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Use of Volar Locking Plate Versus Intramedullary Nailing for Fixation of Distal Radius Fractures: A Retrospective Analysis of Clinical and Radiographic Outcomes

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Background: The objective of this study was to evaluate clinical and radiographic outcomes of volar plate versus intramedullary nailing for fixation of distal radius fractures.

Material/Methods: This retrospective study included 64 patients with extra-articular and simple intra-articular fractures of the distal radius who underwent intramedullary fixation using volar locking plate (n=35, mean age 47.3±16.4 years, 82.9% female) or intramedullary nailing (n=29, mean age 51.3±10.1 years, 58.6% female). Outcome measures were range of motion (ROM); visual analog scale (VAS); Disabilities of the Arm, Shoulder, and Hand (DASH) score; Gartland-Werley score; Stewart score; and radiographic findings.

Results: Time to fracture union was 5.5±1.2 and 5.2±0.6 weeks after volar plate fixation and intramedullary nailing, respectively (p>0.05). Compared to volar plate fixation, intramedullary nailing provided better restoration of volar tilt (6.9±6.3° *vs.* 9.4±1.6°, p=0.004) and wrist flexion (74.3±15.1° *vs.* 67.9±13.1°, p=0.003). However, volar plate fixation was significantly better in restoration of supination (85.0±8.3° *vs.* 81.9±5.1°, p=0.001) and radio-ulnar variance (0.7±0.8 mm *vs.* 1.1±0.9 mm, p=0.05), DASH score (9.2± 9.0 *vs.* 15.0 ±3.3, p=0.035), and Gartland-Werley score (1.8±0.9 *vs.* 4.9±5.4, p=0.004). Volar plate and intramedullary nailing groups were comparable with respect to Stewart score (1.5±0.7 and 1.6±1.3, p>0.05) and complication rates (34.3% *vs.* 37.9%, p>0.05).

Conclusions: Both volar plate fixation and intramedullary nail fixation provide good clinical and radiographic outcomes for primarily extra-articular or simple intra-articular distal radius fractures. As intramedullary nailing provides better restoration of volar tilt and wrist flexion, volar plate fixation provides better restoration of radio-ulnar variance and wrist supination.

MeSH Keywords: Fracture Fixation, Intramedullary • Radiography • Radius Fractures • Volar Plate

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Background

Fracture of the distal radius is a common injury, with lifetime acquisition risk of 15% in women and 2% in men and accounts for 8% to 15% of all skeletal injuries encountered in orthopedics practice [1–6].

Ranging from cast immobilization, percutaneous pinning, and external fixation to internal fixation with plates and intramedullary fixation, various treatment alternatives for distal radius fractures are available depending on the fracture pattern, degree of displacement, co-morbid injuries, and patient characteristics [4–7].

Volar locking plate fixation is increasingly used in treating distal radius fractures, given its advantages over standard volar fixation because it provides stable fixation, even in comminuted fractures of osteoporotic bone [8,9], it has a lower rate of complications than dorsal fixation [10,11], and many studies of patients with distal radius fractures showed favorable radiological and clinical outcomes, with early mobilization and rapid recovery and improved wrist function reported [8,9,12–15].

However, while open reduction and internal fixation with metal implants on the surface of the distal radius is becoming a more widely used technique that allows better reduction of the fracture fragments and more secure fixation, it necessitates more extensive surgical exposure and soft tissue stripping, as well as the risk of hardware problems such as prominence and tendon irritation, which may require removal of the implant [3,7,16–18].

Therefore, while volar plating of the distal radius provides an improved soft tissue envelope during re-approximation of pronator quadratus over the implant, tendon ruptures and hardware problems are still reported [7,19–23]. In addition, the improved function achieved during the early period after surgery, functional and radiographic outcomes may become similar to those of other treatment modalities during later periods of follow up [9].

Combining stable fixation with minimal soft tissue dissection, intramedullary fixation of fractures of the distal radius has become an emerging concept, with specific implants and intramedullary devices designed and currently available for the surgical treatment of various distal radius fractures [3,7,24,25].

While the initial techniques of intramedullary nailing of the distal radius with percutaneous pins (rods) failed to provide support of the subchondral bone and thus to prevent articular collapse [25], modified intramedullary devices such as the intramedullary nail (Wright Medical Technology Inc., Arlington, TN) [7] allow for fixed-angle support of the subchondral bone, and combine stable fixation with minimal soft tissue dissection [3,25,26].

