EDITOR'S CHOICE

Evaluating Outcomes Following Open Fractures of the Distal Radius

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Purpose A paucity of evidence exists regarding the optimal treatment of open fractures of the distal radius. The purpose of this study was to compare short-term complication rates between various treatment options following open fractures of the distal radius.

Methods We performed a retrospective review of all open fractures of the distal radius at a single level 1 trauma center over a 10-year period. The primary outcome measure was the number of minor and major complications. Demographic and clinical characteristics of patients across treatment and outcome groups were compared and models were used to describe the relationships between outcome and treatment.

Results Ninety patients met the inclusion criteria for evaluation. An even distribution between high-energy (n = 45) and low-energy (n = 45) injuries was seen with 61 fractures Gustilo I (67%), 19 Gustilo II (22%), and 10 Gustilo III (11%). The majority of fractures were intra-articular (n = 48 AO type C vs n = 42 AO type A/B). Fractures were treated with immediate open reduction internal fixation (ORIF) in 67 cases (74%), external fixation in 12 (13%), initial external fixation followed by ORIF at a later time in 8 (9%), or closed reduction and percutaneous pinning in 3 (4%). We observed 33 complications (37%) of which 24 were major and 9 minor. Mechanism of injury and type of treatment were the only variables shown to correlate with an increased rate of complications.

Conclusions We conclude that open fractures of the distal radius treated by immediate ORIF at the time of index debridement can result in satisfactory outcomes compared with other forms of treatment. *(J Hand Surg Am. 2020;45(1):41−47. Copyright © 2020 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Distal radius fracture, open fracture, treatment.

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Distal radius fractures are extremely common, with more than 643,000 occurring annually in the United States.[1,2] The incidence of open fractures is unknown but is approximately 6% in the largest case series.[3] The majority of open distal radius fractures are low-grade with studies reporting 67% to 94% Gustilo I injuries.[4−6]

The treatment of open distal radius fractures remains controversial. Those studies that have been published are small, retrospective case series with the largest study comprising 42 patients.[3] Earlier studies focused on comparing debridement and definitive external fixation in a single stage to initial debridement and external fixation followed by a return to the operating room for open reduction and internal fixation at a later time (staged ORIF).[4] However, more recent studies show definitive ORIF at the time of initial debridement may be a safe alternative to staged debridement and fixation.[5,7,8]

The purpose of our study was to attempt to replicate earlier findings in a larger patient population to determine the incidence of early major and minor complications associated with treatment of open fractures of the distal radius. We sought to compare complication rates between patients treated with single-stage debridement and ORIF versus patients undergoing staged treatment (initial external fixation with wound care followed by definitive ORIF). We hypothesized that single-stage debridement with definitive internal fixation would result in an equivalent overall complication rate compared with patients treated in a staged fashion or those treated with definitive external fixation.

METHODS

Study design

Using a protocol approved by our institutional review board, we performed a retrospective review of all open fractures of the distal radius treated at a single level 1 trauma center over 10-year period (2005−2015). Inclusion criteria included all patients older than 18 years with an open fracture of the distal radius. Exclusion criteria included polytrauma, dysvascular limbs, transfers from outside hospitals with previous surgical procedures, ipsilateral arm fractures, and periprosthetic fractures. Our primary outcome measure was complications (minor vs major) observed within the first 3 months of treatment. Minor complications were defined as persistent pain (visual analog scale score > 5 or a patient's subjective statement of pain remaining no better or worse when given the options of improved, the same, or worse at 6 weeks after surgery), stiffness/loss of range of motion compared with the contralateral extremity (range of motion $< 50\%$ of the total combined arc of motion of the contralateral unaffected wrist [either flexion/extension or pronation/supination]) and superficial infection treated with oral antibiotics. Major complications were defined as a return to the operating room for any reason (excluding planned conversion to ORIF from external fixation or soft tissue coverage), infection requiring readmission or intravenous antibiotics, malunion (defined radiographically as dorsal tilt $> 10°$, intra-articular incongruity > 2 mm, or 5 mm radial shortening), and paresthesiae in either the median, the radial, or the ulnar nerve distribution 3 months after surgery that were not present before surgery.[9]

Operative management

All patients underwent irrigation and debridement within 24 hours of presentation. Six attending orthopedic surgeons, of whom 2 were fellowship-trained hand surgeons, 2 fellowship-trained trauma surgeons, and 2 general orthopedists, were involved in the treatment of these patients.

