

OUTCOMES FOLLOWING OPERATIVE TREATMENT OF OPEN FRACTURES OF THE DISTAL RADIUS: A CASE CONTROL STUDY

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ABSTRACT

Purpose: To report radiographic, clinical, and patient-based functional outcomes following contemporary operative treatment of patients who sustained an open distal radius fracture and compare them to a similar group of patients treated operatively for closed distal radius fractures.

Methods: Over five years, 601 patients with a distal radius fracture presented to our academic medical center, including one Level 1 trauma hospital, and were prospectively enrolled in an upper extremity trauma database. Patients with open distal radius fractures underwent irrigation, debridement, and operative fixation within 24 hours of presentation. Closed distal radius fractures requiring operative fixation were treated electively. Retrospective review of the database identified eighteen open fractures of the distal radius (11 type I, 6 type II, 1 type IIIa). The open fracture patients were individually matched with eighteen closed distal radius fracture patients who underwent surgical fixation based on age, sex, injury to dominant extremity, fracture pattern, and method of fracture fixation. Clinical, radiographic, patient-based functional outcomes, and complications were recorded at routine postoperative intervals.

Results: Follow-up was greater than 77% in both groups at all time points. The open and closed groups were similar in regards to age, gender, BMI, race, tobacco use, income, employment status, hand dominance, injury to dominant extremity, mechanism of injury, fracture classification, method of fracture fixation, and presence of concomitant injury. Postoperative complications and reoperation rates were similar between the open and closed groups. Union rates and radiographic

alignment one year postoperatively were similar between the open and closed fracture groups. At final follow-up, range of motion parameters, grip strengths, DASH indices, and subjective pain scores were similar between both groups.

Discussion: Open distal radius fractures treated with early debridement and fixation achieved similar outcomes to surgically treated closed fractures of the distal radius when followed for a year or more postoperatively.

INTRODUCTION

Open fractures are high-energy injuries that present with a spectrum of soft tissue and bony injury¹. These injuries can be complicated by infection, nonunion, and need for soft tissue coverage¹. While there is robust research on open long bone fractures^{2,8}, there is little outcome data on open distal radius fractures. Numerous studies have addressed clinical, radiographic, and functional outcomes after treatment of closed fractures of the distal radius⁹⁻²⁸. A better understanding of outcomes after treatment of open distal radius fractures may facilitate improvements in patient care and counseling regarding post-injury expectations.

The purpose of this study is to report radiographic, clinical, and patient-based functional outcomes following contemporary operative treatment of patients who sustained an open distal radius fracture and compare them to a similar group of patients treated operatively for closed distal radius fractures.

PATIENTS AND METHODS

Over a period of five years, six hundred and one patients presented to our academic medical center, including one Level 1 trauma hospital, with a distal radius fracture (OTA type 23)²⁹, and consented to prospective enrollment in an upper extremity trauma database. Our Institutional Review Board approved retrospective review of the database to evaluate outcomes following surgical treatment of open distal radius fractures. Eighteen of these patients sustained an open fracture of the distal radius (ODRF) (Gustilo and Anderson type I, n=11; type II, n=6, type IIIa, n=1)³. The open fracture patients were individually matched with eighteen closed distal radius fracture patients who underwent surgical fixation (CDRF)

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Table 1a: Patient Characteristics

Fracture Type		Mean	Standard Deviation	P Value
Age at Injury (years)	Open	56.83	17.71	0.92
	Closed	56.28	14.65	
BMI (kg/m2)	Open	23.88	9.84	0.70
	Closed	24.99	7.05	

based on age, sex, injury to dominant extremity, fracture pattern, and method of fracture fixation.