The advantages of intramedullary fixation have been reported to include minimally invasive surgical techniques, less opportunity for hardware irritation, decreased postoperative pain, and stable fixation allowing for early range of motion (ROM) and patient rehabilitation [3,24,25]. However, several complications have also been reported, including injury to the superficial branch of the radial nerve, screw penetration into the distal radial ulnar joint, and loss of reduction [25]. Although early clinical reports provide promising results for the intramedullary fixation for extra-articular (AO type 23-A) and simple intra-articular (AO type 23-C1 and C2) distal radius fractures, limited data are available on the outcome of these techniques [4,7,25–30].

This retrospective study was therefore designed to compare clinical and radiographic outcomes associated with use of volar locking plate versus intramedullary nailing for fixation of primarily extra-articular or simple intra-articular distal radius fractures.

Material and Methods

Study population

A total of 64 patients with primarily extra-articular and simple intra-articular fractures of the distal radius who underwent volar locking plate (n=35) or intramedullary nail (n=29) fixation at our clinic between February 2011 and March 2016 were included in this retrospective study. Patients with unstable extra-articular distal radius fractures and simple intra-articular distal radius fractures suitable for closed reduction (AO types; A2.2, A2.3, A3.1 C2.1, and C2.2) were included in the study. Patients with open or contaminated wounds without adequate soft tissue coverage, open physes, significantly displaced intra-articular fragments, irreducible articular or extra-articular fractures, partial articular fractures involving the volar or dorsal rim (AO type 23-B), and cases in which the articular fragments are small, comminuted, and cannot be reduced adequately by closed or percutaneous means and fracture extension proximally into the metaphyseal-diaphyseal bone were excluded from the study.

The study was conducted in full accordance with local Good Clinical Practice (GCP) guidelines and current legislation, and permission was obtained from our institutional ethics committee for the use of patient data for publication purposes.

Operative techniques

All operations were performed by the same surgeon (MC). Initially, closed reduction and circular casting were applied in

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all the patients with primarily extra-articular or simple intra-articular fractures of the distal radius. Cases with subsequent findings on radiography following casting including volar tilt >20°, articular incongruity >2 mm, radial inclination>15°, and radial shortening >5 mm were treated surgically.

The Micronail® (Wright Medical Technologies, Arlington, TN) is a rigid distal radius nail used for a minimal invasive intramedullary fixation for two-part dislocated extra-articular fractures and average displaced intra-articular fractures. Use of the Micronail® reduces soft tissue complications and provides fixed-angle support [32].

Intramedullary nailing was performed under local or general anesthesia and fluoroscopic control in supine position. First, closed reduction and temporary fixation using a K-wire introduced from the ulnar side of the radius were performed. Subsequently, an incision 2 cm in length over the radial styloid process was made to create a cortical window between the first and second compartments, through which an appropriately sized implant was placed following the scraping process. Fixation was performed via 3 distal subchondral (locking) screws. A new incision 2 cm in length was made dorsally for proximal locking and fixated using 2 screws under fluoroscopy. Incisions sites were sutured.

In the volar plate group, a 10–12 cm dissection was made over the flexor carpi radialis extending to the wrist line at the distal end. The tendon sheath of the FCR was opened and retracted laterally to reach the pronator quadratus muscle. The pronator quadratus was split from the radial border, and the muscle was retracted ulnarly. When necessary, the brachioradialis muscle was released to prevent it from applying load to the fragments in the radial styloid region. The distal segment was pronated and fracture fragments in the dorsal cortex were reduced. The volar aspect of the distal radius and the fracture were identified. The fracture was reduced using direct and indirect means. A volar locking plate (Acumed Acu-Loc® Wrist Plating System, Acumed Headquarters, Hillsboro, Oregon) was applied on the volar aspect of the distal radius. The repositioning of the fragments and localization of the plate were rechecked with C-arm fluoroscopy. A screw was placed first in the hole of the plate located on the shaft of the distal radius, then in the hole at the side of ulnar notch, and finally in the holes located on the side of the styloid process. The position was checked with intra-operative radiographs in the posteroanterior and lateral projections, and we examined the range of motion and fracture stability before skin closure.

Postoperative treatment consisted of a wrist splint for 5 days and finger motion was started immediately after the operation. Approximately 1 week after surgery, the splint was removed and radiographs were taken. As long as there were no complications, load-carrying physical therapy was initiated. Clinical results were evaluated during 6-month follow-up by 4 consecutive visits at week 3, week 6, week 12, and month 6.