Antibiotic protocol

All patients received intravenous antibiotic treatment upon arrival to the emergency department—a first-generation intravenous cephalosporin or equivalent medication if they had a penicillin allergy. Patients continued to receive intravenous antibiotics until they were taken to the operating room and for at least 24 hours after the initial debridement.

Statistical methods

A power analysis was performed using incidence of complications following open distal radius fractures cited in the literature (range, 15%−50%). A study population of 80 to 90 patients was sufficient to provide power of 0.8 assuming an alpha of 0.05 and a medium effect size of 0.5. We sought to compare demographic and clinical characteristics of patients (age categories, sex, race/ethnicity, mechanism and classification of fracture as well as comorbidities approximated by the Charleson Comorbidity Index) across treatment and outcome groups; however, the power of the sample was insufficient. Therefore, only the raw data are reported. Fracture classification was determined using the AO classification scheme by independent radiographic review of all preoperative images by 1 attending hand surgeon (C.M.H.) and 1 attending radiologist. Gustilo classification was determined by direct chart review in which the wound class was noted in the history and physical examination or operative report.[10]

To describe the relationships between demographic variables and treatment selected as well as demographic variables/treatment selected and complications, we performed logistic regression analysis using 4 variables (Treatment: Age, Charleson Comorbidity Index [CCI], mechanism of injury, AO classification; Complication: Treatment, CCI, AO classification, and mechanism of injury). These were selected based upon clinical suspicion and bivariate analyses. We chose to limit our model to 4 variables in order to avoid overfitting. In the logistic regression analysis, (1) Firth's penalized likelihood approach was used to address small-sample bias. When a sample size is small, or the outcome of interest is rare, analysis using logistic regression is subject to bias. By applying Firth's method, finite, consistent estimates of regression parameters are generated and the potential for small sample size bias is mitigated[11]; (2) A binary outcome (complication: minor or major complication vs no complication) was used as the dependent variable and treatment (ORIF, external fixation, or staged external fixation) as the primary independent variable of interest; (3) stepwise variable selection was applied in order to choose demographic and clinical characteristics that could potentially confound the association between treatment and complications; and (4) treatment-outcome association was assessed with or without adjustment for 2 potential confounding factors (mechanism and comorbidity) that were selected by the stepwise variable selection procedure. Any *P* values less than .05 were considered statistically significant.

TABLE 1. Patient Demographics

Variable	
Age (y)	59.1 (SD, 21)
Sex	57 Female
	33 Male
Gustillo-Anderson classification	I: 60
	II: 19
	III A: 10
AO classification	A: 28
	B: 14
	C: 48
CCI	2.2 (SD, 2)
Mechanism of injury	Ground level fall: 45
	Fall from height: 23
	Motor vehicle collision: 17
	Gunshot wound: 7
Treatment	ORIF: 67
	Definitive external fixation: 12
	Staged external fixation: 8
	Other: 3
Duration of follow-up (mo)	6.2 ± 6

RESULTS

We identified 90 patients who met the inclusion criteria. The average patient was 59 years old (± 21 years). There was an even distribution between high-energy (50%) and low-energy (50%) injuries. The majority of injuries were low grade (67% Gustilo I vs 11% Gustilo III injuries) with over half classified as intra-articular AO type C injuries (n = 48; 53%). Most fractures (74%) underwent ORIF at the time of index irrigation and debridement and 13% underwent definitive external fixation. A total of 8 fractures were treated with initial external fixation followed by ORIF at a later date (9%) and 3 fractures were treated with closed reduction and percutaneous pinning (4%). The mean follow-up was 6 months with a range of 6 weeks to 12 months (Table 1).

Younger patients (< 50 years) were more likely to undergo ORIF (83%) than patients aged 50 to 70 (72%) and patients older than 70 years (69%). The majority of patients were treated with immediate ORIF regardless of mechanism of injury (72% of low-energy and 76% of high-energy injuries). Similarly, the majority of patients underwent immediate ORIF regardless of Gustilo grade (75% Gustilo I, 63% Gustilo II, and 90% of Gustillo IIIA) or AO classification (A, 75%; B, 78.6%; C, 72.9%) Healthier patients (ie, lower CCI) had a higher rate of definitive operative fixation (CCI 0−3, 0%−83% vs CCI 4−7, 61%) (Table 2). Logistic regression analysis demonstrated that age older than 70 ($P < .05$) and CCI greater than 3 ($P < .05$) were associated with selection of treatment other than immediate ORIF. We found no association between mechanism of injury ($P > .05$) or AO classification ($P > .05$) on the type of treatment selected (Table 3).

