpus fractures, as well as PLD, or lesser arc injuries, which are purely ligamentous.⁴

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Up to one quarter of PLD/PLFD occurs in conjunction with a polytrauma, acute carpal tunnel syndrome is often seen on presentation (24–45%), and the diagnosis may be missed in as many as 25% of cases.^{5–8} Furthermore, a delay in diagnosis has been associated with poor outcomes.^{9–11} In addition, closed reduction and immobilization are often insufficient to maintain appropriate reduction, necessitating expedient operative intervention.^{12,13} Short- (39–49 months), mid- (8 years), and long-term (13–18 years) outcomes have been reported.^{6,7,13–17} These studies have found that most patients go on to experience a reasonable arc of motion (57–83% as compared with contralateral side) and grip strength (73–87% as compared with contralateral side) at up to 13 years of average follow-up.^{6,14,16} However, these series are of limited size (11–25 patients), given the rarity of these injuries and none has evaluated outcomes among athletes or populations with consistently intense daily upper extremity demands.^{6,7} A young, highly active population, such as the military, not only has increased postoperative functional demands but also has greater functional expectations, the combination of which may lead to worse subjective outcomes. The military requires participation in daily physical fitness, unit-specific activities, and semiannual physical fitness testing. These events include pushups, an activity which axially loads a hyperflexed wrist and can be difficult to perform with wrist pathology.^{18–21} The purpose of this analysis is to characterize the demographics, surgical outcomes, and complications following PLDs/PLFDs in the U.S. military. We hypothesize that following reduction and surgical fixation of PLDs, active duty service members will experience poor functional outcomes and a respectively low return to duty rate.

Patients and Methods

Institutional Review Board approval was obtained at the study's onset. We retrospectively collected all triservice U.S. military service members undergoing open treatment of perilunate or transscaphoid PLDs (Current Procedural Terminology codes 25695 and 25685, respectively) through the Military Health System Management Analysis and Reporting Tool (M2) between June 1, 2010, and June 1, 2014. Patient identifiers as well as pertinent demographic and occupational information were extracted and subsequently cross-referenced with the Armed Forces Health Longitudinal Technology Application electronic medical record to confirm the diagnosis and surgical procedure. Patients who underwent other open procedures of the wrist in the absence of perilunate dissociation/PLD (e.g., internal fixation of isolated scaphoid, carpal, or radial styloid fractures), those of nonmilitary status at the time of surgery, and patients with under 24-month follow-up were excluded.

For those individuals which met inclusion/exclusion criteria, we subsequently collected patient-based (age, gender, tobacco use), injury-related (laterality, hand dominance, mechanism, concomitant fractures, whether the injury was initially missed or misdiagnosed, median nerve paresthesia at presentation, and whether this resolved following reduc-

tion), and surgical factors (time to surgery, procedures, method of scapholunate [SL] and lunotriquetral [LT] fixation).

Clinical and functional outcomes were obtained including whether the patient remained active within the military was separated due to disability attributable to the wrist, postoperative combat deployment, return to both activities of daily living and sports, as well as the level at which patients were able to return as compared with preinjury, and whether patients were able to return to pushups and to what degree. Final range of motion (ROM) and grip strength were both obtained from the most recent electronic medical record note and compared with the unaffected contralateral extremity. Pain at rest and with activity was evaluated by visual analog scale (VAS, range 0–10. VAS scores ≤ 3.4 correspond to mild interference with functioning, 3.5–6.4 moderate interference, and ≥ 6.5 severe interference for musculoskeletal pain.²² In addition, Mayo wrist and Disabilities of the Arm, Shoulder, and Hand (DASH) scores were obtained for all patients at the time of final follow-up. All interviews were performed by the same primary investigator (N.A.K.) to minimize variability. For the Mayo wrist score, a score more than 90 points were considered as an excellent outcome, 75 to 89 a good outcome, 60 to 74 a fair outcome, and less than 60 a poor outcome. For the DASH score, a score is generated between 0 and 100, with 0 corresponding with no disability and 100 to complete disability. A score less than 30 are considered to correspond to little to no disability of the limb, while more than 69 are considered significantly limiting. Finally, perioperative complications, reoperation, and revision surgeries were additionally collected for each patient.

