

Outcomes of volar locking plate (VLP) fixation for treatment of die-punch fracture of the distal radius

A retrospective single-surgeon study

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Abstract

Distal radius fracture involving the lunate facet is a tough issue for surgeons, but currently there is scarcity of data on these injuries. This study aims to evaluate results of volar locking plate (VLP) for treatment of die-punch fractures of the distal radius.

Between January 2013 and June 2017, a total of 37 patients with die-punch fractures of the distal radius were admitted and underwent VLP fixation. Clinical and radiographic data on these patients were extracted from their electronic medical records. Preoperative radiographs, CT scanning and 3D reconstruction were used to definitely diagnose this injury. Radiographs taken at immediate postoperation and at last follow-up were analyzed. Data on radial subsidence, articular step-off status, volar tilt, radial inclination, wrist motion range, grip strength and related complications at the final follow-up were documented for analysis. The overall outcomes of the injured limb were evaluated, based on the Gartland and Werley scoring system.

The mean radial subsidence was 0.8 mm (0–3.3 mm), and articular step-off finally occurred in 4 patients (10.8%). The mean volar tilt was 9.5° (6°–15°), radial inclination 21° (12°–27°). The mean wrist was 84.2% in flexion of the contralateral uninjured wrist, 87.0% in extension, 92.2% in pronation and 94.5% in supination, respectively. The mean grip strength was 86% (range 56%–108%) of the contralateral un-injured upper limb. Gartland and Werley score demonstrated the excellent and good rate of 83.8%, with excellent result in 21 patients, good in 10, fair in 4 and poor in 2. Incidence of overall complications was 27.0% (10/37), with one requiring surgical intervention.

VLP demonstrated its efficacy and safety for treatment of die-punch fractures. Prospective comparative studies with larger sample are required to compare the outcomes among different fixation methods, with expectation of precise and individualized treatment for every patient.

Type of study/level of evidence: Therapeutic III.

Abbreviations: CTS = carpal tunnel syndrome, EMR = electronic medical records, VLP = volar locking plate.

Keywords: die-punch fracture, effectiveness, prognosis, volar locking plate

1. Introduction

Fracture of the radius or ulnas is the most commonly seen fracture type in emergency department and accounts for approximately 1/6 of fractures in adults, with 41% to 50%

involving distal articular surfaces.^[1] Generally, patients with extra-articular or simple intra-articular fractures could obtain favorable clinical and radiographic results via non-operative methods. However, for unstable intra-articular fractures, it is almost impossible to restore the anatomical alignment and articular congruity by non-operative methods, with high risk of reduction loss, poor functional outcomes and increased complications.^[2,3] Accordingly, for these complex intra-articular fractures, open reduction and internal fixation has been always considered as the mainstream choice.^[4,5]

In 1962, Scheck et al^[6] first described die-punch fracture that the dorso-medial fragments separated from the lunate facet. Nowadays, definition of this type of fracture is extended to the impaction fracture of the lunate fossa. Mechanically, it is caused by high-energy impaction when young patients fall from height or suffer from vehicle accidents, with subsequent collapse of lunate fossa and fragments impaction proximally into the radial metaphysics. According to the AO/OTA classification system, die-punch fracture was classified as AO type 23B or 23C, based on the comminution extent, displacement in direction and presence or not of metaphysis fractures.

Die-punch fracture represents a great challenge for orthopedics surgeons, due to the lunate facet compression, significant displacement (>2 mm) and multi-fragments. Earp et al^[7] evalu-

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ated a series of AO/OTA C3 type of distal radius fractures treated by a single volar plate and found most cases (5/8) of postoperative significant reduction loss occurred in those with initial lunate facet involvement. Likewise, in a study of 41 dorsally displaced unstable fractures of the distal radius, Rozenal et al^[8] reported 50% (2/4) incidence of secondary reduction loss in fractures with lunate facet involved.^[13] The aim of treatment of die-punch fracture is to restore anatomical alignment and articular congruity, which is essential for satisfactory functional results. Otherwise, modification of the joint congruence is closely related to the subsequent poor functional outcomes and symptomatic arthrosis, which have significant negative impact on patients' daily activities.^[9]

Numerous studies have evaluated the results of intra-articular distal radius fractures by various types of treatments. However, due to the rarity nature, there is scarcity of data on the treatment of die-punch fractures.^[10,11] It is of importance to understand the characteristics and its prognostic information of this complex intra-articular fracture, not only because of its special mechanism but more of high technical demanding and difficulty in fracture reduction and fixation procedure.