Assessments

Data on patient demographics (age and sex), handedness, type of injury, type of distal radius fracture, concomitant fractures, duration of follow-up, length of hospital stay (LOS), total surgery and scopy time, and time to fracture healing were recorded for each patient. Clinical outcome measures included ROM, visual analog scale (VAS), functional outcomes [patient-reported Disabilities of the Arm, Shoulder, and Hand (DASH) score and clinician-based Gartland-Werley score], radiographic scores (Stewart score), and parameters (radial inclination, volar tilt, radial height, and radio-ulnar variance) related to quality of radiographic reduction and complications. Radiographic criteria of acceptable healing defined by Graham et al. were used for evaluation [31]. All parameters were compared between volar plate and intramedullary nailing groups.

DASH score

The DASH score is a patient-reported functional outcome measure that aims to assess the patient's own perception of upper-extremity function, based on 6 subscales (30 items) including activities of daily living (105 points), social activities (5 points), work activities (5 points), symptoms (5 points), sleeping (5 points), and confidence (5 points). The scores are normalized to 100, with a minimum score of zero points and a maximum score of 100 points. Higher scores indicate lower function [33–35].

Gartland-Werley score

Gartland-Werley score is one of the most commonly used clinician-based outcome measures for evaluating wrist and hand function; it relies on the concept that a minimum of 45° dorsiflexion, 30° palmar flexion, 15° ulnar and radial deviation and 50° pronation and supination is normal. It consists of 4 subscales and evaluates objective findings (ROM and pain), subjective assessment, and radiographic findings, in addition to complications and residual deformity. Higher scores indicate lower function [35,36].

Radiographic score and parameters

Radiographs of the anteroposterior and lateral view of the involved wrist were obtained preoperatively, postoperatively, and at all follow-up time points to assess the adequacy of reduction. Radiographic confirmation of distal radius fracture union was defined as the complete disappearance of fracture lines in the anteroposterior, lateral, and internal oblique views

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as determined by a single radiologist who was blinded to the aim and protocol of this study.

The Stewart score system relies exclusively on radiological findings, classified into 3 scales: final dorsal angle (4 points), loss of radial angle (4 points), and loss of radial length (4 points). The resulting score is classified into 1 of 4 categories: excellent (0 points), good (1–3 points), fair (4–6 points), and poor (7–12 points) [37].

Statistical analysis

Statistical analysis was made using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY). The chi-square (χ^2) or Fisher exact test were used for the comparison of categorical data, while the Student t test or Mann-Whitney U test were used to compare continuous data according to the normality of the data. To compare preoperative and postoperative continuous variables, the paired t test or Wilcoxon signed rank test were used according to the normality of the difference in variables. Data are expressed as mean ± standard deviation (SD) or and percent (%), as appropriate. $p<0.05$ was considered statistically significant.

Results

Baseline characteristics in study groups

Mean age was 47.3±16.4 and 51.3±10.1 years; and 82.9% and 58.6% were females in the volar plate and intramedullary nail groups, respectively. The percentage of females was significantly higher in the volar plate group than in the intramedullary nail group (82.9% *vs.* 58.6%, p=0.032), while the 2 groups were homogenous in terms of age. Falls were the leading type of injury in both groups (57.1% and 65.5%, respectively) and distribution of distal radius fractures according to AO type was similar in both groups (Table 1).

Intra-operational characteristics and outcome measures in study groups

Patients in the intramedullary nail group had significantly longer follow up (33.3±2.7 weeks *vs.* 12.6±2.1 weeks, p<0.001) and scopy time (21.4±3.9 min *vs.* 15.7±2.5 min, p<0.001), but they had shorter total surgery time (33.6±2.6 min *vs.* 41.1±10.1 min, p=0.001) compared with patients in the volar plate group. No significant difference was noted between volar plate and intramedullary nail groups in terms of time to fracture union (5.5±1.2 weeks and 5.2±0.6 weeks, respectively) and LOS (3.5±1.5 days and 4.0±0.5 days, respectively) (Table 2).

ROM scores were similar for wrist extension and pronation between groups, but the volar plate had significantly lower ROM for wrist flexion (67.9±13.1° *vs.* 74.3±15.1°, p=0.003) and higher ROM for wrist supination (85.0±8.3° *vs.* 81.9±5.1°, p=0.001) than in the intramedullary nail group (Table 2).

DASH scores (15.0±3.3 *vs.* 9.2±9.0, p=0.035) and Gartland-Werley scores (4.9±5.4 *vs.* 1.8±0.9, p=0.004) were significantly higher in the intramedullary nail group than in the volar plate group, with no significant difference between groups in terms of Stewart scores, indicating good reduction in both groups (1.5±0.7 and 1.6±1.3, respectively) (Table 2).

