


CLINICAL ARTICLE

Open Reduction and Internal Fixation by Volar Locking Plates and the “Poking Reduction” Technique in Distal Radius Fractures with Displaced Dorsal Ulnar Fragments: A Retrospective Study

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Objective: To investigate the clinical and radiological outcomes of distal radius fractures (DRFs) with displaced dorsal ulnar fragments treated with volar locking plate (VLP) and the “poking reduction” technique.

Methods: Between January 2014 and January 2019, 78 unilateral DRFs with displaced dorsal ulnar fragment (AO type C3) treated with VLP were conducted. According to the reduction technique of the dorsal ulnar fragment, the patients were divided into the conventional reduction (CRG) group (33 patients, 14 males and 19 females, mean age 57.2 ± 12.1 years old) and the “poking reduction” (PRG) group (45 patients, 11 males and 34 females, mean age 60.1 ± 12.4 years old). According to the AO classification, there were 21 cases of C3.1 and 12 of C3.2 in the CRG group, 27 cases of C3.1 and 18 of C3.2 in the PRG group. Clinical and radiographic data were extracted from the electronic medical record system. These data were reviewed for clinical outcomes (range of motion, grip strength), radiological outcomes (volar tilt, radial inclination, radial height, step of articular surface), and postoperative complications. The final functional recovery was evaluated by the disabilities of the arm, shoulder, and hand (DASH) score.

Results: The mean duration of follow-up was 27 months (range from 12 to 56). The average operation time and intraoperative blood loss did not significantly differ between groups ($p > 0.05$). Postoperative CT examination showed that the step of articular surface in CRG group (0.8 ± 0.3 mm) was larger than that in PRG group (0.5 ± 0.2 mm) ($p < 0.001$). The DASH score did not significantly differ between groups (26.1 ± 4.6 in CRG and 24.7 ± 4.0 in PRG, $p > 0.05$) at 3 months postoperatively. At 6 months and 12 months postoperatively, the DASH score was better in PRG group (11.8 ± 2.5 and 10.4 ± 2.0) than in CRG group (13.6 ± 2.7 and 12.2 ± 2.5) ($p = 0.004$, $p = 0.001$, respectively). At 12 months postoperatively, wrist range of motion did not significantly differ between groups ($p > 0.05$). There was no significant difference in radiological parameters between the two groups ($p > 0.05$). The incidence of complications was higher in the CRG group (7/33) than in the PRG group (2/45) ($p = 0.009$).

Conclusion: The “poking reduction” technique is a wise option for reduction of dorsal ulnar fragment in DRFs. This innovative technique could restore smoothness of the radiocarpal joint effectively, and the dorsal ulnar fragment could be fixed effectively combined with the volar plate.

Key words: Displaced dorsal ulnar fragment; Distal radius fracture; Internal fixation of fracture; Volar locking plate

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Introduction

Fractures of the distal radius are the most common fracture of the upper extremity, accounting for approximately 1/6 of emergency fracture cases^{1,2}. The incident rate shows a bimodal distribution, namely, high-energy injury for adolescents and low-energy injury for the elderly^{3,4}. Most distal radius fractures (DRFs) can be treated conservatively, although there is a slight malunion, it may not cause a significant loss of wrist joint function^{5,6}. However, when the radial shortening is more than 3 mm, the dorsal angle is more than 10°, or the articular step-off is more than 2 mm after manual reduction, surgical treatment is recommended⁷. Surgical methods for DRFs include external fixator fixation, percutaneous Kirschner wire fixation, volar or dorsal plate fixation, and intramedullary nail fixation^{2,8}. For intra-articular comminuted DRFs (AO type C3), the volar locking plate (VLP) could provide stable support and avoid the risk of abrasion or even of extensor tendon. Therefore, it is widely used in the treatment of DRFs^{2,9,10}.

In 2016, based on the combination of Rikli and Regazzoni's three-column model¹¹ and Melone's four-part classification¹², Brink and Rikli¹³ proposed the four-corner concept for the distal radius and ulna. The concept shows that the dorsal corner plays an important role in maintaining articular congruity and distal radioulnar joint stability. Meanwhile, because the dorsal cortex is weaker than the volar cortex in the distal radius, severe intraarticular comminuted fractures are often associated with dorsal cortical comminuted fractures, and the comminuted bone fragments tend to displace toward the dorsal and ulnar corners¹⁴. For DRFs involving lunate fossa fractures, 61.6% of patients had displaced dorsal ulnar fragments¹⁵.

The Henry approach can directly reduce the volar fragment, but for the dorsal fragments, especially the dorsal ulnar fragments, cannot be directly reduced through the volar incision. They can only be reduced by indirect reduction or traction. It is difficult for the dorsal bone block to achieve a good reduction, which may cause steps on the articular surface. Therefore, how to effectively reset the dorsal bone mass is particularly important. However, few studies have focused on how to restore and fix DRFs with displaced dorsal ulnar fragment effectively. Considering traditional opinion, we could choose a dorsal plate with the dorsal approach or dorsal and volar plates together with volar and dorsal approaches¹⁶ as necessary, but such methods could result in extensor tendon irritation or even rupture. In this situation, VLP seems to be a good choice, but they are sometimes associated with poor restoration of the dorsally displaced fragment and postoperative redisplacement^{9,17}. In 2013, Japanese scholars reported two cases of DRFs treated using the volar cortical fenestration technique to reset the dorsal metacarpal bone¹⁸. The postoperative functional recovery was good, and it was applicable to the DRFs of the completed volar cortex. A large research sample may be required to provide more results.

