Displaced Intra-Articular Fractures Involving the Volar Rim of the Distal Radius

Alejandro Marcano, MD, David P. Taormina, MD, Raj Karia, MSc, Nader Paksima, DO, Martin Posner, MD, Kenneth A. Egol, MD

Purpose To describe the features of displaced intra-articular fractures confined to the volar rim of the distal radius and compare outcomes after their operative fixation to complete intra-articular and extra-articular fractures treated with operative fixation.

Methods A total of 627 distal radius fractures were treated over a 6-year period. Twenty-eight patients had volar rim fractures (type 23-B3, as classified by the Orthopaedic Trauma Association [OTA]), all treated with operative reduction and fixation using a volar buttress plate. Clinical outcome information including radiographs, Short Form−36 health survey, and Disabilities of the Arm, Shoulder, and Hand questionnaire were collected at regular postoperative intervals. Patients with volar rim fractures were compared with patients who sustained other types of operatively managed distal radius fractures (OTA types 23-A, 23-B1/B2, and 23-C).

Results The most common type of volar rim fracture consisted of a single large fragment (OTA 23-B3.2; 46%), followed by comminuted fractures (OTA 23-B3.3; 36%). Restoration of radiographic parameters was similar between groups except for an increased volar tilt in volar rim fractures compared with group 23-B1/B2. Active wrist and finger motion improved in all groups except for wrist extension, which was less in the 23-B1/B2 groups. The 23-B1/B2 group had the greatest pain and worst Short Form−36 scores. Disabilities of the Arm, Shoulder, and Hand questionnaire scores were similar and without differences between groups.

Conclusions Our data suggest that patients with volar rim distal radius fractures can expect a rapid return to function with minimal risk for complications and have outcomes similar to other types of operatively treated distal radius fractures. Further investigation of type 23-B fractures (23-B1/B2) is warranted owing to evidence of diminished outcomes. *(J Hand Surg Am. 2015;40(1):42−48. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic III.

Key words Dislocation, distal radius, intra-articular, marginal, shearing.

From the Department of Orthopaedic Surgery, Hospital for Joint Diseases, NYU Langone Medical Center, NYU School of Medicine, New York; and the Department of Orthopaedic Surgery Jamaica Hospital Medical Center, Jamaica, NY.

Received for publication March 20, 2014; accepted in revised form September 8, 2014.

N.P. is a consultant for Stryker. K.A.E. receives grant support from OTA, OREF, and OMEGA and is a consultant for Exactech.

Corresponding author: Kenneth A. Egol, MD, Department of Orthopaedic Surgery, Hospital for Joint Diseases, NYU Langone Medical Center, 301 East 17th Street, New York, NY 10003; e-mail: ljegol@att.net.

0363-5023/15/4001-0009$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2014.09.013

INTRA-ARTICULAR FRACTURES INVOLVING the dorsal or volar rim of the distal radius are usually associated with subluxation or dislocation of the radiocarpal joint. Barton[1] described fractures involving the dorsal rim in 1838. Conversely, when the volar rim of the radius is fractured, it is referred to as a volar Barton fracture, although the eponym has been challenged and its use discouraged.[1,2] Regardless of whether the dorsal or volar rim is fractured, these fractures are uncommon and comprise 1% to 11% of all distal radius fractures (DRFs).[3,4] According to the

Orthopaedic Trauma Association (OTA), they are classified as 23-B3 fractures resulting from either low- or high-velocity trauma.[4,5]

Nonsurgical treatment is usually unsuccessful and is likely to result in early osteoarthritis, deformity, subluxation, and instability.[5] Various surgical techniques have been reported in the literature[6–9]; the current treatment of choice is open reduction and internal fixation using a volar buttress plate. The plate provides a stable reduction that allows the patient to begin early active wrist exercises; generally, the clinical outcome is excellent.[5,10–13] Few studies have compared treatment outcomes of volar rim fractures (VRFs) with other types of DRFs. The purpose of our study was to describe the clinical and radiographic characteristics of VRFs and their outcomes, and to compare them with other DRFs also treated operatively. Our null hypothesis was that there were no significant differences between VRFs and other DRFs treated operatively with regard to clinical and functional outcomes.