In this study, our aim was to evaluate the clinical and radiographic results of volar locking plate (VLP) fixation of die-punch fractures and the postoperative complications. The primary outcomes were radial subsidence during the bony union and articular step-off at the last follow-up visit; the secondary outcomes were volar tilt, radial inclination, wrist motion range, grip strength, Gartland and Werley score and the postoperative complications.

2. Materials and methods

2.1. Inclusion and exclusion criteria

This was a retrospective study. This study was approved by the institutional review board of the 3rd Hospital of Hebei Medical University before it commenced. Written informed consent was obtained from all patients. In this study, we set the review period as 3.5 years, being from January 2014 to June 2017. Two researchers (YK and ZX) inquired their electronic medical records (EMR), imaging system and operation reports for data collection.

All patients over 18 years old with acute distal radius fractures involving the lunate facet treated by VLP were included. The exclusion criteria were as follows: age <18 years, pathological fractures, metastatic fracture, and those with incomplete medical data. A total of 51 consecutive patients definitely diagnosed as Die-punch fractures of the distal radius were treated in our department.

The following criteria were used to select eligible patients: aged between 18 and 65 years; definitely diagnosed die-punch fracture by preoperative radiographs, CT scanning and reconstruction; no history of fracture or arthropathy in the injured hand; unilateral fracture for comparison with the contralateral uninjured hand; no concomitant injury in the injured upper extremity; complete follow-up data available. Exclusion criteria were age beyond the range of 18 to 65 years; patients unwilling to participate in this study; old fracture (>2 weeks); severely open injury with large damaged soft tissue; lost to follow up.

Finally, 37 patients were deemed to be eligible and included for data analysis. Of them, 26 were males and 11 were females and their median age was 39.5 years (range, 21–63) and 42 years (range, 19–65 years), respectively. The right wrist was involved in

22 patients and the left in 15, while 25 involved the dominant hand. According to the AO/OTA classification system, most were AO type 23-C3 (17 cases), followed by C1 (7), C2 (4), B1 (4) and B3 (2). Accident from electric bicycles was the most common cause, accounting for 43.2% (15/37) of all the injuries, followed by fall from height (9), accidents from motor vehicles (9) and sports injuries (4). Open fracture was in 9 patients without severely damaged soft tissues, which allowed non-delayed operation. Eleven patients have concomitant injuries including skin contusion and bruise, ankle sprain, ulnar styloid fracture, rib fracture and tibial and fibula fracture. Four patients had paresthesias and subjective numbness, considered as median nerve irritation at the time of initial injury. We performed carpal tunnel release and median nerve symptoms resolved afterwards. The mean interval between initial injury and surgery was 4.5 days (1–14 days).