Therefore, in order to reduce and fix the displaced dorsal ulnar fragment effectively, while avoiding complications

of the extensor tendon, we used a novel "poking reduction" technique to reduce the displaced dorsal ulnar fragment, and fixed it with a VLP. We used the "poking reduction" technique and the traditional traction reduction technique to compare whether different reduction techniques will lead to the difference in fracture reduction and wrist function recovery.

The purpose of our study was to evaluate the clinical and radiological results of treating DRFs with displaced dorsal ulnar fragment through VLP and the "poking reduction" technique, considering: (i) Does the "poking reduction" technique more successfully restore joint surface? (ii) Can volar tilt, radial inclination, and radial height recover better? (iii) Can the wrist joint function be better restored?

Materials and Methods

Inclusion and Exclusion Criteria

Inclusion criteria: (i) fresh DRFs with displaced dorsal ulnar fragment (Figure 1, the displacement is defined as the distance of the dorsal ulnar fragment exceeding 2 mm) diagnosed by preoperative X-ray and CT examinations (AO type C3); (ii) treated by volar locking plate; (iii) age \geq 18 years; (iv) follow-up for 12 months or more. Exclusion criteria: (i) old fracture ($>$ 2 weeks); (ii) pathological fracture; (iii) open fracture; (iv) combined with neurovascular injury; (v) impairment of the function of the shoulder, elbow, and wrist joint on the same side before injury; and (vi) incomplete follow-up data. The subject was approved by the ethics committee of our hospital (2019-C-054-E01).

From January 2014 to January 2019, 317 patients with DRFs underwent open reduction and internal fixation (ORIF) in our hospital. Of them, 78 patients with complete follow-up data who had unilateral DRFs with displaced dorsal ulnar fragments were analyzed. According to whether the displaced dorsal ulnar fragment was reduced by "poking reduction" technique during the operation, it was divided into a conventional reduction (CRG) group and a "poking reduction" (PRG) group. There were 33 cases (14 males and 19 females) in the CRG group and 45 cases (11 males and 34 females) in the PRG group. Baseline data of two groups are shown in Table 1.

Surgical Technique

All the surgery was performed by the same group.

Anesthesia and Surgical Position

All procedures were performed under general or brachial plexus anesthesia. With the patient in the supine position, the injured limb was stretched 90° externally and placed on a side operating table. A tourniquet (pressure 250–300 mmHg) was used to control bleeding.

Surgical Approach and Exposure

A standard volar Henry approach was performed, the incision is about 5–6 cm. Exposing the flexor carpi radialis

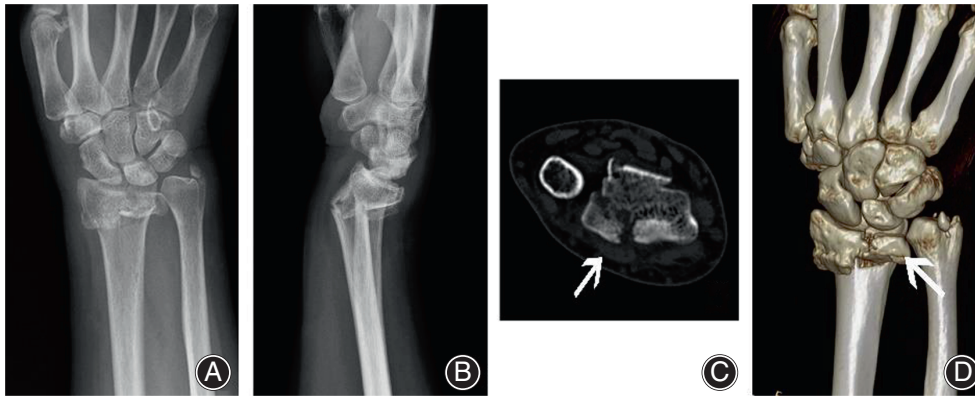


FIG. 1 This figure demonstrated the distal radius fracture combined with displaced dorsal ulnar fragment (white arrow). We define “displacement” as the displacement of fracture fragment exceeding 2 mm. (A, B) X-ray indicated the distal radius fracture, and the distal end of the fracture shifted to the back. (C, D) CT transverse-section and three-dimensional reconstruction indicated that there is a displaced dorsal-ulnar fragment

TABLE 1 Comparison of basic data between the two groups

| Groups | CRG group | PRG group | Test value | p value |
|---------------------------------|-------------|-------------|------------------|---------|
| Number | 33 | 45 | — | — |
| Sex | 14/19 | 11/34 | $\chi^2 = 2.826$ | 0.093 |
| Side | 15/18 | 13/32 | | 0.132 |
| Average age | 57.2 ± 12.1 | 60.1 ± 12.4 | $t = -1.015$ | 0.313 |
| Causes of injuries | | | | |
| High energy injury | 7 | 9 | $\chi^2 = 0.017$ | 0.896 |
| Low energy injury | 26 | 36 | | |
| AO classification | | | | |
| C3.1 | 21 | 27 | $\chi^2 = 0.106$ | 0.744 |
| C3.2 | 12 | 18 | | |
| Ulnar styloid fracture (Yes/No) | 19/14 | 32/13 | $\chi^2 = 1.541$ | 0.214 |
| Time from injury to surgery | 3.1 ± 0.9 | 3.7 ± 1.8 | $t = -1.816$ | 0.073 |

(FCR) tendon, an interval was created between the FCR tendon and the radial artery. Attention was paid to protecting the median nerve and radial artery. Then, the pronator quadratus (PQ) was exposed and incised near its radial attachment point. Then, the fracture site could be identified.