MATERIALS AND METHODS

A total of 627 consecutive DRFs treated in the trauma and hand divisions of our department were prospectively enrolled in a database between February 2004 and January 2010. Patients whose fractures underwent surgical repair (n = 281) were retrospectively identified. The fractures included 28 displaced VRFs classified according to OTA criteria as 23-B3, which was our study group. All had been treated operatively by 1 of 2 surgeons, 1 fellowship trained in hand surgery and 1 fellowship trained in trauma surgery. The cohort was composed of 4% of the total number of patients and 10% of patients who required surgery. There were 12 men (43%) and 16 women (57%), mean age 52 years (range, 19–82 y). The dominant hand was involved in 16 patients (57%). To assess outcomes of partial articular fractures, we compared the VRF group with DRFs treated operatively (n = 253). We studied 3 groups of fractures classified according to OTA criteria. Group 1 was extra-articular DRFs (OTA 23-A, n = 97; 38%). Group 2 was partial articular fractures involving the volar rim (OTA 23-B1 and 23-B2, n = 15; 6%). Group 3 was complete articular DRFs (OTA 23-C, n = 141; 56%). Table 1 lists demographic compositions and comparisons of all groups. All fracture classifications were made from either the injury computed tomography scans or by the treating surgeon from initial x-rays at the time of injury. The surgeon's findings were confirmed by one research assistant and by the senior author (K.A.E.).

The most common type of VRF consisted of one large fracture fragment (Fig. 1) (OTA 23-B3.2, n = 13; 46%), followed in frequency by comminuted fractures of the rim (OTA 23-B3.3, n = 10; 36%) and fractures comprising one small fragment (OTA 23-B3.1, n = 5; 18%). Fractures of the ulnar styloid were noted in 47% of cases, compared with 58% of 23-A fractures ($P = .380$), 54% of 23-B1/B2 fractures ($P = .740$), and 62% of 23-C fractures ($P = .150$). There were no statistically significant differences among the groups regarding demographic characteristics, body mass index, and dominant hand injury, except that group 23-B1/B2 had a significantly higher percentage of Hispanic patients. This group also had a greater number of high-energy injuries, although the difference was not significant (Table 1). All radiographic measurements except volar tilt were similar on the initial postinjury radiographs. Volar rim fractures averaged 10° from neutral; OTA 23-A, 1° from neutral ($P < .010$); 23-B1/B2, 3° ($P = .010$); and 23-C, 2° from neutral ($P < .010$).

Treatment in each patient with a VRF was operative reduction and fracture fixation using a volar buttress plate. In each case a similar approach and technique was used. Care was taken to ensure that the plate was placed distal enough to capture the entire distal fragment(s). The plate length and number of distal and proximal screws was left up to the discretion of the surgeon. The postoperative protocol was the same for all patients. The wrist was immobilized for 7 to 10 days in a plaster orthosis that was then changed to a removable orthosis to permit supervised therapy 2 to 3 times each week that consisted of active assisted and gentle passive range of motion exercises for the wrist and fingers. Radiographs were obtained at follow-up examinations at 6 and 12 weeks and at 6 and 12 months. Any operative and postoperative complications were documented. We reviewed radiographs for fracture healing, defined as bridging of three-quarters cortices or loss of fracture lucency, as were the anatomic radiographic parameters of volar tilt, radial inclination, and radial length, including any ulnar variance. The treating surgeon determined healing by radiographic appearance combined with resolution of pain. Range of motion of the wrist and fingers was measured using a goniometer and grip strength was measured using a dynamometer. We compared measurements with the uninjured side and reported them as a percentage of those measurements. The Short Form–36, version 2.0 (SF-36) and Disabilities of the Arm, Shoulder, and Hand (DASH) outcome questionnaires were obtained at each follow-up examination. The