Statistical Analysis

Means and standard deviations were calculated for continuous variables. Frequencies were reported for categorical variables. The two-sample *t*-test (for categorical independent variables) and linear regression analysis (for continuous independent variables) were performed. With significant *t*-test results, the mean and standard deviation for the continuous outcome variable were reported by the categories of the independent variable. In addition, for the binary outcome variables, logistic analysis was performed. Corresponding odds ratio (OR) and 95% confidence interval (CI) were reported for significant logistic results. A *p*-value of less than 0.05 was considered statistically significant. All calculations were performed using SAS version 9.4 (SAS Institute Inc.)

Results

Demographics

In this study, 40 patients from 33 different surgeons met inclusion criteria with 47.8 ± 15.7 (28.0–79.9) months follow-up. Average age was 28.8 ± 8.5 years with one female (2.5%); 17.5% reported routine tobacco use (**Table 1**).

Epidemiology and Injury Characteristics

Overall, 55% were greater arc fracture dislocations, with the remainder involving purely ligamentous lesser arc injuries.

Table 1 Complete patient roster

Patient	Demographics		Injury characteristics			Surgical characteristics		Outcomes							Complications		
	Age	Laterality	Mechanism	Injury	Presentation	Time to surgery (d)	Procedure	F/u (mo)	% grip strength	% ROM	Mayo score	DASH score	Return to sports at same level	Satisfied	Still in military	Pain (rest/activity)	
1	37	ND	Bicycling	PLD	Paresthesia, improved	2	ORPP, SL/LT LR	80	65	70	70	20.5	y/h	y	n	1/4	0
2	31	ND	Parachuting	PLD	Paresthesia, improved	2	ORPP, LR, CTR	74	75	50	75	20	y/y	y	n	0/4	0
3	26	ND	Football	PLD		4	Sc ORIF, SL/LT LR	72	80	60	75	12.5	y/y	y	y	0/3	0
4	29	ND	Fall	PLFD (TS, RS)		1	Sc ORIF, ORIF of SL/LT, LT LR	69	80	90	80	9.1	y/h	y	y	0/1	0
5	20	ND	Soccer	PLFD (TS)		4	Sc ORIF, ORIF SL/LT, LT LR	69	45	50	55	30.8	n	n	n	0/4	0
6	23	ND	Fall	PLFD (CA-Ha)	Paresthesia	28	ORPP SL/LT, SL/LT LR	68	85	70	85	17.5	y/h	y	n	1/3	1
7	22	D	Skateboarding	PLFD (TS)		2	Sc ORIF, ORIF of SL/LT	67	100	60	80	0.8	y/y	y	y	0/0	0
8	30	ND	Crush	PLD		44	ORPP SL/CL	64	30	40	50	20.7	n	y	y	0/5	0
9	22	ND	Crush	PLD	Paresthesia, improved	5	ORPP SL/CL	64	80	80	85	9.1	y/h	y	n	0/4	0
10	23	D	MVC	PLFD (TS)		4	Sc ORIF, ORPP SL/LT, LT LR	63	55	60	60	22.5	y/h	y	n	0/3	Revision (S, 4CF)
11	39	ND	Parachuting	PLD		14	ORPP SL/CL, SL LR	62	85	85	80	9.1	y/y	y	n	0/1	0
12	35	ND	Crush	PLFD (TS)	Paresthesia	12	Sc ORIF, ORPP of SL/LT, SL LR/LR	61	20	30	45	52.3	n	n	n	5/9	Paresthesia
13	33	D	MVC	PLD	Missed, paresthesia, improved	5	ORPP SL/CL, SL LR, CTR	58	80	60	65	13.3	y/h	y	y	0/2	0
14	26	ND	Fall	PLFD (TS)	Missed, paresthesia, improved	2	Sc ORIF, ORPP SL/LT, LR LT	58	90	95	90	2.5	y/y	y	y	0/1	0
15	26	ND	MVC	PLFD (Tq, RS)	Paresthesia	7	RS ORIF, ORPP SL/LT, SL/LT LR	56	70	60	70	12.5	y/h	n	n	0/3	Paresthesia
16	27	D	Softball	PLFD (Tq, RS)		4	ORPP SL/CL, SL LR	54	55	65	55	40.9	n	n	n	0/5	HWR (screw)
17	31	D	MVC	PLD		2	ORIF SL/LT	49	75	50	85	4.5	y/y	y	y	0/0	0
18	28	D	Football	PLD		15	ORIF SL/LT, SL/LT LR	49	50	50	60	36.4	y/h	n	n	3/5	0
19	20	ND	Skateboarding	PLFD (RS)	Missed	8	ORPP SL/LT	49	95	95	90	4.5	y/y	y	y	0/0	0
20	27	D	Snowboarding	PLD	Missed	3	ORIF SL/LT	47	85	60	75	12.5	y/h	y	y	0/0	0
21	22	D	Basketball	PLFD (RS, Lu)	Missed	16	ORPP SL/SC, SL/LT LR, CTR	43	80	25	60	11.7	y/y	y	y	0/3	0
22	22	ND	Football	PLD		3	ORIF SL, ORPP SL/SC, SL/LT LR	41	95	95	90	2.3	y/y	y	y	0/0	0
23	27	D	MVC	PLFD (TS, US)	Paresthesia, improved	6	Sc ORIF, ORPP LT, LT LR	40	70	50	60	31.8	y/h	y	n	4/7	0