“Poking Reduction” Technique

Subperiosteal dissection, revealed and cleaned the fractured end hematoma and soft tissue, and assisted longitudinal traction from the distal end of the fracture. In the CRG group, a periosteal stripper was inserted from the volar side of the fracture end to the dorsal cortical bone to separate and reposition the two inserted fracture ends. In the PRG group, vascular forceps were inserted through the fracture gap of the middle column, with the tip of the vascular forceps pointing to the proximal side. When the tip of the vascular forceps reached the back side of the displaced dorsal ulnar fragment, the vascular forceps were turned over 180°, and the distal arc structure of the vascular forceps was used to poke and squeeze the tip of the vascular forceps to the displaced fragment to complete fracture reduction (Figures 2 and 3).

Manual traction was used to correct ulnar and radial lateral displacement and evaluate articular surface reduction. After satisfactory reduction, 2–3 Kirschner wires were used for temporary fixation, and the reduction was seen through a C-arm X-ray machine. Select appropriate VLP, implant common screw through proximal sliding hole, fix plate to bone surface, slide and adjust the plate to a satisfactory position, temporarily fix it with Kirschner wire through distal positioning hole, and confirm joint surface is flat through re-perspective, after volar tilt, radial inclination and radial height are restored to be satisfactory. Screw fixation was implanted in turn to check the stability of the fracture end and wrist joint mobility. During the operation, the stability of fracture fixation is evaluated. Suture layer by layer after complete hemostasis and flushing, no drainage. All combined ulnar styloid fractures were unfixated.

Postoperative Management

Conventional analgesia was conducted after the surgery. For high-risk patients such as smoking and diabetes, a dose of antibiotics was used to prevent postoperative infection on

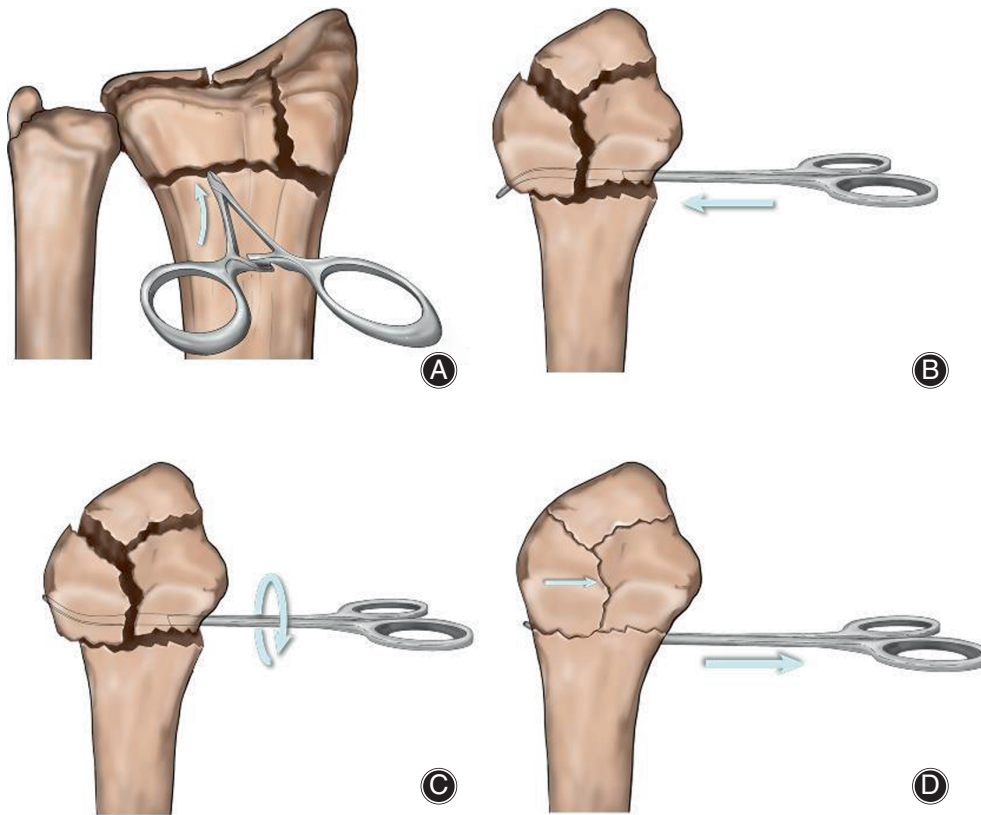


FIG. 2 Moed diagram of "poking reduction" technique. (A, B) Insert the vascular clamp from the volar fracture gap. (C) The vascular forceps are turned over by 180°, and the distal arc structure of the vascular forceps are used to poke and squeeze the tip of the vascular forceps to the displaced fragment to complete fracture reduction. (D) The displaced dorsal ulnar fracture is reduced and the articular surface is flat