Quality of radiographic reduction in study groups

When compared to preoperative values, intramedullary nail fixation was associated with improved scores for radial inclination (from 16.5±3.9° to 17.8±5.7°, p=0.005), radial height (from 3.3±2.9 mm to 9.5±1.8 mm, p<0.001), volar tilt (from –14.1±12.3° to 6.9±6.3°, p<0.001), and radio-ulnar variance (from 2.5±1.7mm to 1.1±0.9 mm, p=0.001), postoperatively. In the volar plate group, significant changes were also noted in radial inclination (from 23.1±1.8° to 17.8±2.9°, p<0.001), radial height (from 10.3±0.9 mm to 8.3±2.3 mm, p<0.001), volar tilt (from –10.1±1.1° to 9.4±1.6°, p=0.002), and radio-ulnar variance (from 1.7±1.5 mm to 0.7±0.8 mm. p=0.002). We found that the intramedullary nail group had significantly higher initial preoperative values for radial inclination, volar tilt, and radial height than in the volar plate group (p<0.001 for each), and we found decreased rather than increased radial inclination and radial height values during follow up in the volar plate group, the intramedullary nail group had better restoration of volar tilt (p=0.004) and the volar plate group had better radio-ulnar variance (p=0.05) (Table 3).

Assessment of fulfilling rates of the radiographic healing criteria revealed that radial inclination was >15° and volar tilt was <20° in most patients, and distal radio-ulnar joint incongruity was <5 mm in all patients in both groups postoperatively, while radial shortening (<5 mm) *vs.* normal wrist was evident in 4 (11.1%) patients in the volar plate group and in none of the patients in the intramedullary nail group (Table 4).

Figures 1 and 2 show samples for preoperative, postoperative, and latest follow-up radiological images of distal radius fractures treated by using volar locking plate or intramedullary nailing.

Complications in study groups

Overall, 12 (34.3%) patients in the volar plate group and 11 (37.9.5%) patients in the intramedullary nail group developed complications, with no significant difference between groups

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Table 1. Baseline characteristics.

	Volar plate (n=35)	Intramedullary nail (n=29)	p Value
	Mean ±SD	Mean ±SD	
Age (year)	47.3± 16.4	51.3± 10.1	0.290[a]
Gender	n (%)	n (%)	
Male	6 (17.1)	12 (41.4)	**0.032**[b]
Female	29 (82.9)	17 (58.6)	
Handedness, n (%)	n (%)	n (%)	
Right	20 (57.1)	13 (44.8)	0.326[b]
Left	15 (42.9)	16 (55.2)	
Type of injury, n (%)	n (%)	n (%)	
Fall	20 (57.1)	19 (65.5)	0.882[c]
Vehicle accident	7 (20.0)	5 (17.2)	
Sports injury	7 (20.0)	4 (13.8)	
Assault injury	1 (2.9)	1 (3.5)	
Type of distal radius fracture, n (%)	n (%)	n (%)	
A21	8 (22.85)	6 (20.7)	0.978[c]
A2.2	6 (17.14)	5 (17.2)	
A23	6 (17.14)	7 (24.1)	
A3	8 (22.85)	5 (17.2)	
C2.1	7 (20)	6 (20.7)	
Concomitant fractures, n (%)	n (%)	n (%)	
None	26 (74.3)	23 (79.3)	0.926[c]
Calcaneus fracture	1 (2.9)	0 (0.0)	
Humerus fracture	1 (2.9)	1 (3.5)	
Lumbar vertebral fracture	1 (2.9)	0 (0)	
Shoulder fracture	1 (2.9)	1 (3.5)	
Femur fracture	2 (5.7)	2 (6.9)	
Malleolus fracture	1 (2.9)	2 (6.9)	
Shoulder dislocation	2 (5.7)	0 (0.0)	

[a] Student's t test; [b] Chi square test; [c] Fisher exact test.

in terms of complication rates. Radial nerve paresthesia and infection (8.6% for each in the volar plate group and 10.3% for each in the intramedullary nail group) were the most common complications in both groups (Table 5).

Primary tendon repair was performed by the Department of Hand Surgery for patients with tendon rupture, and resulted in complete recovery. Patients with infection in the locking screw were treated via removal of screws in the early period (week 3), followed by antibiotic treatment and dressing. Physical therapy and contrast bath therapy were applied for Sudeck atrophy, and physical therapy resulted in recovery in patients with carpal tunnel syndrome. In patients with radial nerve paresthesia, recovery was observed by the 3rd month of follow up.

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Table 2. Intra-operational characteristics and outcome measures.