(Continued)

Table 1 (Continued)

Patient	Demographics		Injury characteristics			Surgical characteristics		Outcomes							Complications		
	Age	Laterality	Mechanism	Injury	Presentation	Time to surgery (d)	Procedure	F/u (mo)	% grip strength	% ROM	Mayo score	DASH score	Return to sports at same level	Satisfied		Still in military	Pain (rest/activity)
24	25	ND	MVC	PLD	Paresthesia, improved	8	ORIF SL, ORPP SL/SC, SL/LT LR	39	70	90	85	2.3	y/y	y	n	0/0	0
25	28	D	Snowboarding	PLFD (TS, RS)	Paresthesia, improved	5	Sc ORIF, ORPP SL, LT LR	38	100	75	90	1.7	y/n	y	y	0/0	0
26	25	D	MVC	PLFD (TS)		12	Sc ORIF, ORPP SL, LT LR	37	100	35	85	0.8	y/y	y	y	0/0	0
27	31	D	Football	PLFD (Tq, US)	Missed	10	ORPP SL/LT/SC, LR LT, PINN	36	90	90	90	0.8	y/y	y	y	0/3	0
28	25	D	MVC	PLFD (TS, US, Tq, Ha)	Missed, paresthesia	12	Sc ORIF, LT LR, ORPP SL/LT	35	50	50	70	12.5	n	n	n	4/7	Paresthesia
29	23	ND	Fight	PLD	Paresthesia	1	ORPP SL/LT, LR SL/LT	34	100	50	75	25	y/n	y	n	2/8	Paresthesia
30	28	D	Football	PLFD (TS)	Missed, paresthesia, improved	3	Sc ORIF, ORPP SL/LT	34	55	75	65	20.7	n	y	y	0/6	0
31	28	D	MVC	PLFD (TS, RS, US)	Paresthesia, improved	1	ORPP SL/CL/SC	33	33	0	20	38.6	n	y	y	3/8	Revision (S, 4CF)
32	58	D	MVC	PLFD (TS, Tq, Ha)	Missed, paresthesia	0	Sc ORIF, ORPP SL/LT	33	90	90	85	1.7	n	y	y	2/6	Paresthesia
33	26	ND	MVC	PLFD (TS, US, Tq)		16	ORPP SL/LT	31	75	50	70	20.5	y/n	y	y	0/1	0
34	31	D	MVC	PLFD (US)	Missed	10	ORPP SL/LT/SC, LR LT/SL	30	70	50	60	29.5	n	y	n	0/4	0
35	29	ND	MVC	PLFD	0	0	ORPP SL/LT, LR SL/LT	30	100	100	90	2.3	y/y	y	y	0/1	0
36	30	ND	Bicycling	PLFD (TS, Ca, RS)	Paresthesia, improved	3	Sc/Ca ORIF, ORPP LT/SC	29	95	85	90	4.2	y/y	y	y	0/0	0
37	24	D	MVC	PLFD (TS, US, Lu, RS, Tq)		2	Sc/Lu ORIF, ORPP SL/LT, CTR	29	40	50	50	32.5	n	n	n	3/10	0
38	62	ND	Paragliding	PLFD (RS)	Paresthesia, improved	7	RS ORIF, ORPP SL/LT, SL/LT LR	29	70	80	80	1.7	y/y	y	n	0/3	0
39	22	ND	Basketball	PLFD (Tq)	Missed, paresthesia	3	ORPP SL/LT, CTR	28	90	65	80	15.8	y/y	y	y	0/5	Paresthesia
40	34	ND	Skateboarding	PLD	Paresthesia, improved	11	ORIF RS, ORPP SL/LT LR, CTR	28	100	100	90	0.8	y/y	y	y	0/1	0
AVG TOT	28.8	ND: 22 (55%)	MVC: 14 (35%)	CA: 22 (55%) LS: 18 (45%)	Missed: 11 (27.5%) ACTS: 20 (50%)	7.4	ORIF: 9 (22.5) ORPP: 31 (77.5%)	47.8	64.6	73.4	72.9	15.2	30 (75%)/23 (57.5%)	33 (82.5%)	22 (55%)	0.7/3.25	9 (22.5%)