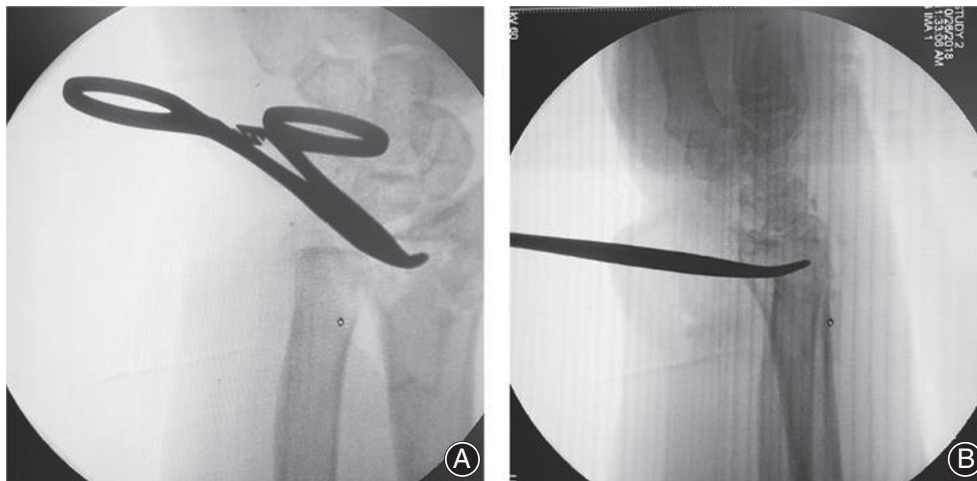


FIG. 3 Perspective view of intraoperative "poking reduction" technique. (A) The vascular clamp inserted through the fracture space, (B) and the vascular clamp inserted into the back side of the displaced fracture fragment to realize the "poking reduction" processes.

the day after operation. The sutures were removed 2 weeks after the operation. Patients were encouraged to start elbow and finger functional exercises as soon as possible under tolerable conditions. Active and passive flexion, extension, and rotation exercises of the wrist were started 1 week later without pain. According to the bone healing situation, wrist joint weight-bearing should be gradually restored. The lifting of heavy objects was prohibited before the fracture had healed.

Follow-Up and Efficacy Analysis

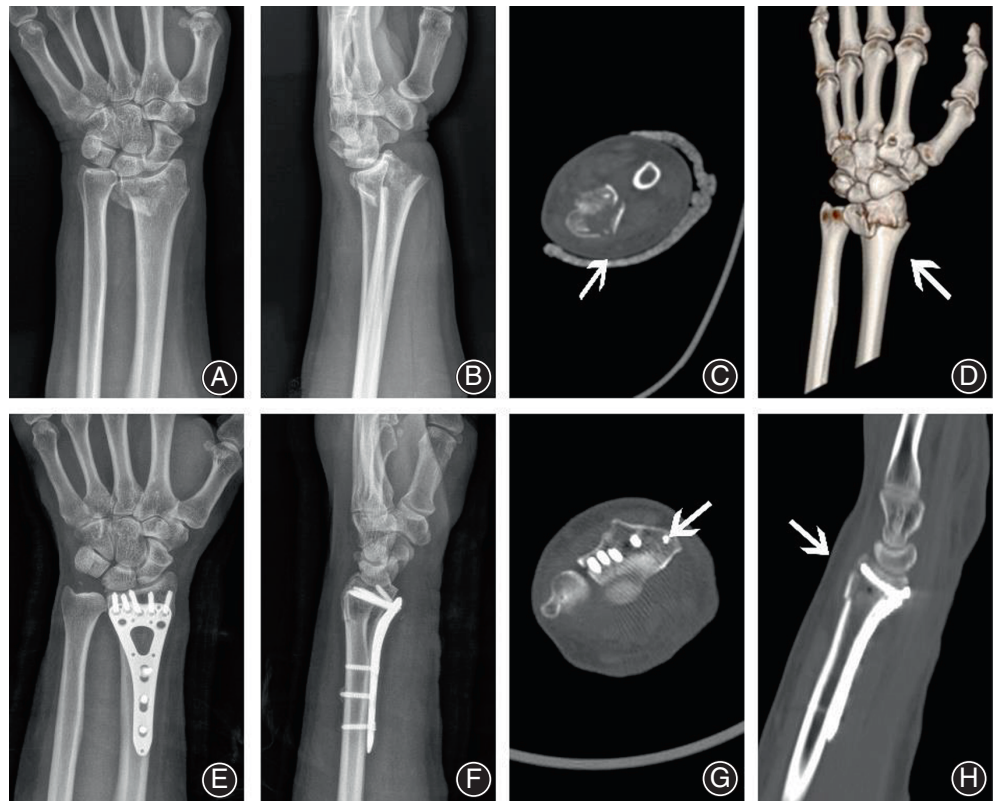
According to the protocol, all patients underwent a follow-up examination at 4 weeks, 12 weeks, 6 months, and 12 months postoperatively. The follow-up duration was defined as ranging from the date of operation to the date of the latest follow-up. Complete CT examination to observe the recovery of articular surface after operation. X-ray images were obtained at each follow-up. At 12 weeks, 6 months, and 12 months after the operation, the DASH score¹⁹ was

