RESEARCH ARTICLE

A Comparative Prospective Study Between Ligamentotaxis Versus Volar Plating in Displaced Intra-articular Fractures of Distal End Radius in Adults

Mada Sai Krishna, MBBS, MS(Ortho)DNB(Ortho); Krishna Chaitanya Reddy. Y, MBBS, D.Ortho, DNB (Ortho); Siva Sai Kumar Reddy.Y, MBBS, MS (Ortho); Govardhan Reddy.G, MBBS, MS (Ortho)

Research performed at Gitam Institute of Medical Sciences and Research, Visakhapatnam

Received: 5 May 2025 *Accepted: 23 June 2025*

Abstract

Objectives: The objectives of the study are to compare the efficacy of external fixator/ligamentotaxis and volar plating in the treatment of displaced intra-articular distal end radius fracture by comparing the functional outcome using the Green and O'Brien score and to assess the radiological outcome of displaced intra-articular distal end radius fracture treated with external fixator/ligamentotaxis and volar plate.

Methods: This randomized study was done on 70 patients from August 2022 to May 2024 at GIMSR Medical College and Hospital. We enrolled 35 patients in the volar plating and 35 patients in the external fixation groups. Functional outcomes were assessed at 3 and 6 months using Cooney modification of Green and O'Brien scores, and radiological outcomes were evaluated using Sarmiento radiological score.

Results: By 6 months, both groups had comparable functional outcomes. The volar plating group achieved excellent results in 71.4% of cases, compared to 48.5% in the external fixation group. Radiological parameters like palmar tilt, radial shortening, and deviation showed no significant differences. Complications were similar between groups. Superficial pin tract infections were found to be common in the external fixation group and surgical site infections in the volar plating group.

Conclusion: Volar plating provided superior early functional outcomes, particularly in grip strength; however, both methods show comparable long-term results. Treatment choice should consider patient-specific factors, including bone quality and the need for early mobilization.

Level of evidence: I

Keywords: Distal radius fractures, Ligamentotaxis, Volar plating

Introduction

Fractures of the distal end of the radius are the most common injuries orthopedic surgeons encounter. They constitute over 18% of fractures presented to emergency or casualty departments.[1,2] In younger subjects, these fractures occur due to high-velocity trauma, like road traffic accidents (RTA). Among older adults, falls on an outstretched hand (FOOSH) is the leading cause. This bimodal distribution shows the differing mechanisms of injury across age groups.[3–5] Distal radius fractures are classified as either extra-articular or intra-articular. Nearly half of these fractures involve the articular surface. Anatomical reduction is required to prevent complications like persistent pain, decreased range of motion, reduced grip strength, and post-traumatic arthritis.[6] Extra-articular fractures are generally stable, easily reducible, and managed conservatively through methods like cast application.[7] Intra-articular fractures are unstable, difficult to reduce, and prone to complications if not anatomically

Corresponding Author: Mada Sai Krishna, Department of orthopaedics, GITAM institute of medical sciences and research, Visakhapatnam

Email: saikrishna2812@gmail.com

THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

Arch Bone Jt Surg. 2026;14(9):590-596 Doi: 10.22038/ABJS.2025.87939.3982 http://abjs.mums.ac.ir

Copyright © 2026 Mashhad University of Medical Sciences. This work is licensed under a Creative Commons Attribution-Noncommercial 4.0 International License https://creativecommons.org/licenses/by-nc/4.0/deed.en

