EDITOR'S CHOICE

Volar Locking Plate Compared With Combined Plating of AO Type C Distal Radius Fractures: A Randomized Controlled Study of 150 Cases

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Purpose The optimal way to stabilize intra-articular distal radius fractures is unclear despite recent advances in surgical management. Volar plating is the most common treatment but may not be sufficient for more complex intra-articular AO type C fractures. The purpose of this randomized controlled study was to evaluate the radiographic and clinical outcomes following surgical treatment of AO type C distal radius fractures, comparing volar with combined plating.

Methods In this study, 150 patients were randomized to volar locking plate (n = 75) or combined plating (n = 75) following a distal radius fracture AO type C. The 1-year follow-up included radiographic outcome (Batra score), visual analog scale pain score, hand grip strength, wrist range of motion, Patient-Rated Wrist Evaluation score, and Quick Disabilities of the Arm, Shoulder, and Hand score.

Results Overall, 147 patients (median age 61 years) completed the 1-year follow-up (73 patients with volar plate and 74 with combined plating). No difference was found in radiographic outcome between the treatment groups. The volar plate group had significantly better Patient-Rated Wrist Evaluation scores, Quick Disabilities of the Arm, Shoulder, and Hand scores, hand grip strength, visual analog scale scores during activity, and flexion, extension, ulnar and radial deviation than the combined plate group. Hardware removal was performed in 10% in the volar plate group and in 31% in the combined plate group. There was no postoperative infection in the volar plate group but 3 cases in the combined plate group.

Conclusions In patients with complex AO type C intra-articular fractures, volar and combined plating yielded the same radiographic result. The differences in Patient-Rated Wrist Evaluation and Quick Disabilities of the Arm, Shoulder, and Hand scores between the groups did not reach the thresholds for minimal clinically important differences, suggesting similar clinical outcome. The combined plating group had a considerably higher frequency of hardware removal and postoperative infections. *(J Hand Surg Am. 2022;47(9):813–822. Copyright © 2022 by the American Society for Surgery of the Hand. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).)*

Type of study/Level of evidence Therapeutic I.

Key words Articular, distal radius fractures, dorsal plate, outcomes, trauma.

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Distal radius fractures (DRFs) are common among adults, accounting for 18% of all fractures reported in the orthopedic trauma unit, and the incidence of DRFs is increasing because of an aging population.[1–4]

Operative treatment is often considered for displaced and unstable fractures that cannot be reduced.[5] There has been a shift during recent decades from nonsurgical and other surgical treatments, toward volar plate fixation with the aim to restore the anatomy and improve the clinical and radiographic outcomes.[6,7] This shift has taken place despite a low degree of evidence.[8]

The volar locking plate was introduced in the 1990s and has shown good clinical and radiographic outcomes.[9] It allows for early mobilization, which may be beneficial for early return of function. Known complications include flexor and extensor tenosynovitis, tendon rupture, and median nerve palsy.[10] The frequency of hardware removal has been reported to be 15% to 30%.[10-12] However, volar plating may not be sufficient for complex intra-articular AO type C fractures.[13] In fractures involving the dorsal ulnar corner (DUC), the DUC fragment is often small and difficult to stabilize with a volar plate.[14] In these cases, volar plating can be combined with dorsal plate fixation (combined plating) as an option for reduction.[15] Combined plating has shown good outcomes and anatomical restoration but high frequencies of hardware removal and tendon ruptures.[16–19]

There are several studies comparing volar locking plate fixation with closed reduction for DRFs, but these studies were generally based on data including different AO types.[20,21] To our knowledge, there are no previous randomized trials comparing volar plating with combined plating after AO type C DRFs.

The aim of this randomized controlled study was to evaluate radiographic and clinical outcomes following surgical treatment of AO type C DRFs with either volar plating or combined plating.

MATERIALS AND METHODS

This single-center, prospective, randomized study was conducted at the Department of Hand Surgery, Örebro University Hospital, a tertiary referral center in Sweden. The study sample consisted of adult patients with AO type C fractures treated between June 2017 and July 2019. The inclusion and exclusion criteria are listed in Table 1. The study was approved by the regional ethical committee of Örebro University Hospital.