TABLE 1. Patient Data

Variable	OTA 23-B3 Fractures (VRF)	OTA 23-A Fractures	*P*	OTA 23-B1/B2 Fractures	*P*	OTA 23-C Fractures	*P*
Mean age, y (range)	52 (19–82)	53 (20–87)	.67	42 (19–74)	.08	51 (18–87)	.86
Sex (%)			.58		.37		
Male	43	37		62		44	
Female	57	63		39		56	
Race/ethnicity (%)			.21		.02*		.14
Caucasian	58	46		15		43	
African American	8	11		15		12	
Hispanic	12	27		54		27	
Asian	12	7		8		6	
Indian	12	4		0		4	
Other	0	6		8		7	
Mean body mass index (± SD), kg/m^2	27 (5)	26 (6)	.37	27 (5)	.84	27 (4)	.57
Dominant hand injury (%)	58	39	.28	47	1	49	.92
Type of injury (%)							
High energy	29	14	.08	47	.56	24	.59
High-velocity fall	11	5		7		7	
Motor vehicle accident	7	5		27		2	
Bicycle falls	7	2		7		4	
Motorcycle fall	3	1		7		4	
Low energy	71	86	.08	53	.56	76	.59
Low-velocity fall	68	83		53		72	
Sports	4	2		0		2	
Direct impact	0	0		0		1	
Crush	0	1		0		2	

*$P < .05$. There was a significantly greater number of Hispanic patients in OTA 23-B1/B2.

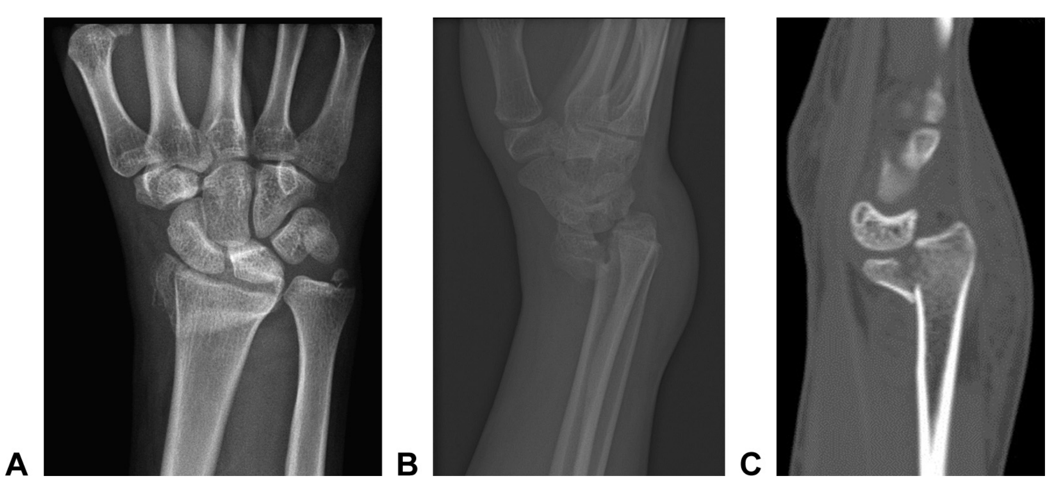

FIGURE 1: The most common pattern in the VRF group was the 23-B3.2. **A** Anteroposterior and **B** lateral radiographic views of a type 23-B3.2 and **C** a CT scan demonstrating the large fracture fragment.

