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A comparison of minimally invasive approach *vs* conventional approach for volar plating of distal radial fractures

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ABSTRACT

Background: The aim of this study was to introduce and to evaluate the functional results of volar plating of distal radial fractures through a longitudinal minimally invasive approach.
Methods: From January 2010 to January 2013, 157 patients with distal radial fractures were randomly allocated to group A (n = 83; 49 men, 34 women; mean age: 42 (18–67)) and B (n = 74; 46 men, 28 women; mean age: 41 (22–65)), including type A2, A3, B3, C1, and C2 fractures, based on AO Foundation and Orthopaedic Trauma Association Classification. Patients in group A were treated through a 1.5- to 2-cm longitudinal incision, and patients in group B were treated through the conventional flexor carpi radialis approach. All fractures were treated with a locking volar plate. The functional results were compared with range of motion, grip and pronation strengths for each fracture type.
Results: After a follow-up of 2 years, similar measurements were noted on range of motion and grip strength in both groups. Regarding pronation strength, group A was superior to group B ($p < 0.05$).
Conclusions: Minimally invasive volar plating of distal radial fractures is a safe and reliable technique, resulting in better pronation function and appearance.
Level of Evidence: Level I, Therapeutic study

Introduction

Distal radius is the most common fracture site in upper limb.[1,2] The fractures account for approximately 1/6 of all fractures.[3] Unstable distal radius fractures are often treated surgically using a T-shaped locking plate via a 6–8 cm volar approach.[3] Recently, minimal approaches have been advocated.

A minimally invasive technique is that it is a less intrusive or destructive surgery.[4] Chmielnicki et al[5] treated the distal radius fractures by volar plating via a transverse 2–3 cm incision, with sparing the pronator quadratus (PQ). Postoperatively, the patients experienced minimal scar pain and rapid recovery of grip strength. The rotational motion was almost undisturbed. However, the transversal incisions carry a risk of iatrogenic injury to the palmar cutaneous branch of the median nerve. In addition, when difficulties arise, lengthening the incision is difficult. In order to avoid the disadvantages, we developed a small longitudinal approach.

The objective of this report is to introduce minimally invasive volar plating of distal radial fractures with preserving the PQ. We also conducted a comparison between the technique and the conventional technique.

Materials and methods

The study was approved by the Institutional Review Board of the hospital involved. Informed consent was obtained from each patient.

From January 2010 to January 2013, 304 consecutive patients with distal radial fractures were collected from our hospital (Fig. 1A and B). Eligibility criteria for the study were as follows: age ≧18 or <70 years old; a closed distal radial fracture; AO/OTA (AO

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Foundation and Orthopaedic Trauma Association) Classification type A2, A3, B3, C1, and C2 fractures; and the need for volar plating. B1 fractures were excluded because the fracture may be treated with pins; B2 fractures were excluded because a dorsal approach is more appropriate; C3 fractures were excluded because the fractures are too complex to be treated through a small approach. Patients were also excluded if they had one of the following: decline to participate; open fractures; the use of a dorsal approach; fixation with K-wires or screws alone; fixation with an external fixator; combined carpal fractures and/or dislocations or ulna fracture-dislocations; old fractures over 14 days; multiple fractures; pathological fractures; need for aid of arthroscope; uncooperative adults, such as dementia patients; or an associated infection or underlying diabetes, rheumatoid arthritis, or gout. Patients with combined ligament injuries shown on preoperative magnetic resonance images were also excluded.

Thus, a total of 182 patients were included in the study. The patients were randomly allocated to group A (via volar minimally invasive approach) and B (via conventional flexor carpi radialis approach) using a pseudorandom number generator. Immediately after fracture fixation, we excluded patients (2 in group A; 3 in group B) with distal radioulnar joint instability that was confirmed by physical examination. In group A, we converted the small incision to the conventional incision in 2 patients due to difficult reduction (type C2). The two patients were excluded. In group B, we excluded 6 patients whose PQ could not be repaired. We excluded patients who were lost to follow-up (2 in group A; 5 in group B) and who could not complete the entire follow-up (3 in group A; 2 in group B). Pre- and post-operative assessments were performed by one senior orthopaedic surgeon (XS). He was blinded after assignment to the interventions, and he did not involve in the treatments. Patient allocation ratio was approximately 1:1. All operations were performed by the same senior orthopaedic surgeon (XZ). Consort flow is shown in Fig. 2.

Via mini-approach (group A)

