Outcomes After Volar Plate Fixation of Low-grade Open and Closed Distal Radius Fractures Are Similar

Jae Kwang Kim MD, PhD, Sang Doo Park MD

Received: 24 September 2012 / Accepted: 8 January 2013 / Published online: 24 January 2013
© The Association of Bone and Joint Surgeons® 2013

Abstract

Background Low-grade (Gustilo and Anderson Type I or II) open distal radius fractures (DRFs) have been treated by volar locking plate fixation. However, it is unclear whether the outcomes after volar locking plate fixation for low-grade open DRFs are comparable to those for closed DRFs. **Questions/purposes** We asked whether low-grade open DRFs had worse DASH scores and higher infection rates than closed DRFs when the DRFs were treated by volar plate fixation.

Methods Twenty consecutive patients treated by volar locking plate fixation for low-grade open DRFs constituted the open fracture group, and 40 patients were selected from among the total number of patients treated by volar, locking plate fixation for closed DRFs as the closed

fracture group. Complications including infection were recorded. Clinical outcomes and radiographic assessments were performed postoperatively at 3 months and 1 year.

Results At 3 postoperative months, wrist flexion and extension, grip strengths, and DASH scores were better in the closed fracture group; however, no difference was observed postoperatively between the two groups in terms of any functional outcome measure at 1 year. Any of the radiographic parameters were not different between the groups. There were no differences in infection rate and in any other complication rate between the groups.

Conclusions Although functional outcomes of open DRFs were inferior to those of closed DRFs at 3 months, at 1 year, outcomes of low-grade open DRFs were found to be comparable to those of closed DRFs when volar plate fixation was used.

Level of Evidence Level III, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he has no commercial association (eg, consultancies, stock ownership, equity interest, patent/licensing arrangement, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request.

Clinical Orthopaedics and Related Research neither advocates nor endorses the use of any treatment, drug, or device. Readers are encouraged to always seek additional information, including FDA approval status, of any drug or device before clinical use. Authors certify that our institution has approved the reporting of these cases, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participating in the study was obtained.

J. K. Kim (✉), S. D. Park
Department of Orthopedic Surgery, Ewha Womans
University School of Medicine, Ewha Womans University
Medical Center, Seoul, Korea
e-mail: kimjk@ewha.ac.kr

Introduction

Although distal radius fractures (DRFs) are among the most common extremity fractures, little information is available in the literature regarding management of open DRFs because they are uncommon [21]. Although several studies have reported results for treatment of open DRFs [5, 12, 21], these studies were case series (not comparative studies) that mainly focused on risk factors for development of deep infection. In addition, several treatment methods were used in those studies, although external fixators were used in most cases.

Open fractures should be stabilized using a method that provides adequate fracture stability yet causes little

additional trauma to the zone of injury [21]. At the time of initial débridement, plate fixation can lead to successful fracture healing without infection or serious complications after low-grade open fractures of the upper extremity [4, 16]. Kurylo et al. [12] suggested immediate plate fixation during initial débridement of low-grade open DRFs was safe and had minimal risks of infection or serious complications. However, there has been no study showing the outcomes of volar plate fixation of consecutive patients with low-grade open DRFs. Furthermore, no study has determined whether the outcomes after volar locking plate fixation for low-grade open DRFs are comparable to those for closed DRFs.

We hypothesize the functional and radiographic outcomes of low-grade open and closed DRFs after volar plate fixation should not be different. We assessed whether there were differences in (1) clinical outcomes (grip strength, wrist ROM, VAS, and DASH), (2) radiographic assessment (radial inclination, volar angulation, ulnar variance, articular step-off, and arthritic changes), and (3) the risk of development of complications 1 year after volar plate fixation of closed and low-grade open (Gustilo and Anderson [7] Type I or II) DRFs.

Patients and Methods

This study was approved by our institutional review board. Four hundred five consecutive patients, 18 years or older, were treated surgically for DRFs at our institution between March 2006 and May 2010. The indications for surgery were unstable fractures with one or more of the following radiographic parameters: dorsal angulation greater than 0°, palmar angulation greater than 20°, an articular gap or step-off greater than 1 mm, a radial inclination less than 15°, or radial shortening greater than 3 mm after a single attempt at closed reduction.

