


CLINICAL ARTICLE

Volar, Splitting, and Collapsed Type of Die-Punch Fracture Treated by Volar Locking Plate (VLP): A Retrospective Study

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Objective: To compare the results of different types of die-punch fractures treated by volar locking plate (VLP).

Methods: Between January 2013 and February 2018, a total of 71 patients with die-punch fracture of distal radius were treated by VLP and their medical records were retrospectively reviewed. Of them, 18 were classified as volar type, 24 as splitting type, and 28 as collapsed type of fracture, based on the preoperative radiographs and CT scans. The minimum follow-up period was 12 months. Radiological parameters, wrist function, range of motion (ROM), and complications were evaluated and compared. Pearson chi-square test was used to assess the difference of gender distribution, injury side, dominance, mechanism, type and classification of fracture, and postoperative complications, when necessary ($P < 0.05$), followed by pairwise comparisons using partitions of chi-square test. Two-tailed P value < 0.05 was considered as statistically significant. For pairwise comparisons, adjustment of statistical level as $P < 0.017$ ($0.05/3$) was used. SPSS 21.0 was used to perform all the analyses.

Results: The mean follow-up time was 14.5 months, and at the mean of postoperative 8 weeks all patients obtained bony union, without delayed or non-union. The grip strength was 26.6 ± 7.9 kg for patients in volar fracture group, 27.0 ± 9.4 kg in splitting group, and 26.2 ± 9.4 kg in collapsed group, without significant difference ($P = 0.628$). The disabilities of the arm, shoulder, and hand (DASH) (9.2 ± 10.0 for volar group, 8.8 ± 7.9 for splitting group, and 10.6 ± 8.7 for collapsed group) or Gartland–Werley score (5.1 ± 2.8 for volar group, 4.8 ± 3.2 for splitting group, and 6.4 ± 2.7 for collapsed group) either did not differ among the three groups (all $P > 0.05$). There was a poorer ROM in the group of collapsed fractures, but the difference was non-significant for any parameter ($P > 0.05$). As for radiographic parameters, we did not find any significant difference for volar tilt, radial inclination, radial height, and ulnar variance (all $P > 0.05$), except for articular step-off ($P < 0.001$). Pairwise comparisons showed a significantly greater step-off (1.2 mm vs 0.4 mm, 0.5 mm) and higher rate of total complications in group of collapsed fracture (39.3%), compared to either volar (10.5%) or splitting type (12.5%).

Conclusions: The collapsed type of die-punch fracture posed a greater articular step-off and a higher rate of complications, especially secondary wrist osteoarthritis, which deserved more attention in clinical treatment.

Key words: Articular step-off; Collapse type; Die-punch fracture; Splitting type; Volar type

Introduction

Fracture of the distal radius or ulnas is the most common injury type in emergency and orthopaedics departments, and almost half of them involve the radio-ulnar or radio-

carpal articular surface^{1, 2}. Die-punch fracture is a special intraarticular fracture, which was firstly described by Scheck in 1962 as the dorsomedial fragment separated from the lunate fossa³. Nowadays, this fracture is known as any

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depression fracture of the lunate fossa caused by a vertical load through the lunate. According to anatomic and radiographic studies, lunate fossa accounted for 46.0% of the whole distal radial-carpal articular surface⁴. The three-column theory of distal radius suggests that lunate facet constitute the intermediate column and is the most predominant bearing surface and axial load transfer area of the wrist⁵. Therefore, adequate reduction of the lunate fossa is very important and any disorder of anatomical structure (lunate fossa fracture or lunate bone aseptic necrosis) would seriously affect the kinetics of the wrist^{6, 7}.