Operation was performed under brachial plexus anesthesia and under upper arm tourniquet control. A longitudinal incision was made between the flexor carpi radialis and radial artery. The incision was 1.5–2.5 cm in length, beginning from the proximal wrist crease (Fig. 3A). The flexor carpi radialis was retracted ulnarward, and the radial artery was retracted radioward. The volar periosteum was incised longitudinally. The periosteum beneath the PQ was raised by pushing a periosteal elevator on the volar surface of radius. The fracture was reduced under direct visualization and fluoroscope. The length of the radius was restored by gent traction. If the fracture lines or parts progressed under PQ, reduction could be achieved by forceps. The fracture was provisionally stabilized with K-wires. If there was a volar-ulnar fragment, it could be easily exposed by radial traction of flexor carpi radialis and ulnar traction of the incision. The hole between the radius and PQ was created by using a periosteal elevator. A volar plate (T-shaped plate for type A2, A3, B3 fractures, Suzhou Sunan Zimmered Medical Instrument Co., Ltd., China; distal radius versatile plate for type C2 and C3 fractures, Zimmer Inc., USA), 7–8 cm in length, was slid into the incision and placed on the volar surface of radius, beneath the PQ muscle. Bone grafting was performed as needed. Correct positioning was confirmed by fluoroscopy. The plate was fixed with distal locking screws. Under fluoroscopic guidance, a 0.8 cm long longitudinal skin incision was made just over the conjunction between the two most proximal plate holes. By blunt dissection, the holes were visualized through the septum between the flexor carpi radialis and palmaris longus. Two locking screws were fixed in the holes (Fig. 3B). Additional K-wires were used to fix the small fragments as needed. Once fracture reduction and implant positioning had been accepted on radiographs (Fig. 4A and B), the additional K-wires were removed and the incision was closed (Fig. 4C). After surgery, the wrist and forearm were placed in a removable ball-peen splint that permits gentle active exercises. The splint was completely removed after 4 weeks, and progressive motion was continued until bone union was solid.

Certain surgical pearls were critical. First, a joy stick technique was helpful for reduction. Second, if there was remaining displacement of the dorsal fragments, we often made drill holes just penetrating the volar cortex, and provisionally stabilized the volar fragments to the plate with shorter locking screws. Once the

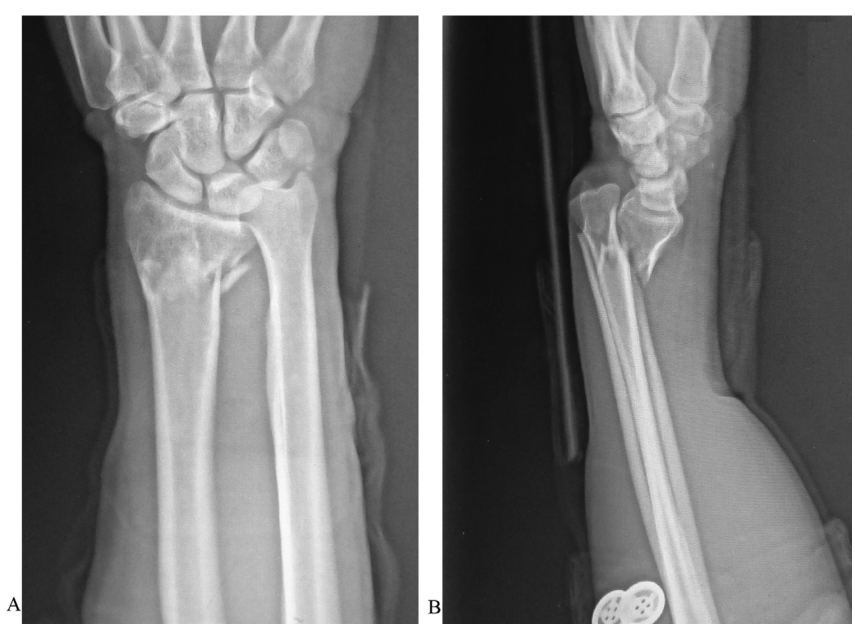


Fig. 1. A. A distal radial fracture on posteroanterior view. B. Lateral view.