At the time of database enrollment, baseline information including: age, gender, height, weight, ethnicity, tobacco use, employment status, income level, hand dominance, mechanism of injury, occurrence of injury to the dominant hand, OTA fracture classification, Gustilo and Anderson classification of the soft tissue injury, and presence of concomitant bony, neurologic, and vascular injury was recorded³⁰⁻³¹. Standard radiographs (anteroposterior, lateral, and oblique views) of the injured and contralateral wrists were obtained during initial evaluation. Contralateral wrist films were used as a reference to determine radiographic articular parameters in the coronal and sagittal plane on the uninjured side for each patient and to assess adequacy of reduction. Additional radiographs of the injured wrist were obtained following closed reduction and splinting. Direction of displacement, volar tilt, radial inclination, radial height, articular step-off, ulnar variance, and osteoarthritis grading as described by Knirk and Jupiter³² were recorded by trained researchers under the supervision of the treating attending physician using initial injury and post-reduction radiographs.

Patients who sustained an open fracture received tetanus, intravenous antibiotics, reduction, sterile dressing application, and splinting in the emergency department. All open fractures underwent irrigation, debridement, and operative fixation within twenty-four hours of presentation (average time 8.1 hours, range 3-22 hours). Fixation in the CDRF group was performed electively for unstable fractures. Standard implants (external fixation, K-wires, volar locked plates, dorsal plates) were used for both the ODRF and CDRF groups, and the selection of the fixation construct was at the discretion of the treating surgeon (three fellowship-trained orthopaedic traumatologists, one fellowship-trained orthopaedic hand surgeon). The surgical approach (volar, dorsal, percutaneous, or combined) utilized and the performance of concurrent carpal tunnel release was recorded.

Patients were evaluated in the outpatient setting at routine postoperative intervals. At all follow-up visits, range of wrist and finger motion (flexion/extension, supination/pronation, and ulnar/radial deviation) was measured with a goniometer and grip strength was measured [in pounds (lbs)] with a dynamometer by a dedicated mus-

Table 1b: Patient Characteristics

		Open	Closed	P Value
Gender	Male	50.0%	50.0%	1.00
	Female	50.0%	50.0%	
Hand Dominance	Right	77.8%	94.1%	0.23
	Left	22.2%	5.9%	
Ethnicity	White	50.0%	44.4%	0.42
	African-American	11.1%	22.2%	
	Other	38.9%	33.3%	
Current Tobacco Use	Yes	27.8%	5.6%	0.18
	No	72.2%	94.4%	
Income	<\$25K	62.5%	50.0%	0.70
	25-50K	18.8%	31.3%	
	>\$50K	18.8%	18.8%	
Employment Status	Yes	50.0%	61.1%	0.75
	No	5.6%	5.6%	
	Student	5.6%	0.0%	
	Disabled	5.6%	11.1%	
	Retired	33.3%	22.2%	

culoskeletal researcher blinded to the objective of the study. Serial postoperative radiographs were obtained to assess restoration of articular parameters and fracture healing. In addition, time to radiographic union, defined as the absence or consolidation of fracture lines on wrist radiographs, was recorded. A standard Visual Analogue Scale (VAS; 0, no pain; 10, severe pain) and the DASH questionnaire³³⁻³⁴ were used to quantify functional outcomes based upon patients' perceived disability. Post-operative complications and secondary surgeries were also recorded.

Descriptive statistics were compiled for all data points. Chi-square analyses were used to compare categorical variables. Independent samples students T-tests were used to compare continuous variables between two groups.

RESULTS

Patient characteristics including: age, gender, BMI, ethnicity, tobacco use, employment status, income level, and handedness of the patients in the ODRF and CDRF groups were compared and found to be similar between the two (Tables 1a, 1b).

Injury and treatment characteristics including: occurrence of injury to dominant hand, mechanism of injury, OTA fracture classification, presence of concomitant injury, treating surgeon, surgical approach, fracture fixation method, use of supplemental Kirschner wire fixation, acute carpal tunnel release, and occurrence of intraoperative complication were similar between the ODRF and CDRF groups (Table 2).