realigned. To ensure successful treatment, preserving articular congruency and maintaining radial length and height are vital. Surgical fixation is necessary for intra-articular fractures to achieve an excellent anatomical reduction and minimize complications. Various surgical methods, including closed reduction percutaneous pinning, external fixation (EF) through ligamentotaxis, and open reduction with plate fixation (volar or dorsal), were used. Among these, external fixation and volar plating have shown promising outcomes. However, there is insufficient evidence regarding which method provides superior functional and radiological outcomes. Patients with distal radius fractures commonly present with pain, swelling, and a visible deformity at the wrist. A complete history should include an assessment of other areas of pain in the ipsilateral limb to rule out concomitant injuries. Patients should be asked about numbness or paresthesia, which may indicate involvement of the median or ulnar nerve. This is important, as nerve injuries require more urgent intervention.[8–10] Physical examination should focus on inspecting the skin for open wounds to rule out acute carpal tunnel syndrome, which is a surgical emergency. Swelling is often visible around the wrist, and deformity may be present in displaced fractures. The main deformity is dorsal angulation at the distal radius, accompanied by compensatory flexion of the carpus, creating a "dinner fork" deformity.[11] Radiological evaluation involves X-ray views to confirm the diagnosis and guide treatment. Standard views include posteroanterior (P.A.), lateral, and oblique views. The radial incline view is useful for assessing the articular surface of the distal radius. The lateral view provides the best assessment of dorsal and volar tilt, carpal bone alignment, metaphyseal comminution, volar cortex displacement, and the position of the distal radioulnar joint (DRUJ).[12] The oblique view helps evaluate radial comminution, depression of the dorsal lunate facet, and the radial styloid.[13] Main radiographic measurements include volar/palmar tilt (measured on the lateral view, normal range 11°–12°),[13] radial height (measured on the P.A. view, normal range 11–12 mm),[13] radial inclination (also on the P.A. view, normal range 22°–23°),[14] ulnar variance (on the P.A. view, indicating radial shortening),[11] and the teardrop angle (measured on the lateral view, normal range 70°).[13] This study aims to compare the efficacy of EF/ligamentotaxis and volar plating in the treatment of displaced intra-articular distal end radius fracture by comparing the functional outcome using the Green and O'Brien score and to assess the radiological outcome of displaced intra-articular distal end radius fracture treated with EF/ligamentotaxis and volar plate.

Materials and Methods

This comparative prospective study was conducted at the Department of Orthopaedics, GIMSR Medical College and Hospital, from August 2022 to May 2024 after getting approval from the institutional ethics committee. Patients with displaced intra-articular distal radius fractures were enrolled based on the following criteria. The inclusion criteria were patients aged 18–80 years with displaced intra-articular distal radius fractures and early presentation to the hospital. The exclusion criteria were polytrauma patients, open fractures, patients medically unfit for surgery, fractures associated with neurovascular injuries. Patients were randomly assigned to one of two treatment groups using simple random sampling as group 1 with volar plate fixation (n = 35), and group 2 with ligamentotaxis/external fixation (n = 35).

Preoperative Evaluation and Preparation

Details were taken on: History, Physical Examination, Radiological Imaging: Lateral and posteroanterior (PA) viewof the wrist. Routine Investigations: Liver function tests, renal function tests, blood grouping, complete blood count, random blood sugar, ECG, chest X-ray and viral markers for anesthetic fitness. Patients were admitted and prepared for surgery within three days of admission. Surgical site marking and tetanus toxoid administration were performed before the procedure. A single dose of intravenous antibiotics was administered 1 hour before surgery.

Surgical Procedures

External Fixation (Ligamentotaxis) Under brachial block patient is placed supine on operating table. Incisions: Proximal/radial pins: 1 cm incisions over the dorsomedial aspect of the forearm (5–10 cm from the radial styloid, 3 cm apart). Distal/metacarpal pins: 1 cm incision over the dorsal aspect of the second metacarpal. Procedure: Pre-drilling with a 2.7 mm drill bit for proximal pins and 1.5 mm for distal pins. Insertion of Schantz pins (3.5 mm for proximal, 2.5 mm for distal). Application of two connecting rods (4 mm each) and adjustment under C-arm guidance. Longitudinal traction applied to achieve reduction, followed by tightening of clamps. Joint-spanning static external fixator used without supplementary techniques.

Volar Plating Under brachial block patient is placed supine on operating table. Approach: Modified Henry approach on the volar aspect of the distal radius. Procedure: Incision between the radial artery and the flexor carpi radialis (FCR) tendon. Retraction of the radial artery and FCR tendon to expose the pronator quadratus (PQ) muscle. Incision of the PQ muscle and periosteal dissection to expose the fracture site. Reduction under the C-arm guidance and fixation with a 3.5 mm buttress plate. Distal screws positioned carefully to avoid penetration of the articular surface. Closure in layers and application of below-elbow POP slab.