		Volar plate (n=35)	Intramedullary nail (n=29)	p Value
Time parameters		**Mean ±SD**	**Mean ±SD**	
Duration of follow up (week)		30.5±2.9	33.3±2.7	**<0.257**[b]
Length of hospital stay (day)		5.2±1.5	4.0±0.5	0.051[b]
Total surgery time (min)		41.1±10.1	33.6±2.6	**<0.001**[a]
Scopy time (min)		15.7±2.5	21.4±3.9	**<0.001**[a]
Time to fracture union (week)		5.5±1.2	5.2±0.6	0.440[b]
Outcome measures		**Mean ±SD**	**Mean ±SD**	
ROM(°)	Flexion	67.9±13.1	74.3±15.1	**0.003**[b]
	Extension	65.0±12.8	69.5±4.4	0.322[b]
	Pronation	81.6±10.3	79.6±15.2	0.519[b]
	Supination	85.0±8.3	81.9±5.1	**0.001**[b]
VAS score		1.9±0.9	2.3±1.1	0.144[b]
DASH score		9.2±9.0	15.0±3.3	**0.035**[b]
Gartland-Werley score		1.8±0.9	4.9±5.4	**0.004**[b]
Stewart score		1.5±0.7	1.6±1.3	0.847[b]

DASH –disabilities of the arm; shoulder and hand; ROM – range of motion; VAS – visual analog scale. [a] Student's t test; [b] Mann Whitney U test.

Table 3. Radiographic parameters in study groups.

X-ray findings		Volar plate (n=35)	Intramedullary nail (n=29)	p Value
		Mean ±SD	**Mean ±SD**	
Radial inclination (°)	Preoperative	23.1±1.8	16.5±3.9	**<0.001**[a]
	Postoperative	17.8±2.9	19.8±5.7	0.682[b]
	p Value	**<0.001**[d]	**0.005**[d]	
Volar tilt (°)	Preoperative	–10.1±1.1	–14.1±12.3	**<0.001**[b]
	Postoperative	9.4±1.6	6.9±6.3	**0.004**[b]
	p Value	**0.002**[d]	**<0.001**[d]	
Radial height (mm)	Preoperative	10.3±0.9	3.3±2.9	**<0.001**[a]
	Postoperative	8.3±2.3	9.5±1.8	0.075[b]
	p Value	**<0.001**[c]	**<0.001**[c]	
Radio-ulnar variance (mm)	Preoperative	1.7±1.5	2.5±1.7	**0.050**[b]
	Postoperative	0.7±0.8	1.1±0.9	**0.031**[b]
	p Value	**0.002**[d]	**0.001**[d]	

[a] Student's t test or [b] Mann Whitney U test; [c] Paired t test or [d] Wilcoxon signed rank test.

Discussion

Our findings in a retrospective cohort of primarily extra-articular or simple intra-articular distal radius fractures treated with volar plate or intramedullary nail intramedullary fixation revealed that the intramedullary nail group patients had shorter total surgery time despite longer scopy time, along with better restoration of flexion and volar tilt, whereas patients in the volar plate group had better DASH and Gartland-Werley scores and better restoration supination and radio-ulnar variance. No

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Table 4. Fulfilling rates of the radiographic healing criteria defined by Graham et al. [31].

Maintenance of redution	Volar plate (n=35)	Intramedullary nail (n=29)	p Value
	n (%)	n (%)	
Radial inclination>15°	31 (88.6)	24 (82.8)	0.720
Radial shortening *vs.* normal wrist (<5 mm)	4 (11.4)	0 (0.0)	0.120
Volar tilt <20°	35 (100.0)	27 (93.1)	0.201
Articular incongruity (<5 mm)	35 (100.0)	29 (100.0)	–

Chi square proportion test.

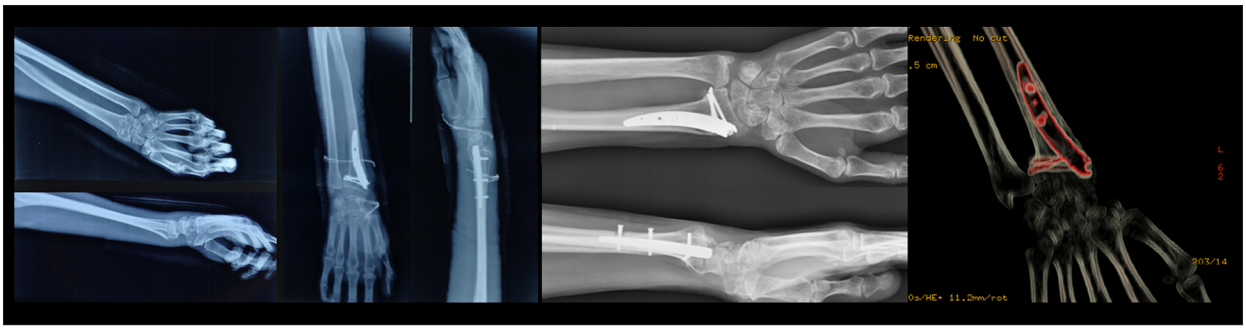

Figure 1. Preoperative, postoperative, and latest follow-up X-ray findings for intramedullary nail fixation and postoperative CT image.