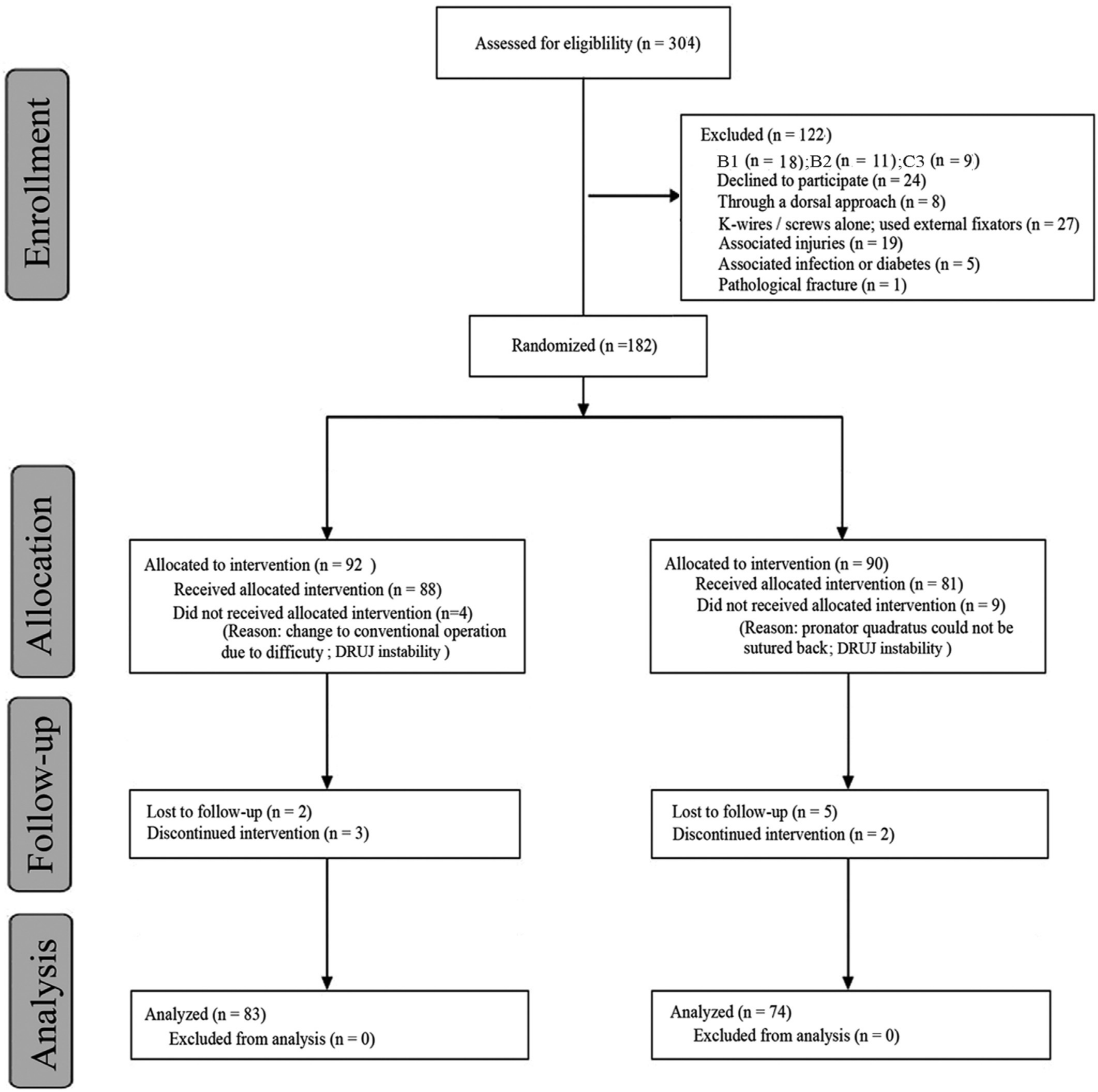


Fig. 2. Consort flow diagram of the groups.

dorsal fragments were reduced, we replaced the short screws with longer ones. In order to prevent redisplacement, the screws should be replaced one by one so that at least two screws engaged in the volar fragments.

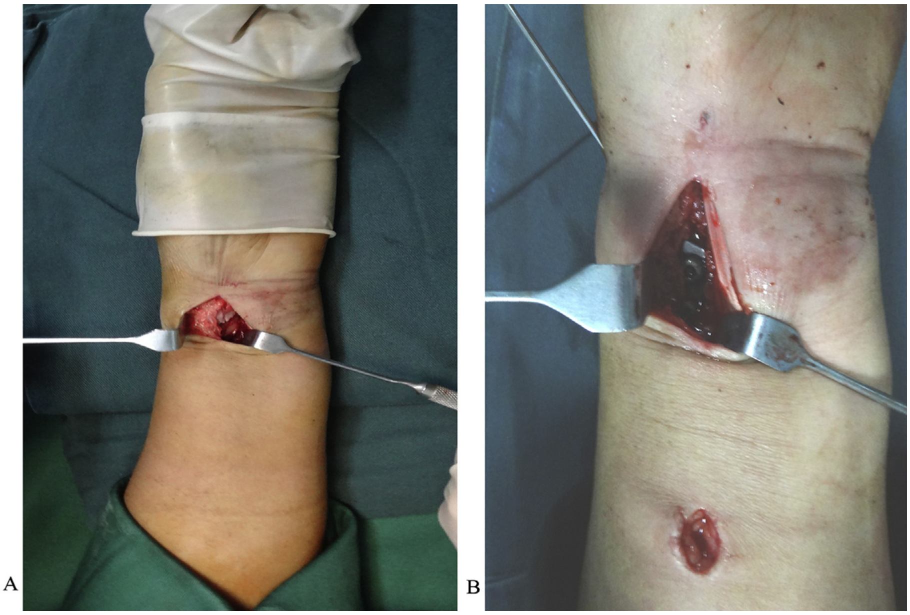
Via conventional flexor carpi radialis approach (group B)

Operation was performed through the conventional flexor carpi radialis approach. The PQ was severed from its origin to expose the radius. We used the same plate and screw system as group A. The PQ was repaired before wound closure. In this group, 7 patients had skin grafting or a delayed wound closure due to edema. Other surgical procedures and postoperative managements were the same as those of group A. No additional procedures were performed.

Outcome evaluation

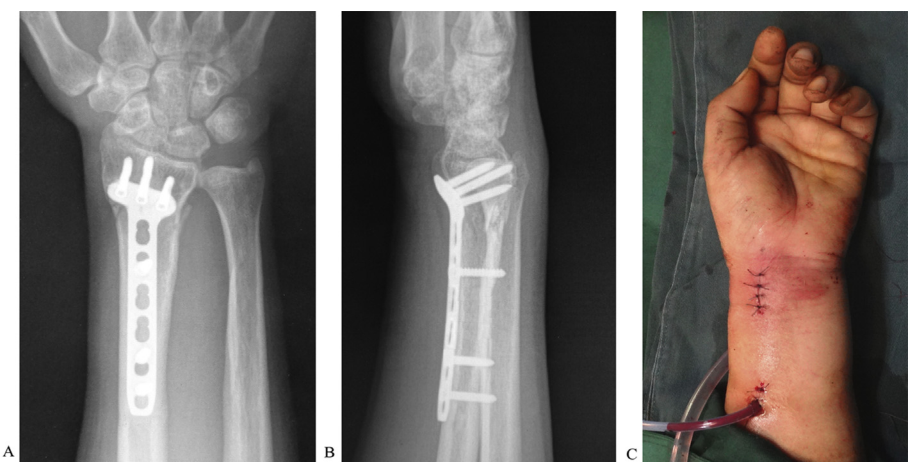
Radiographic evaluation was performed 2 days after surgery. Palmar tilt was measured on lateral view. Radial inclination, scapholunate gap, and ulnar variance were measured on posteroanterior radiograph.[6] Deep wound infection was assessed by both clinical symptoms and blood data analysis.[7] Pain intensity of primary incision was assessed using the visual analog scale (VAS).[8]

