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Results of fixation of comminuted distal radius intra-articular fractures using volar variable angle locked plate

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Abstract

Background: Intra-articular fractures of the distal radius are commonly encountered injury. It is prevalent in the elderly due to osteoporosis. There is still controversy on the most optimal treatment method.

Patient and method: This is a prospective study conducted on forty patients with intra-articular fracture of the distal radius. The mean age of the studied group (n = 40) was 40±15 years, ranging from 25 to 55 years. Six patients (15%) were 50 years of age or older, and 34 patients were younger than 50 years (85%). There were 34 males and 6 females. Thirteen patients were left-handed, and 27 were right-handed. Twenty-six patients were manual workers, and 14 patients were office workers.

Results: At the final follow-up, according to the Mayo wrist score, 70% of patients achieved excellent, 25% good, and 5% fair results. According to the Sarmiento radiological score, eighty-five percent of the patients achieved excellent outcomes, 13% achieved good results, and 2% achieved fair results. In the current study, few complications were recorded in 7 patients, including 2 malunions, 2 superficial infection, 2 complex regional pain syndrome with stiffness, and one carpal tunnel syndrome.

Conclusion: The concept of the volar locking plates with variable-angle screws as becoming widely used for treatment of distal radius fractures is an effective method and associated with excellent and good functional outcome. We are reporting a technical point of inserting the first screw in the ulnar hole of the plate as recommended to achieve proper reduction of the fracture fragments.

Keywords: Fixation, comminuted distal radius, intra-articular fractures, volar, variable angle locked plate

Introduction

Distal radius fractures are a common orthopedic injury with a bimodal distribution pattern. They account for approximately 17% of all fractures [1]. In the younger age group, it is a result of high energy injury, but in elderly, it is the result of low energy falls. Of these injuries, about half are intra-articular. However, despite this high incidence, there remains no consensus regarding the optimal treatment strategy [2]. Common treatment options currently include closed reduction with percutaneous pinning, external fixation, and various open reduction and internal fixation strategies [3].

The main goals of treatment are restoring normal anatomy and obtaining a functional joint. The most complicated fractures of the distal radius are high-energy, comminuted, intra-articular, and unstable fractures. The best treatment choice depends on the characteristics of the fracture (Open/closed, non-displaced/displaced, extra/intra-articular) [4].

External fixation (EF) (With/without percutaneous Kirschner-wires) can be an effective way for treatment with minimal invasion. However, for some displaced or comminuted distal radius fractures, it is very difficult to obtain and maintain an ideal reduction, even with the use of EF. There is a consensus in the literature that these fractures require internal fixation with various forms of implants [5].

Currently, internal fixation with volar locking plates has become increasingly popular as it can provide proper stability and prevent damage of the dorsal extensor tendons [6].

The objective of this study was to assess the clinical and radiological results of fixation of comminuted distal radius intra-articular fractures using a volar variable angle locked plate in 40 skeletally mature patients.

Patients and Methods

This was a prospective study conducted on forty patients with intra-articular fractures of the distal radius managed between January 2023 and January 2024.

Inclusion criteria were cases aged 18 to 60 years old with recent comminuted and closed intra-articular fracture of distal radius with no contraindications for anesthesia.

Cases with extra-articular fractures, neglected fracture, open fracture, associated compromised soft tissue coverage, associated neurovascular injury, or associated ipsilateral limb fracture were excluded from the study.

Operative Procedure

The flexor carpi radialis (FCR) approach (Modified Henery approach) as described by Orbay and Fernandez was used in all cases, under general anesthesia in supine position with pneumatic tourniquet applied on the upper arm and affected forearm supinated. Intravenous broad-spectrum antibiotic was given 15 minutes before the tourniquet was applied. Incision was placed directly over the course of the FCR tendon for about 8-10 cm long, stopping at the wrist flexion crease. The superficial fascia was incised longitudinally, and the same for the FCR sheath; then the FCR tendon was retracted medially, protecting the median nerve and the radial artery was retracted laterally. The floor of the FCR sheath was incised distally till the scaphoid.