All patients gave written informed consent before participation according to the Helsinki declaration.[22] The study was registered in the Swedish research database FoU in Sweden. The sample size was calculated on the basis of the Quick Disabilities of the Arm, Shoulder, and Hand (*Quick*DASH) scores. A sample size of 63 patients in each group available at the 1-year follow-up was considered a minimum to detect a 10-point difference in the *Quick*DASH score at a significance level of $P = .05$ and a common standard deviation of 20 points with 80% power. With an estimated dropout of approximately 20%, the sample size was set to 150 patients.

A total of 150 patients, 75 in each group, were randomized (Fig. 1) to open reduction and fixation using a volar locking plate (TriMed) or combined plating with a volar T-plate and a low-profile dorsal plate with locking screws and variable angles (TriMed) (Fig. 2). The dorsal plate was developed by the manufacturer, in cooperation with our unit, to buttress dorsal displaced intra-articular fragments and stabilize the dorsal rim, considering the well-known tendon-associated complication of this type of implant.[23] All surgeries were performed by hand surgeons. The patients were randomized using sealed opaque envelopes containing the study number and surgical technique. The envelopes were picked and opened outside the operating theater by the operating room nurse directly before surgery. If the surgeon established that the inclusion criteria were not met during the surgery, the patient was excluded from the study and a new envelope was added.

Surgical technique

Surgery was performed under general anesthesia with a brachial plexus block and tourniquet. In the volar locking plate group, a volar central incision was made to visualize the volar ulnar portion of the distal radius, and the carpal tunnel was opened through the same incision.[24] The volar portion of the distal radius was exposed between the finger flexors ulnarly and the median nerve and the thumb flexor radially. The pronator quadratus was divided with a central split, and the volar cortex was reduced; the volar plate was then placed, and the pronator quadratus was repaired using resorbable sutures if feasible. This surgical approach is our clinical routine for AO type C DRFs because it provides good visualization of the volar lunate facet and facilitates fixation of the DUC fragment.

In the combined plating group, in addition to the volar plate procedure, a central, longitudinal incision was made on the dorsal side over the Lister

TABLE 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Age 18–80 y	Previous fracture of the same wrist
Operation within 12 d from injury	Bilateral fractures
AO type C with one or more of the following:	Other concomitant fractures
>20° dorsal angulation of the distal radial articular surface	Open fracture
>2 mm ulnar plus	Fracture extending to the diaphysis
>1 mm incongruence in the radiocarpal joint	Ongoing chemo- or radiotherapy
>1 mm incongruence in the distal radioulnar joint	Metabolic diseases that affect bone
	Dementia
	Mental illness
	Alcohol misuse disorder or opiate addiction
	Difficulty understanding Swedish
	Severe neurological disease
	Severe cardiopulmonary disease
	Associated injuries (eg, ligament injury or other factures in hand/arm)