Postoperative Care and Rehabilitation

External Fixation Group: Elevation of the hand for 2 days; active finger movements encouraged. Weekly pin tract dressing and monitoring for infection or pin loosening. External fixator removal at 6 weeks post-op, contingent on radiological healing. Gradual resumption of wrist movements and avoidance of heavy lifting for 3 months.

Volar Plating Group: Elevation of the hand for 2 days; active finger movements encouraged. Dressing changed on postoperative day 2. Suture removal between days 10–14. POP slab continued for 4 weeks, then removed. Full wrist movements allowed after 4 weeks, with heavy lifting restricted for 3 months.

Assessment of Outcomes

Functional Outcome: Evaluated at 3 and 6 months postoperatively using Cooney modification of Green and O'Brien score [Table 1]. Radiological Outcome: Assessed at 3 months using the Sarmiento radiological score [Table 2].

Statistical Analysis

Data were collected and analyzed using Excel and SPSS software version 17.0. Descriptive Statistics: Frequencies, percentages, means, standard deviations, and ranges were used. Inferential Statistics: Chi-square test or Fisher's exact test for categorical variables. Mann-Whitney U test for quantitative data. A P-value of <0.05 was considered statistically significant.

Table 1. Cooney Modification of Green and O'brien Score for Functional Outcome

Criteria	Findings and Score	Findings and Score	Findings and Score	Findings and Score	Findings and Score
pain	25 no pain	20 mild pain	15 moderate	o severe	
functional status	25 Returned to regular employement	20 Restricted employement	15 Restricted but unemployement	o unable to work	
grip strength	25 normal	15 75-99% of normal	10 50-74% of normal	5 25-49% of normal	0 < 24% of normal
range of movements	25(normal) Palmarflexion dorsiflexion arc is more than 120 degrees	15(75-99% of normal) Palmarflexion dorsiflexion arc is 91-119 degrees	10(50-74% of normal) Palmarflexion dorsiflexion arc is 61-90degrees	5(25-49% of normal) Palmarflexion dorsiflexion arc 31-60 degrees	0(< 24% of normal) Palmarflexion dorsiflexion arc is less than 30 degrees
final score	Excellent 90-100	Good 80-89	Satisfactory 65-79	Poor <65	

Table 2. Sarmiento Radiological Score

outcome	Loss of palmar tilt	Radial shortening	Loss of radial deviation
Excellent	< 0 degree	<3mm	<4 degree
Good	1-10 degree	3-6mm	5-9 degree
Fair	11-14 degree	7-11mm	10-14 degree
Poor	>15 degree	>12mm	> 15 degree

Results

Seventy patients (35 in each group) were included in the study and analyzed for outcomes.

Demographics and Baseline Characteristics

Age distribution: The mean Age was 46.7 ± 10.9 years (range: 25–68 years) with the Most Common Age Group being between 50–60 years. Age Comparison Between Groups: External Fixator Group: 49 ± 11.2 years. Volar Plating Group: 44.3 ± 10.3 years. Statistical Analysis: No significant difference (P = 0.081).

Gender distribution: Out of 70 patients 45.71% (n = 32) were females and 54.29% (n = 38) males.

Mode of injury: Fall on Outstretched Hand (FOOSH) was 60% (n = 48) and Road Traffic Accidents (RTA): 40% (n = 22).

Injury side: Right side distal radius fractures accounted for 51.4% (n=36) and left side for 48.6% (n=34) [Figure 1].