At the final follow-up, active range of motion of the wrist was measured using a goniometer.[9] (Figs. 5A and B; 6A–D) All measurements were compared to those on the opposite side. Grip strength of the hand was assessed using a Baseline hydraulic hand dynamometer (Fabrication Enterprises Inc., White Plains, NY).[10] Isometric testing of pronation torque was assessed using



A B

Fig. 3. A. A 2.5-cm longitudinal incision is made on the radiovolar aspect of the distal forearm. B. Through the small incision, volar plating is accomplished with a 7 cm long angle volar plate inserted beneath the pronator quadratus.



A B C

Fig. 4. A. A posteroanterior radiograph shows reduction and plate positioning. B. Lateral view. C. Incisions are closed.

McConkey method at 5 positions of rotation (90° of supination, 45° of supination, neutral, 45° of pronation, and 80° of pronation).[11] To exclude any discrepancy between the dominant and non-dominant hand strength, we based the scores for analysis on the premise that the grip strength was 6% higher for the dominant side compared with the non-dominant side.[12] These measurements were compared to the opposite side. The patients rated their wrist pain using a visual analogue scale.[13] We used the Mayo Wrist Score to assess wrist function (90–100, excellent; 80–90, good; 60–80, satisfactory; below 60, poor).[14] Scar appearance and patient's satisfaction on the upper-limb were assessed using the 10-mm visual analog scale.[15]

Statistical analysis

Quantitative variables were described as mean and standard deviation for symmetric distribution or median and interquartile range for asymmetric distribution. We used Pearson's chi-square test to compare categorical variables, and Mann–Whitney U test to symmetric and asymmetric distribution. A $p < 0.05$ was considered statistical significance. The collected data were analyzed with the Statistical Package for Social Sciences 13.0 (SPSS, Inc., Chicago, Ill).

Results

Patient's details and results are shown in Tables 1 and 2.

In group A, the mean incision length was 1.8 ± 0.3 cm. Difficult reduction was encountered in 4 patients (type C2), and we converted the small incision to the conventional approach. Two patients lost to follow-up, and 3 patients did not complete the follow-up. Those 9 patients were excluded. Thus, a total of 83 patients were analyzed.

In group B, the mean incision length was 7.6 ± 2.7 cm. A total of 69 patients were excluded, because their PQ could not be sutured back to its origin, or the injuries combined with distal radioulnar joint

Fig. 5. A. Incision appearance and wrist radial deviation 26 months after surgery. B. Ulnar deviation.

Fig. 6. A. Flexion. B. Extension. C. Supination. D. Pronation.

instability. Seven patients were also excluded because they lost to follow-up or did not complete the follow-ups. Thus, a total of 74 patients were analyzed (Fig. 2). Fixation failure or osteomyelitis was not observed in both groups. Bone union was achieved in all patients.

Table 1
Demographic data on the patients.

	Group A (n = 83)	Group B (n = 74)	*p*-value
Men	49	46	0.205
Women	34	28	
Dominant hand	44	39	0.07
Nondominant hand	39	35	
Age (mean, range, yr)	42 (18–67)	41 (22–65)	0.15
Cause			
Fall	32 (39%)	29 (39%)	0.17
Road traffic accident	25 (30%)	20 (27%)	
Sports	21 (25%)	22 (30%)	
Others	5 (6%)	3 (4%)	
AO/OTA			
A2	23 (28%)	22 (30%)	0.396
A3	28 (34%)	25 (34%)	
B3	7 (8%)	6 (8%)	
C1	14 (17%)	13 (18%)	
C2	11 (13%)	8 (11%)	

AO/OTA, AO Foundation and Orthopaedic Trauma Association.

Statistical outcomes

We found no significant difference between the two groups in patient age, gender, cause of injury, fracture type, time from injury to operation, amount of reduction, etc. However, there were significant differences in incision length, and duration of operation.

We found no significant difference in duration of follow-up, grip strength of hand, scar pain, wrist joint pain, and wrist function. Regarding active range of motion of wrist, we found there was significant difference in pronation, but no significant difference in other motions. Pronation torque of wrist was significantly different between the groups. There were significant differences in scar appearance and patient satisfaction.

Discussion

We found that the minimally invasive technique produces similar results in main function of the wrist. However, since preservation of PQ, pronation function is better than that of the conventional technique. In addition, the small incision produces better cosmetic appearance.

Type A2, A3, B3, C1, and C2 (AO/OTA classification) distal radial fractures are often treated by volar plating. The flexor carpi radialis

Table 2
Main surgical details and primary outcomes based on fracture type.