		Open	Closed	Open	Closed	P Value
Injury to Dominant Hand	Yes	11	10	61.1%	55.6%	1.00
	No	7	8	38.9%	44.4%	
Mechanism of Injury	Fall	14	16	77.8%	88.9%	0.75
	Sports Injury	1	1	5.6%	5.6%	
	Motor Vehicle Accident	2	1	11.1%	5.6%	
	Pedestrian Struck	1	0	5.6%	0.0%	
OTA Fracture Classification	A	9	9	50.0%	50.0%	1.00
	B	1	1	5.6%	5.6%	
	C	8	8	44.4%	44.4%	
Associated Injury	Yes	14	4	53.8%	66.7%	0.71
	No	12	2	46.2%	33.3%	
Surgical Approach	Volar	12	11	66.7%	61.1%	0.69
	Dorsal	0	2	0.0%	5.6%	
	Percutaneous (Ex-Fix)	5	4	27.8%	22.2%	
	Combined (Open/Ex-Fix)	1	1	5.6%	11.1%	
Fracture Fixation	Locking Plate	12	13	66.7%	66.7%	0.80
	External Fixation	5	4	27.8%	22.2%	
	Combined (Locking Plate/Ex-Fix)	1	1	5.6%	11.1%	
Kirschner Wire Fixation	Percutaneous	4	4	36.4%	26.7%	0.25
	Internal	1	0	9.1%	0.0%	
	None	6	11	54.5%	73.3%	
Surgeon	1	7	6	41.2%	33.3%	0.63
	2	4	6	23.5%	33.3%	
	3	6	5	35.3%	27.8%	
	4	0	1	0.0%	5.6%	
Intraoperative Complication	Yes	0	18	0.0%	0.0%	1.00
	No	0	18	100.0%	100.0%	
Acute Carpal Tunnel Release	Yes	3	0	16.7%	0.0%	0.23
	No	15	18	83.3%	100.0%	

Table 2: Injury and Treatment Data: In the ODRF group, associated injuries included: eight ulnar styloid fractures, three ulnar neck fractures, one DRUJ dislocation, three median nerve neuropraxias, five additional extremity injuries (phalangeal fracture, ulnar collateral ligament rupture, thumb interphalangeal dislocation, great toe fracture), and one non-orthopaedic injury (facial fracture). There were nine ulnar styloid fractures, one scapholunate ligament tear, three additional extremity injuries (proximal humerus fracture, calcaneus fracture, patella fracture), and one non-orthopaedic injury (eye contusion) in the CDRF group.

Follow-up data is presented for the ODRF and CDRF groups at three and twelve months postoperatively. There was no difference in rate of follow-up between the two groups at either time point and it was greater than 77.8% for both groups at each time point (Table 3).

Radiographically, there was no difference in union rates between the ODRF and CDRF groups at three and twelve months with all fractures healed by one year postoperatively (Tables 4a, 4b). Volar tilt was decreased in the ODRF group as compared to CDRF group at three months, but any coronal and sagittal plane radiographic parameter differences were diminished in both groups one year postoperatively and found to be independent of wound status at the time of injury (Tables 4a, 4b). Articular step-off and osteoarthritis grading was similar between the two groups at all follow-up time points (Tables 4a, 4b).

Range of motion, grip strength, VAS pain scores, and DASH scores were compared between the ODRF and CDRF groups (Tables 5, 6). The ODRF group had decreased supination as compared to the CDRF group three months postoperatively, but all range of motion parameters were similar at one year follow-up. There was no difference in grip strength, VAS pain scores, or DASH scores at any follow-up time point.

The ODRF and CDRF groups experienced a similar rate of postoperative complications (Table 7). There was one pin tract infection in each group, both successfully treated with oral antibiotics. In the ODRF group, three patients had postoperative neuropraxias. Two of these patients presented to the emergency room with symptoms of carpal tunnel syndrome and had acute carpal tunnel releases at time of irrigation, debridement, and fracture fixation. Both of these patients had continued

Table 3: Postoperative Follow-Up

		Open	Closed	P Value
Follow-up 3 months	Yes	83.3%	100.0%	0.23
	No	16.7%	0.0%	
Follow-up 1 year	Yes	77.8%	83.3%	1.00
	No	22.2%	16.7%	