2.2. Surgery techniques

All the operations were performed by Bing Zhang. The operation procedure was performed with patient's supine and the involved upper extremity extended; axial block anesthesia in 33 patients and general anesthesia in the remaining 4 patients (concomitant fractures or severe injuries). With the use of tourniquet, we made the traditional Henry approach and extended it distally 2 cm if necessary but without crossing the wrist crease for adequate exposure of fracture fragment. After retracting flexor carpi radialis, medial nerve medially and brachioradialis and radial artery and vein laterally, the pronator quadratus was exposed and incised from proximity of its radial insertion, with 1 to 2 cm preserved for suture. Then, retract the pronator quadratus ulnarly, fracture site is exposed and fracture fragments are identified and reduced under fluoroscopic guidance. For classical Die-punch fracture that fracture line at the plane of impaction is transverse, periosteum elevator is introduced into the transverse impaction line to elevate the fragments until obtaining flatness of the subchondral bone line of the lunate facet with that of the scaphoid facet. For the non-classical type of die-punch fracture (classified as AO 23-B1) where fracture fragments are impacted longitudinally and separated from the lunate facet, periosteum elevator is introduced into the longitudinal fracture line to disimpact the fracture fragments. For cases of severely comminuted intra-articular or metaphyseal fractures where a large defect is created after reduction, autologous iliac crest bone grafts are used to fill the gap and buttress the reduced fragments. Kirschner wires are used to temporarily stabilize the reduced fragments. Under the control of fluoroscopy, A T-shape locking plate (Synthes™, Shanghai, China; Wego™, Shandong, China) is then applied on the volar side and the sliding hole is fixed first which allows readjustment according to status of articular surface. Distal screws are placed just beneath the subchondral bone, which provides the maximum ability to buttress the lunate facet fragments. Temporary K wires were removed and the proximal locking screws were then placed. Re-confirm the placement of VLP radiographically and particular care is taken to prevent the distal locking penetrating beyond the dorsal cortex. After desired reduction and fixation, the pronator quadratus is repaired with absorbable suture material and a drape was placed.

Postoperatively, remove the drape at 2 to 4 days based on exudation status. All wrists were placed in a short-arm plaster splint for 4 weeks, active finger motion was started the day after the surgery. Dressings and sutures were removed in the

fourteenth postoperative day. After removal of plaster at 4 weeks, exercises should be started for all joints.

2.3. Outcome measurements

Based on the protocol, patients were followed up routinely at 2 weeks, 1 month, 3 months, 6 months and 1 year postoperatively. X-rays taken at immediate postoperation and at each follow-up were used to evaluate radiographic parameters. We defined satisfactory reduction as dorsal tilt less than 10° , volar tilt $<20^\circ$, radial inclination $>10^\circ$, radial shortening <2 mm and articular step-off <1 mm,^[20,21] at the immediate postoperative X-rays. We defined radius subsidence as the absolute difference value between both ulnar variances measured at X-rays of immediate postoperation and patients' last follow-up. Articular step-off was evaluated via the last-visit X-rays, with the value of 2 mm or greater defined as significant.^[12] Likewise, at the last follow-up visit, grip strength was measured in kilograms with a dynamometer; wrist motion range including flexion, extension, pronation and supination was measured and calculated as the percentage of the contralateral normal side.

Overall outcome was evaluated by Gartland and Werley scale,^[13] which emphasizes clinical and radiographic data and consisted of 4 elements: residual deformity, pain, wrist motion range and complications. The higher score represents the poorer recovery that, a score of 0 to 2 as excellence, 3 to 6 as good, 7 to 18 as fair and 19 or more as poor.

The potential complications were documented: including infection, tendon tenosynovitis, tendon contractures, carpal tunnel syndrome (CTS), implant failure (plate fracture or screw loosening), delayed or non-union, and symptomatic traumatic

arthritis. After routine follow-up (1 year), latter-period complications were also documented for evaluation.

3. Results

The median follow-up time was 15 months (range, 12–37 months). At the median time of 8 weeks (6–14 weeks), bony union was reached in all participants. At the last visit, the mean volar tilt was 9.5° (range 6° – 15°), radial inclination 21° (range 12° – 27°), radial subsidence 0.8 mm (range 0–3.3 mm) and articular step-off >2 mm occurred in 4 patients (10.8%). The mean wrist flexion measured 64° (52° – 80°), wrist extension 62° (45° – 75°), pronation 85° (70° – 90°), and supination 87° (77° – 90°). Compared to the contralateral uninjured wrist, patients regained wrist motion as 84.2% in flexion, 87.0% in extension, 92.2% in pronation and 94.5% in supination, respectively. The mean grip strength in the injured limb was 86% (range 56%–108%) of the contralateral un-injured limb, with 75% (range 56%–92%) in dominant hand and 98% (82%–108%) in nondominant hand, respectively. Outcomes of Gartland and Werley at the latest follow-up showed the excellent and good rate of 83.8%, with excellent result in 21 patients, good in 10, fair in 4 and poor in 2 (Table 1).