	A2			A3			B3			C1			C2		
	Group A (n = 23)	Group B (n = 22)	*p*	Group A (n = 28)	Group B (n = 25)	*p*	Group A (n = 7)	Group B (n = 6)	*p*	Group A (n = 14)	Group B (n = 13)	*p*	Group A (n = 11)	Group B (n = 8)	*p*
TBIO (mean ± SD) (day)	6 ± 5.73	7 ± 6.35	0.058	7 ± 6.11	7 ± 6.46	0.126	7 ± 6.93	8 ± 5.42	0.213	8 ± 3.22	8 ± 8.16	0.131	8 ± 5.33	8 ± 7.12	0.067
Time of operation (mean ± SD) (min)	42 ± 16	47 ± 28	**0.006**	42 ± 15	45 ± 25	**0.021**	46 ± 27	43 ± 24	0.442	64 ± 21	57 ± 19	**0.028**	75 ± 37	56 ± 27	**0.022**
Palmar tilt (°)	11 ± 2.83	11 ± 3.11	0.532	12 ± 2.17	11 ± 2.31	0.664	11 ± 2.21	11 ± 1.78	0.723	12 ± 3.21	12 ± 2.36	0.148	12 ± 4.12	12 ± 3.84	0.105
Radial inclination (°)	22 ± 4.78	23 ± 1.68	0.267	22 ± 3.73	23 ± 2.98	0.378	21 ± 6.88	22 ± 4.66	0.334	21 ± 3.78	22 ± 3.41	0.264	21 ± 4.47	22 ± 3.27	0.324
Scapholunate gap (mm)	1 ± 0.7	1 ± 0.3	0.521	1 ± 0.7	1 ± 0.3	0.521	1 ± 0.7	1 ± 0.3	0.521	1 ± 0.7	1 ± 0.3	0.521	1 ± 0.7	1 ± 0.3	0.521
Ulnar variance (mm)	1 ± 1.2	1 ± 1.1	0.157	1 ± 1.2	1 ± 1.1	0.673	1 ± 1.1	1 ± 1.2	0.772	1 ± 1.6	1 ± 1.5	0.274	1 ± 1.7	1 ± 1.4	0.113
Reduction of articular fragments															
≤1 mm (n)	–	–	–	–	–	–	7	6	0.5	13	12	0.5	10	8	0.205
>1 mm (n)	–	–		–	–		0	0		1	1		1	0	
Primary wound closure (n)	23	19	0.656	28	25	0.795	7	6	0.5	14	12	1	11	7	0.656
Incision pain (VAS; day 10 postop)	1.73 ± 0.92	6.34 ± 6.22	**0.026**	2.43 ± 1.68	7.44 ± 6.37	**0.001**	4.42 ± 4.26	7.47 ± 6.38	**0.001**	4.77 ± 3.74	7.15 ± 6.22	**0.008**	5.23 ± 3.67	8.36 ± 6.28	**0.012**
Final follow-up time (month)	27 ± 1.48	26 ± 4.57	0.264	29 ± 4.13	29 ± 3.65	0.782	27 ± 2.56	28 ± 1.34	0.158	27 ± 2.78	28 ± 3.73	0.662	28 ± 3.23	29 ± 4.77	0.237
Active ROM (°; mean ± SD)															
Flexion	75 ± 10.56	73 ± 12.21	0.4538	72 ± 18.23	73 ± 13.23	0.624	71 ± 12.63	73 ± 14.61	0.265	71 ± 12.66	74 ± 10.72	0.321	74 ± 15.23	73 ± 12.34	0.377
Extension	69 ± 10.58	66 ± 13.44	0.436	67 ± 8.45	66 ± 12.38	0.422	64 ± 10.56	66 ± 13.75	0.125	67 ± 8.37	65 ± 16.44	0.139	67 ± 10.67	65 ± 10.85	0.237
Radial deviation	31 ± 8.32	30 ± 6.28	0.65	30 ± 8.72	28 ± 7.43	0.573	31 ± 8.87	30 ± 6.12	0.109	30 ± 8.72	31 ± 6.72	0.183	30 ± 8.72	31 ± 6.72	0.183
Ulnar deviation	18 ± 23.15	17 ± 15.11	0.751	17 ± 11.28	15 ± 13.55	0.238	15 ± 11.53	14 ± 13.65	0.723	17 ± 10.11	15 ± 11.69	0.097	19 ± 11.57	16 ± 13.12	0.263
Pronation	81 ± 12.72	75 ± 12.11	**0.000**	86 ± 11.02	75 ± 12.65	**0.012**	84 ± 10.98	80 ± 11.47	**0.000**	80 ± 14.52	72 ± 14.32	**0.000**	80 ± 12.74	74 ± 15.25	**0.000**
Supination	86 ± 9.73	85 ± 13.6	0.514	85 ± 11.36	84 ± 12.27	0.266	85 ± 11.2	83 ± 12.55	0.237	82 ± 11.33	82 ± 12.24	0.168	86 ± 010.26	84 ± 10.87	0.255
Grip strength (%; mean ± SD)[a]	98 ± 4.56	97 ± 6.255	0.322	96 ± 2.27	95 ± 3.11	0.821	96 ± 2.77	95 ± 4.16	0.133	96 ± 2.61	95 ± 3.48	0.155	93 ± 3.16	91 ± 2.88	0.153