Of the patients treated surgically for DRFs, 22 consecutive patients were treated for open DRFs. According to the Gustilo and Anderson [7] classification, 11 DRFs were Type I and nine were Type II (Orthopaedic Trauma Association [OTA] Fracture Classification [13]: three A3, one C1, 11 C2, five C3) and two were Type III. Twenty patients with low-grade (Gustilo and Anderson Type I or II), open DRFs were treated by open reduction and volar locking plate fixation and constituted the open fracture group. Two patients with high-grade (Gustilo and Anderson Type III) open DRFs were treated by external fixation and excluded from this study.

Of the patients treated surgically for DRFs, 383 were treated for closed DRFs, and of these, 361 patients were treated by open reduction and volar locking plate fixation. Twenty-two patients underwent fracture fixation using

other methods. Four patients with fracture of the dorsal articular margin with dorsal radiocarpal subluxation were treated by dorsal plating. Six patients with a severe comminuted intraarticular fracture were treated using volar and dorsal plating. Four patients who had a displaced fracture of the scaphoid facet alone (OTA Type B1) were treated with radial column plating. Eight patients who refused plate application were treated using K-wire fixation. These 22 patients treated by other than volar locking plate fixation were excluded from this study.

The study exclusion criteria were: (1) a neurologic injury or disorder; (2) a systemic disease, such as rheumatoid arthritis, ankylosing spondylitis, multiple myeloma, and chronic renal failure; (3) a combined, ipsilateral, upper extremity fracture (except distal ulnar fracture); and (4) previous wrist fracture. None of the 20 patients with open DRFs was excluded; however, 31 of 361 patients with closed DRFs satisfied at least one exclusion criterion. Finally, 20 patients with open DRFs and 330 with closed DRFs were enrolled in this study.

The dominant wrist was injured in 10 of the patients with open fractures, and the mechanisms for their injuries were slipping ($n = 9$), falls from heights greater than 1 m ($n = 4$), industrial accidents ($n = 2$), and motor vehicle accidents ($n = 5$). All 20 patients initially were treated with intravenous antibiotics and tetanus prophylaxis in our emergency room, and all underwent wound débridement and initial volar locking plate fixation within 48 hours of injury. One patient with a Gustilo and Anderson Type II open fracture subsequently required a split-thickness skin graft. All 20 patients visited our clinic postoperatively at 3 months, but two missed their 12-month followups.

We selected 40 patients (closed fracture group) from among the 330 who were treated by volar locking plate fixation for closed DRFs. These patients were individually matched to members of the open fracture group at a 2:1 ratio, by sex, age, the presence of a distal ulnar fracture, injury mechanism, plate design, and the fracture type defined by the OTA fracture classification [13] (Table 1). All patients in the open fracture group had more than two matched patients. If there were more than three matched patients, we selected two among the matched patients who had the closest surgical dates to those of the open fracture group, chronologically.

Postoperative clinical assessments were performed by a trained physiotherapist (JMN) who was blinded to treatment details at 3 months and 1 year. Clinical assessments included grip strength, wrist ROM, wrist pain, and DASH scores [8]. Grip strengths were measured using a Jamar[®] dynamometer (Lafayette Instrument, Lafayette, IN, USA) with the elbow flexed at 90° and the forearm in neutral rotation. Values are expressed as percentages of the values of contralateral (uninjured) wrists. Regarding grip strength

Table 1. Demographics of the two groups

Variable	3-month followup			1-year followup		
	Open (n = 20)	Closed (n = 40)	p value	Open (n = 18)	Closed (n = 40)	p value
Age (years)	54	52	0.78	54	52	0.73
Sex (male/female) (number of patients)	8/12	16/24	0.75	7/11	16/24	0.87
OTA fracture classification (A3/C1/C2/C3) (number of patients)	3/1/11/5	6/2/22/10	1.0	3/1/10/4	6/2/22/10	0.98
Open type (Gustilo and Anderson Type I/II) (number of patients)	11/9			10/8		

OTA = Orthopaedic Trauma Association.

calculations, we allowed 10% for the greater strength of the dominant hand when the right hand was dominant but made no allowance when the left hand was dominant [3, 20]. Wrist ROM (extension, flexion, supination, pronation) was measured using a hand-held goniometer, and results were also expressed as percentages of the contralateral wrists. Wrist pain during daily activities was assessed using a VAS, where 0 indicated no pain and 10 indicated the most severe pain. The DASH questionnaire consisted of 30 items addressing abilities to perform specified activities (21 items) and symptoms (nine items). DASH scores range from 0 to 100 and higher scores indicate greater disability. DASH scores were used as the primary outcome variables in this study.