TABLE 2 Comparison of the average operation time, average blood loss during the operation, DASH score, range of motion and radiographic parameters between the two groups

| Group | CPG group | PRG group | T value | p value |
|--|-------------|------------|---------|---------|
| Number | 33 | 45 | — | — |
| Average operation time (min) | 94 ± 11 | 99 ± 10 | -1.904 | 0.061 |
| Step of articular surface (mm) | 0.8 ± 0.3 | 0.5 ± 0.2 | 4.308 | <0.001* |
| Average blood loss during operation (ml) | 22 ± 8 | 23 ± 11 | -0.611 | 0.543 |
| DASH score | | | | |
| 3 months after the operation | 26.1 ± 4.6 | 24.7 ± 4.0 | 1.338 | 0.185 |
| 6 months after the operation | 13.6 ± 2.7 | 11.8 ± 2.5 | 2.975 | 0.004* |
| 12 months after the operation | 12.2 ± 2.5 | 10.4 ± 2.0 | 3.417 | 0.001* |
| Range of motion | | | | |
| Palmar flexion (°) | 56.1 ± 5.3 | 57.6 ± 5.8 | -1.168 | 0.246 |
| Dorsal extension (°) | 58.2 ± 5.3 | 59.6 ± 5.6 | -1.094 | 0.277 |
| Radial deviation (°) | 20.5 ± 3.8 | 19.9 ± 4.3 | 0.598 | 0.551 |
| Ulnar deviation (°) | 31.4 ± 5.3 | 32.2 ± 6.8 | -0.602 | 0.549 |
| Pronation (°) | 77.6 ± 8.8 | 79.4 ± 9.7 | -0.984 | 0.322 |
| Supination (°) | 68.3 ± 10.6 | 70.1 ± 9.1 | -0.669 | 0.586 |
| Radiographic parameters | | | | |
| Volar tilt (°) | 12.0 ± 3.6 | 12.2 ± 4.7 | -0.260 | 0.796 |
| Radial inclination (°) | 19.7 ± 4.1 | 18.7 ± 3.6 | 1.178 | 0.242 |
| Radial height (mm) | 10.2 ± 2.8 | 9.5 ± 2.6 | 0.995 | 0.323 |

Abbreviations: DASH, disabilities of the arm, shoulder and hand; CRG, conventional reduction group; PRG, poking reduction group.; * $p < 0.05$.

FIG. 4 Poking reduction (PRG) group. A 65-year-old female had an AO C3-type distal radius fracture on the left. (A, B) Preoperative X-ray shows comminuted fracture of distal radius. (C, D) Preoperative CT and three-dimensional reconstruction show the displaced dorsal ulnar fragment (white arrow). (E, F) Postoperative X-ray shows fracture internal fixation, imaging parameters (volar tilt, radial inclination, radial height) achieved a good recovery. (G, H) Postoperative CT showed that the articular surface recovered smoothness. The dorsal ulnar fragment was fixed effectively (white arrow)



evaluated. At 12 months post-operation, the range of motion (including flexion, extension, radial deviation, ulnar deviation, pronation, and supination) and radiographic

results (including volar tilt, radial inclination, and radial height) were measured. During the follow-up, the incidence of postoperative complications was recorded.



FIG. 5 Functional follow-up after 24 month of patient in Figure 4. (A–D) indicated that the patient's function (A, palmar flexion, B, dorsal extension, C, pronation, D, supination) recovered well

The Quick Disabilities of the Arm, Shoulder, and Hand Questionnaire Score

DASH score is a questionnaire for evaluating upper limb function from the patient's point of view. The DASH score consists of two parts, with a total of 30 indicators. The first part contains 23 indicators, mainly investigating activities related to daily life. The second part contains seven indexes, which mainly investigate the discomfort symptoms of upper limbs, and their influence on sleep, and patients' self-satisfaction. Each index corresponds to five grades, namely, no difficulty (1 point), a little difficulty (2 points), moderate difficulty but can do it (3 points), very difficult (4 points), and impossible (5 points). DASH score is calculated by adding the scores of 30 indexes, and then calculating according to the following formula: DASH

score = (sum of scores of 30 indexes-30)/1.20, so that the original score can be converted into 0–100 points. Among them, 0 indicates normal upper limb function, and 100 indicates extremely limited upper limb function.

Statistical Analysis

The SPSS statistical package (Version 22.0) was used for statistical analysis. Numerical variables are described as the mean \pm SD ($\bar{x} \pm s$). The age, injury to surgery time, follow-up time, DASH score, radiographic parameters, and range of motion of the two groups were compared by independent sample *t* test. Enumeration data are expressed as rates. The comparison of gender, side, and ulnar styloid fracture

between the two groups was compared by chi-square test. $p < 0.05$ was considered statistically significant (bilateral test).

Results

Patient Demographics and Clinical Characteristics

Patient demographic and clinical characteristics for both groups are summarized in Table 1. There was no significant difference in the variables.

Operation Time and Blood Loss

The operation time and blood loss are listed in Table 2. There was no significant difference in the average operation time or intraoperative blood loss between the two groups ($p > 0.05$).

Clinical and Radiographic Outcomes

Postoperative CT examination showed that the step of articular surface in CPG group was larger than that in PRG group ($p < 0.001$, Table 2). At 3 months after the operation, there was no significant difference of the average DASH score between the two groups ($p > 0.05$, Table 2). At 6 and 12 months after the operation, the DASH score of the PRG group was better than that of the CRG group ($p = 0.004$, $p = 0.001$, respectively, Table 2).

At 12 months after the operation, the range of motion of the wrist joint was measured. There was no significant difference between the two groups in the range of

motion, including palmar flexion, dorsal extension, radial deviation, ulnar deviation, pronation, and supination ($p > 0.05$, Table 2). X-rays of patients were reexamined 12 months after the operation. There was no significant difference in volar tilt, radial inclination, or radial height between the two groups ($p > 0.05$, Table 2).