Pronation torque (%; mean ± SD)b															
90° of supination	94 ± 4.25	91 ± 8.15	0.083	95 ± 3.42	94 ± 4.77	0.137	96 ± 3.67	94 ± 7.33	0.112	96 ± 2.79	98 ± 7.44	0.233	97 ± 2.89	97 ± 9.65	0.121
45° of supination	95 ± 3.77	94 ± 4.8	0.266	96 ± 3.47	94 ± 7.23	0.155	96 ± 3.16	94 ± 2.9	0.255	97 ± 5.16	95 ± 7.27	0.070	96 ± 4.26	96 ± 4.55	0.77
Neutral	95 ± 3.16	94 ± 12.13	0.211	94 ± 3.17	93 ± 11.53	0.152	93 ± 3.44	91 ± 13.22	0.086	95 ± 3.31	94 ± 14.36	0.312	92 ± 4.11	91 ± 14.27	0.274
45° of pronation	95 ± 3.66	90 ± 8.45	**0.000**	94 ± 2.57	88 ± 10.15	**0.000**	95 ± 3.16	79 ± 11.22	**0.000**	95 ± 4.24	90 ± 9.75	**0.000**	96 ± 3.27	90 ± 9.75	**0.000**
80° of pronation	94 ± 3.42	87 ± 3.15	**0.000**	93 ± 2.88	87 ± 5.46	**0.000**	94 ± 2.78	84 ± 5.17	**0.000**	95 ± 3.61	90 ± 3.47	**0.002**	96 ± 2.69	90 ± 4.39	**0.015**
Supination torque (%; mean ± SD)[b]															
90° of supination	98 ± 2.16	97 ± 3.01	0.244	95 ± 4.67	95 ± 4.22	0.145	94 ± 3.27	96 ± 2.74	0.538	95 ± 2.66	97 ± 1.59	0.068	95 ± 3.95	96 ± 3.27	0.254
45° of supination	97 ± 2.35	96 ± 3.81	0.547	95 ± 3.28	96 ± 3.61	0.137	96 ± 3.84	95 ± 3.17	0.695	96 ± 4.52	95 ± 4.41	0.152	94 ± 4.73	95 ± 4.31	0.089
Neutral	97 ± 2.16	95 ± 4.62	0.171	93 ± 5.66	95 ± 4.24	0.092	95 ± 4.66	94 ± 5.48	0.74	96 ± 3.53	95 ± 3.18	0.157	95 ± 3.83	94 ± 5.48	0.624
45° of pronation	96 ± 3.24	97 ± 2.36	0.416	95 ± 3.87	95 ± 3.18	0.254	93 ± 6.58	74 ± 5.29	0.481	94 ± 5.28	96 ± 3.43	0.282	94 ± 5.26	93 ± 6.36	0.063
80° of pronation	95 ± 3.27	95 ± 4.22	0.155	96 ± 2.49	95 ± 3.15	0.75	95 ± 4.97	94 ± 5.63	0.782	96 ± 3.16	95 ± 3.53	0.268	97 ± 2.38	96 ± 3.84	0.352
Wrist joint pain (MWS)	8.9 ± 7.27	11.3 ± 9.41	0.215	8.5 ± 9.41	10.5 ± 8.24	0.33	7.9 ± 5.68	8.6 ± 9.75	0.255	8.4 ± 6.39	10.4 ± 9.2	0.07	9.6 ± 4.98	11.3 ± 8.44	0.463
Scar pain (VAS)	3.8 ± 4.5	8.22 ± 6.57	**0.001**	3.5 ± 3.2	7.47 ± 6.61	**0.000**	4.2 ± 3.2	6.3 ± 6.51	**0.035**	5.8 ± 3.6	9.3 ± 8.17	**0.003**	5.7 ± 4.7	12.41 ± 7.85	**0.000**
Wrist function (MWS; mean ± SD)	85 ± 14.36	79 ± 16.21	0.178	84 ± 11.58	81 ± 16.44	0.142	83 ± 14.51	80 ± 12.16	0.251	82 ± 13.24	78 ± 14.52	**0.012**	80 ± 15.87	75 ± 13.22	**0.001**
DASH	3.3 ± 3.41	3.7 ± 2.78	0.523	3.6 ± 3.71	3.9 ± 3.66	0.421	3.4 ± 3.27	3.5 ± 3.36	0.741	3.5 ± 3.15	4.8 ± 3.66	**0.021**	3.2 ± 3.27	5.6 ± 4.38	**0.000**
Aesthetics (VAS)	9.7 ± 0.34	7.5 ± 2.67	**0.000**	9.6 ± 0.57	7.4 ± 1.46	**0.000**	9.7 ± 0.24	7.5 ± 1.03	**0.000**	9.3 ± 0.61	7.8 ± 2.06	**0.000**	9.4 ± 0.38	7.3 ± 2.11	**0.000**
Satisfaction (VAS)	8.77 ± 1.32	7.51 ± 1.24	**0.000**	8.92 ± 1.01	7.02 ± 1.31	**0.000**	9.13 ± 1.01	7.04 ± 1.59	**0.000**	8.78 ± 1.21	7.03 ± 2.14	**0.000**	8.61 ± 1.95	7.03 ± 1.84	**0.000**