Figure 2. Preoperative, postoperative, and latest follow-up X-ray findings for volar locking plate fixation.

significant difference was noted between volar plate and intramedullary nail groups in terms of LOS, VAS scores, time to fracture union, Stewart scores, and complication rates at an average follow up time of 30.5 weeks and 33.3 weeks, respectively.

In a study of 10 patients (mean age 55 years) with AO type A and C distal radius fractures treated with for intramedullary nail fixation, restoration of volar tilt (2.2°), radial inclination (24.1°), radial height (12.1 mm), radio-ulnar variance (-0.6 mm), and improved ROM in all planes were reported after follow-up of 21 months, along with an average DASH score of 8.1 [30].

In another study of 16 patients who underwent intramedullary nailing for correction of post-traumatic deformity in late-diagnosed distal radius fractures, when compared to preoperative values, significant improvement was reported in postoperative values for radial height [from 8.0 mm (range 6–12) to 12.1 mm (range 7–19)], radial inclination [from 16.4° (range

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Table 5. Complications in study groups.

Complications, n (%)	Volar plate (n=35)	Intramedullary nail (n=29)	p Value
	n (%)	n (%)	
None	23 (65.7)	18 (62.1)	0.971
Tendon rupture	1 (2.9)	2 (6.9)	
Carpal tunnel syndrome	0 (0.0)	0 (0)	
Sudeck atrophy	1 (2.9)	1 (3.5)	
Radial nerve paresthesia	3 (8.6)	3 (10.3)	
Pain at wrist	2 (5.7)	0 (0)	
Infection	3 (8.6)	3 (10.3)	
Tenosynovitis	2 (5.7)	2 (6.9)	
Fisher exact test			
Complications	**Volar plate (n=35)**	**Intramedullary nail (n=29)**	**p Value**
	n (%)	**n (%)**	
Absent	23 (65.7)	18 (62.1)	0.987
Present	12 (34.3)	11 (37.9)	
Chi-square test			

3–24) to 21.9° (range 16–30)], and volar tilt [from 4.0° (range –30 to 11) to 11.2° (range –10 to 11)] (4].

In another prospective study of 23 patients (mostly aged >60 years) with extra-articular A2–A3 and intra-articular C1-C2 distal radius fractures, intramedullary nail implant was reported to be associated with improved wrist motion and highly satisfactory DASH scores, even at the early time point, with decrease in average DASH scores from 29.0 at the first month to 8.0 at the 6th month of follow-up [7].

The present study found that patients who received intramedullary nail implant had significant improved radial height (from an average of 3.3 mm to 9.5 mm), radial inclination (from 16.5° to 17.8°), volar tilt (from –14.1° to 6.9°), and radio-ulnar variance (from 2.5 mm to 1.1 mm) postoperatively, as well as improved wrist ROM. Although our experience with intramedullary nail implant indicates successful fracture reduction and improved ROM, in agreement with previous studies, DASH scores in our intramedullary nail group were higher than those reported in some other studies [4,7,30].

Our findings revealed better restoration of wrist flexion and volar tilt in the intramedullary nail group, and better restoration of wrist supination and radio-ulnar variance in the volar plate group. Similarly, in a meta-analysis of 6 randomized controlled trials (RCTs) on the treatment of unstable distal radial fractures, volar locking plate fixation was reported to be associated with better restoration of ulnar variance at 12 months postoperatively and better supination at 3 months and 6 months postoperatively as compared with external fixation [38].

However, comparison of ulnar variance and volar tilt outcome in intramedullary nailing (Targon DR) *vs.* volar plate fixation of distal radius fractures revealed inconsistent findings with better restoration of both parameters with nail fixation in one study [39] and similar outcome in another study [40], while both studies indicated no significant difference between treatment groups in terms of loss of reduction [39,40].

A previous study reported that volar locking plates as compared with Epibloc System of percutaneous intramedullary fixation generated better ROM outcomes in all planes and better results according to DASH score and VAS score in treatment of elderly patients with extra-articular and intra-articular distal radius fractures at an average of 46 months of follow up, whereas the 2 techniques revealed similar outcome in terms of restoring radial inclination, volar tilt, and ulnar variance [41].