Most die-punch fractures are considered as unstable fractures and the depressed articular surface is difficult to reduce because it is commonly not responsive to ligamentotaxis. The mainstream treatment method for this type of injury is open reduction and volar locking plate (VLP) fixation, which related to favorable clinical and radiographic results^{6, 8}. Current evidence indicated that there was a tendency for higher incidence of reduction loss and secondary osteoarthritis in die-punch fractures compared to those without lunate fossa involvement^{6, 8, 9}. Recently, Ma *et al.*¹⁰ proposed a new classification system of die-punch fractures, wherein four fracture types were classified according to the fracture line and injury mechanism. According to the traditional experience, dorsal incision is commonly chosen for type I fracture (dorsal) and volar incision for type II-IV fractures (volar, splitting, and collapsed) for easy and direct operation. In that study, the authors suggested individualized treatment for each type of fracture; they did not assess and compare the functional or radiographic results among different types¹⁰. Based on previous findings and our clinical practices, we assume there might be some differences in functional, radiographic results or complications among the different types of fractures.

In this study, we selected type II-IV fractures as study objects. The purpose of this study was: (i) to compare the radiological parameters (volar tilt, radial inclination, articular step-off, ulnar variance); (ii) to compare the functional outcomes (wrist motion range, grip strength, disabilities of the

arm, shoulder, and hand [DASH], and Gartland–Werley scoring systems); and (iii) to evaluate the potential complications among the three types of die-punch fractures treated by VLP.

Methods

Inclusion and Exclusion Criteria

The inclusion criteria were: (i) patients with definite diagnosis of volar, splitting, or collapsed type of die-punch fracture patients; (ii) patients treated by VLP with or without auxiliary fixation; and (iii) case series study. The exclusion criteria were: (i) patients aged less than 18 years or older than 75 years; (ii) old fracture (≥ 3 weeks since fracture occurrence); (iii) co-existent wrist osteoarthritis or arthropathy; (iv) concurrent fracture or any previous operation of the injured limb; and (v) follow-up < 12 months.

This study was approved by the institutional review board of The Third Hospital of Hebei Medical University (NO. 2019-4-08) and informed consent of all patients was obtained.

Surgical Technique

Anesthesia, Approach, and Exposure

Under local or general anesthesia and control of tourniquet in supine position, a traditional or modified Henry approach was used, with a 10–12 cm incision not crossing the wrist crease. Flexor carpi radialis and radial nerve were retracted medially and brachioradialis and radial blood vessels laterally.

Reduction and Fixation

Then, we retract the pronator quadratus ulnarly and identify and reduce the fracture fragment under fluoroscopic guidance. According to the fracture displacement and impaction situation, reduction by leverage or reverse traction was used to restore the radial length and articular surface congruence. Satisfactory reduction was defined as dorsal tilt less than 10° ,

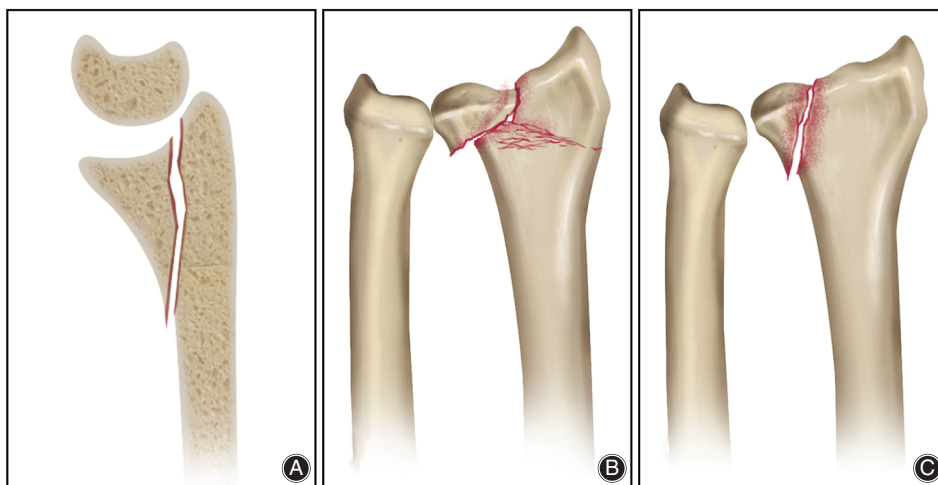


Fig 1 The drawings of 3 types of die-punch fracture, with (A), (B) and (C) representing the volar, splitting and collapsed type of fracture, respectively.

volar tilt $<20^\circ$, radial inclination $>10^\circ$, radial shortening <2 mm, and articular step-off <1 mm in the immediate postoperative radiographs^{11, 12}.