TBIO, time between injury to operation; SD, standard deviation.
ROM, range of motion; VAS, visual analogue scale.
DASH, disabilities of the arm, shoulder and hand scores.
MWS, Mayo Wrist Score.
REEDA, redness, edema, ecchymosis, drainage, approximation.
Statistical significance is set at $p < 0.05$.
[a] Grip strength and supination torque on nondominant limb add 6% to exclude discrepancy, in which percentages show involved limb compared with opposite normal side.
[b] Torque based on McConkey method.

approach and Henry's approach are commonly used. The incisions are often 6–8 cm or longer.[4,16,17] Those conventional approaches provide sufficient exposure in the management of the distal radial fractures.[18–20] During surgery, most of PQ is taken down from its radial origin to expose the underlying radius.[21,23] Armangil et al[24] found that the conventional technique damages the PQ, resulting in 18.5% loss of pronation strength and 12.9% loss of pronator durability. Swigart et al[22] found that PQ repair is generally durable, but has a failure rate of 4%. The PQ over the plate also provides protection against flexor tendon injury.[3] Huh et al[12] reported pronation strength decreased after surgery, but recovered 1 year later.

In a cadaver study, Zemirline et al[4] found volar plating via a 1.5 cm transverse incision was feasible. Recently, several minimally invasive approaches have been reported in the literature. Rey et al[25] reported their minimally invasive technique by sparing the PQ. They found a faster functional recovery. In a comparison between the conventional approach (n = 36) and small transversal approach (n = 30), Zenke et al[26] found no significant differences in volar tilt, radial inclination, ulnar variance, range of motion, grip strength, and disabilities of the arm, shoulder and hand scores. We have the similar data in the main outcomes. Different from Zenke's study, we add measurements on pronation, because PQ relates to the function. The PQ muscle is the main responsible for the pronation of forearm, and is helped by the pronator teres muscle. Our results show preservation of PQ provides benefits to pronation function, but the function may not affect the patient's daily life. Zenke et al found better cosmetic outcomes in the minimally invasive group, but no statistical significance. However, patient's age, culture, occupation, etc. may affect the results. Zenke had older age groups, and older patients often pay less attention on their scar appearance.

However, since the palmar branch of the median nerve arises in the distal forearm, a transverse incision carries a risk of iatrogenic injury to the branch, resulting in persistent pain.[5] In order to avoid those complications, we first preferred a longitudinal small incision between the flexor carpi radialis and the radial artery. Our study showed visualization and reduction of the fracture were acceptable. However, owing to inadequate surgical exposure, more frequent use of fluoroscope may prolong the time of operation, but all procedures were completed within 2 h. Although repair of PQ provides adequate protection on the overlaying tendons, pronation strength may decrease approximately 5%. The functional activities, such as turning a doorknob or a screwdriver, benefit from preservation of PQ.[27–30] Our shorter incision gave a better appearance, more rapid recovery, and better hand function, resulting in better patient satisfaction.

Several issues need to be addressed. First is implant selection. There are numerous plate and screw systems used for distal radius fractures. The selection is based on fracture pattern and surgeon's preference. Generally, a versatile system with multiple screws should be used for comminuted fractures. Second, the surgeons should avoid entrapment of flexor pollicis longus during plate insertion, though not happened in our series.

Advantages of the minimally invasive technique include less incision problems, better appearance, lower risk of iatrogenic injury to the palmar branch of median nerve, and preservation of PQ function. Disadvantage is inadequate surgical exposure, which may result in adequate anatomic reduction. However, repeated checks under fluoroscope can decrease the risk, and surgeon's experience is also critical for success. Nevertheless, the quality of the reduction is more important than scar appearance and desire to preserve the PQ. When technical difficulties arise, our longitudinal short incision can easily be converted to the conventional approach. Indications for our minimally invasive technique are AO/OTA classification type A2, A3, B3, C1, and C2 fractures. Contraindications are combined tendon, nerve, artery, or ligament injuries which need to be extensively exposed; dorsal fractures. Type B1 and B2 fractures are not contraindications, but the fractures are often treated with pins or through a dorsal approach. Type C3 fractures are too complex to treat through a small incision.

Our prospective study has limitations. The operations and assessments were done in different times, and surgeons' experience was improved with time, which may influence ascertaining the effects of the techniques. The patient can easily understand the type of the operation with the incision scar. At least, he or she can understand that the operations are not all the same. That can be an assessment bias.

Conclusion

Minimally invasive volar plating of distal radial fractures is a safe and reliable technique, resulting in better pronation function and cosmetic appearance.