Quality of radiographic reduction (radial inclination, volar angulation, ulnar variance, and an articular step-off) and arthritic degeneration of the radiocarpal joints each was assessed on the immediate (3-month) and 1-year postoperative plain posteroanterior and lateral wrist radiographs. Radial inclination and volar angulation were measured as described by Goldfarb et al. [6], and ulnar variance was measured using the method described by Medoff [15]. An articular step-off was measured using the longitudinal axis method described by Cole et al. [2]. Arthritic grade [11] was measured postoperatively at 1 year as follows: not specific, Grade 0; slight narrowing of the radiocarpal joint, Grade 1; marked joint narrowing with osteophyte formation, Grade 2; and no joint space with osteophyte formation, Grade 3. Radiographic evaluations were performed by two of the authors (KJK, PSD) who were blinded to the fracture condition. One was an expert on hand surgery and the other was in hand fellowship training. Disagreements during radiographic evaluations were settled by consensus.

Postoperative complications were recorded by one of the authors (KJK) who was aware of treatment details. Complications were categorized into seven items: tendon irritation/rupture, failure of reduction, nonunion, infection, skin dehiscence, and finger stiffness. Failure of reduction

was defined as the presence of one of the following: (1) dorsal angulation greater than 10°; (2) volar angulation greater than 25°; (3) articular step-off greater than 2 mm; or (4) radial shortening greater than 5 mm [25]. Complications were dichotomized as major and minor. Major complications were defined as any adverse outcomes requiring additional surgical intervention [25], and minor complications were defined as any bothersome postoperative outcomes not requiring subsequent surgery [25]. For example, a superficial infection requiring prolonged antibiotic therapy for sustained redness and swelling around the wound but which resolved within 2 weeks of antibiotic therapy was considered a minor complication, whereas a deep infection that required irrigation and débridement was considered a major complication.

A post hoc power analysis was performed for DASH score as one of the primary outcome variables of this study. The minimal clinically important difference of a DASH score for a patient with a wrist problem has been reported to be approximately 10 [22], and the SD of a DASH score in a distal radius fracture also is approximately 10 [9, 10]. A sample size of 18 patients in the open fracture group and 40 in the closed fracture group at 1 year after surgery would provide 92% power with a Type I error rate of 0.05.

A post hoc power analysis also was performed for infection rate as another primary outcome variable of this study. The infection rate was reported as 0.3% when closed DRFs were treated by volar plate fixation [23], whereas the incidence requiring a subsequent irrigation and débridement for infection control was reported as 17% in open DRFs [5, 21]. Therefore, when we assumed the infection rate of closed DRFs was 0.3% and the proportion inequality of the infection rate in open DRF was 17%, a sample size of 20 patients in the open fracture group and 40 in the closed fracture group at 3 months postoperation would provide 66% power with a Type I error rate of 0.05.

The Mann-Whitney U test was used to evaluate inter-group differences for continuous variables, and the chi-square test or Fisher's exact test was used to evaluate

differences for categorical variables. All statistical tests were two-sided and $p < 0.05$ was considered significant.

Results

At 3 months after surgery, flexion and extension were better in the closed fracture group than in the open fracture group, and grip strengths and DASH scores also were better in the closed fracture group (Table 2); however, no intergroup differences were observed for wrist ROM, grip strength, and VAS or DASH scores 1 year after surgery (Table 3).

No intergroup difference was found for any radiographic parameter (Table 4). The mean articular step-off was 0.4 mm (SD, 0.6 mm) in the open fracture group and 0.3 mm (SD, 0.4 mm) in the closed fracture group ($p = 0.89$). Two patients in each group showed a Grade 1 radiographic arthritis change at 1 year postoperation, and the incidence of arthritic change was not different between the two groups ($p = 0.83$).