Overall, a 37% complication rate (n = 33) was noted with 24 major and 9 minor complications (Table 4). Patients older than 70 years had the lowest overall complication rate (25%) compared with patients younger than 50 years (44.8%) and 50 to 69 years of age (44%). Female patients had a slightly lower complication rate (33.3%) than males (42.4%). The overall complication rate was similar among the 3 Gustilo grades (I, 32.4%; II, 47.3%; III, 40%). Extra-articular fractures had a lower complication rate (AO A, 28.6%) compared with more complex intra-articular fractures (AO B, 42.8%; AO C, 39.6%). The complication rate was lowest among the highest CCI group (25%), compared with healthier patients (CCI 0, 43.8%, and CCI 1−3,39.4%). Patients undergoing immediate ORIF had the lowest complication rate (31.4%), compared with patients treated with definitive external fixation (33.3%) and those who underwent provisional external fixation

TABLE 2. Patient Demographics Versus Treatment*

Variable	n	ORIF (%)	Definitive External Fixation (%)	Other (%)
Age (y)				
< 50	29	82.8	3.4	13.8
50–69	25	72	8	20
70+	36	69.4	25	5.6
Sex				
Female	57	73.7	17.5	8.8
Male	33	75.8	6.1	18.2
Mechanism				
Ground level fall	43	72.1	18.6	9.3
Fall from height	23	69.6	17.4	13
Motor vehicle collision	17	76.5	0	23.5
Gunshot wound	7	100	0	0
Gustilo classification				
I	60	75	13.3	11.7
II	19	63.2	21.1	15.8
IIIA	10	90	0	10
AO classification				
A	28	75	21.4	3.6
B	14	78.6	7.1	14.3
C	48	72.9	10.4	16.7
CCI				
0	29	82.8	3.4	13.8
1–3	22	78.8	6.1	15.2
4–7	28	60.7	10.4	16.7

*The percentages noted are the percentage of the demographic variable (and their subcategories) listed in the first column.

TABLE 3. Regression Analysis of Treatment Choice*

Demographic	Odds Ratio	95% Confidence Interval	*P* Value
Age > 70 y	0.54	0.46–0.89	<.01
CCI > 3	0.75	0.29–0.95	.02
High-energy mechanism of injury	0.84	0.56–1.2	.25
AO type C classification	.65	0.65–1.13	.08

*Analysis was performed using categories of ORIF vs all other types of fixation.

followed by ORIF (100%) (Table 5). Logistic regression analysis demonstrated that definitive ORIF was associated with a lower overall complication rate ($P < .05$). High-energy mechanism of injury was shown to be associated with higher complication rates ($P < .05$). No association was found between CCI or AO classification and complication rates (Table 6).

TABLE 4. Complications

Minor (n = 9)	Major (n = 24)
Persistent pain (5)	Persistent paresthesia (12)
Wrist stiffness (3)	Tendinitis with removal of hardware (4)
Superficial pin-site infection (1)	Malunion (3)
	Median nerve injury (1)
	Tendon rupture (2)
	Deep infection (2)

DISCUSSION

This study focused exclusively on a large experience of open fractures of the distal radius from a single

TABLE 5. Patient Demographics Versus Complications

Variable	Minor (%)	Major (%)
Age (y)	< 50: 13.8	< 50: 31
	50−69: 8	50−69: 36
	> 70: 8.3	> 70: 16.7
Sex	Male: 9.1	Male: 33.3
	Female: 10.5	Female: 22.8
Mechanism	Ground level fall: 7	Ground level fall: 11.6
	Fall from height: 26.1	Fall from height: 34.8
	Motor vehicle collision: 0	Motor vehicle collision: 47.1
	Gunshot wound: 0	Gunshot wound: 42.9
Gustilo classification	I: 11.7	I: 21.7
	II: 10.5	II: 36.8
	III: 0	III: 40
AO classification	A: 10.7	A: 17.9
	B: 7.1	B: 35.7
	C: 10.4	C: 29.2
CCI	0: 13.8	0: 31
	1-3: 6.1	1-3: 33.3
	4-7: 10.7	4-7: 14.3
Treatment	ORIF: 6	ORIF: 25.4
	Definitive external fixation: 33.3	Definitive external fixation: 0
	Staged external fixation: 12.5	Staged external fixation: 87.5