Abbreviations: 4CF, four-corner fusion; ACTS, acute carpal tunnel syndrome; CL, capitulunate; CTR, carpal tunnel release; D, dominant; DASH, Disabilities of the Arm, Shoulder, and Hand; F/u, final follow-up (at which outcome scores were obtained); CA, greater arc injury involving; Ha, hamate; LR, ligament repair; LT, lunotriquetral; Lu, lunate; ND, nondominant; ORIF, open reduction with internal (screw) fixation; ORPP, open reduction with percutaneous pinning; PLD, perilunate dislocations; PLFD, perilunate fracture dislocations; ROM, range of motion; RS, radial styloid; SC, scaphocapitate; Sc, scaphoid; SL, scapholunate; Tq, triquetrum; TS, transscaphoid perilunate injury; US, ulnar styloid.

Furthermore, 37.5% of all injuries were transscaphoid PLD, comprising 68.2% of greater arc injuries. Total 55% of cases involved the nondominant extremity; 37.5% of injuries were sustained during recreational sports, 35% were attributable to high-energy motor vehicle collisions, 10% to high-energy military training accidents, 7.5% to ground-level falls, 7.5% to crush injuries, and 1 (2.5%) to an axial load sustained during a night club brawl.

On initial presentation, 27.5% were missed by primary care providers. In addition, 50% of patients were presented with acute median nerve symptoms, and all of these (100%) improved acutely following reduction but only 65% completely resolved.

Surgical Variables

The average time to surgery was 7.4 days and five patients had more than 2 weeks delay. Most patients (77.5%) underwent open reduction with percutaneous pinning of the SL interval, while the rest (22.5%) had internal screw fixation.

Clinical and Functional Outcomes

At final follow-up, 75.0% were able to return to recreational sports, of which 57.5% reported that they were able to at their preinjury level. Specifically, 60% of patients reported that they returned to palm-flat pushups (average: 34 ± 34 , range: 20–100).

While 85% remained active within the military at the 2-year postoperative time point, only 55% were presently active at the time of final follow-up. Of the 18 that separated, only 3 were medically separated due to persistent disability attributable to the wrist, while the remaining patients chose to end their service without reenlisting. Postoperatively, 60% underwent combat deployments.

Compared with the contralateral wrist, the average ROM was $74.3 \pm 21.4\%$ (20.0–100%) and grip strength averaged $64.6 \pm 22.7\%$ (0–100%). Two patients (5.0%) regained symmetric ROM, while six (15.0%) regained full symmetric grip strength. Overall, 62.5% of patients regained at least 50% ROM and grip strength as compared with the contralateral side. Three quarters (75.0%) of patients reported no pain at rest, and all but three (92.5%) reported VAS pain scores consistent with only mild interference with daily function. However, the majority of patients (77.5%) had pain with activity, albeit most (57.5%) reporting VAS pain scores again consistent with only mild interference with daily function and only 15% with severe interference with activities.

The average Mayo wrist score was fair, but close to good, at 72.9 ± 15.8 (20–90), with 20% (8 patients) reporting excellent, 37.5% (15 patients) reporting good, and 15% (6 patients) reporting poor functional outcomes. The average DASH score was 15.2 ± 13.3 (0.8–52.3) and 82.5% reported minimal daily disability (DASH score < 30).