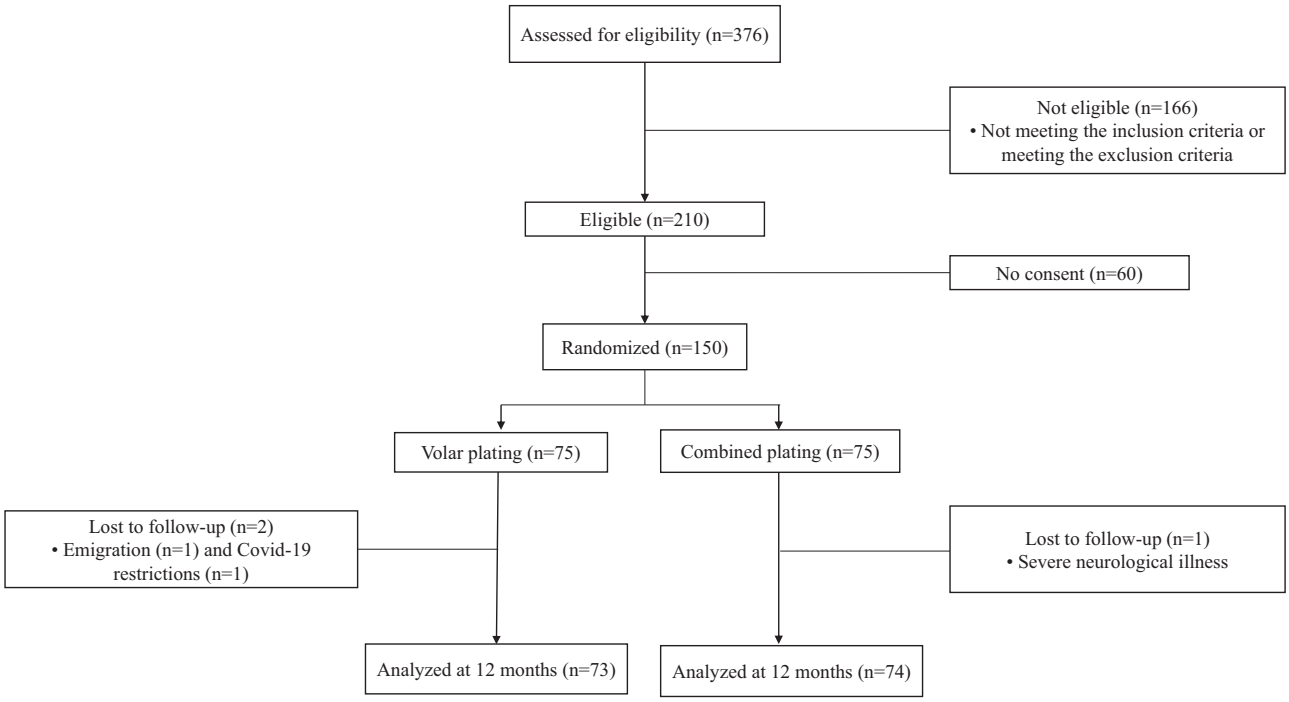

FIGURE 1: Consolidated Standards of Reporting Trial flowchart of trial enrollment and analysis.

tubercle. A Z-shaped division of the extensor retinaculum was performed, and the fracture was exposed through the fourth extensor compartment after subperiosteal dissection. Impacted articular fragments were reduced. The dorsal plate was fixed with screws proximally to distally, using the plate as a reduction tool.

All patients were seen by an experienced hand therapist on the first day after the surgery for instructions concerning exercises to reduce edema and to begin active finger range of motion (ROM) exercises. A cast was applied for 2 weeks, followed by an orthosis for an additional 2 weeks. Gentle mobilization was initiated 2 weeks after the surgery, and the

FIGURE 2: Radiographs of two patients with intra-articular distal radius fractures AO type C. A 73-year-old woman (**A**) fixated with a volar locking plate, and an 80-year-old woman (**B**) fixated with combined plating.

orthosis was removed during active wrist and finger ROM exercises with a maximum load of 1 kg. The maximum load was gradually increased. At 3 months, clinical outcome measurements and radiographic evaluation were performed. If the fracture was considered healed, there were no further load restrictions.

In case of an associated ulnar styloid fracture, the stability of the distal radioulnar joint (DRUJ) was assessed intraoperatively after plate fixation of the DRF. If DRUJ instability was found, the styloid was reduced and fixed with either a 3.0-mm cannulated screw (DePuy Synthes) or a 2.0-mm locking ulna hook plate (DePuy Synthes).

Antibiotic prophylaxis (intravenous cloxacillin 2 g, or in case of intolerance to β-lactam antibiotics, clindamycin 600 mg) was used if the duration of surgery exceeded 2 hours or if wounds were present in the area of the surgery.

Clinical evaluation

At the 1-year follow-up, a hand therapist performed clinical measurements, including ROM, hand grip strength, visual analog scale (VAS) pain scores, and patient-reported outcome measurements (PROMs).

Both the Patient-Rated Wrist Evaluation (PRWE) score and the short version of the *Quick*DASH questionnaire were used. Validated Swedish translations were used for both questionnaires.[25,26] The PRWE is a 15-item questionnaire with a maximum score of 100, where 0 represents no pain or disability in activities of daily living. The *Quick*DASH questionnaire evaluates a patient's upper-extremity disability during the past week. A score (range 0−100) is calculated from an 11-item questionnaire, where 100 represents the most severe disability and symptoms.