TABLE 2. Comparison of Radiographic Measurements Between Groups

	OTA 23-B3 Fractures (VRF)	OTA 23-A Fractures	*P*	OTA 23-B1/B2 Fractures	*P*	OTA 23-C Fractures	*P*
Injured wrist after reduction							
Palmar tilt (degrees from neutral)	10 ± 8	1 dorsal ± 12	< .001*	3 ± 9	.007*	2 dorsal ± 15	< .001*
Radial inclination (degrees)	17 ± 6	18 ± 6	.560	22 ± 3	.001*	17 ± 6	.900
Radial length, mm	9 ± 3	9 ± 3	.870	11 ± 4	.046*	9 ± 3	.780
Ulnar variance, mm	1 ± 2	1 ± 2	.160	0 ± 2	.260	1 ± 3	.950
Articular stepoff, mm	1 ± 1	0 ± 1	.330	0 ± 1	.300	0 ± 1	.430
Injured wrist before final follow-up							
Palmar tilt (degrees from neutral)	8 ± 6	5 ± 7	.046*	4 ± 8	.080	5 ± 9	.100
Radial inclination (degrees)	20 ± 4	20 ± 5	.900	22 ± 4	.320	20 ± 4	.790
Radial length, mm	10 ± 3	10 ± 3	.950	11 ± 2	.860	11 ± 8	.680
Ulnar variance, mm	1 ± 2	0 ± 2	.018*	0 ± 2	.130	1 ± 3	.340
Articular stepoff, mm	0 ± 1	0 ± 1	.380	1 ± 1	.160	0 ± 5	.480
Injured wrist at final follow-up							
Palmar tilt (degrees from neutral)	8 ± 6	5 ± 9	.090	3 ± 7	.020*	5 ± 8	.060
Radial inclination (degrees)	21 ± 8	20 ± 5	.740	20 ± 6	.640	21 ± 5	.850
Radial length, mm	10 ± 3	10 ± 3	.350	11 ± 3	.470	11 ± 8	.440
Ulnar variance, mm	1 ± 2	1 ± 2	.810	1 ± 2	.470	1 ± 2	.200
Articular stepoff, mm	0 ± 1	0 ± 1	1.00	0 ± 1	.500	0 ± 1	.940

*Statistically significant difference ($P \leq .050$), Student *t* test.

SF-36 questionnaire provided a psychometrically based physical and mental health summary in which 0 points represent worst quality of life and 100 points represent best quality of life. The DASH questionnaire provides a score ranging from 0 points (no disability) to 100 points (maximum disability). Research assistants and the treating surgeons performed all clinical and radiographic measurements.

We used statistical analyses to describe the patient population and treatment outcomes. Fisher exact test, chi-square test, or Student *t* test was applied as appropriate to all analyses. Statistical significance was defined as $P \leq .050$; values are reported as means ± standard deviations.

RESULTS

We compared outcomes of 28 patients with VRFs with the other patients who had sustained different patterns of DRFs that also required surgery (n = 253). The VRFs healed in a similar time frame as other types of DRFs; healing averaged by 9 weeks compared with 11 weeks for OTA 23-A fractures ($P = .430$), 8 weeks for 23-B1/B2 fractures ($P = .330$), and 10 weeks for 23-C fractures ($P = .740$). Measurements of the radiographic parameters of the distal radius, including volar tilt, were similarly restored at the final examination with the exception of OTA 23-B1/B2 fractures, which were significantly less and averaged 3° versus 8° in VRF ($P = .020$) (Table 2).

Wrist motion before final follow-up was significantly restricted compared with extra-articular DRFs (OTA 23-A) (Table 3). However, at final follow-up all groups regained proportionally similar wrist motion compared with the uninjured wrist. When comparing each of the 3 subtypes of volar rim fractures against all DRFs, VRFs composed of one small or one large fracture fragment (OTA 23-B3.1 and B3.2) had better recovery of wrist extension at final follow-up ($P < .010$). Comminuted VRFs (type 23-B3.3) had statistically significant different ulnar variance measurements at final follow-up; 1 mm from neutral versus 1 mm ($P = .020$). The clinical importance of this difference was not established. Digital motion improved more rapidly in VRFs before final follow-up, but as with wrist measurements, it was similar in all groups at final follow-up.