It should be noted that while flexion in the intramedullary nail group and supination in the volar plate group improved more, overall ROM values in all planes in each treatment method in our cohort of patients with distal radius fractures were compatible with ranges defined for functional wrist ROM for normal daily living activities [41,42].

Also, despite the differences between these 2 methods in terms of restoration of volar tilt and radio-ulnar variance, our

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findings showed that fracture union occurred at an average of 5 weeks postoperatively in both groups, with satisfactorily improved radiographic parameters, similar VAS and Stewart scores, and similar risk of loss of reduction during the follow up period. This seems consistent with the lack of correlation between functional outcome and restoration of the radiographic parameters or reduction of the fracture to acceptable radiographic levels in past studies, indicating no influence of radiological values on ROM in patients treated for distal radius fractures [43–45].

Notably, in the present study, despite similar Stewart scores and similar quality and stability of reduction between groups, DASH and Gartland-Werley scores were significantly higher in the intramedullary nail group than in the volar plate group, indicating less favorable functional outcome with intramedullary nail implants in terms of both patient-reported and clinician-based assessment. This emphasizes the need to consider not only the fracture pattern, but also the patient functional requests and preferences in the decision-making process during treatment of distal radius fractures [41].

Volar plate fixation of distal radius fractures was reported to be associated with better functional scores in terms of DASH and Green and O'Brien scores or Gartland-Werley score as compared with closed reduction and percutaneous fixation [46], pins fixation [47], external fixation [48], and percutaneous Kirschner-wires combined with external fixation (PKEF) [49], whereas the advantages of volar plate fixation over other techniques in terms of functional outcome were considered to be limited to the early postoperative period, with equalization of overall scores at 1 year after the operation [46–49]. However, in studies comparing volar plate with intramedullary nail implants for fixation of distal radius fractures, although the 2 methods also revealed similar efficacy at the later periods of follow up, intramedullary fixation was associated with better functional and radiographic outcome at the earlier period [50,51].

Accordingly, in a meta-analysis of 6 RCTs with 463 patients with extra-articular or simple intra-articular distal radius fractures, intramedullary nail and volar locking plate fixation were reported to be similar in terms of all functional scores, radiographic parameters, and motion range in the late postoperative period (6, 12, and 24 months), while better scores in all functional scoring systems were obtained using nailing *vs.* volar plate fixation at the earlier postoperative period (6 weeks and 3 months) [50].

In another study, equivalent radiographic and functional outcomes of volar locking plate fixation were also shown with other intramedullary nailing implants (Targon DR nail) among patients with distal radius fractures of AO 23 C2.1 type at 8 weeks, while better ROM in extension and better restoration of volar tilt and ulnar variance were shown in the volar plate group at 2 years after the operation, with similar reduction maintenance and complications rates in both groups [39].

The higher percentage of female patients in the volar plate group than in the intramedullary nail group in our study may be important in terms of better restoration of radio-ulnar variance in females, given their higher likelihood of reduced bone density and the association of osteoporotic bone fractures with higher likelihood of ulna shortening after fracture, as well as better ulna deviation postoperatively in distal radius factures treated with volar plate fixation [8].

Moreover, given the higher frequency of intra-articular fractures with a fracture in the coronal plane (AO type 23-C3) in the intramedullary nail group than in the volar plate group in our study, our findings emphasize the association of radial-to-ulnar direction of distal locking screw insertion in intramedullary nail device with the likelihood of limited ability to stabilize coronal plane fractures or ulnar column fragments [30].

Consistent with our findings, intramedullary nail fixation with the Targon DR nail was reported to be associated with shorter median operative time than with volar plate fixation in treatment of distal radius fractures, despite higher fluoroscopy times with Targon DR nails due to less direct exposure and indirect reduction technique, necessitating frequent fluoroscopic controls [39,40].

In a systemic review of 16 studies (3 biomechanical studies, 8 case series, and 5 randomized controlled trials) on biomechanics, functional outcome, and complications of intramedullary nailing of fractures of the distal radius, intramedullary nails were concluded to be as strong as volar locking plates according to biomechanical studies, and to have a comparable ROM and functional outcome to other fixation techniques in the clinical studies [52].