Generally, as for volar or splitting type of fracture, a T-shape locking plate (Synthes™, Shanghai, China; Wego™, Shandong, China) fixation could obtain satisfactory results, without additional need of Kirschner wire or bone grafting. As for collapsed type of fracture, a periosteum elevator is introduced into the impaction line to elevate the fragments and autogenous bone grafting is needed to fill the defects. If a VLP fixation cannot adequately support the reduced fragments or some small fracture fragments are unable to be fixed, auxiliary Kirschner wires are applied for auxiliary fixation. Distal screws were placed beneath the subchondral bone as close as possible to provide the maximum ability to buttress the lunate fossa fragments, especially in osteoporotic patients. Fig. 1A–C shows drawings of the three types of die-punch fracture. Figures 2–4 shows three typical cases of volar, splitting, and collapsed type of die-punch fractures fixed by VLP.

Postoperative Management

Postoperatively, cast immobilization was applied for 4 weeks. Under the surgeon's guidance, patients were encouraged to perform early motion of finger, elbow, and shoulder since the first day after operation. At postoperative 4 to 6 weeks, the cast and auxiliary Kirschner wires were removed and thereafter wrist rehabilitation begun. For the first 3 months after operation, follow-up was performed once a month on an outpatient basis, and after that, once every 3 months until removal of fixation devices. The minimum follow-up period was 12 months. At each follow-up, X-ray was taken to evaluate the fracture union and the radiographic parameters.

Evaluation Methods

Measurement of Range of Motion (ROM)

The functional outcomes were range of motion (ROM) of the wrist and grip strength. A goniometer was used to measure the wrist flexion, extension supination and pronation; a Jamar dynamometer (Jamar, Preston, USA) was used to



Fig 2 A male patient, aged 32 years old, sustained a left wrist fracture from a motor injury. Volar type of die-punch fracture. (A) and (B): the preoperative posteroanterior and lateral X-ray; (C) and (D) CT scan showed he obvious depressed and volar displacement; (E) and (F) showed the good reduction and fixation by Volar Locking Plate(VLP).



Fig 3 A female patient, 41 years old, presented with a left wrist fracture, classified as splitting type of die-punch fracture. (A) and (B): the preoperative posteroanterior and lateral X-ray; (C) and (D) CT scan and reconstruction showed the medial splitting displacement; (E) and (F) showed the Volar Locking Plate (VLP) fixation.

measure the grip strength. All of these measurements were assessed with the contralateral uninjured wrist as references.

DASH Score

Subjective functional assessment was performed using the DASH score¹³ and the Gartland–Werley scale¹⁴. The DASH questionnaire is a validated questionnaire to evaluate patients' ability to perform the daily activities, with a score range from 0 points, representing no disability, to 100 points, representing maximum disability.

Gartland–Werley Scale

Gartland–Werley scale is a validated physician-based scoring system, which combines residual deformity, subjective findings, ROM, postoperative complications, and poor finger function. The scale ranges from 0 points to 52 points, with lower scores representing better function and higher scores representing poorest function.

Radiographic Parameters

Standard posteroanterior and lateral radiographs were used to measure volar tilt, radial inclination, radial length, ulnar variance, and articular step-off. At each visit (postoperative 2 weeks, 6 weeks, 3 months, 6 months, and 12 months), any complication was documented, either from patients' self-reports or doctors' check-ups, including infection, plate/screw loosening, neuropathy or nerve injury, tendon injury or tendinopathy, chronic regional pain syndrome, malunion, nonunion, re-fracture, and others.