We found no significant differences in median nerve symptoms among groups at final follow-up (7% in VRFs, 4% in OTA 23-A, 7% in 23-B1/B2, and 4%

TABLE 3. Comparison of Clinical Outcomes Between Groups

Outcome	OTA 23-B3 Fractures (VRF)	OTA 23-A Fractures	P	OTA 23-B1/B2 Fractures	P	OTA 23-C Fractures	P
Healing time, wk	9 ± 3	10 ± 6	.210	8 ± 6	.330	10 ± 6	.740
Before final follow-up (%)							
Pain	2 ± 2	3 ± 2	.220	3 ± 3	.300	3 ± 3	.310
Wrist extension	65 ± 15	49 ± 27	< .010*	49 ± 26	.090	58 ± 28	.170
Wrist flexion	56 ± 14	50 ± 25	.240	47 ± 9	.200	60 ± 26	.450
Supination	86 ± 17	67 ± 29	< .010*	50 ± 43	.130	70.5 ± 29	< .010*
Pronation	92 ± 20	79 ± 26	.050*	82 ± 19	.350	85.9 ± 19	.270
Ulnar deviation	56 ± 2	50 ± 33	.410	53 ± 10	.830	59.9 ± 28	.610
Radial deviation	64 ± 23	42 ± 39	.030*	50 ± 50	.420	52.6 ± 31	.170
Grip strength	46 ± 24	33 ± 25	.090	23 ± 26	.140	32.9 ± 28	.100
Final follow-up (%)							
Pain	2 ± 2	2 ± 2	.680	5 ± 4	.040*	1.3 ± 2	.510
Wrist extension	92 ± 18	82 ± 24	.140	70 ± 21	.010*	82.3 ± 19	.070
Wrist flexion	83 ± 22	80 ± 20	.730	74 ± 19	.130	82.4 ± 19	.990
Supination	95 ± 15	90 ± 22	.400	95 ± 11	.910	94.8 ± 10	.880
Pronation	96 ± 12	95 ± 11	.860	99 ± 2	.720	96.6 ± 9	.800
Ulnar deviation	77 ± 17	74 ± 24	.640	87 ± 13	.410	76.3 ± 23	.870
Radial deviation	80 ± 26	70 ± 27	.230	67 ± 28	.320	77.0 ± 24	.710
Grip strength	74 ± 28	74 ± 29	.940	62 ± 30	.480	80.0 ± 64	.860
SF-36	83 ± 13	80 ± 16	.360	70 ± 19	.030*	79.9 ± 17	.100
DASH	13 ± 17	15 ± 17	.630	26 ± 22	.090	12.2 ± 15	.810

Note: Range of motion and grip strength measurements are reported as a percentage of the contralateral side.
*Statistically significant difference ($P \leq .050$), Student *t* test.

TABLE 4. Fracture Type Distribution Comparison According to AO/OTA Classification

Study	N	23-B3.1	23-B3.2	23-B3.3
Jupiter et al (1996)[10]	49	2 (4%)	3 (6%)	44 (90%)
Zoubos et al (1997)[15]	35	11 (31%)	21 (60%)	3 (9%)
Aggarwal and Nagi (2004)[5]	16	2 (13%)	4 (25%)	10 (63%)
Jalil et al (2010)[14]	11	4 (36%)	6 (55%)	1 (9%)
Tang et al (2012)[13]	16	5 (31%)	8 (50%)	3 (19%)
Marcano et al (current study)	28	5 (18%)	13 (46%)	10 (36%)
Total	155	29 (19%)	55 (35%)	71 (46%)

in 23-C). The SF-36 and DASH scores improved in comparable ratios among groups. At final follow-up, the SF-36 score was slightly better for VRFs. The differences were statistically significant compared with the OTA 23-B1/B2 group (Table 3).