Complications

There were seven cases of complications in the CRG fracture group, including two cases of superficial wound infection, which healed after oral antibiotics and local dressing change. One case had loosening of the distal locking screw at 6 months after surgery, but there was no obvious wrist discomfort or movement disorder. The internal fixation was removed 15 months after surgery. Three cases of chronic wrist pain and one case of carpal tunnel syndrome were relieved after oral medication. There were two cases of complications in the PRG fracture group, one case of superficial wound infection, healing after oral antibiotics, and local dressing change. One case of chronic wrist pain was relieved after oral medication. No deep wound infection, nonunion, malunion, or internal fixation failure occurred in either group. The incidence of complications in the CRG group was higher than that in the PRG group ($p = 0.009$). The typical case of the PRG group was shown in Figures 4–7.

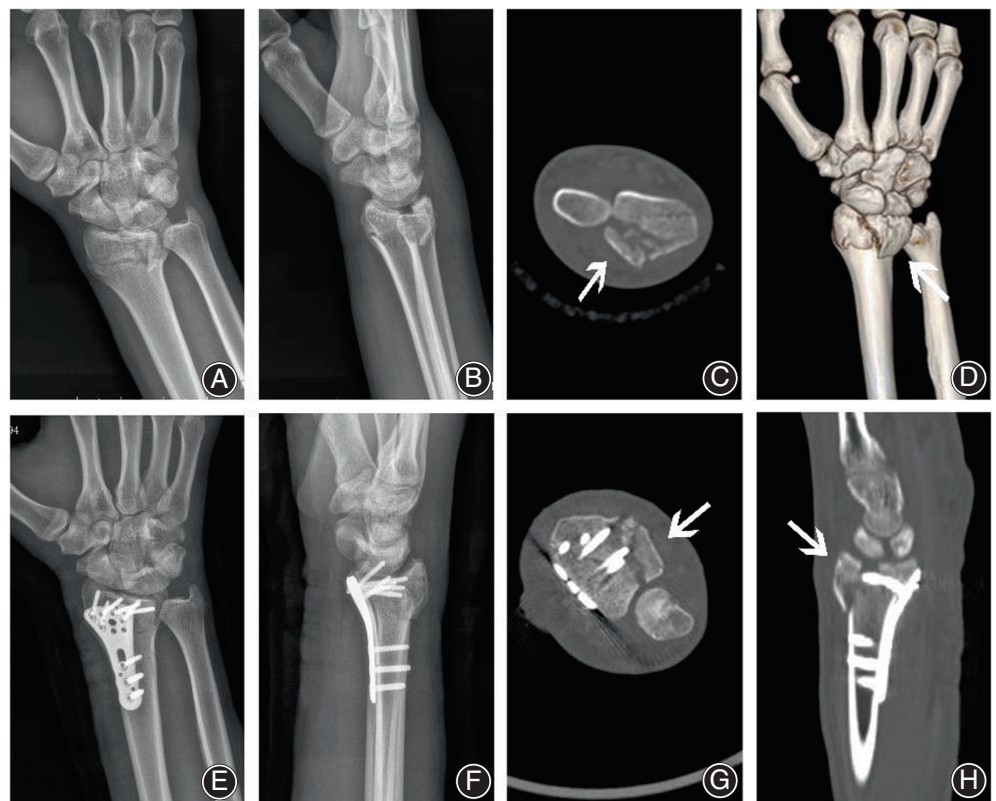


FIG. 6 Conventional reduction (CRG) group. A 28-year-old male had an AO C3-type distal radius fracture on the right. (A, B) Preoperative X-ray shows comminuted fracture of distal radius. (C, D) Preoperative CT and three-dimensional reconstruction show the displaced dorsal ulnar fragment (white arrow). (E, F) Postoperative X-ray shows fracture internal fixation. (G, H) Postoperative CT showed that there was a gap in the articular surface, and the displaced dorsal ulnar fragment was not fixed effectively (white arrow)



FIG. 7 Functional follow-up after 30 months of patient in Figure 6. (A–D) indicated that the patient's function (A, palmar flexion, B, dorsal extension, C, pronation, D, supination) recovered well. DASH score: 16

Discussion

DRFs with displaced dorsal ulnar fragments are a specific type of intraarticular comminuted fracture. In our study, all patients were treated with VLPs and achieved bone healing, and most of them achieved favorable functional recovery. Although there is no difference in the postoperative imaging parameters, the poking reduction technique reduces the steps of articular surface and achieves better long-term functional recovery. There is also an advantage in the incidence of complications.

How to Reduce the Displaced Dorsal Ulnar Fragment Effectively

According to the three-column model¹¹, the intermediate column consists of the lunate fossa and the sigmoid notch,

and it supports more than 50% of the axial compressive forces that are transmitted across the wrist²⁰. When the intermediate column has a sagittal split and is divided into two separate parts, the dorsal part is called the dorsal corner according to the four-corner concept and was referred to as the dorsal ulnar fragment in this study. The malunited dorsal ulnar fragment will affect the congruency of the radiocarpal joint surface and the distal radioulnar joint (DRUJ), leading to poor functional recovery¹³. In our study, it was found that poor reduction of the dorsal ulnar fragment would lead to a step of the radiocarpal joint surface and affect the long-term wrist function (higher DASH scores). It was difficult to reduce the displaced dorsal ulnar fragment directionally because of the occlusion of the metaphysis in the single volar approach.

To restore and fix the fragment effectively, a special method that we refer to as the "poking reduction" technique was used. The most important technical point is to utilize the arc structure of the end of the vessel clamp. We inserted a vessel clamp through the fracture gap of the middle column. When the tip of the vascular forceps reached the back side of the displaced dorsal ulnar fragment, the vascular forceps were rotated 180°, and the tip of the vascular forceps manipulated the displaced fragment to achieve fracture reduction.