Statistical Analysis

The continuous variables (age, volar tilt, radial inclination, grip strength, and others) were expressed as mean and standard deviation (SD) and categorical variables as number and percentage. One-way analysis of variance (ANOVA) or Mann–Whitney U test was used to assess the difference of age, time between fracture and operation, ROM (wrist flexion, extension supination, and pronation), grip strength, and



Fig 4 A male patient, 37 years, presented with a right wrist fracture, classified as collapsed type of die-punch fracture. (A) and (B): the preoperative posteroanterior and lateral X-ray; (C) and (D) CT scan and reconstruction showed the central collapse and displacement; (E) and (F) showed the anatomic reduction and Volar Locking Plate (VLP) fixation.

radiographic parameters (volar tilt, radial inclination, radial length, ulnar variance, and articular step-off) among three groups; when necessary ($P < 0.05$), followed by pairwise comparisons using Least Significant Difference (LSD) test. Pearson chi-square test was used to assess the difference of gender distribution, injury side, dominance, mechanism, type and classification of fracture, and postoperative complications, when necessary ($P < 0.05$), followed by pairwise comparisons using partitions of chi-square test. Two-tailed P value < 0.05 was considered as statistically significant. For pairwise comparisons, adjustment of statistical level as $P < 0.017$ ($0.05/3$) was used. All the analyses were performed by the SPSS 21.0 software (IBM, Armonk, NY, USA).

Results

General Results

From January 2013 to February 2018, a total of 168 patients with die-punch fractures were treated surgically in our hospital, of which 71 met the criteria and were included for data analysis. There were 28 men and 43 women, with average age of 47.1 years (SD, 14.6 years). Fall from standing height was the

most common cause (42 patients), followed by vehicle accident (15), fall from height (five), sports injury (three), and other (six). Twelve (16.9%) patients have concomitant ulnar styloid fracture. Most were closed fracture (61/71), and 10 were open fractures (10/71), of which three were classified as type I, five as type II, and two as type IIIA, based on the Anderson-Gustilo classification system¹⁵. There were no significant differences among three types of fractures in term of age, gender distribution, injury side, dominance, injury mechanism, fracture type (open or closed), and AO classification (all $P > 0.05$). The detailed comparisons were presented in Table 1.

The mean follow-up time was 14.5 months (range, 12 to 38 months), and at the mean of postoperative 8 weeks (range, 6 to 18 weeks) all patients obtained bony union without delayed or non-union. There were no significant differences between three groups in term of surgical time ($P = 0.218$), which was 109.7 ± 27.6 min in volar fracture group, 106.3 ± 22.3 min in splitting fracture group, and 113.9 ± 30.6 min in the collapsed fracture group. There was either no difference of intraoperative blood loss between the three groups ($P = 0.589$), which was 156.4 ± 67.6 mL, 151.8 ± 55.3 mL, and 160.2 ± 70.4 mL in volar, splitting, and collapsed fracture groups, respectively.

Table 1 Comparison of demographic and injury-related data

	Volar type [%]	Splitting type [%]	Collapsed type [%]	P
Age (years)	46.4 (SD, 17.2)	43.5 (SD, 15.2)	48.2 (SD, 15.8)	0.261
Gender				0.949
Male	7 (36.8%)	10 (41.7%)	11 (39.3%)	
Female	12 (63.2%)	14 (58.3%)	17 (60.7%)	
Injured side				0.919
Left	6 (31.6%)	9 (37.5%)	10 (35.7%)	
Right	13 (68.4%)	15 (62.5%)	18 (64.3%)	
Dominant wrist fracture	12 (63.2%)	16 (66.7%)	20 (71.4%)	0.832
Mechanism				0.821
Fall from standing height	10 (58.8%)	15 (62.5%)	17 (58.6%)	
Vehicle accident	5 (17.6%)	4 (16.7%)	6 (20.7%)	
Fall from height	1 (5.9%)	2 (8.3%)	2 (10.3%)	
Sports injury	0	2 (8.3%)	1 (3.4%)	
Others	3 (17.6%)	1 (4.2%)	2 (6.9%)	
Type of fracture				0.762
Open	3 (15.8%)	3 (12.6%)	4 (14.3%)	
Closed	16 (84.2%)	21 (87.5%)	24 (85.7%)	
AO classification				0.381
Type B	12 (63.2%)	13 (54.2%)	12 (42.9%)	
Type C	7 (36.8%)	11 (45.8%)	16 (57.1%)	
Time interval between fracture and operation (days)	2.8 (SD, 1.6)	2.4 (SD, 1.4)	3.3 (SD, 1.9)	0.187