Wrist ROM, including flexion, extension, radial deviation, ulnar deviation, and pronation and supination (degrees), was evaluated using a goniometer according to the guidelines of the Swedish National Quality Registry for Hand Surgery.[27]

Hand grip strength (in kg) was measured with a Jamar Hand Dynamometer (Biometrics Ltd) in handle position 2. The mean value of 3 measurements was calculated.[27] For right-handed patients, correction of grip strength was calculated as a percentage of the uninjured side assuming that the right upper extremity was 10% stronger. No correction was made for patients who were left-handed.[28]

Pain was evaluated both at rest and during activity using the VAS pain score (0 = no pain, 10 = worst imaginable pain).

Radiographic assessment

The definitive AO classification was performed by the operating hand surgeon on the basis of preoperative radiographs and intraoperative findings.[29]

Radiographic examination (anteroposterior and lateral views) of the wrist was performed 1 year after the surgery to calculate the Batra radiographic score and assess ulnar variance. Radiographic measurements were performed by a single orthopedic resident (3 years of training) who did not take part in the treatment or follow-up of the patients. The orthopedic resident was instructed by a hand surgeon in assessing the radiographic examinations. The Batra radiographic score includes radial angle, radial length, volar tilt, and articular incongruency and congruency of the DRUJ. The parameters were summarized and graded in four categories: excellent (90−100), good (80−89), fair (70−79), or poor (<70).[30]

Statistical analysis

Demographic data were presented as the number of cases with median and interquartile range (IQR). The Shapiro-Wilk test was used to assess normal distribution. Because data were not normally distributed and ordinal data were used, the results were presented as median and IQR. The Mann-Whitney U test (continuous data) and chi-square test (categorical data) were used for comparisons between the volar and combined plating groups. P values $< .05$ were considered statistically significant.

RESULTS

Of the 150 patients included, 147 patients completed the 1-year follow-up (73 in the volar plate and 74 in the combined plate group). Three patients were lost to follow-up, 1 because of neurological illness (combined plate group), 1 because of COVID-19 pandemic restrictions (volar plate group), and 1 because of emigration (volar plate group) (Fig. 1). Demographic characteristics are listed in Table 2. The groups had similar baseline data.

All 150 patients were treated as randomized, and no cases of fracture redisplacement after surgery leading to a secondary procedure were reported. The ulnar styloid was surgically stabilized in 8 patients. In the volar plate group, the ulnar styloid was fixed using a locking distal ulnar plate in 4 patients and a cannulated screw in 3 patients. In the combined plate group, 1 patient underwent stabilization of the ulnar styloid using a locking distal ulna plate. One patient did not reach the inclusion criteria during surgery because the fracture was reclassified intraoperatively

TABLE 2. Demographic Characteristics

Treatment Group	M/F	Median Age, (y) (Range)	Fractured Side: Right/Left	Fractured Side: Dominant/ Non-Dominant	AO Type C1/C2/ C3	Type Of Trauma: Low/ High	Age Group 18−59/ ≥60 (y)
Total	30/117	61 (51−70)	62/85	59/88	36/60/51	120/27	67/80
Volar plate	13/60	60 (50−68)	31/42	27/46	17/32/24	59/14	36/37
Combined plating	17/57	62 (52−71)	31/43	32/42	19/28/27	61/13	31/43

as an AO type B DRF. The operative time in the volar plate group was significantly shorter than that in the combined plate group. The median time was 53 (IQR 42−67) minutes in the volar plate group versus 85 (IQR 74−98) minutes in the combined plate group; $P < .05$).

Radiographic outcome

The median Batra radiographic score was 88 in both treatment groups. In the volar plate group, 47/73 patients (64%) had a good to excellent Batra score compared with 25/74 patients (68%) in the combined plate group (no significant difference) (Table 3). Ulnar variance was 0.7 mm (0.0−1.6) in the volar plate group and 0.6 mm (0.0−1.6) in the combined plate group, with no significant difference between the groups.

Clinical outcome

There was a significant difference in the *Quick*-DASH (4.5 in the volar plate group vs. 12.5 in the combined plate group; $P < .05$) and PRWE (3.5 vs. 13.5; $P < .05$) scores between the treatment groups in favor of the volar plate group. The median VAS pain score at rest was zero (0) in both the groups. However, the median VAS pain score during activity was significantly lower in the volar plate group (0 vs. 2; $P < .05$). Hand grip strength in the volar plate group was 89% of the uninjured side compared with 86% in the combined plate group ($P < .05$). Median ROM was significantly superior ($P < .05$) in the volar plate group, except for pronation and supination, for which there was no significant difference (Tables 4, 5).