TABLE 6. Regression Analysis of Risk Factors for Complications*

Variable	Odds Ratio	95% Confidence Interval	*P* Value
Definitive ORIF	0.45	0.63−0.94	< .01
CCI > 3	0.84	0.64−1.04	.10
AO type C fracture	0.96	0.76−1.23	.23
High-energy mechanism of injury	1.69	1.15−2.34	.04

*Analysis was performed using categories of ORIF vs all other types of fixation.

center. Trends seen in the literature are consistent with the findings in this study. We observed a lower overall short-term complication rate in patients treated with definitive internal fixation at the index procedure versus staged procedures. The precedent exists in more common open fractures (ie, diaphyseal forearm) for performing definitive internal fixation at the time of index debridement.[12,13] In more recent studies evaluating open fractures of the distal radius, it has been shown that ORIF at the time of initial debridement is safe and effective, with infection rates equivalent to that of a closed fracture in matched cohorts.[6−8] The basis for this observation is likely multifactorial. Provided that surrounding soft tissues can be adequately debrided in a single-stage procedure, modern locked volar plates or dorsal spanning plates afford the surgeon the ability to achieve adequate skeletal stability despite significant comminution. Patients are able to begin a rehabilitative program more expeditiously without the need for further procedures, which would serve to increase the risk of postoperative stiffness and the infection rate.

The other characteristic that was found to be associated with increased complication rate was mechanism of injury, with high-energy injuries resulting in a higher rate of complication. This fact has also been demonstrated previously. In a study of 18 patients with open distal radius fractures, a higher incidence of postoperative infection, as well as a higher overall complication rate and worse functional outcome was seen in patients who suffered a high-energy injury versus a low-energy mechanism.[4] It is possible that the mechanism of injury and not the Gustilo classification has a greater impact on the overall complication rate. This is due to the fact that contamination is not directly correlated with the Gustilo classification but may be more associated with the mechanism of injury. One of the largest published series of open distal radius fractures (42 patients) demonstrated no association between complication/infection rate and Gustilo classification; yet when contamination was introduced as an independent variable, an association was found.[6] More recent retrospective case series have demonstrated similar findings with no difference observed in complication or infection rate in Gustilo grade I/II versus grade III injuries.[14] Our study was limited to the use of mechanism of injury and Gustilo classification to estimate the overall injury severity. It is possible that a more rigorous definition of contamination or soft tissue injury would yield a different result.

The limitations of this study lie in its retrospective nature and relatively small sample size. Whereas sufficient power was present to identify a difference in overall complication rate, post hoc analysis failed to show sufficient power for bivariate subgroup analysis. We attempted to account for this utilizing logistic regression analysis; however, the number of variables we were able to include in our models was also limited by sample size and complication rate. Owing to the lack of a standardized treatment algorithm, it remains unclear why certain fixation methods were selected. Specifically, it is unknown why surgeons elected to perform staged external fixation versus other options. This decision likely had an impact on the overall complication rates. Furthermore, although we attempted to account for confounding variables (mechanism and comorbidities), it is possible that certain variables influenced both treatment selection and outcomes, which we were unable detect owing to sample size. In addition, there were other variables that simply could not be classified owing to the study's retrospective nature. For example, a surgeon's assessment of the soft tissue envelope (irrespective of Gustilo classification or mechanism of injury) may have had an impact on treatment in a manner than was not identified by this study.

Whereas the primary goal of this study was to address the short-term complication rates of treatment of open distal radius fractures, we were only able to achieve a mean follow-up of 6 months and thus long-term complications could not be investigated. In particular, the ability to separate neurapraxias from persistent paresthesiae was predicated on accurate documentation at the initial physical examination. Similarly, our ability to characterize persistent pain attempted to utilize several metrics, as noted in the Methods section, but was not necessarily uniform in its implementation. As a result, it is possible that, owing to the retrospective nature of this study and its limited follow-up, the complication rate was higher than observed, which may have had an impact on the overall findings. In addition, the focus on short-term or early complications may not accurately reflect overall long-term outcomes. Finally, we lacked sufficient validated outcome metrics such as Patient-Reported Outcome Measures (PROMS) or Disabilities of the Arm, Shoulder, and Hand (DASH) and thus no assessment of patient rated function could be made.

The treatment of open fractures of the distal radius remains controversial. Based on the results of this study, we believe that definitive internal fixation at the time of debridement of open fractures of the distal radius can provide satisfactory clinical outcomes. Whereas we have demonstrated success using a technique that employs single-stage debridement and definitive ORIF, issues such as soft tissue contamination and mechanism of injury should continue guide surgeons' treatment.[15–18]

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