There was no difference in the incidence of major ($p = 0.26$) or minor ($p = 0.10$) complications between groups. Two major complications occurred in the open fracture group and one major complication occurred in the closed fracture group (Table 5). One patient in the open fracture group experienced a flexor tendon irritation which was postoperatively treated by plate removal at 1 year; the other experienced skin dehiscence at the open wound and subsequently underwent postoperative split-thickness skin grafting at 1 week. The major complication in the closed fracture group was an extensor tendon irritation, which was treated postoperatively by plate removal and tenosynovectomy at 1 year. Three minor complications occurred in the open fracture group, and one minor complication occurred in the closed fracture group. A superficial skin

infection developed in two patients of the open fracture group and in one patient of the closed fracture group, but all were resolved by intravenous antibiotics. The patient requiring a split-thickness skin graft in the open fracture group experienced prolonged finger stiffness until 3 months after surgery, but it had resolved at 1 year.

Discussion

Low-grade (Gustilo and Anderson Type I or II) open DRFs have been treated by volar locking plate fixation. However, it is unclear whether the outcomes after volar locking plate fixation for low-grade open DRFs are comparable to those for closed DRFs. We therefore asked whether low-grade open DRFs had worse DASH scores and higher infection rates than closed DRFs when the DRFs were treated by volar plate fixation. This study showed wrist flexion and extension, grip strength, and DASH scores of the open fracture group were inferior to those of the closed fracture group 3 months after surgery, although no intergroup difference in functional outcomes was seen 1 year postoperatively. These findings suggest it takes more time to recover wrist function after low-grade open DRFs, but the long-term functional results of low-grade open and closed DRFs are similar when they are treated with a volar locking plate.

This study had several limitations. First, we compared outcomes between open and closed DRF groups after volar plate fixation. However, the closed DRF group was selected from a patient pool with closed DRFs by a matching technique, which eventually could be influenced by selection bias. Second, although there had been no report on major complications, such as infection and nonunion in low-grade open DRFs after plate fixation, this study was slightly underpowered for statistical analysis of the infection rate.

Table 2. Functional outcomes of low-grade open and closed distal radius fractures at 3 months' followup

Variable	Open fracture group (n = 20)		Closed fracture group (n = 40)		p value	
	Value*	Percentage of contralateral side	Value*	Contralateral side (%)	Outcome value	Percentage of contralateral side
ROM (°)						
Flexion	45 ± 11	68	51 ± 11	77	0.02	< 0.01
Extension	47 ± 11	69	53 ± 10	78	0.01	< 0.01
Supination	82 ± 7.1	91	82 ± 6.7	91	0.88	0.82
Pronation	83 ± 6.2	92	84 ± 4.7	92	0.63	0.78
Grip strength (kg)	15 ± 7.2	62	18 ± 6.3	74	0.04	< 0.01
VAS score (points)	3.3 ± 2.1		3.0 ± 2.4		0.59	
DASH score (points)	23 ± 17		17 ± 15		0.02	

* Values are expressed as mean ± SD.

Table 3. Functional outcomes of low-grade open and closed distal radius fractures at 1-year followup

Variable	Open fracture group (n = 18)		Closed fracture group (n = 40)		p value	
	Value*	Percentage of contralateral side	Value*	Percentage of contralateral side	Outcome value	Percentage of contralateral side
ROM (°)						
Flexion	60 ± 16	86	61 ± 14	87	0.58	0.53
Extension	62 ± 15	89	63 ± 17	89	0.61	0.78
Supination	83 ± 12	95	84 ± 11	95	0.63	0.79
Pronation	86 ± 10	99	86 ± 11	99	0.83	0.86
Grip strength (kg)	25 ± 12	86	26 ± 13	89	0.62	0.29
VAS score (points)	1.1 ± 2.1		1.1 ± 1.8		0.83	
DASH score (points)	11 ± 10		10 ± 8.2		0.65	

* Values are expressed as mean ± SD.