Our experience also suggests that volar plate and intramedullary nail are both very useful options in the fixation of distal radius fractures, with satisfactory radiological outcome, improved wrist ROM, and high stability and quality of reduction, as well as short time to fracture union. This seems consistent with potential clinical and biomechanical benefits of minimally invasive intramedullary nail fixation, including load transfer across the fracture site, minimized risk of soft tissue disruption and irritation, and less postoperative adhesion formation, decreased postoperative pain, and promoted fracture healing [7,24,53]. Notably, volar plate fixation has also consistently been associated with favorable radiological and clinical outcomes in past studies among patients with distal radius fractures [8,9,12–15].

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Overall, 12 (34.3%) patients in the volar plate group and 11 (37.9%) patients in the intramedullary nail group developed complications in our cohort, with no significant difference between groups in terms of complication rates. Radial nerve paresthesia and infection (8.6% for each in the volar plate group and 10.3% for each in the intramedullary nail group) were the most common complications in both groups.

Complication rates after volar locking plate fixation of distal radius fractures was reported to range from 3% to 36%, including carpal tunnel syndrome (3–8%), complex regional pain syndrome (1–6%), flexor tendon ruptures (0.5–1.6%), and extensor tendon ruptures (0.5–3.4%) [6,22,23,54–56]. Tendon rupture and tenosynovitis are considered likely in case of volar plate fixation, as it is associated with drill-bit penetration or inaccurate screw length due to obscured views of the distal cortex in lateral radiographs [51,57,58]. In a retrospective analysis of 576 patients (median age 63 years, 78% females) with distal radius fracture treated with a volar plate, although no complications occurred in most patients after a mean observation time of 3.2 years, the overall complication rate was still remarkable (14.6%) with carpal tunnel syndrome or change in sensibility in 5.2% and tendon complication in 4.7% of patients [6].

Past studies revealed that intramedullary nail fixation of the distal radius was associated with high complication rates, including superficial radial sensory neuritis (13% and 20%) [7,30], screw penetration into the distal radio-ulnar joint (0% and 30%) [30,59] and loss of reduction (13% and 20%) [7,30]. In a systemic review of 16 studies, the mean complication rate of intramedullary nailing was reported to be 17.6% (0–50%), exceeding the complication rates reported in studies of volar plating [52], while risk of injury to the superficial branch of the radial nerve and a narrower spectrum of indications than volar locking plates were considered as the main disadvantages of the intramedullary nail fixation system [51].

Intramedullary nail implants were reported to be associated with minimal risk of tendon complications [4,30], given that the distal aspect is not affixed on the dorsal cortex of the distal radius adjacent to extensor tendons, and mobilization of the extensor pollicis longus and removal of Lister's tubercle are not required during its insertion [7]. However, use of percutaneous nail insertion has been associated with likelihood of injury to superficial branches of the radial nerve, which has been considered to be among the potential disadvantages of the intramedullary nail fixation system [7,26]. However, our findings revealed that tendon- and radial nerve-related complications were similar between intramedullary nail and volar plate fixation groups (3 patients for each in both groups).

Likewise, in a meta-analysis of 6 RCTs with 463 patients comparing intramedullary nail and volar locking plate fixation for treatment of extra-articular or simple intra-articular distal radius fractures, the authors concluded that apart from significantly higher incidence of carpal tunnel syndrome in the volar plate group than in the intramedullary nail group (8.7% *vs.* 0.8%), the 2 treatment methods have similar complication rates for infection, tendinous damage, tenosynovitis, pain, and radial nerve paresthesia [50].

The retrospective single-center design of the present study seems to be major limitation that restricts establishing the temporality between cause and effect, as well as generalizing our findings to the overall patient population. Nonetheless, by providing comparative data on intramedullary fixation and volar plate fixation of distal radial factures in a relatively large cohort, our findings are a valuable contribution to the literature.

Conclusions

Our findings indicate that both volar plate fixation and intramedullary nail fixation are reasonable options for treatment of primarily extra-articular or simple intra-articular distal radius fractures, providing reliably good results with satisfactory reduction and stable fixation, along with minimal pain and improved ROM. Although intramedullary nail fixation was associated with better restoration of volar tilt and wrist flexion, and volar plate fixation resulted in better restoration of radioulnar variance and wrist supination, the 2 methods achieved similar quality and stability of reduction in the treatment of distal radius fractures. Nonetheless, volar plate fixation seems to be more advantageous in terms of patient-reported and clinician-based functional outcome scores, emphasizing the importance of considering not only fracture pattern, but also the patient functional requests and preferences in the decision-making process during treatment of distal radius fractures. Longer-term outcome studies are needed to clearly define the advantages of intramedullary nail fixation or volar plate fixation over other techniques in treatment of distal radius fractures, given the non-negligible postoperative complication rates.

Conflict of interest

None.

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