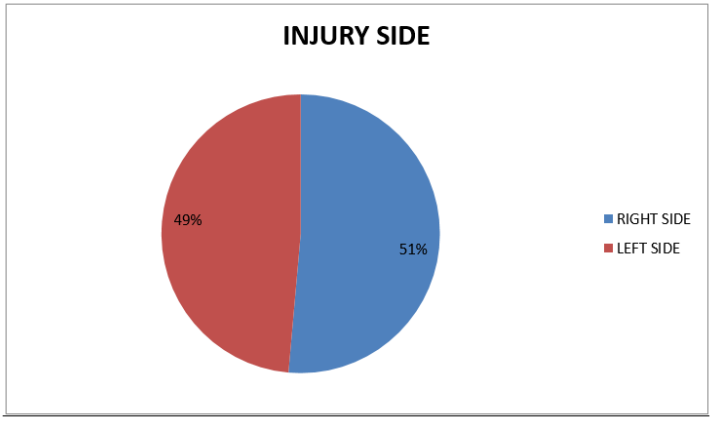

Figure 1. Distribution of injury side (n=70)

Functional Outcome Variables

Functional outcomes were assessed using the Green and O'Brien scoring system at 3 and 6 months postoperatively [Table 3]. At 3 Months: Volar plating showed significantly better grip strength (P = 0.02). At 6 Months: No significant difference in grip strength or pain scores between groups. The overall functional outcome of the volar plating group at 6 months showed excellent results in 25 (71.4%), Good in 5 (14.2%), Satisfactory in 4 (11.4%) and Poor: 1 (2.8%) patient. The overall functional outcome of the external fixator group at 6 months showed excellent results in 17 (48.5%), Good in 13 (37.1%), Satisfactory in 4 (11.4%) and poor in 1 (2.8%) patient.

Table 3. Functional Outcome Using The Green And O'Brien Scoring System At 3 And 6 Months Postoperatively

Functional Outcome	3 Months	6 Months
Pain Score	22.2 ± 3.7 (Volar) vs. 20.8 ± 3.5 (EF) P = 0.06	23.8 ± 2.1 (Volar) vs. 23.4 ± 2.3 (EF) P = 0.42
Functional Status Score	23.8 ± 2.7 (Volar) vs. 23.0 ± 3.2 (EF) P = 0.17	24.1 ± 2.2 (Volar) vs. 23.4 ± 2.6 (EF) P = 0.16
Grip Strength Score	22 ± 4.8 (Volar) vs. 19.2 ± 5 (EF) P = 0.02	21.8 ± 4.7 (Volar) vs. 20.2 ± 5 (EF) P = 0.18

EF: External fixator

Radiological Outcomes

Radiological outcomes were assessed using the Sarmiento Radiological Score at 3 months postoperatively [Table 4]. In the volar plating group, excellent results were seen in 20 (57.1%) patients, Good in 8 (22.8%), Fair in 6 (17.1%) and Poor in 1 (2.8%) patient [Figure 2]. At 3 months, the External Fixator Group had Excellent results in 15 (42.8%) patients, Good in 12 (34.2%), Fair in 5 (14.2%) and Poor in 3 (8.5%) patients. Statistical Analysis: No significant difference (Chi-square = 2.6052, df = 3, P = 0.4566) [Figure 3].

Complications

Complications are detailed in [Table 5]. Superficial pin tract infections were found to be common in the external fixation group and surgical site infections in the volar plating group.

Table 4. Radiological Outcome Assessed Using The Sarmiento Radiological Score At 3 Months Postoperatively

Radiological Parameter	External Fixator	Volar Plating	P-value
Loss of Palmar Tilt (°)	4.80 ± 5.43	3.60 ± 5.07	0.255
Radial Shortening (mm)	4.42 ± 3.76	3.34 ± 2.99	0.18
Loss of Radial Deviation (°)	6.40 ± 4.09	5.37 ± 3.59	0.23

Table 5. Complications

Complications	External Fixation (n = 3/6)	Volar Plating (n = 3/6)
Superficial Pin Tract Infection	2 (66.6%)	0
Loss of Reduction	1 (33.3%)	0
Surgical Site Infection	0	2 (66.6%)
Hypertrophic Surgical Scar	0	1 (33.3%)

Figure 2. Illustration of a case treated with Volar Plating

Figure 3. Illustration of a case treated with External Fixator

Discussion

Different surgical fixation techniques have been proposed for the management of displaced intra-articular distal end radius fractures, yet none has showed definitive superiority over others. The optimal method of treatment remains a topic of ongoing debate. In this comparative study, we evaluated the functional and radiological outcomes of ligamentotaxis (external fixation) and volar plating for displaced intra-articular distal radius fractures. Seventy patients were randomly assigned to two groups: 35 in the external fixator group and 35 in the volar plating group.