The dissection was taken down to the surface of the distal radius by developing the space between the flexor pollicis longus (FPL) tendon and the radial septum (A fascial structure consisting of the inter-muscular membrane insertion of the brachioradialis and the first extensor compartment), then the virtual space between the flexor tendons and the volar surface of the pronator quadratus (PQ) (Space of Parona) was developed. The PQ was then mobilized subperiosteally by releasing its lateral and distal borders with an L-shaped incision, leaving a rim of the muscle for late repair after plate application. The site for the transverse distal limb of this incision was determined by palpation of the volar rim of the lunate fossa. This subperiosteal mobilization of the PQ from its bed exposed the fracture site.

Proper fracture reduction was obtained by disimpacting the palmar cortex of the distal fragments with traction, then hyperflexion of the wrist to restore the normal volar tilt. In some cases with intra-articular step-off and fragment depression, we used a small bone lever to elevate the depressed fragment, then a variable angle volar locked plate for distal radius was applied after confirming the reduction on the image intensifier. The plate should not project above the watershed line (Imaginary line marking the most distal aspect of the volar margin of the radius that is distal to the PQ line and it is covered by the volar capsule). After checking fracture reduction, the position of the plate, and the radial height on image intensifier, the distal screws were applied, fixing the distal fragment and supporting the subchondral bone. We fixed the first screw under the lunate fossa, which allowed us to restore the middle column of the distal radius that acts as a constant fragment helped in reduction and restoration of the other columns. It also

helped in restoration of the normal axis of the radiocarpal joint which passes through the capitate and the third metacarpal bone, and the center of rotation of the wrist joint that lies on the proximal pole of the capitate. Radiological imaging was essential in this step, taking anterior-posterior, lateral, and oblique views to ensure regaining of the normal radiological parameters of the distal radius and confirming extra-articular position of the screws. (Figure 1)

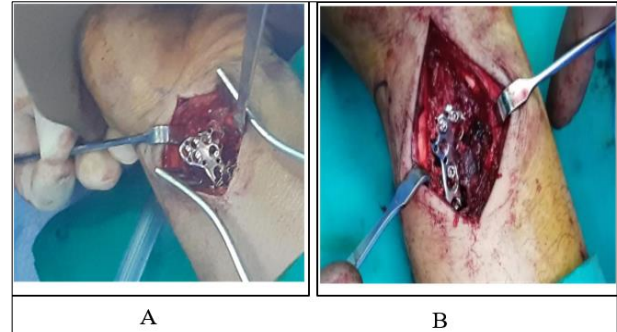


Fig 1: Insertion and fixation of the plate after reduction of fracture (A: insertion of distal screws, B: insertion of the proximal screws)

A final imaging check was done after seating all the screws, which included anterior-posterior, lateral, oblique, and dorsal horizon views, to confirm no screws penetrated the joint. The L-shaped incision of the PQ muscle was repaired by interrupted sutures to cover the plate and avoid frictional irritation of the flexor tendons. Stability of the distal radioulnar joint was assessed clinically and on the image intensifier; in cases of instability, a transverse Kirschner wire from the distal ulna to the distal radius was inserted, and its position was checked on the image intensifier. The tourniquet was deflated, and hemostasis was carried out before subcutaneous and skin closure. A removable wrist support was applied. Broad-spectrum antibiotics were given for 2 days.

Postoperative Regimen

Wrist support was removed at the time of stitches removal 2 weeks after surgery. Cases with distal ulno-radial wires were kept in an above elbow posterior slab for 4 weeks, to prevent supination and pronation stressing the transfixing wire. Active range of movements started after wound healing. Strenuous movements and activities were prohibited, except after radiological fracture union.

Methods of Radiological Assessment

All cases were evaluated by X-rays with anterior-posterior and lateral views immediately postoperatively, at periods of 2, 4, 6, 12 weeks, and thereafter at 6 and 12 months for bone union, position of the hardware, radiological parameters of the distal radius and assessment of the DRUJ. At the final follow up, clinical results were evaluated by the Mayo wrist score and radiological results by the Sarmiento radiographic score. The follow up duration was about 12 months.