Table 4. Radiographic outcomes of low-grade open and closed distal radius fractures

Variable	3-month followup		p value	1-year followup		p value
	Open fracture group (n = 20)	Closed fracture group (n = 40)		Open fracture group (n = 18)	Closed fracture group (n = 40)	
Radial inclination (°)	22 ± 4.2	22 ± 4.5	0.78	22 ± 5.1	22 ± 3.9	0.73
Volar angulation (°)	4.6 ± 4.1	4.2 ± 4.8	0.51	4.7 ± 4.5	4.4 ± 4.2	0.64
Ulnar variance (mm)	0.8 ± 2.1	1.0 ± 2.0	0.67	0.9 ± 1.8	0.9 ± 1.9	0.89

Table 5. Postoperative complications

Variable	Open fracture		Closed fracture		p value	
	Major	Minor	Major	Minor	Major	Minor
Tendon irritation/rupture	1	0	1	0	1.0	*
Failure of reduction	0	0	0	0	*	*
Infection	0	2	0	1	*	0.26
Nonunion	0	0	0	0	*	*
Skin dehiscence	1	0	0	0	0.33	*
Finger stiffness	0	1	0	0	*	0.33
Total	2	3	1	1	0.26	0.10

* No p values were computed, as no patient showed this complication in either group.

Three studies [5, 12, 21] in the English literature have addressed the outcomes of open DRFs. These studies showed low-grade (Gustilo and Anderson Type I or Type II) open fractures were more common than high-grade (Gustilo and Anderson Type III) fractures in the distal radius, which corresponded to our study. In a study by Rozental et al. [21], 12 (67%) of 18 open DRFs were low-grade, and in a study by Glueck et al. [5], 34 (81%) of 42 open DRFs were low-grade. Similarly, in a study by Kurylo et al. [12], 31 (94%) of 32 open DRFs were low-grade. Thus, we focused on low-grade open DRFs in the current study.

Although several studies have indicated that immediate plate fixation is a safe treatment method for low-grade open

fractures of the upper extremity [4, 16], the main treatment modality used for open DRFs is external fixation. In fact, immediate plate fixation rarely was used in previous studies [5, 21]. In a study by Rozental et al. [21], immediate plate fixation was used in only two of 18 patients, and in a study by Glueck et al. [5], none of the 42 patients were treated by immediate plate fixation. In a recent study by Kurylo et al. [12], however, seven of 32 patients were treated by immediate plate fixation, and they [12] concluded immediate plating was probably a safe treatment option for low-grade open DRFs because no deep infection was encountered in their series. In our study, we prospectively used volar plate fixation for all low-grade open DRFs

at initial débridement, and all fractures healed uneventfully without deep infection and nonunion.

The use of open reduction and internal fixation for treatment of DRFs has increased substantially [1, 14], probably because of the introduction of the volar locking plate system for treatment of unstable DRFs [17–19]. We believe a volar locking plate can be a reasonable treatment option, especially for low-grade open DRFs, because it firmly stabilizes fracture fragments, and sufficient volar soft tissue is available to completely cover the plate, regardless whether the open wound is located on the volar or dorsal side of the wrist.

Although a couple studies [21, 24] have suggested low-grade open fractures of the upper extremity behave like closed fractures, no study has compared the functional outcomes of low-grade open and closed fractures. The situation is similar for DRFs. Previous studies [5, 12, 21] on open DRFs could not compare outcomes of their series with those of closed DRFs because any type of open wound and treatment was included in their series. Accordingly, it is a strong point of this study that the cohort was limited to low-grade open and closed DRFs, and all fractures were treated by volar plate fixation, which enabled comparisons of the functional outcomes of low-grade open and closed DRFs.

Volar plate fixation for low-grade open DRFs provides a safe and reliable treatment option. Although functional outcomes of open DRFs were inferior to those of closed DRFs at 3 months, 1-year outcomes of low-grade open DRFs were comparable to those of closed DRFs when volar plate fixation was used.

Acknowledgments We thank Kyoung Ae Gong MD, PhD, of the Department of Preventive Medicine for help and advice on the statistical analysis and Jung Mee No BD, for performing physical examinations and collecting the self-reported questionnaires.