Importance of Restoring Normal Joint Anatomy to Wrist Joint Function

The ultimate goal of DRF treatment is to restore wrist function, and the recovery of normal anatomical structure of distal radius (volar tilt, radial inclination, radial height, step of articular surface) is the key to functional recovery²¹. The decrease of volar tilt or even dorsiflexion will lead to the narrowing of wrist joint space, and the stress between wrist joint surface and ulnar will be too high. At the same time, the tension of ulnar and radial interosseous membrane increased, which affected the forearm rotation^{22,23}. Lateral displacement or axial compression of the distal end of fracture will cause shortening of radius. Compared with the loss of volar tile and radial inclination, radial shortening will have a greater change in the stability of the lower radioulnar joint and the stress of the triangular fibrocartilage complex. However, the degree of surgical treatment to correct radial shortening is closely related to the degree of postoperative functional improvement. In the conservative treatment of fracture with plaster external fixation, it is also found that radius shortening greater than 4 mm can cause long-term wrist pain²⁴. Therefore, some scholars even suggested that the recovery of radial height should be the primary goal of treatment²¹. The change of radial height is usually accompanied by the change of radial inclination, which affects the axial stress conduction of wrist joint. The change of axial stress conduction is related to the degeneration of lower radioulnar joint and radiocarpal joint, and the loss of radial inclination greater than 10 may lead to poor DASH function score²⁵. In this study, the volar tilt, radial inclination, and radial height were all recovered well after operation, and no post-operation dislocation of fracture occurred. The increase of articular surface step will lead to the development of traumatic arthritis and the deterioration of wrist function. This is also the main reason for the functional differences between the two groups of patients in our study (Figures 6, 7).

Indications and Key Points of the "Poking Reduction" Technique

The "poking reduction" technique is suitable for intra-articular comminuted distal radius fractures (AO type C3), especially C3.1 and C3.2. A fracture line needs to exist on the volar side of the distal radius, allowing the insertion of vascular forceps to complete poking produce. In addition, the displacement distance of the dorsal ulnar fragment is larger than 2 mm, then we think that the fragment is displaced. In this case, reduction by traction or manual pressing may lead to uneven joint surface. We suggest that the displacement fragment should be

raised and then reduced to avoid the formation of intra-joint gap or step. This may also explain the difference in DASH scores when there is no difference in radiographic parameters.

There have been few studies on methods for the reduction and fixation of displaced dorsal ulnar fragments. In 2013, Japanese scholars reported two cases of DRFs treated using the volar cortical fenestration technique to reset the dorsal metacarpal bone¹⁸. Both patients achieved excellent functional recovery, however, the technique was suitable for treating complete dorsal and partial intraarticular fractures of the volar cortex (AO type B2). This means that complete volar cortical bone is a prerequisite for this technique to be used. At the same time, the fenestration technique requires window opening in the volar cortex, and the bone healing of the window itself needs further observation. In clinical work, we need to note that there are many classifications for distal radius fractures^{26,27}. The preoperative X-ray and three-dimensional reconstruction must be used to clarify the fractures of the articular surface and metaphysis in order to better evaluate the treatment.

Limitations and Defects of the "Poking Reduction" Technique

Although our research shows that good therapeutic effects were achieved, we still do not recommend the use of single VLP fixation and "poking reduction" technique for all severe intraarticular comminuted fractures. The "poking reduction" technique may not be applicable to the following fracture types. First, the volar ulnar cortex is intact, and the vascular clamp cannot be inserted from the volar side. Second, the dorsal ulnar bone is severely comminuted and cannot be reduced by a single vascular clamp. Third, elderly patients with severe osteoporosis, with thin cortical and less cancellous bone, which cannot be effectively reduced, or cannot be effectively fixed by the volar plate after reduction, so they need to be fixed by combined volar and dorsal approach. Medlock²⁸ combined both volar and dorsal approaches to treat 18 patients with AO type C3 fractures. The treatment results were satisfactory. If the dorsal side is severely crushed, and the dorsal fragment cannot be fixed well by a volar locking plate after reduction, it should be fixed by the dorsal approach. We treated two cases of DRFs using a double approach and double plate fixation because we found that the fracture was difficult to fix using a single plate after the intraoperative assessment.

Limitations

This study was a single-center, retrospective study, and the number of cases was small. Whether the outcomes of this study can be generalized to patients managed at other centers is not clear. In future studies, we will conduct a randomized controlled study and include more cases to compare therapeutic effects between the above methods and double plates.

Conclusion

For distal radius fractures (AO type C3) with displaced dorsal ulnar fragments, the "poking reduction" technique reduces the steps of articular surface and achieves better long-term functional recovery. Moreover, to reduce related complications, we adopted the "poking reduction" technique and single VLP fixation. Clinical and radiological outcomes confirmed that the method was effective and seemed to be an effective surgical option for these intraarticular comminuted DRFs.

Author Contribution

Linyuan Zhang, Mengran Wang and Yin Cui: Correction of data and original draft preparation. Zhiqing Liu, Yueting Wang and Yuehua Sun: research design. Zhen'an Zhu, Xiuhui Wang and Fengxiang Liu: Statistical analysis. All authors have read and approved this article.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Ethics Statement

All patients provided written informed consent.