Results

Demographic results and mechanism of injury

The mean age of the studied group (n=40) was 40±15 years, ranging from 25 to 55 years. Six patients (15%) were 50 years or older, and 34 patients were younger than 50 years (85%). There were 34 males, and 6 females. Thirteen patients were left handed, and 27 were right handed.

Twenty-six patients were manual workers, and 14 patients were office workers (Table-1).

Table 1: Demographic results of study group.

Age Group of Patients	Less than 50 years old	34 (85%)
	More than 50 years old	6 (15%)
Sex	Male	34 (85%)
	Female	6 (15%)
Side	RT	27 (77%)
	LT	13 (23%)
Occupation	Manual worker	26 (65%)
	Office worker	14 (35%)

Regarding the cause of trauma, falling on outstretched hand was the most frequent cause followed by falling from a height while road traffic accident was the least common cause (falling on an outstretched hand 80%, fall from height 15%, RTA 5%) (Table-2). Regarding injury-to-treatment interval, 70% of patients were operated on the same day of trauma and 30% of patients within 10 days of trauma due to severe swelling at the fracture site. The mean operation time was 45.5 ± 10.75 minutes.

Table 2: Mechanism of injury

Category	Subgroup	Number (%)
Cause of Trauma	Falling on outstretched hand	32 (80%)
	Falling from height	6 (15%)
	RTA	2 (5%)
Injury to Treatment Interval	On the same day	28 (70%)
	Within 10 days	12 (30%)

Clinical outcome according to the Mayo wrist score: At the final follow-up, the clinical evaluation tests pain, ROM, grip strength, and restoration of wrist activities or functional status. It showed that 70% of patients achieved excellent outcome, 25% good, and 5% were fair results (Table-3).

Table 3: Treatment outcome according to the Mayo wrist score.

Total score	80.5(65-90)
Pain	20(15-25)
ROM	18.5(10-25)
Grip strength	16(10-25)
Function status	20(15-25)
Classification	
Excellent	28 (70%)
Good	10 (25%)
Fair	2 (5%)
Poor	0

Radiological outcome according to the Sarmiento radiological score: At the final follow up, 85% of the patients achieved excellent radiological outcome, 13% good and 2% fair results (Table-4).

Table 4: Treatment outcome according to the Sarmiento radiological score.

Radiological Parameters Evaluated	
Volar tilt	5.4° (0-10.7) $^\circ$
Radial height	9.5 (3-16) mm
Radial inclination	20.75° (13.4-28.1) $^\circ$
Classification	
Excellent	34(85%)
Good	5(13%)
Fair	1(2%)
Poor	0

Post-operative complications

We encountered in our study few complications in 7 patients including 2 mal-unions, 2 superficial infections, 2 complex regional pain syndrome with stiffness and one patient with transient median nerve symptoms. Superficial infection was managed by meticulous wound care undercover of broad spectrum antibiotic. The patient with median nerve symptoms and those with reflex sympathetic dystrophy responded well with conservative treatment. Mal-union in 2 cases was due to residual fracture displacement caused by the severe comminution that affected the radiological results (Table-5).

Table 5: Post-operative complications.

Total number of Patients	7
Malunion	2
Complex regional syndrome & decreased ROM	2
Superficial Infection	2
Median nerve symptoms	1

Discussion

Intra-articular fractures of the distal radius are commonly encountered injury. Current treatment goals are centered on restitution of bony anatomy of the distal radius (radial inclination, radial length, and volar tilt), with specific attention to restoration of the articular surfaces of the radiocarpal and radioulnar joints [7].

Various implants are used for the treatment of intra-articular distal radius fractures. Locking variable-angle volar plates provide an absolutely stable construct with stable alignment between the metaphysis and diaphysis, which might not be possible with the conventional non-locking volar plates or external fixation [8].