Complications

There was no mechanical failure resulting in secondary surgery in either of the groups. Furthermore, there were no patients with load restrictions after the 3-month follow-up. In the combined plate group, there were 2 cases of infections after surgery, which were treated with oral antibiotics, and one deep infection after surgery, which healed after reoperation with debridement and intravenous antibiotic treatment. There were no cases of tendon ruptures or complex regional pain syndrome. Hardware removal was performed in 7/73 patients (10%) in the volar plate group and in 23/74 (31%) in the combined plate group ($P < .05$).

DISCUSSION

The hypothesis was that standard volar plating may not be sufficient for complex intra-articular AO type C fractures, especially considering the DUC, which plays a critical role in the DRUJ anchoring the dorsal distal radioulnar ligament as well as providing dorsal rim stability and preservation of appropriate dorsal tilt.[13] To prevent postoperative displacement of a dorsal ulnar fragment, stabilization with at least 1 screw through a volar locking plate is necessary; however, the size of the DUC fragment is often small.[14] Combined plating can provide direct visualization of the DUC, which can facilitate reduction and stabilization of the DUC fragment and provide sufficient stability for early mobilization and good functional and radiographic outcomes in complex fractures.[15-18,31-33] The drawbacks of using combined plating include prolonged duration of surgery, more extensive soft tissue dissection, and tendon irritation from the dorsal plate. The introduction of low-profile plates has reduced this problem.[17,23] There were more cases with a poor Batra result in the volar plate group, which may have affected the development of post-traumatic arthritis (PA). The follow-up time was too short to evaluate PA. In addition, PA has not been shown to correlate to clinical outcome measures or to the accuracy of anatomical reduction.[18] Our results showed equal radiographic outcomes in both treatment groups.

Pain is the most significant factor in determining the outcome following wrist surgery.[34] In this study, the median VAS pain score at rest was zero (0) in both groups, although it was significantly lower

TABLE 3. Batra Score Groups*

Batra Score Groups	Batra Score	Total	Volar Plate	Combined Plate
Excellent	100–90	50	26	24
Good	80–89	47	21	26
Fair	70–79	34	16	18
Poor	<70	16	10	6
Total		147	73	74

*chi-square test, not significant ($P = 0.632$).

TABLE 4. Outcome Measures 1 Year After Surgery*

Outcome Measure	Volar Plate	Combined Plate	*P* Value
Pronation	80° (80 to 90°)	80° (75 to 90°)	NS
Supination	80° (70 to 90°)	80° (70 to 90°)	NS
Volar flexion	70° (65 to 70°)	55° (45 to 63°)	< .05
Dorsal extension	60° (50 to 65°)	50° (40 to 55°)	< .05
Radial deviation	20° (20 to 25°)	15° (15 to 20°)	< .05
Ulnar deviation	30° (30 to 40°)	30° (25 to 35°)	< .05
Grip strength (kg)	23.1 (19.2–27.3)	21.9 (16.5–25.7)	< .05
VAS score at rest (mm)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	NS
VAS score during activity (mm)	0.0 (0.0–1.2)	2.0 (0.0–3.0)	< .05
PRWE score (points)	3.5 (0.0–9.5)	13.5 (3.8–27.0)	< .05
*Quick*DASH score (points)	4.5 (0.0–9.1)	12.5 (4.5–25.0)	< .05
Batra score (points)	88 (70–94)	88 (70–94)	NS
Ulnar variance (mm)	0.7 (0.0–1.6)	0.6 (0.0–1.6)	NS

*Results are presented as median and interquartile range. *P* values were calculated using Mann-Whitney U test. NS = not significant

TABLE 5. Outcome Measures 1 Year Postoperatively, Given as a Percentage of the Uninjured Side*

Outcome Measure	Volar Plate	Combined Plate	*P* Value
Pronation	100% (99%–100%)	100% (94%–100%)	NS
Supination	100% (89%–100%)	100% (89%–100%)	NS
Volar flexion	88% (83%–100%)	75% (63%–87%)	< .05
Dorsal extension	86% (77%–94%)	71% (56%–84%)	< .05
Radial deviation	100% (80%–100%)	80% (67%–100%)	< .05
Ulnar deviation	100% (83%–100%)	83% (71%–100%)	< .05
Grip strength, corrected	89% (80%–97%)	86% (71%–94%)	< .05