References

1. Chung KC, Shauver MJ, Birkmeyer JD. Trends in the United States in the treatment of distal radial fractures in the elderly. *J Bone Joint Surg Am.* 2009;91:1868–1873.
2. Cole RJ, Bindra RR, Evanoff BA, Gilula LA, Yamaguchi K, Gelberman RH. Radiographic evaluation of osseous displacement following intra-articular fractures of the distal radius: reliability of plain radiography versus computed tomography. *J Hand Surg Am.* 1997;22:792–800.
3. Crosby CA, Wehbe MA. Hand strength: normative values. *J Hand Surg Am.* 1994;19:665–670.
4. Duncan R, Geissler W, Freeland AE, Savoie FH. Immediate internal fixation of open fractures of the diaphysis of the forearm. *J Orthop Trauma.* 1992;6:25–31.
5. Glueck DA, Charoglu CP, Lawton JN. Factors associated with infection following open distal radius fractures. *Hand (NY).* 2009;4:330–334.
6. Goldfarb CA, Yin Y, Gilula LA, Fisher AJ, Boyer MI. Wrist fractures: what the clinician wants to know. *Radiology.* 2001;219:11–28.
7. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am.* 1976;58:453–458.
8. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *Am J Ind Med.* 1996;29:602–608.
9. Kim JK, Koh YD, Do NH. Should an ulnar styloid fracture be fixed following volar plate fixation of a distal radial fracture? *J Bone Joint Surg Am.* 2010;92:1–6.
10. Kim JK, Koh YD, Kook SH. Effect of calcium phosphate bone cement augmentation on volar plate fixation of unstable distal radial fractures in the elderly. *J Bone Joint Surg Am.* 2011;93:609–614.
11. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am.* 1986;68:647–659.
12. Kurylo JC, Axelrad TW, Tornetta P 3rd, Jawa A. Open fractures of the distal radius: the effects of delayed debridement and immediate internal fixation on infection rates and the need for secondary procedures. *J Hand Surg Am.* 2011;36:1131–1134.
13. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, Prokuski L, Sirkin MS, Ziran B, Henley B, Audigé L. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma.* 2007;21(10 suppl):S1–133.
14. Mattila VM, Huttunen TT, Sillanpää P, Niemi S, Pihlajamäki H, Kannus P. Significant change in the surgical treatment of distal radius fractures: a nationwide study between 1998 and 2008 in Finland. *J Trauma.* 2011;71:939–942; discussion 942–943.
15. Medoff RJ. Essential radiographic evaluation for distal radius fractures. *Hand Clin.* 2005;21:279–288.
16. Moed BR, Kellam JF, Foster RJ, Tile M, Hansen ST Jr. Immediate internal fixation of open fractures of the diaphysis of the forearm. *J Bone Joint Surg Am.* 1986;68:1008–1017.
17. Orbay J. Volar plate fixation of distal radius fractures. *Hand Clin.* 2005;21:347–354.
18. Orbay J, Badia A, Khoury RK, Gonzalez E, Indriago I. Volar fixed-angle fixation of distal radius fractures: the DVR plate. *Tech Hand Up Extrem Surg.* 2004;8:142–148.
19. Orbay JL, Fernandez DL. Volar fixed-angle plate fixation for unstable distal radius fractures in the elderly patient. *J Hand Surg Am.* 2004;29:96–102.
20. Petersen P, Petrick M, Connor H, Conklin D. Grip strength and hand dominance: challenging the 10% rule. *Am J Occup Ther.* 1989;43:444–447.
21. Rozental TD, Beredjiklian PK, Steinberg DR, Bozentka DJ. Open fractures of the distal radius. *J Hand Surg Am.* 2002;27:77–85.
22. Scheer JH, Adolfsson LE. Radioulnar laxity and clinical outcome do not correlate after a distal radius fracture. *J Hand Surg Eur Vol.* 2011;36:503–508.
23. Soong M, van Leerdam R, Guitton TG, Got C, Katarincic J, Ring D. Fracture of the distal radius: risk factors for complications after locked volar plate fixation. *J Hand Surg Am.* 2011;36:3–9.
24. Yang EC, Eisler J. Treatment of isolated type I open fractures: is emergent operative debridement necessary? *Clin Orthop Relat Res.* 2003;410:289–294.
25. Yu YR, Makhni MC, Tabrizi S, Rozental TD, Mundanthanam G, Day CS. Complications of low-profile dorsal versus volar locking plates in the distal radius: a comparative study. *J Hand Surg Am.* 2011;36:1135–1141.