Volar locking plates have shown better results in comparison to non-locking volar and dorsal plates in biomechanical studies. Rausch *et al*, found that these plates have higher construct stiffness and superior properties under cyclic loading than mono-axial fixed-angle plates. [9] Locking variable-angle volar plate allows variation in the angle of insertion of each screw, which allows the surgeon to respond to any variation in the normal bony anatomy and to target specific bone fragments to allow for secure subchondral placement of the distal screws, which is more difficult in fixed-angle plates [10].

The aim of our study was to evaluate the outcome of management of intra-articular distal radius comminuted fractures with variable angle volar locked plates using the Mayo wrist score and Sarmiento radiological score. The Mayo wrist score depends on evaluating only the wrist joint. On the other hand, the DASH score as it is a 30 items self-reported questionnaire includes several moves, functions and activities which can depend on other joints or parts of the upper limb to be done with individual differences. In addition, the Mayo wrist score evaluation is done by the surgeon himself which is a fixed factor between all the patients.

In our current study, there were 40 patients with an intra-articular fracture of the distal radius. The mean age of the studied group was 40 ± 15 years. They were 34 males and 6 females. The most common mode of trauma was falling on outstretched hand (80%), followed by falling from a height and RTA (20%). The duration of follow-up was about 12 months.

At the end of the follow-up period, according to the Mayo wrist score, 28 patients (70%) had excellent results (Score 90-100), 10 patients (25%) had good results (Score 80-90), and 2 patients had fair results (5%) (Score 60-80), with no patients had poor results. The score ranged from 65 to 90 with a mean of 80.5.

In a study by Kwan K *et al.*, on 75 patients with distal radius fractures managed by locking variable-angle volar plates, an excellent or good result was obtained in 96% of patients according to the modified Green and O'Brien score. ⁽¹¹⁾ In our current study, excellent and good results were obtained in 95%, which is comparable to their study. In another study by Jagodzinski NA *et al.*, excellent results were reported in 36% of patients, good results in 51%, and fair results in 13%. ⁽¹²⁾ Fig. M, *et al.*, reported a mean quick DASH score of 18.2 in patients treated with locking variable-angle volar plates ⁽¹³⁾.

The range of motion of the wrist was evaluated at the end of the follow up period. Dorsiflexion ranged from 50 to 70° with a mean of 60° while palmar flexion ranged from 65 to 80° with a mean of 70.4°. Supination ranged from 55 to 75° with a mean of 63.8°, while pronation ranged from 65 to 85 degrees with a mean of 70.4 degrees. Radial deviation ranged from 7 to 16° with a mean of 11.5°, while ulnar deviation ranged from 18.2 to 30° with a mean of 20.9°. These values corresponded well with the functional daily requirements. By comparing our results with those of Ross M *et al.*, ⁽¹⁴⁾ our study was found to have comparable results. They used variable angle volar locked plate in 23 unstable distal end radius fractures. According to Gartland and Werley score excellent results were reported in 65%, while good results were present in 35%, the mean flexion was 71.91 °±8.08, the mean extension was 76.95 °±5.70, the mean pronation was 77.65 degrees ±6.01 and the mean supination was 81.86 degrees ±6.28 ⁽¹⁴⁾.

Spiteri M *et al.*, found that postoperative ROM was variable and grip strength was 71% of the uninjured contralateral side with the use of variable angle locked plate in their study ⁽¹⁵⁾. In Vleck M *et al.*, study they compared the performance of the poly-axial locking plate with mono-axial plate and reported an improved range of radial and ulnar deviation with the variable angle locked plate ⁽¹⁶⁾.

At the end of the follow up period, using the Sarmiento radiological score, 34 patients had excellent results, 5 patients had good results and one patient had fair result with no poor results. Radial inclination ranged from 13.4° to 28.1° (mean 20.75°), the volar tilt ranged from 0° to 10.7° (mean 5.4°) and the radial height ranged from 3-16 mm (mean 9.5 mm). By comparing our study to Ross M *et al* study, we found our results comparable to which they reported, the radial height mean was 10.84 mm±2.04, radial inclination mean was 22.89°±2.64 and the volar angulation mean was 5.21°±2.72 ⁽¹⁴⁾.