Complications

Persistent median nerve paresthesias were present in 17.5% of patients. Three patients (7.5%) went on to reoperation, one of which entailed hardware removal of a radial styloid screw secondary to hardware irritation, and two were revised to

scaphoidectomy with four-corner fusion within this time period.

Statistical Analysis

Nondominant extremity injuries were significantly more likely to experience a good to excellent outcome (by the Mayo wrist score) than dominant wrist injuries (OR: 4.19; 95% CI: 1.10, 15.90; $p = 0.035$) and regained a more ROM percentage as compared with the uninjured wrist (72.3 ± 21.2 vs. $55.3 \pm 21.6\%$; $p = 0.017$). They were also more likely to return to sports and do so at the same level, though neither reached statistical significance (OR: 4.00; $p = 0.077$ and OR: 3.13; $p = 0.094$, respectively) (►Table 2).

Patients with ligamentous perilunate dissociations had significantly less pain at rest (0.3 ± 0.7 vs. 1.4 ± 1.9 ; $p = 0.011$) and were much more likely to be able to return to sports (OR: 6.41; 95% CI: 1.33, 31.03; $p = 0.021$) than the transscaphoid variety. They were also more likely to have minimal functional disability (by the DASH score), though this only approached significance (OR: 5.75; $p = 0.057$). Lesser arc injuries were also more likely to attain a good to excellent outcome (by the Mayo wrist score), though also only approaching significance (OR: 3.13; $p = 0.093$).

Discussion

This investigation sought to characterize the demographics, outcomes, and complications of PLDs/PLFDs among the U.S. active duty service members. We hypothesized that active duty service members would experience poor functional outcomes and a similarly low return to duty rate. There were three key findings to this analysis. First, active duty service members demonstrated relatively poor functional outcomes as compared with their civilian counterparts. Second, nearly one half (45%) of patients were unable to return to active duty due to persistent disability attributable to the wrist. Finally, despite over one quarter of patients presenting to orthopaedics with a missed injury (27.5%) and/or acute carpal tunnel syndrome (50%), these factors did not negatively affect outcomes. Highly active individuals with significant daily physical demands may have moderate postoperative disability despite timely surgical fixation of PLD/PLFD.

Although the present analysis found a trend toward higher Mayo wrist scores and a higher likelihood of return to sport in lesser arc injuries, the largest study of PLD/PLFD found no difference in outcomes between the two cohorts.⁸ Similarly, in a review of 7 PLFDs and 11 PLDs with average 13-year follow-up, there was no difference between PLD/PLFD injury patterns.¹⁶ As a group, the 18 patients averaged a Mayo wrist score of 70 with 76% return of ROM and 87% return of grip strength. Similar results were demonstrated among several other cohorts^{6,11,13,15,23} (►Table 3). These variables are slightly better than the present active duty cohort, which achieved a fair functional outcome (average Mayo wrist score: 72.9), 73% the ROM, and 65% the grip strength of the contralateral uninjured side. The majority of patients (77.5%) also reported persistent pain with activity.

Table 2 Outcomes and complications: nondominant versus dominant side, ligamentous versus transscaphoid, lesser versus greater arch, and ORPP versus ORIF