Superficial infection occurred in 2 patients and was resolved by a single course of oral antibiotics. Superficial radial nerve irritation developed in 1 patient at early postoperative period, the symptoms persisted several weeks and disappeared without intervention. One patient complained of persistent regional wrist pain due to prominent hardware and relieved after hardware removal in advance (8 month). Three patients complained of subjective finger stiff 1 patient had a finger flexor tendon contracture after physical examination at postoperative

Table 1

The results of wrist motion, radiographic parameters, functional recovery and complications after VLP fixation of die-punch fractures (n=37).

Variable	Mean or n	Range or %	% of value on contralateral side
Wrist motion	Mean	Range	% of value on contralateral side
Flexion	64	53 to 80	84.2
Extension	62	45 to 75	87.0
Pronation	85	70 to 90	92.2
Supination	87	77 to 90	94.5
Radiographs	Mean or n	Range or %	
Volar tilt (deg)	9.5	6 to 15	
Radial inclination (deg)	21	12 to 27	
Radial subsidence (mm)	0.8	0 to 3.3	
Articular step >2 mm	4	10.8	
Grip strength (kg)	25.4	17 to 31	86.0
Gartland and Werley grade	n	%	
Excellent	21	56.8	
Good	10	27.0	
Fair	4	10.8	
Poor	2	5.4	
Complications	n	%	
Total	10	27.0	
Superficial infection	2	5.4	
Nerve irritation	1	2.7	
Regional wrist pain	1	2.7	
Subjective finger stiff	3	8.1	
Cosmetic defect	1	2.7	
Symptomatic traumatic arthritis	2	5.4	

VLP=volar locking plate.

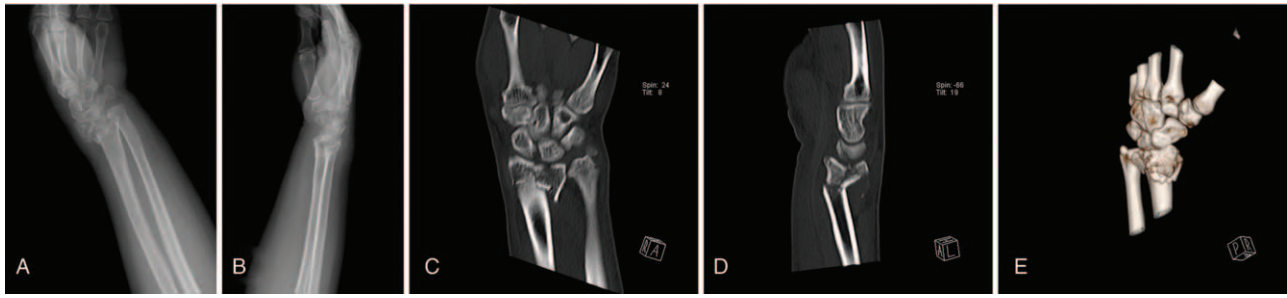


Figure 1. The preoperative X-ray (A, B), CT scanning (C, D) and reconstruction (E) showed a complete intra-articular fracture of the left distal radius involving the lunate facet, classified as AO type C fracture.

3 to 6 months, and after intensive rehabilitation training and physiotherapy all of them restored to normal activities. One young female patient complained of the cosmetic defect from extended scar at the latest follow-up. There were 2 cases of symptomatic post-traumatic arthritis in 2 young males with significant articular step-off, 1 developing at 21 months and the other in 27 months after the index surgery. No extensor tendon tendinitis and rupture and flexor tendon tenosynovitis were found during the follow-up period.

Figures 1 to 3 presented a typical case of right die-punch fracture of the distal radius in a 33-year-old man.

4. Discussion

Die-punch fracture of distal radius was a specific unstable fracture that was characterized by compressed lunate facet fragments. In this study, we found that patients with Die-punch fractures treated by VLP could gain favorable reduction and maintenance to bony union, nearly the same motion range as the contralateral uninjured side and relative few complications.