Range of Motion (ROM)

Compared to the contralateral uninjured wrist, patients could obtain an excellent recovery of ROM of the operated wrist, with a 90% recovery rate (range, 87.6%–95.2%). The flexion was $56.3^\circ \pm 9.2^\circ$, $55.2^\circ \pm 9.6^\circ$, and $55.1^\circ \pm 9.6^\circ$ in groups of volar, splitting, and collapsed fractures, respectively, which was 90.4%, 88.6%, and 91.1% of that in the contralateral uninjured side. The extension was $61.1^\circ \pm 10.8^\circ$, $61.4^\circ \pm 10.4^\circ$, and $58.4^\circ \pm 10.4^\circ$ in groups of volar, splitting, and collapsed fractures, respectively, which was 91.9%, 92.0%, and 89.0% of that in the contralateral uninjured side. The pronation was $80.2^\circ \pm 9.2^\circ$, $77.2^\circ \pm 7.9^\circ$, and $78.0^\circ \pm 7.9^\circ$ in groups of volar, splitting, and collapsed fractures, respectively, which was 92.0%, 87.6%, and 89.6% of that in the contralateral uninjured side. The supination was $85.1^\circ \pm 10.6^\circ$, $83.4^\circ \pm 8.8^\circ$, and

$86.2^\circ \pm 8.8^\circ$ in groups of volar, splitting, and collapsed fractures, respectively, which was 95.2%, 91.5%, and 90.2% of that in the contralateral uninjured side (Table 2).

Grip Strength

The grip strength was 26.6 ± 7.9 kg for patients in volar fracture group, 27.0 ± 9.4 kg in splitting group, and 26.2 ± 9.4 kg in collapsed group, without significant difference ($P = 0.628$).

Functional Score

The DASH was 9.2 ± 10.0 in patients of volar group, 8.8 ± 7.9 in splitting group, and 10.6 ± 8.7 in collapsed group, being not significantly different between the three groups ($P = 0.148$). Regardless, the Gartland–Werley score was not significantly different among the three groups ($P = 0.662$), with

Table 2 Comparison of range of motion (ROM), grip strength and functional score of the operated wrist among 3 groups

	Volar type		Splitting type		Collapsed type		P
	Mean (SD)	% of Value on Contralat. Side*	Mean (SD)	% of Value on Contralat. Side	Mean (SD)	% of Value on Contralat. Side	
Flexion (deg)	56.3 (9.2)	90.4	55.2 (9.6)	88.6	55.1 (9.6)	91.1	0.645
Extension (deg)	61.1 (10.8)	91.9	61.4 (10.4)	92.0	58.4 (10.4)	89.0	0.776
Pronation (deg)	80.2 (9.2)	92.0	77.2 (7.9)	87.6	78.0 (7.9)	89.6	0.472
Supination (deg)	85.1 (10.6)	95.2	83.4 (8.8)	91.5	86.2 (8.8)	90.2	0.136
Grip strength (kg)	26.6 (7.9)	92.9	27.0 (9.4)	94.2	26.2 (9.4)	92.0	0.628
DASH (points)	9.2 (10.0)	—	8.8 (7.9)	—	10.6 (8.7)	—	0.148
Gartland–Werley score (points)	5.1 (2.8)	—	4.8 (3.2)	—	6.4 (2.7)	—	0.662

* Note: all of these measurements were assessed with the contralateral uninjured wrist as references, and expressed as percentage (%).

Table 3 Comparison of radiographic parameters among 3 groups

Variable	Volar type (n = 19) (mean [SD])	Splitting type (n = 24) (mean [SD])	Collapsed type (n = 28) (mean [SD])	P
Volar tilt (deg)	5.6 (3.7)	5.6 (4.1)	5.2 (3.5)	0.713
Radial inclination (deg)	22.8 (3.2)	22.1 (3.7)	20.7 (4.3)	0.297
Radial height (mm)	10.7 (1.6)	10.5 (1.3)	10.3 (1.4)	0.898
Ulnar variance (mm)	0.8 (0.8)	0.8 (1.0)	0.7 (0.9)	0.872
Articular step-off (mm)	0.4 (0.6)	0.5 (0.5)	1.2 (0.7)	<0.001

5.1 ± 2.8 in the volar group, 4.8 ± 3.2 in the splitting group, and 6.4 ± 2.7 in the collapsed group (Table 2).