	Mayo score (continuous) mean $\pm$ SD (p-value)	Mayo score (≥ 75 vs. < 75) OR (95% CI) (p-value)	DASH score (continuous) mean $\pm$ SD (p-value)	DASH score (< 30 vs. ≥ 30) OR (95% CI) (p-value)	Return to sports OR (95% CI) (p-value)	Return to sports at pre-injury level of activity OR (95% CI) (p-value)	% Grip strength (continuous) mean $\pm$ SD (p-value)	% ROM strength (continuous) mean $\pm$ SD (p-value)	Pain at rest (continuous) mean $\pm$ SD (p-value)	Pain with activity (continuous) mean $\pm$ SD (p-value)
Nondominant vs. dominant wrist	77.3 $\pm$ 13.2 vs. 67.5 $\pm$ 17.4 (0.050)	4.19 (1.10, 15.9) (0.035)	NS (0.3572)	NS (0.139)	4.00 (0.86, 20.0) (0.077) ^a	3.13 (0.83, 11.1) (0.094) ^a	NS (0.381)	55.3 $\pm$ 21.6 vs. 72.3 $\pm$ 21.2 (0.016)	NS (0.143)	NS (0.241)
Ligamentous vs. transscaphoid	NS (0.162)	NS (0.286)	NS (0.41)	5.75 (0.95, 34.8) (0.057) ^a	6.41 (1.33, 31.03) (0.021) ^a	NS (0.123)	NS (0.164)	NS (0.291)	0.3 $\pm$ 0.7 vs. 1.4 $\pm$ 1.9 (0.011)	NS (0.126)
Lesser vs. greater arc	NS (0.173)	3.22 (0.83, 11.1) (0.094) ^a	NS (0.150)	NS (0.103)	4.54 (0.83, 25.0) (0.081) ^a	NS (0.135)	NS (0.200)	NS (0.520)	NS (0.131)	NS (0.103)
ORPP vs. screw fixation of SLI	NS (0.493)	0.176	NS (0.469)	NS (0.673)	NS (0.295)	NS (0.373)	NS (0.848)	NS (0.702)	NS (0.373)	3.8 $\pm$ 2.8 vs. 1.4 $\pm$ 2.0 (0.027)

Abbreviations: CI, confidence interval; DASH, Disabilities of the Arm, Shoulder, and Hand; NS, not significant or approaching significance; OR, odds ratio; ORIF, open reduction with internal fixation; ORPP, open reduction with percutaneous pinning; ROM, range of motion; SD, standard deviation; SLI, scapholunate interval.

^aApproaching significance (p-value < 0.1).

Table 3 Comparison of results

Study	Number of patients	Average age (y)	Average follow-up (mo)	Mayo	DASH	ROM ^a	Grip strength ^a	Fixation	Complication
Current study	40	28.8	47.8	72.9	15.2	73.40%	64.60%	Screw, K-wire	22.50%
Souer et al ²⁶	22	29	49	NR	4.1	87%	77%	Cerclage	9.90%
Viegas et al ²⁴	18	35.5	44	71	11	71%	76%	Screw, K-wire	27.80%
Adkison and Chapman ¹²	22	32	37	66	16	57%	73%	ORIF	77.30%
Herzberg et al ⁸	18	34	156	76	NR	76%	87%	Screw, K-wire	NR
Inoue and Imaeda ¹⁰	166	32	75	76	NR	NR	NR	ORIF, arthrodesis	NR
Massoud and Naam ²³	11	38	30	65.5	NR	71%	77%		NR
Krief et al ¹⁷	25		44	NR	NR	83%	80%	Screw, K-wire	NR
An et al ¹⁸	12	27	45	80.8	NR	95–129	60–79%	Screw, K-wire	NR

Abbreviations: DASH, Disabilities of the Arm, Shoulder, and Hand; NR, not reported; ORIF, open reduction and internal fixation; ROM, range of motion.

^aCompared with contralateral extremity.

There are three possible explanations for the slightly inferior outcomes in the present population. First, our cohort contained relatively high rate of transscaphoid PLFDs. In a review of seven young (23 years average age) transscaphoid PLFDs, the average grip strength was 68%, ROM 67%, and Mayo wrist score of 72; nearly identical to our findings.²⁴ These injuries are so rare and complex that it is possible that most surgeons are not able to amass enough to fully appreciate and adequately treat these injury patterns successfully.²⁵

The second reason for lower standardized outcome scores is that the present military cohort is young (mean age of 28 years) and foreseeably has increased daily demands and postoperative functional expectations. Physical fitness standards are rigidly enforced and frequently assessed among military patients. Roughly half (42.5%) of the patients in the present study could not return to athletic activities at their preinjury level. The high preoperative expectations likely contribute to the low subjective outcome scores as a whole in this athletic cohort. Specifically, injuries occurring to the dominant extremity were more likely to have a lower Mayo wrist score ($p = 0.035$), a lower ROM ($p = 0.02$), trended toward a lower return to sport ($p = 0.07$), and athletic function ($p = 0.09$). Expectation of function also likely contributed to the lower subjective outcome scores on the dominant extremity.