Table 4a: Radiographic Outcomes

		Fracture Type	Mean	Standard Deviation	P Value
Volar Tilt Postop (degrees)	Open		4.61	5.39	0.53
	Closed		5.75	5.38	
Radial Inclination Postop (degrees)	Open		13.85	10.67	0.64
	Closed		15.43	9.14	
Radial Length Postop (millimeters)	Open		7.69	6.08	0.57
	Closed		8.73	4.54	
Articular Step-Off Postop (millimeters)	Open		0	0	0.16
	Closed		0.11	0.32	
Volar Tilt 3 months (degrees)	Open		2.39	5.74	0.05
	Closed		6.17	5.12	
Radial Inclination 3 months (degrees)	Open		15.61	10.42	0.38
	Closed		18.15	5.96	
Radial Length 3 months (millimeters)	Open		9.03	6.13	0.85
	Closed		9.34	3.14	
Articular Step-Off 3 months (millimeters)	Open		0.28	0.67	0.71
	Closed		0.36	0.68	
Ulnar Variance 3 months (millimeters)	Open		0.64	2.25	0.82
	Closed		0.81	2.24	
Volar Tilt 1 year (degrees)	Open		4.17	7.4	0.93
	Closed		3.94	7.13	
Radial Inclination 1 year (degrees)	Open		15.75	11.1	0.43
	Closed		18.56	10	
Radial Length 1 year (millimeters)	Open		7.81	5.53	0.57
	Closed		8.77	4.51	
Articular Step-Off 1 year (millimeters)	Open		0.05	0.21	0.08
	Closed		0.3	0.54	
Ulnar Variance 1 year (millimeters)	Open		0.62	1.43	0.75
	Closed		0.83	2.45	

median nerve dysfunction postoperatively which resolved without further surgical intervention. One ODRF patient had a postoperative ulnar nerve neuropraxia that resolved without surgical intervention. One ODRF patient had loosening of their ulnar Kirschner wire. Seven patients required return trips to the operating room after their index surgery (three ODRF patients: one Kirschner wire removal, one external fixator removal, one distal ulna resection for ulnar impaction; four CDRF patients: one Kirschner wire removal, two external fixator removals, one external fixator removal with concomitant locked plating). During follow-up, there were four patients that developed carpal tunnel syndrome (three ODRF patients, one CDRF patient).

DISCUSSION

In this study, open fractures of the distal radius with lower grade soft tissue injuries treated with expedient debridement and definitive fixation were found to do as well clinically, radiographically, and functionally as closed distal radius fractures requiring open reduction and internal fixation. There is currently no other study

Table 4b: Radiographic Outcomes

		Open	Closed	P Value
Distal Radial Tilt Postoperatively	Volar	81.8%	80.0%	0.50
	Dorsal	9.1%	13.3%	
	Neutral	9.1%	6.7%	
Osteoarthritis Grading Postoperatively	0	94.4%	83.3%	0.60
	1	5.6%	16.7%	
	2	0.0%	0.0%	
	3	0.0%	0.0%	
Distal Radial Tilt 3 months	Volar	53.8%	87.5%	0.06
	Dorsal	15.4%	12.5%	
	Neutral	30.8%	0.0%	
Osteoarthritis Grading 3 months	0	83.3%	88.9%	0.60
	1	11.1%	11.1%	
	2	5.6%	0.0%	
	3	0.0%	0.0%	
Fracture Healed? 3 months	Yes	100.0%	93.3%	0.14
	No	0.0%	6.7%	
Distal Radial Tilt 1 year	Volar	61.5%	66.7%	0.77
	Dorsal	23.1%	13.3%	
	Neutral	15.4%	20.0%	
Osteoarthritis Grading 1 year	0	72.2%	61.1%	0.37
	1	22.2%	38.9%	
	2	5.6%	0.0%	
	3	0.0%	0.0%	
Fracture Healed? 1 year	Yes	100.0%	100.0%	1.00
	No	0.0%	0.0%	