DISCUSSION

We report a relatively large series of a subset of unstable volar rim DRFs that were treated operatively. The outcomes data on these injuries suggest uniform outcomes result compared with other subtypes of DRFs with no unique complications seen. Volar rim fractures represent 1% to 11% of all DRFs and are associated with high-energy injuries in 64% to 81% of cases.[5,13,14] In our study they represented 5% of the total number of cases and the mechanism of injury did not differ from the other types of fractures; 29% of VRFs resulted from high-energy injuries. Previous investigators have reported a widely heterogeneous distribution of the 3 types of VRFs that may be due to the difficulty in accurately visualizing fractures with multiple fragments, assessing the size of a single fracture fragment, and the limited number of patients with each type (Table 4).[5,10,13–15]

Final radiographic follow-up in our study demonstrated averages consistent with those previously reported.[7,10,13] Compared with other DRF subtypes, volar tilt was greater in VRFs, consistent with the pathophysiology of the fracture. Disruption and displacement of the volar articular rim naturally increased volar tilt that usually resulted in subluxation of the carpus, the defining feature of the fracture. We encountered ulnar styloid fractures in 47% of cases, compared with a reported range of 49% to 62%.[10,16]

Time at fracture healing in our study averaged 9 weeks, within the range reported in the literature of 7.5 to 12.9 weeks.[5,13,14] Patients regained excellent active wrist motion compared with the uninjured wrist, similar to results achieved in the study of Jupiter et al,[10] who reported averages of 90% of extension, 88% of flexion, 96% of radial deviation, and 91% of ulnar deviation. No patient in our study had median nerve symptoms or deficits at final follow-up, which was consistent with other studies. Therefore, routine decompression of the median nerve in the carpal tunnel in conjunction with plate fixation of the fracture appears to be unnecessary.[3,5,14,15]

Satisfactory outcomes for patients with VRFs in the good to excellent range should be anticipated in 75% to 94% of patients.[3–5,7,10,13–16] Fair and poor results have been reported in patients whose fractures were severely comminuted and not adequately reduced.[16] The DASH scores were similar to the scores we obtained in patients with other types of DRFs who also required surgery. At final follow-up, SF-36 scores were similar to those of other patients in the study with the exception of scores for other partial articular fractures (OTA 23-B1/B2), which were significantly lower.

Previous studies reported various complications in the treatment of VRFs, such as posttraumatic osteoarthritis,[3,5,7,10,16] loss of reduction leading to malunion,[10,13,14] Sudeck atrophy,[5] scapholunate dissociation, subluxation of the distal radioulnar joint, painful hardware, median nerve compression, sympathetic chronic regional pain syndrome, tenosynovitis of the flexor carpi radialis and/or the tendons in the first dorsal extensor compartment, and rupture of the extensor pollicis longus.[10] None of these problems were encountered in our study.

An early report of surgical treatment for VRFs with volar subluxation of the carpus recommended operative reduction and fixation using a volar buttress plate to prevent carpal re-subluxation.[17] Despite the biomechanical advantages of plate fixation, some studies report no outcome differences between volar buttress plate and closed reduction with pinning and an external fixator.[7,18] However, most investigators recommend using volar plates to treat VRFs and have reported good to excellent results, which we confirmed.[5,13]

Two articles described a variant of VRF that has a concomitant fracture through the dorsal metaphyseal cortex that, if unrecognized, could lead to dorsal translation and angulation of the articular surface of the distal radius after fixation with a volar buttress plate.[11,19] Those authors recommended routine use of a contoured volar locking plate with screws inserted into the distal fragment in all VRFs to prevent dorsal translation of this fragment.[11] When treated accordingly, this subtype had no different outcomes compared with VRFs without the dorsal cortex fracture.[19] Harness et al[20] stated that the stability of some comminuted fractures of the distal radius with volar fragmentation, including VRFs, should be determined by correct fixation of the lunate facet fragment. This fragment may also be easily missed and is not securely supported by standard fixation devices. The key to fixation of many of these fractures is appropriately placing the implant distally enough to buttress the involved fragments. However, this must be balanced with recognition of plate prominence (owing to varying design) at the watershed line which, if violated, could predispose to flexor pollicis longus rupture.[21] It is critical that these complex fractures be carefully assessed preoperatively.[20] We did not experience loss of reduction or flexor pollicis longus rupture in patients in the VRF group in our study, all of whom were treated with 1 of 2 plate designs.

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