The anatomic study and 3-column theory suggested that lunate facet constitutes the intermediate column and is the dominating load-bearing elements of wrist articular surface, accounting for 51.7% to 53.0% of the whole distal radius articular surface.^[14,15] Therefore, restoration of the lunate fossa and adequate stabilization is the key to reconstruction of distal radius articular surface. In this study, we applied the traditional Henry or extended approach to obtain maximum exposure of the articular surface. For fractures with significant collapse (>2 mm), we recommend routine autologous iliac crest bone grafts to fill the gap, which is also considered as an important measure for prevention of reduction loss, bone non-union and hardware failure. In this study, autologous bone graft was applied in 6 cases and none of them developed significant reduction loss. One female with slight osteoporosis declined autologous bone grafts in fear of secondary trauma and developed reduction loss at early postoperative period. Surprisingly, she did not complain of any discomfort, although with evidence of significant articular step-off and radiographic osteoarthritis in the later-period. Analyses of other 3 cases of significant reduction loss suggested that the inability to fix the relatively small fragment and inaccurate



Figure 2. Intraoperative radiographs (A, B) demonstrated nearly anatomic reduction and the thereafter fixation by VLP. VLP = volar locking plate.



Figure 3. At the final follow-up at postoperative 13 months, the patient got the favorable functional results of the operated wrists (A–D).

placement of distal screws are the predominant contributing factors. Therefore, exact evaluation of required autologous bone grafts in indicated patients and accurate placement of distal locking screws were crucial factors of stable fixation.

Pronator quadrates played an important role in the Henry approach, not only allowing direct exposure of distal radius, but also separating the volar plate from the flexor tendons. However, where to incise and whether to suture the pronator quadrates has been in controversy. Some authors incised the pronator quadrates just at its radial insertion, leaving the muscle un-repaired, and demonstrate no influence on the functional results.^[16,17] Fang et al^[18] suggested the function of pronator quadrates was largely compensated by pronator teres. In our clinical practice, distal attachment part of pronator quadrates (1–2 cm) was preserved for suture repair, so as to restore the anatomy of radius to a great extent. The authors demonstrated the better results of non-incision relative to incision and no-repairs of pronator quadrates for treatment of distal radius fractures by VLP, in term of wrist motion range, grip strength and functional recovery and complications.^[18] The positive influences of pronator quadrates repairs on the wrist functional recovery requires to be further investigated; at least, an intact or nearly intact (repaired) pronator quadrates would not produce more negative results.

Compared to experience of previous literature, this study demonstrated the similar clinical efficacy and safety of VLP for treatment of die-punch or other intra-articular distal radius fractures. The incidence of excellent and good results based on Gartland and Werley scoring system was 83.8%, which was in range of reported data in literature. In a retrospective review of 13 die-punch fractures treated by VLP, Bao et al^[19] found the DASH score was 6.5, being an excellent score. Chen et al^[20] applied 3D printing technology and plate/screw fixation to treat 52 cases of die-punch fractures, and found the similar Gartland–Werley score compared to the routine method (VLP or non-VLP fixation). We found a relatively higher incidence of overall complications that was 27.0%, which might be related to the wider definition of complication. However, the major complications that required further intervention were relatively few, which was consistent of most previous reports, ranging from 0% to 15%.^[20–22] We believed these results were predictable, under the premise of precise reduction and stable fixation according to fundamental treatment principles.

This study suffered from several limitations. First, the number of participants was small. Therefore, for different fracture types, we were unable to compare the results. Second, the retrospective design might compromise the data accuracy. Third, the last but the most important limitation of this study was lack of a control group to compare the results.

In conclusion, this study demonstrated VLP fixation as an efficient and safe method for die-punch fractures, in term of favorable maintenance of reduction, radiographic parameters, wrist function and complications. In the future, well-designed studies with larger number of patients are required to further confirm our results and compare treatment outcomes among different fixation methods.

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