Osteoarthritis Grading as per Knirk and Jupiter Classification

Table 5: Range of Motion

		Fracture Type	Standard		
			Mean	Deviation	P Value
Wrist Extension 3 months (degrees)	Open	35.39	25.54	0.26	
	Closed	43.94	18.23		
Wrist Flexion 3 months (degrees)	Open	30.89	22.26	0.30	
	Closed	38.11	19.09		
Supination 3 months (degrees)	Open	39.11	33.81	0.01	
	Closed	65.83	25.51		
Pronation 3 months (degrees)	Open	57.06	36.79	0.23	
	Closed	70.44	28.36		
Ulnar Deviation 3 months (degrees)	Open	15.78	14.78	0.72	
	Closed	17.61	15.49		
Radial Deviation 3 months (degrees)	Open	9.11	8.68	0.57	
	Closed	10.89	9.92		
Grip Strength 3 months (pounds)	Open	18.22	27.92	0.65	
	Closed	22.22	24.49		
Wrist Extension 1 year (degrees)	Open	37.72	26.87	0.82	
	Closed	39.56	21.88		
Wrist Flexion 1 year (degrees)	Open	35.17	23.5	0.91	
	Closed	36.06	21.55		
Supination 1 year (degrees)	Open	53.22	35.86	0.49	
	Closed	61.5	35.7		
Pronation 1 year (degrees)	Open	60.56	39.03	0.48	
	Closed	69.28	33.13		
Ulnar Deviation 1 year (degrees)	Open	19.56	15.87	0.73	
	Closed	21.56	18.39		
Radial Deviation 1 year (degrees)	Open	10.94	10.53	0.27	
	Closed	15.5	13.41		
Grip Strength 1 year (pounds)	Open	33.06	37.21	0.55	
	Closed	43.5	62.52		

that has compared this injury pattern with its closed counterpart using prospectively collected data.

Nyquist and Stern reviewed ten open radiocarpal dislocations treated with combinations of debridement, open reduction, casting, internal fixation, and external fixa-

Table 6: Subjective Outcome

	Fracture Type	Mean	Standard Deviation	P Value
DASH (3 month)	Open	38.52	26.08	0.66
	Closed	33.72	25.89	
VAS (3 month)	Open	1.11	1.91	0.86
	Closed	1.22	1.93	
DASH (1 year)	Open	13.33	21.39	0.56
	Closed	9.86	12.73	
VAS (1 year)	Open	1.28	2.08	1.00
	Closed	1.28	2.35	

DASH=The Disabilities of the Arm, Shoulder, and Hand Score
VAS=Visual Analog Pain Score

tion³⁵. Soft tissue injury and contamination were not specifically addressed. At variable follow-up (~15 months), they found high rates of neurologic deficit, wrist pain, and limited motion³⁵. Rozental et. al. published on eighteen patients with open distal radius fractures (Gustilo and Anderson type I, n=9; type II, n=3; type IIIa, n=6)³⁶. Wound severity (Gustilo and Anderson classification) was directly correlated with number of surgical procedures, number of postoperative complications, and functional deficit³⁶. They stated that there is no similarity between open and closed distal radius fractures other than the location of injury³⁶. Yang et. al. found no postoperative infection in twelve Gustilo and Anderson grade I open distal radius fractures debrided greater than twelve hours after injury, suggesting that timing of debridement is not related to incidence of postoperative infection in fractures with minimal soft tissue injury. Glueck et. al. presented forty-two open distal radius fractures (Gustilo and Anderson type I, n=24; type II, n=12; type III, n=8) followed for approximately fifteen months³⁸. Contamination and number of debridements, but not Gustilo and Anderson classification of soft tissue injury, time to debridement, or type of fixation, were found to be predictive of subsequent infection³⁸. Kurylo et. al. retrospectively reviewed thirty-two open distal radius fractures (Gustilo and Anderson type I, n=19; type II, n=11; type IIIa, n=2)³⁹. There were no postoperative infections in their series, leading to the conclusion that timing of debridement (< 6 hours after hospital admission vs > 6 hours after hospital admission) and initial type of fracture fixation (external fixation, locked plating, external fixation with planned conversion to locked plating) have no influence on occurrence of postoperative infection in Gustilo and Anderson type I and II open distal radius fractures³⁹. They found a higher rate of postoperative complication and reoperation in those patients treated with external fixation and planned conversion to locked plating as compared to those open fractures treated solely with external fixation or locked plating³⁹. Furthermore, they concluded that treatment of Gustilo and Anderson grade I and II open distal radius