References

- Ogunleye AA, Mullner DF, Skochdopole A, Armstrong M, Herrera FA. Remote injuries and outcomes after distal radius fracture management. *Hand (N Y)*. 2018;14:102–6.
- Lee JK, Lee Y, Kim C, Kim M, Han SH. Volar locking plate removal after distal radius fracture: a 10-year retrospective study. *Arch Orthop Trauma Surg*. 2020;141:1711–9.
- Jo YH, Lee BG, Kim HS, Kim JH, Lee CH, Kim SJ, et al. Incidence and seasonal variation of distal radius fractures in Korea: a population-based study. *J Korean Med Sci*. 2018;33(7):e48.
- Stirling ERB, Johnson NA, Dias JJ. Epidemiology of distal radius fractures in a geographically defined adult population. *J Hand Surg Eur*. 2018;43(9):974–82.
- Gamba C, Fernandez FAM, Llavall MC, Diez XL, Perez FS. Which immobilization is better for distal radius fracture? A prospective randomized trial. *Int Orthop*. 2017;41(9):1723–7.
- Park MJ, Koh KH, Lee KW, Lee YJ, Lee HI. Patient-perceived outcomes after nonoperative treatment of distal radius fracture in older adults. *Orthopedics*. 2020;44:e190–6.
- Lichtman DM, Bindra RR, Boyer MI, Putnam MD, Ring D, Slutsky DJ, et al. American Academy of Orthopaedic Surgeons clinical practice guideline on: the treatment of distal radius fractures. *J Bone Joint Surg Am*. 2011;93(8):775–8.
- Mellstrand-Navarro C, Pettersson HJ, Tornqvist H, Ponzer S. The operative treatment of fractures of the distal radius is increasing: results from a nationwide Swedish study. *Bone Joint J*. 2014;96-B(7):963–9.
- Soong M, Earp BE, Bishop G, Leung A, Blazar P. Volar locking plate implant prominence and flexor tendon rupture. *J Bone Joint Surg Am*. 2011;93(4):328–35.
- Drobetz H, Koval L, Weninger P, Luscombe R, Jeffries P, Ehrendorfer S, et al. Volar locking distal radius plates show better short-term results than other treatment options: a prospective randomised controlled trial. *World J Orthop*. 2016;7(10):687–94.
- Rikli DA, Regazzoni P. Fractures of the distal end of the radius treated by internal fixation and early function. A preliminary report of 20 cases. *J Bone Joint Surg Br*. 1996;78(4):588–92.
- Melone CP Jr. Articular fractures of the distal radius. *Orthop Clin North Am*. 1984;15(2):217–36.
- Brink PR, Rikli DA. Four-corner concept: CT-based assessment of fracture patterns in distal radius. *J Wrist Surg*. 2016;5(2):147–51.
- Kim JK, Cho SW. The effects of a displaced dorsal rim fracture on outcomes after volar plate fixation of a distal radius fracture. *Injury*. 2012;43(2):143–6.
- Zhang J, Ji XR, Peng Y, Li JT, Zhang LH, Tang PF. New classification of lunate fossa fractures of the distal radius. *J Orthop Surg Res*. 2016;11(1):124.
- Karlsson E, Wretenberg P, Björling P, Sagerfors M. Combined volar and dorsal plating vs. volar plating of distal radius fractures. A single-center study of 105 cases. *Hand Surg Rehabil*. 2020;39(6):516–21.
- Thorninger R, Madsen ML, Wæver D, Borris LC, Rölfing JHD. Complications of volar locking plating of distal radius fractures in 576 patients with 3.2 years follow-up. *Injury*. 2017;48(6):1104–9.
- Tsuchiya F, Naito K, Mogami A, Obayashi O. New technique for dorsal fragment reduction in distal radius fractures by using volar bone fenestration. *J Orthop Case Rep*. 2013;3(2):8–11.
- 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(6):602–8.
- Rikli DA, Honigmann P, Babst R, Cristalli A, Morlock MM, Mittlmeier T. Intra-articular pressure measurement in the radioulnocarpal joint using a novel sensor: in vitro and in vivo results. *J Hand Surg Am*. 2007;32(1):67–75.
- Batra S, Gupta A. The effect of fracture-related factors on the functional outcome at 1 year in distal radius fractures. *Injury*. 2002;33(6):499–502.
- Kihara H, Palmer AK, Werner FW, Short WH, Fortino MD. The effect of dorsally angulated distal radius fractures on distal radioulnar joint congruency and forearm rotation. *J Hand Surg Am*. 1996;21(1):40–7.
- Short WH, Palmer AK, Werner FW, Murphy DJ. A biomechanical study of distal radial fractures. *J Hand Surg Am*. 1987;12(4):529–34.
- Jenkins NH, Mintowt-Czyz WJ. Mal-union and dysfunction in Colles' fracture. *J Hand Surg (Br)*. 1988;13(3):291–3.
- Wilcke MK, Abbaszadegan H, Adolphson PY. Patient-perceived outcome after displaced distal radius fractures. A comparison between radiological parameters, objective physical variables, and the DASH score. *J Hand Ther*. 2007;20(4):290–8. quiz 9.
- Wæver D, Madsen ML, Rölfing JHD, Borris LC, Henriksen M, Nagel LL, et al. Distal radius fractures are difficult to classify. *Injury*. 2018;49(1):S29–S32.
- Frykman G. Fracture of the distal radius including sequelae—shoulder-hand-finger syndrome, disturbance in the distal radio-ulnar joint and impairment of nerve function. A clinical and experimental study. *Acta Orthop Scand*. 1967;Suppl 108:3+.
- Medlock G, Smith M, Johnstone AJ. Combined volar and dorsal approach for fixation of comminuted intra-articular distal radial fractures. *J Wrist Surg*. 2018;7(3):219–26.