Radiographic Parameters

We found that there was no significant difference in terms of volar tilt ($5.6^\circ \pm 3.7^\circ$, $5.6^\circ \pm 4.1^\circ$, and $5.2^\circ \pm 3.5^\circ$ for each group), radial inclination ($22.8^\circ \pm 3.2^\circ$, $22.1^\circ \pm 3.7^\circ$, and $20.7^\circ \pm 4.3^\circ$ for each group), radial height (10.7 ± 1.6 mm, 10.5 ± 1.3 mm, and 10.3 ± 1.4 mm for each group) and ulnar variance (0.8 ± 0.8 mm, 0.8 ± 1.0 mm, and 0.7 ± 0.9 mm for each group) ($P > 0.05$). However, we observed a significant difference of articular step-off among three groups (0.4 ± 0.6 mm for volar type, 0.5 ± 0.5 mm for splitting type, and 1.2 ± 0.7 mm for collapsed type) ($P < 0.001$). Pairwise comparisons showed a significantly greater step-off in collapsed fractures, compared to those of volar or splitting type ($P < 0.001$, $P = 0.002$), indicating a poorer articular surface congruence; but in the latter two groups, the difference was non-significant ($P = 0.713$) (Table 3).

Incidence of Complications

The overall rate of complications following VLP fixation of die-punch fracture was 22.5% (16/71), with tendon-related complications being the most common type (9.9%, 7/71), followed by CRPS (4.2%) and traumatic osteoarthritis (4.2%). The incidence of total complications was significantly different among the three groups ($P = 0.002$); and pairwise comparisons showed a significantly higher rate in collapsed type of fractures than volar type (39.3% vs 10.5%, $P = 0.008$) or splitting type (39.3% vs 12.5%, $P = 0.011$), but this was non-significant between the latter two groups ($P = 0.976$) (Table 4).

Discussion

Main Findings

The lunate fossa accounted for 46% of the articular surface of the wrist, greater than the scaphoid fossa and the triangular fibrocartilage surface⁴, constituting the intermediate column of the wrist⁵. Die-punch fracture, especially with displacement more than 1–2 mm, posed a greater challenge for orthopaedic surgeons and was associated with poorer results⁶. This study partially demonstrated our previous hypothesis that there was a difference of radiographic, functional or radiographic outcomes among different types of die-punch fractures treated by VLP. In this study, at the last visit (>12 months), we found no differences among the three types of die-punch in term of ROM, the grip strength, DASH and Gartland–Werley scores and most radiographic parameters (volar tilt, radial inclination, radial height, and ulnar variance). However, with regard to the articular step-off and the rate of complications, the collapsed type of fractures showed worse results compared to the other types of die-punch fractures.

Interpretation of Results and Comparison with Previous Studies

The difficulty in reduction of the collapsed lunate fossa fragments has always been a focus of attention, and even if initial anatomic reduction was obtained the displacement may reappear with the passage of time. Compared to those without involvement of lunate fossa, die-punch fracture was associated with a higher rate of articular step-off >2 mm (19.0% vs 4.2%) than in our previous study of AO type B distal radius fractures⁶. Earp *et al.*⁹ and Rozental *et al.*¹⁶ presented similar findings that over 50% of cases of reduction loss were found in cases of lunate fossa fracture. In a study of 51 cases