The mean age of patients in our study was 46.72 ± 10.98 years. There was no significant difference in mean age between the two groups (P = 0.08). Similar findings were reported by Trine Ludvigsen et al.[15] (mean age 56 vs. 57 years) and Xiaofei Yu et al.[16] (P = 0.37), suggesting no substantial age-related differences between groups.

Regarding gender distribution, 54.29% of patients were men and 45.71% were women. No significant gender distribution difference was seen between groups (P = 0.810). This is similar to studies by Rajeev Shukla et al.[17] (44.54% men, 55.45% women) and Aryan Sharma et al.[18] (60% men). In distal radius fractures, women over 50 are more prone due to decreased bone density post-menopause. In our study, 63.33% of women were above 50, showing osteoporosis's role.

The primary mode of injury was FOOSH (Fall on Outstretched Hand) in 60% of patients and RTA (Road Traffic Accident) in 40% of patients. These findings are similar to those of Aryan Sharma et al.[18] (56.6% FOOSH, 33.3% RTA) and Jeudy J et al.[19] (67% FOOSH). The mean age of patients with FOOSH-related fractures was 48 ± 5.6 years. In our study, 81% of women sustained fractures due to FOOSH, consistent with literature linking osteoporosis to higher fragility in women.

Functional outcomes at 3 months showed that volar plating resulted in significantly better pain scores (P= 0.06) and grip strength (P = 0.02). However, by 6 months, no significant differences were observed in pain (P = 0.42) or grip strength (P = 0.18) between the groups. This suggests an early functional superiority of volar plating, potentially due to early mobilization facilitated by rigid fixation. As external fixator patients began functional exercises post-fixator removal, their outcomes improved over time, minimizing long-term differences. When evaluating the overall functional status using Green and O'Brien Scores, volar plating was significantly superior at the 3-month follow-up (P = 0.01). However, at the 6-month follow-up, there was no significant difference (P = 0.13). This supports findings by Gouk CJC et al.,[20] Fu Q et al.,[21] and Trine Ludvigsen et al.[15] where long-term outcomes were comparable between groups. The early advantage of volar plating may stem from direct fracture visualization and rigid fixation, enabling early wrist mobilization.

Radiological outcomes showed no significant differences in parameters like Palmar Tilt, Radial Deviation, and Radial Shortening (P > 0.05) between the two groups at 3 months. Despite initial anatomical reduction, late collapse occurred in one external fixator case, consistent with Fu Q et al.[21] findings on secondary displacements. Hammer OL et al.,[22] Trine Ludvigsen et al.,[15] and Marco Rizzo et al.[23] reported similar results, indicating comparable radiological outcomes between groups.

Overall, the complication rates were similar in both groups. Walenkamp et al.[24] and Xie et al.[25] also reported comparable complication rates, while Esposito et al.'s[26] meta-analysis suggested a higher infection rate with external fixation.

Strengths and Limitations

The strengths of this study include its randomized design, the inclusion of uniform fracture types, and the fact that all procedures were performed by a single surgeon. Limitations include the relatively small sample size, the six-month follow-up period (a longer follow-up could provide more insights into long-term arthritis and functional status), and the exclusion of cases with associated injuries, which might limit generalizability to more complex trauma scenarios.

Conclusion

This prospective, randomized study compared the efficacy of ligamentotaxis (external fixation) and volar plating in managing displaced intra-articular distal end radius fractures. Early Outcomes: Volar plating showed superior functional outcomes at three months (P = 0.01). Long-Term Outcomes: No significant differences were seen between groups at 6 months (P = 0.13). These findings stress the importance of early mobilization and suggest that while volar plating may provide early benefits, both techniques are effective in the long term for these fractures. Treatment choice should consider patient-specific factors, including bone quality and the need for early mobilization.

Acknowledgement

We sincerely acknowledge our Hod Dr. G. rajasekhara Rao for giving us general support to carry out our research.