Table 7: Postoperative Complications

		Open	Closed	P Value
Infection	Yes	5.6%	5.6%	1.00
	No	94.4%	94.4%	
Loss of Reduction	Yes	0.0%	0.0%	1.00
	No	100.0%	100.0%	
Complex Regional Pain Syndrome	Yes	0.0%	0.0%	1.00
	No	100.0%	100.0%	
Carpal Tunnel Syndrome	Yes	16.7%	5.6%	0.60
	No	83.3%	94.4%	
Nerve Deficit	Yes	16.7%	0.0%	0.23
	No	83.3%	100.0%	
Hardware Failure	Yes	5.6%	0.0%	1.00
	No	94.4%	100.0%	
Return to OR	Yes	16.7%	22.2%	1.00
	No	83.3%	77.8%	
Tendon Rupture	Yes	0.0%	0.0%	1.00
	No	100.0%	100.0%	

fractures leads to more postoperative complications than treatment of similar closed injuries³⁹.

There is no published data on radiographic outcomes after surgical fixation of open distal radius fractures. Our study showed no difference between the dorsal tilt, radial inclination, radial height, and ulnar variance of the ODRF and CDRF groups at one-year follow-up. Furthermore, the ODRF mean values for these radiographic parameters are similar to those reported in recent literature for surgical fixation of closed distal radius fractures^{9,28}.

By objective and subjective functional measures, the ODRF patients in this study did as well as the operatively treated closed distal radius patients in numerous other studies and achieved sufficient range of motion to complete activities of daily living^{9,28,40,41}. This finding is in contrast to the existing literature. Nyquist and Stern reported decreased range of motion and wrist pain with activity for all of their patients with open fractures at final follow-up³⁵. Rozental et. al. found decreased range of motion (avg. flexion, extension, supination, and pronation: 37°, 40°, 47°, and 57°, respectively), decreased grip strength (50.6 lbs), and high levels of perceived disability (avg. DASH score 33) in their study patients twenty-four months post-injury³⁶. The improved performance of our open fracture patients is likely attributable to the predominance of low-grade soft tissue injuries that did not require complex or multiple reconstructive procedures.

Postoperative complications were similar in the ODRF and CDRF groups. This is not consistent with the current literature^{35,36,38}. Rozental et. al. reported an overall complication rate of 66% and an infection rate of 44%³⁶. Glueck et. al. noted a 7.1% infection rate in their series³⁸. Kurylo

et. al. concluded that treatment of Gustilo and Anderson grade I and II open distal radius fractures leads to more postoperative complications than treatment of similar closed injuries³⁹. The improved outcomes of the open fractures in our series is likely related to lower grade soft tissue injuries in the current study in combination with our institution's policy of thorough initial debridement and attempts to minimize further injury to the soft tissue with repeat manipulations/surgeries and multiple percutaneous implants.

The results should be appreciated in the context of the study's limitations. The ODRF patients were closely matched with CDRF patients based on age, sex, injury to dominant extremity, fracture pattern, and method of fracture fixation. Baseline patient demographic and injury/treatment data was statistically compared to further validate the similarity of the groups being compared. Yet, there is still the possibility that these two groups are dissimilar with regards to some other variable that may have confounded the results, thereby introducing selection bias. Furthermore, the study is unable to comment on the treatment outcomes of Gustilo and Anderson type III injuries as only one Gustilo and Anderson type IIIa open fracture was included for analysis. Yet, our data suggests that these high-grade soft tissue injuries represent a very small percentage of an already uncommon injury pattern.

In conclusion, this study suggests that Gustilo and Anderson type I and II open distal radius fractures treated with early debridement and definitive bony fixation achieve similar outcomes to surgically treated closed distal radius fractures. This information helps guide treatment of an injury pattern that could be seen by any practicing orthopaedic surgeon and provides information necessary for counseling patients and families in the perioperative period.

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