References

1. Skouras E, Hosseini Y, Berger V, Wegmann K, Koslowsky TC. Operative treatment and outcome of unstable distal radial fractures using a palmar T-miniplate at a non-specialized institution. *Strateg Trauma Limb Reconstr*. 2013;8:155–160.
2. Protopsaltis TS, Ruch DS. Volar approach to distal radius fractures. *J Hand Surg Am*. 2008;33:958–965.
3. Ahsan ZS, Yao J. The importance of pronator quadratus repair in the treatment of distal radius fractures with volar plating. *Hand (N Y)*. 2012;7(3):276–280.
4. Zemirline A, Naito K, Lebailly F, Facca S, Liverneaux P. Distal radius fixation through a mini-invasive approach of 15 mm. Part 1: feasibility study. *Eur J Orthop Surg Traumatol*. 2014;24:1031–1037.
5. Matloub HS, Yan JG, Mink Van Der Molen AB, Zhang LL, Sanger JR. The detailed anatomy of the palmar cutaneous nerves and its clinical implications. *J Hand Surg Br*. 1998 Jun;23(3):373–379.
6. Alm-Paulsen PS, Rod O, Rød K, Rajabi B, Russwurm H, Finsen V. Percutaneous pinning of fractures of the distal radius. *J Plast Surg Hand Surg*. 2012;46:195–199.
7. Ido K, Shimizu K, Nakayama Y, Shikata J, Matsushita M, Nakamura T. Suction/irrigation for deep wound infection after spinal instrumentation: a case study. *Eur Spine J*. 1996;5:345–349.
8. Li-hai Z, Ya-nan W, Zhi M, et al. Volar locking plate versus external fixation for the treatment of unstable distal radial fractures: a meta-analysis of randomized controlled trials. *J Surg Res*. 2015;193:324–333.
9. Morshed S. Current options for determining fracture union. *Adv Med*. 2014;9:1–14.
10. Rajan P, Premkumar R, Rajkumar P, Richard J. The impact of hand dominance and ulnar and median nerve impairment on strength and basic daily activities. *J Hand Ther*. 2005;18:40–45.
11. McConkey MO, Schwab TD, Travlos A, Oxland TR, Goetz T. Quantification of pronator quadratus contribution to isometric pronation torque of the forearm. *J Hand Surg Am*. 2009;34:1612–1617.
12. Huh JK, Lim JY, Song CH, Baek GH, Lee YH, Gong HS. Isokinetic evaluation of pronation after volar plating of a distal radius fracture. *Injury*. 2012;43:200–204.
13. Crosby CA, Wehbé MA, Mawr B. Hand strength: normative values. *J Hand Surg Am*. 1994;19:665–670.
14. Mac Dermid JC, Turgeon T, Richards RS, Beadle M, Roth JH. Patient rating of wrist pain and disability: a reliable and valid measurement tool. *J Orthop Trauma*. 1998;12:577–586.
15. Green DP, O'Brien ET. Classification and management of carpal dislocations. *Clin Orthop Relat Res*. 1980;149:55–72.
16. Fernandez DL. Distal radius fracture: the rationale of a classification. *Chir Main*. 2001;20:411–425.
17. Orbay J, Badia A, Khoury RK, Gonzalez E, Indriago I. Volar fixed-angle fixation of distal radius fractures: the DVR plate. *Tech Hand Up Extrem Surg*. 2004;8:142–148.
18. Rampoldi M, Palombi D, Tagliente D. Distal radius fractures with diaphyseal involvement: fixation with fixed angle volar plate. *J Orthop Traumatol*. 2011;12:137–143.
19. Shin EK, Jupiter JB. Current concepts in the management of distal radius fractures. *Acta Chir Orthop Traumatol Cech*. 2007;74:233–246.
20. Valentini R, De Fabrizio G, Piovan G, Bolcic S, Bernobi S, Fancellu G. Distal radius fractures: surgical treatment with internal fixation. *Acta Biomed*. 2014;22(85):31–36.
21. Sreedharan S, Mohd Fadil MF, Lim WS. Intra-operative correction of volar tilt of distal radius fractures using volar locking plate as reduction tool: review of 24 cases. *Hand Surg*. 2014;19:363–368.

22. Swigart CR, Badon MA, Bruegel VL, Dodds SD. Assessment of pronator quadratus repair integrity following volar plate fixation for distal radius fractures: a prospective clinical cohort study. *J Hand Surg Am*. 2012;37:1868–1873.
23. Stuart PR. Pronator quadratus revisited. *J Hand Surg Br*. 1996;21:714–722.
24. Armangil M, Bezirgan U, Başarır K, Bilen G, Demirtaş M, Bilgin SS. The pronator quadratus muscle after plating of distal radius fractures: is the muscle still working? *Eur J Orthop Surg Traumatol*. 2014;24:335–339.
25. Rey PB, Rochet S, Loisel F, Obert L. Technical note: how to spare the pronator quadratus during MIPO of distal radius fractures by using a mini-volar plate. *Chir Main*. 2014;33:95–99.
26. Zenke Y, Sakai A, Oshige T, et al. *J Orthop Trauma*. 2011;25:425–431.
27. Bhandari M, Fong K, Sprague S, Williams D, Petrisor B. Variability in the definition and perceived causes of delayed unions and nonunions: a cross-sectional, multinational survey of orthopaedic surgeons. *J Bone Jt Surg Am*. 2012;94(15):e1091–e1096.
28. Williams KG, Smith G, Luhmann SJ, Mao J, Gunn 3rd JD, Luhmann JD. A randomized controlled trial of cast versus splint for distal radial buckle fracture: an evaluation of satisfaction, convenience, and preference. *Pediatr Emerg Care*. 2013;29:555–559.
29. Chmielnicki M, Prokop A. New minimally invasive approach for palmar plating in distal radius fractures. *Z Orthop Unf*. 2015;153:25–28.
30. Timm WN, O'Driscoll SW, Johnson ME, An KN. Functional comparison of pronation and supination strengths. *J Hand Ther*. 1993;6:190–193.