Authors Contribution: Authors who conceived and designed the analysis: M. Sai Krishna/Authors who collected the data: G. Govardhan Reddy/Authors who contributed data or analysis tools: Krishna Chaitanya Reddy. Y/Authors who performed the analysis: Y. Siva Sai kumar Reddy/Authors who wrote the paper: M. Sai Krishna

Declaration of Conflict of Interest: The authors do NOT

have any potential conflicts of interest for this manuscript.

Declaration of Funding: The authors received NO financial support for the preparation, research, authorship, and publication of this manuscript.

Declaration of Ethical Approval for Study: This study received ethical approval from the institutional ethics committee of GIMSR Medical College and Hospital; GIMSR/Admin/Ethics/approval/IEC-110/2022, DATE: 12/10/2022

Declaration of Informed Consent: There is no information (names, initials, hospital identification numbers, or photographs) in the submitted manuscript that can be used to identify patients.

Mada Sai Krishna MBBS, MS (Ortho) DNB (Ortho) [1]
Krishna Chaitanya Reddy Y. MBBS, D.Ortho, DNB (Ortho) [1]
Siva Sai Kumar Reddy MBBS, MS (Ortho) [1]
Govardhan Reddy G. MBBS, MS (Ortho) [1]

1 Department of orthopaedics, GITAM institute of medical sciences and research, Visakhapatnam, India

References

1. Zhang Y. Clinical epidemiology of orthopaedic trauma. Su Y, Chen W, Wang J, Hao J, eds. Georg Thieme Verlag; 2020.
2. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury. 2006;37(8):691-7. doi: 10.1016/j.injury.2006.04.130.
3. Shauver MJ, Yin H, Banerjee M, Chung KC. Current and future national costs to Medicare for the treatment of distal radius fracture in the elderly. J Hand Surg Am. 2011;36(8):1282-1287. doi: 10.1016/j.jhsa.2011.05.017.
4. Nguyen TV, Center JR, Sambrook PN, Eisman JA. Risk factors for proximal humerus, forearm, and wrist fractures in elderly men and women the dubbo osteoporosis epidemiology study. Am J Epidemiol. 2001;153(6):587-95. doi: 10.1093/aje/153.6.587.
5. Palvanen M, Kannus P, Parkkari J, et al. The injury mechanisms of osteoporotic upper extremity fractures among older adults: a controlled study of 287 consecutive patients and their 108 controls. Osteoporos Int. 2000;11(10):822-31. doi: 10.1007/s001980070040.
6. Lind T, Amer M, Hagberg L. Intra-articular lesions in distal fractures of the radius in young adults: a descriptive orthoscopic study in 50 patients. J Hand Surg Br. 1997;22(5):111-115. doi: 10.1016/s0266-7681(97)80364-6.
7. Bucholz RW, Heckman JD, Court-Brown CM, Tornetta P, eds. Rockwood and Green's fractures in adults. 8th ed. Philadelphia: Lippincott Williams & Wilkins; 2015.
8. Ma C, Deng Q, Pu H, et al. External fixation is more suitable for intra-articular fractures of the distal radius in elderly patients. Bone Res. 2016:4:16017. doi: 10.1038/boneres.2016.17.
9. Jebson PJ, Blair WF. A surgical protocol for combined internal and external fixation of complex intra-articular distal radius fractures using dorsal and volar approaches. Iowa Orthop J. 1996;16:35-38.
10. Trumble TE, Culp R, Hanel DP, Geissler WB, Berger RA. Instructional course lectures, the American academy of orthopaedic surgeons-intra-articular fractures of the distal aspect of the radius. J Bone Joint Surg Am. 1998;80:582-600.
11. Hozack BA, Tosti RJ. Fragment-Specific Fixation in Distal Radius Fractures. Curr Rev Musculoskelet Med. 2019;12(2):190-197. doi: 10.1007/s12178-019-09538-6.
12. Yeh GL, Beredjiklian PK, Katz MA, Steinberg DR, Bozentka DJ. Effects of forearm rotation on the clinical evaluation of ulnar variance. J Hand Surg Am. 2001;26(6):1042-6. doi: 10.1053/jhsu.2001.26657.
13. Stirling E, Jeffery J, Johnson N, Dias J. Are radiographic measurements of the displacement of a distal radial fracture reliable and reproducible? Bone Joint J. 2016;98-B(8):1069-73. doi: 10.1302/0301-620X.98B8.37469.
14. Koval K, Haidukewych GJ, Zirgibel BJ. Controversies in the management of distal radius fractures. J Am Acad Orthop Surg. 2014;22(9):566-75. doi: 10.5435/JAAOS-22-09-566.
15. Ludvigsen T, Matre K, Gudmundsdottir RS, Krukhaug Y, Dybvik EH, Fevang JM. Surgical treatment of distal radial fractures with external fixation versus volar locking plate: a multicenter randomized controlled trial. J Bone Joint Surg Am. 2021;103(5):405-414. doi: 10.2106/JBJS.20.00275.
16. Yu X, Yu Y, Shao X, Bai Y, Zhou T. Volar locking plate versus external fixation with optional additional K-wire for treatment of AO type C2/C3 fractures: a retrospective comparative study. J Orthop Surg Res. 2019;14(1):271. doi: 10.1186/s13018-019-1309-4.
17. Shukla R, Jain RK, Sharma NK, Kumar R. External fixation versus volar locking plate for displaced intra-articular distal radius fractures: a prospective randomized comparative study of the functional outcomes. J Orthop Traumatol. 2014;15(4):265-70. doi: 10.1007/s10195-014-0317-8.
18. Sharma A, Pathak S, Sandhu H, et al. Prospective randomized study comparing the external fixator and volar locking plate in intra-articular distal radius fractures: which is better? Cureus. 2020;12(2):e6849. doi: 10.7759/cureus.6849.
19. Jeudy J, Steiger V, Boyer P, Cronier P, Bizot P, Massin P. Treatment of complex fractures of the distal radius: a prospective randomised comparison of external fixation 'versus' locked volar plating. Injury. 2012;43(2):174-9. doi: 10.1016/j.injury.2011.05.021.
20. Gouk CJ, Bindra RR, Tarrant DJ, Thomas MJ. Volar locking plate fixation versus external fixation of distal radius fractures: a meta-analysis. J Hand Surg Eur Vol. 2018;43(9):954-960. doi:

10.1177/1753193417743936.
21. Fu Q, Zhu L, Yang P, Chen A. Volar locking plate versus external fixation for distal radius fractures: A meta-analysis of randomized controlled trials. Indian J Orthop. 2018;52(6):602-610. doi: 10.4103/ortho.IJOrtho_601_16.
22. Hammer OL, Clementsen S, Hast J, Šaltytė-Benth J, Madsen JE, Randsborg PH. Volar locking plates versus augmented external fixation of intra-articular distal radial fractures: functional results from a randomized controlled trial. J Bone Joint Surg Am. 2019;101(4):311-321. doi: 10.2106/JBJS.18.00014.
23. Rizzo M, Katt BA, Carothers JT. Comparison of locked volar plating versus pinning and external fixation in the treatment of unstable intra-articular distal radius fractures. Hand (N Y). 2008;3(2):111-117. doi: 10.1007/s11552-007-9080-0.
24. Walenkamp MM, Bentohami A, Beerekamp MS, et al. Functional outcome in patients with unstable distal radius fractures, volar locking plate versus external fixation: a meta-analysis. Strategies Trauma Limb Reconstr. 2013;8(2):67-75. doi: 10.1007/s11751-013-0169-4.
25. Xie X, Xie X, Qin H, Shen L, Zhang C. Comparison of internal and external fixation of distal radius fractures: A meta-analysis of randomized controlled trials. Acta Orthop. 2013;84(3):286-91. doi: 10.3109/17453674.2013.792029.
26. Esposito J, Schemitsch EH, Saccone M, Sternheim A, Kuzyk PR. External fixation versus open reduction with plate fixation for distal radius fractures: a meta-analysis of randomised controlled trials. Injury. 2013;44(4):409-16. doi: 10.1016/j.injury.2012.12.003.