Sim JC *et al.*, and Mulder *et al.*, analyzed the results of 45 cases treated by a variable-angle volar-locked plate. At the end of the follow-up period, the mean radial length was 10.25 mm (6.2-14.3) mm, the radial inclination was 23.9° (15.9-31.6) °, and the volar tilt was 8.5° (1.3-15.8) °. ⁽¹⁷⁻¹⁸⁾

In the current study, eight patients had an associated ulnar styloid fracture; two of them were fixed. There was no significant difference in the final outcome score between patients who underwent ulnar styloid fixation and those who did not. There was no significant difference regarding the

final outcome score between patients with associated ulnar styloid fracture and those without.

Kale SY *et al.* reported that no significant differences were found in Patient-Rated Wrist Evaluation scores, range of motion, grip strength, pain scores, ulnar-sided wrist pain and distal radio-ulnar joint instability between patients with and without ulnar styloid process fracture after one year of follow-up. Moreover, no significant differences were found between ulnar styloid base and non-base fractures ⁽¹⁹⁾.

In the current study, there was a significant correlation between radiological and functional end results. Patients with excellent radiological results achieved excellent functional end results, patients with good radiological results achieved excellent and good functional results, and none of the patients with fair radiological results achieved excellent functional results. Kale SY *et al.*, reported that radiological parameters have an effect on functional outcome in at six months of follow up and the more the number of radiological parameters affected, the poorer the functional outcome ⁽¹⁹⁾.

In our study, we fixed the first screw under the lunate fossa, which allowed us to restore the middle column that acts as a constant fragment which helped in reduction and restoration of the other columns. It also helped in restoration of the normal axis of the radiocarpal joint which passes through the capitate and the third metacarpal bone, and the center of rotation of the wrist joint that lies in the proximal pole of the capitate. This was reflected on patient's outcome clinically and radiologically (Figure 2). The presence of severe comminution might not help in accurate restoration of the medial column of the distal radius first, and this will be reflected on the outcome of the patient (Figure 3).



Fig 2: Pre-operative and 12 months post-operative X-rays with excellent radiological and clinical outcomes



Figure (3): Pre-operative and follow up X-rays with residual displacement and decrease radial high 8 months after surgery, with fair outcome.

We encountered few complications in our study in 7 patients, where two patients had a superficial infection treated with proper wound care and antibiotics as outpatients. These patients achieved excellent and good results in both functional and radiological scores; however, two other patients developed complex regional pain syndrome associated with decreased ROM. Both of them responded well to physiotherapy, pain management, and medical treatment and had good results in both the radiological and functional scores. Mal-union was observed

in two male patients. The first patient, an office worker, sustained a fracture type OTA-2R3C2 on his non-dominant left side. He frequently skipped his physiotherapy sessions, and no reoperation was performed as he accepted the functional status of the affected wrist with fair radiological and functional results were reported. The second patient was a reconstruction worker who sustained a severe comminuted fracture of his dominant hand. He started strenuous and full-active movements before full and proper healing despite repeated warnings from us. At the end of follow-up, he recorded a fair result in the functional score and a good result in the radiological score, but the patient refused a revision surgery as he was satisfied with his results. Transient median nerve symptoms occurred in one housewife patient and improved after 2 weeks with conservative treatment.

The limitations of the current study were represented by the small number of patients, the short duration of the follow-up, and the heterogeneity of the patient's occupations. We suggest future studies with larger group of patients and longer follow-up period for the results to be more conclusive.

Conclusion

The concept of the volar locking plates with variable angle screws is an effective method associated with excellent and good functional outcomes for fixation of intra-articular distal radius fractures. Fixation of the styloid process fracture of the ulna is not a must and does not functionally affect the outcome. We recommend fixing and restoring the middle column by inserting the screw under the lunate fossa first to facilitate reduction of the other columns and to restore the normal axis of the radiocarpal joint and the center of rotation of the wrist joint.

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