The final potential cause of diminished outcome scores in the present cohort is the vast majority (77.5%) of patients were treated with K-wire fixation. Military patients treated with K-wire fixation of their SL/LT intervals were nearly four times more likely to experience pain with activity compared with those who received screw fixation ($p = 0.027$), while a direct comparison of PLFD/PLD of nine patients treated with K-wire fixation versus nine patients treated with intercarpal screws demonstrated a difference neither in radiographic parameters nor clinical outcomes.²⁶ Despite the findings of

this short comparative analysis, it is possible that intercarpal screw fixation provides a stouter fixation; however, this is speculative and further investigation will need to be performed to expound this finding.

While at follow-up, only 55% remained on active duty, comparable civilian cohorts were much more likely to remain employed postoperatively (82–100%) following a PLD/PLFD.^{6,13–15} The military has fundamentally different physical demands as compared with a civilian cohort. Specifically, pushups, which are a core component of daily training and physical fitness assessments, axially load the hyperextended wrist and may be difficult to perform even after less invasive procedures, such as dorsal ganglion excision.^{18–21} The patients in the present military cohort lost on average 27% of their flexion–extension arc, with 15 (37.5%) patients experiencing a loss of 50% or more of their ROM, and only 60% of the cohort reported the ability to return to standard pushups. The inability to perform physically demanding activities likely lead contributed most significantly to the low return to duty rate.

It is concerning that half of the patients presented with acute carpal tunnel syndrome and 27.5% were missed upon initial presentation. The high rate of missed diagnoses has also been reported by other series as well and poor initial imaging has been hypothesized as a contributing factor to the frequency of missed injury.^{1,8,17,24} However, neither the patients with a missed injury nor those with median nerve paresthesias fared significantly worse in the present investigation. While the patient with the longest time to surgery in the present cohort (44 days) reported poor functional outcomes, he remained on active duty at 5-year follow-up. A significant delay generally leads to poor outcomes and may lead to necrosis of the carpus.^{10,18,20} Herzberg et al reported a series of 166 PLDs/PLFDs who were sorted based on time to treatment; < 7, 7 to 45, and > 45 days.⁸ Worse functional

outcomes were identified in patients who had more than a 45-day delay to treatment. In addition, there was a trend toward diminished functional outcomes in the 7 to 45-day cohort, although this was not statistically significant ($p = 0.07$). In the present analysis, most dislocations were reduced the same day of injury and the average time from dislocation to surgery was 7 days. Furthermore, only five patients had a time to surgery more than 2 weeks and no patient had a delay more than the critical 45-day window.⁸ Therefore, there was insufficient power to stratify outcomes or identify any trend based on a delay in treatment.

There were a handful of limitations in our study. First, because patients were treated at multiple medical centers, radiographic analysis was not possible. In other short-term (2–4-year follow-up) reports, the incidence of mid-carpal arthritis range from 16 to 22%.^{7,9–11,27} However, in a larger study after 6 years, the incidence of posttraumatic arthritis was considerably higher (56%) and by 18 years, the incidence of arthritis was reported as high as 70%.^{8,18} As such, this study was unable to detect a correlation between demographics and outcomes with radiographic arthritic changes of the carpus, although the correlation between radiographic evidence of posttraumatic arthritis and functional outcomes may be negligible.^{11,16,17} Second, the study has limited power, which inhibits risk stratification, particularly with regard to a delay in diagnosis. However, despite this, the present study reports 43-month follow-up in an ample-sized, uniquely high-demand cohort reporting specific outcome measures. These results may be extrapolated to young athletic populations and have greater external validity than existing studies in regard to appropriately counseling these high-demand patients who sustains a PLD/PLFD.

In conclusion, physically active patient who sustains PLD/PLFD will experience greater functional limitations and achieve inferior outcomes as compared with their more sedentary counterpart. Specifically, worse outcomes can be expected for the dominant extremity, greater arc, and transscaphoid injuries. Future investigation should be directed toward correlating arthritic changes with functional outcomes in this active cohort.

Note

Some authors are employees of the U.S. Federal Government and the U.S. Army. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of William Beaumont Army Medical Center, the Department of Defense, or U.S. government.

Ethical Review Committee

The authors have Institutional Review Board approval for this study.

Conflict of Interest

None.

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