Table 4 Comparison of postoperative complications

Complication	Volar type (n, %)	Splitting type (n, %)	Collapsed type (n, %)	P
Total	2 (100)	3 (100)	11 (100)	0.024
Tendon complications	1 (50.0)	2 (66.7)	4 (36.4)	
Infection	0	0	1 (9.1)	
Traumatic osteoarthritis	0	0	3 (27.3)	
Neuropathy or nerve injury	0	0	1 (9.1)	
Complex regional pain syndrome Type I (CRPS)	0	1 (33.3)	2 (18.2)	
Carpal tunnel syndrome	1 (50.0)	0	0	

of AO type B3 distal radius fractures, Beck *et al.*¹⁷ suggested that in AO type B3.3, <15 mm of lunate fossa fragment available for fixation and >5 mm of initial lunate fossa subsidence were identified as significant risk factors for reduction loss and subsequent articular step-off, even if a VLP was properly placed. In this study, we re-confirmed that collapsed type of fracture caused a poorer articular congruity than the other two types (1.2 mm vs 0.4 or 0.5 mm). Accordingly, future research should continue to focus on the innovative design and development of internal implants and improvement of technical skills for fixation of small lunate facet fragments.

For volar, splitting, and collapsed types of die-punch fractures, volar incision was advocated, with aims to obtain relatively straight and easy reduction. VLP fixation via the combination of locking screw and multiple holes (locking hole and sliding pressure hole) could provide secure, reliable, and biological fixation for complex intra-articular fractures, which was of special importance in management of osteoporotic fractures. The results showed that there were no statistically significant differences in the wrist ROM, the grip strength, DASH, and Gartland–Werley scores and most radiographic parameters (volar tilt, radial inclination, radial height, and ulnar variance) among the volar, split, and collapsed types of fractures, which indicated the similar therapeutic effect of locking plate system. This is mostly related to the fact that the locking plate can effectively maintain the distal radius height by virtue of biomechanical stability, which allows early wrist motion and rehabilitation exercises⁹.

We also found higher incidence rate of total complications in collapsed type of fractures, especially traumatic osteoarthritis. Previous literature combined with the current study presents the following possible findings^{6, 8, 9, 18}. Firstly, most of the collapsed type fractures require bone grafting, and the surgical injury is relatively large, which will affect the bone and tendon sheath structure. Secondly, due to the collapse of the articular surface, the articular cartilage is seriously damaged, which cannot be repaired after injury. Thirdly, collapsed fractures are mostly located in the central part of the wrist joint with collapse displacement of more than 1 cm, therefore, they are more likely to result in postoperative wrist joint pain and stiffness. To reduce the complications to the maximum extent, we used intraoperative prying technology to restore the congruity of articular surface and radial length, and auxiliary fixation by one or several Kirschner wires for coexistent fragments and iliac bone grafts to fill the large bone defect. Additionally, attention

should be paid to the placement of the distal screws beneath the subchondral bone, which should be as close as possible to provide the maximum ability to buttress the lunate fossa fragments, especially in osteoporotic elderly patients.

Limitations

There were several limitations that should be mentioned. Firstly, the retrospective nature of this study was subject to data inaccuracy and recall bias. Secondly, the sample size was small, 19 to 28 in various types of die-punch fractures, which likely led to a poor statistical power or type II statistical error. Thirdly, the follow-up period was not so long, therefore not allowing further detection of the possible radiocarpal osteoarthritis, especially in those with significant articular step-off (>2 mm). Therefore, the future prospective studies with large sample size and longer follow-up are required to confirm the present results and further investigate long-term functional results and arthritis change.

Conclusion

In conclusion, VLP fixation of die-punch fractures of the distal radius showed the non-significant difference in results among three types of fracture, in terms of wrist ROM, grip strength, DASH, and Gartland–Werley scores and most radiographic parameters (volar tilt, radial inclination, radial height, and ulnar variance). In contrast, the collapsed type of fractures exhibited the poorer wrist joint congruity and a higher rate of total complications, especially traumatic osteoarthritis. These results could provide references for surgeons in management of this type of injury and postoperative complication risk consulting. More well-designed studies with longer follow-up are needed to confirm our results and track the long-term results, especially for those with significant articular step-off.

Ethics Approval and Consent to Participate

This study was approved by the institutional review board of The Third Hospital of Hebei Medical University and all the patients signed the written consent to participate in this study.

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