*Values are given as median and interquartile range. For right-handed patients, correction of grip strength was calculated according to the 10% rule.[28] Median percentages are given for the injured relative to the uninjured side. *P*-values were calculated using the Mann-Whitney U test. NS = not significant.

during activity in the volar plate group. Dorsal tendinitis is common after combined plating and may be an explanation for the higher VAS pain scores during activity.[18]

We found no previous randomized studies comparing volar locking plate fixation with combined plating in the treatment of AO type C DRFs. Karlsson et al[35] compared volar locking plate fixation with

combined plating in a retrospective study of 105 patients, including AO type A to type C fractures. They found that combined plating resulted in inferior ROM and a higher frequency of hardware removal than volar plating, although there was no difference in the radiographic results. In a randomized study comparing volar with dorsal locking plates, Jakubietz et al[36] found that the volar plate group had significantly better results in terms of ROM, grip strength, and pain, which are comparable to our results. In a consecutive series of 74 AO type C DRFs fixed with combined plating, the median grip strength was 26 kg compared with 22 kg in the combined group in our study but inferior PROM values, PRWE 18, and *Quick*DASH 14.8 compared to PRWE 13.5 *Quick*DASH 12.5 in this study.[17]

The results of this study, as well as those of previous studies,[35,36] indicate that the dorsal plate may have a negative effect on wrist ROM and that hardware removal is more frequently needed in patients treated with combined plating. Landgren et al[37] obtained better results regarding flexion and extension using a volar plate and a fragment-specific dorsal plate compared with our results using combined plating. Dorsoradial wrist pain, often caused by extensor tenosynovitis around the second dorsal tendon compartment, was the main reason for hardware removal in this study. The second compartment is elevated when inserting the dorsal plate and is subsequently repositioned over the plate, where tendon irritation may arise. The decision regarding hardware removal was based on subjective and objective complications from the dorsal plate. No standardized algorithm was used. A previous study with a 7-year follow-up of combined plating reported a frequency of hardware removal of 51.5%.[18] The introduction of modern dorsal, low-profile plates could theoretically reduce this issue.[23] However, our findings indicate that the hardware removal following dorsal plating is still an important problem, and with longer follow-up, the frequency of hardware removal may be higher.

Three patients were diagnosed with postoperative infection, all in the combined plating group. Prolonged duration of surgery and more extensive soft tissue dissection with 2 incisions required by combined plating are probable reasons for the higher infection rate. Our results must be interpreted in context. The thresholds for minimal clinically important differences, regarding *Quick*DASH and PRWE scores, were not reached in this study.[38,39] The significant difference in hand grip strength is probably not clinically relevant.[40] Therefore, we conclude that the functional outcomes for the treatment groups were similar. However, the volar plate group had significantly shorter operative time, lower incidence of postoperative infections, and lower need for a second surgery for hardware removal.

This study was randomized but not blinded, which means that the patients and examiners knew at the follow-up which surgical technique had been used. Another limitation of this study was the difficulty in classifying DRFs because of relatively poor interobserver and intraobserver reliability.[41] Computed tomography was not routinely performed. The central volar approach, used for fixation of the volar plate, has been associated with median nerve irritation.[42] However, the approach can improve the exposure of the ulnar side of the radius and facilitate the reduction of the volar lunate facet.[43] Median nerve dysfunction was not assessed in our study, which is a limitation.

In conclusion, the findings in this study suggest that combined plating does not improve radiographic results in the treatment of DRF AO type C compared with volar plating. Patients treated with combined plating had significantly inferior outcome, but this difference did not reach the threshold of clinical relevance, indicating that both treatments yield similar functional outcomes. We found a higher incidence of postoperative infections and need for hardware removal following combined plating. On the basis of the results of this study, there may be a limited role for combined plating in select cases, for example, when satisfactory reduction and fixation cannot be achieved using only a volar plate, but not as a routine technique. Further studies are warranted to determine the role of volar plating in relation to the other methods, such as fragment-specific fixation and the dorsal spanning plate, in the management of complex distal radius fractures.

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