Original Article Cukurova Anestezi ve Cerrahi Bilimler Dergisi

Efficacy of an External Fixator in Treating Intra-Articular Fractures of the Distal Radius

İdris Perktaş[1], *Serdar Menekşe*[2]

1 Department of Orthopaedics, Gaziantep City Hospital, Gaziantep, Türkiye
2 Department of Orthopaedics, Seyhan State Hospital, Adana, Türkiye

Abstract

Aim: Distal radius fractures are among the most common injuries in daily practice. The medical community continues to debate the best treatment methods for joint surface involvement in this condition. This study investigated how closed reduction with external fixator treatment benefits patients who have intra-articular distal radius fractures.

Methods: Between January 2021 and December 2022, 53 patients treated in our clinic were retrospectively analyzed. Uniplanar radiocarpal external fixator was applied to all patients after closed reduction. The fractures were grouped as C1, C2, and C3 according to the AO/OTA classification. Radial inclination, volar tilt, radial height, ulnar variance, and articular step-off (mm) were measured in the radiological evaluation. Functional outcomes were evaluated using modified Gartland-Werley scoring, and radiological results were evaluated using Sarmiento criteria. Pain was assessed using the visual analog scale (VAS) and upper extremity function with the DASH score. The patients were followed for a mean of 16 months.

Results: The mean age of the patients was 48.6 years and the majority of them were female. Significant improvement was observed in all postoperative radiological parameters ($p<0.001$). At the final follow-up, the VAS score decreased from 7.2 to 1.5 and the DASH score decreased from 48.6 to 12.2. Grip strength reached 93.8% of the healthy side. Functionally, 54.7% of the patients had good or very good results. Outcomes worsened as fracture complexity increased ($p<0.05$). The complication rate was determined as 30.2%.

Conclusions: External fixation serves as a suitable treatment method which provides satisfactory results in both radiographic evaluations and patient function for patients who have intra-articular distal radius fractures.

Keywords: *Distal radius fractures; external fixators; fracture fixation*

1. Introduction

The upper extremity experiences distal radius fractures as its most prevalent skeletal injury which occurs in one-sixth of all fracture cases.[1] The treatment process becomes more complex because intra-articular injuries make up 60% of all cases.[1] The incidence of these fractures grows because osteoporotic bone structure becomes more common in elderly people which threatens to create permanent wrist function damage.[2] Although methods such as volar lock plates (VLP) and external fixation (EF) are widely used today, there is still debate about which method is superior.[3]

Although the current literature states that volar plates offer better functional outcomes and reduce pain faster in the early period,[4] the advantage of external fixation to preserve soft tissue, especially in cases with severe intra-articular fragmentation, cannot be ignored. However, there is still no clear consensus among studies on the long-term clinical outcomes and complication rates of external fixation; **as** a matter of fact, current meta-analyses show that the methods do not provide a clear superiority over each other in different fracture types (intra-articular or extra-articular).[5] In particular, up-to-date data are needed on the effectiveness of uniplanar radiocarpal external fixation applied together with closed reduction in preserving the anatomical integrity of the joint surface and its contribution to patient quality of life.[6]

2. Materials and Methods

Study Population and Sample

This retrospective study was conducted between January 2021 and December 2022 in our clinic. Patients over 18 years of age who were diagnosed with acute intra-articular distal radius fracture and treated with closed reduction and external fixator were included in the study. Open fractures, patients who had previously undergone surgical intervention on the same wrist, patients with systemic diseases that adversely affected bone quality, those who were dismissed from follow-up, and patients with missing file data were excluded from the study. In line with these criteria, 68 patients were

Corresponding Author: Serdar Menekse, dr.serdarmenekse@gmail.com, *Received: 15.01.2026, Accepted: 04.03.2026, Available Online Date: 15.03.2026. https://doi.org/10.36516/jocass.1863928*

evaluated and 53 patients were included in the study, 15 of whom were excluded for various reasons.

Data Collection and Evaluation Methods

Age, gender, affected side, dominant hand involvement, mechanism of injury, and presence of concomitant ulna styloid fracture were recorded from the patient files. In addition, the time from injury to surgery, operative time, external fixator application time, fixator removal time, and radiological union time were also obtained from the files. The fractures were grouped according to AO/OTA classification as types C1, C2, and C3. Standard anteroposterior and lateral wrist radiographs were used for radiological evaluation. Radial inclination, volar tilt, radial height, ulnar variance, and articular step-off (mm) measurements were performed preoperatively, early postoperatively, and at the final follow-up. Range of motion measurements were evaluated with goniometer in the directions of flexion, extension, pronation, supination, radial and ulnar deviation. Grip strength was compared with the Jamar hand dynamometer, measured on both the affected and intact sides.

Surgical Technique and Follow-up Protocol

All patients underwent closed reduction under local or regional anesthesia. The quality of reduction was checked by C-arm fluoroscopy. The reduction aimed to restore radial inclination, volar tilt, and ulnar variance to near-anatomical values. Then, a uniplanar radiocarpal external fixator was placed. Two 3.0 mm Schanz pins were inserted into the second metacarpal shaft and two into the distal radial diaphysis. No additional Kirschner wires were used. During the external fixation period, patients were instructed to perform active finger flexion–extension and shoulder range-of-motion exercises. After fixator removal, a structured rehabilitation program including progressive wrist range-of-motion and grip-strengthening exercises was initiated. The patients were followed up at regular intervals at 2 weeks, 6 weeks, 3 months, 6 months, 12 months, and then postoperatively. The mean follow-up period was 16 months. Clinical examination and radiological evaluation were performed at each visit. Pain was assessed using the visual analog scale (VAS) on a scale of 0 to 10. DASH scoring and grip strength measurement were started from the 6th week onwards, considering that reliable evaluation could not be made in the presence of external fixators. Fixator removal was performed after radiological union was achieved.

Outcome Criteria

Functional outcomes were classified as very good, good, fair and poor by modified Gartland-Werley scoring. Radiological results were graded similarly using Sarmiento criteria. Complications were recorded under the headings of pinsite infection, complex regional pain syndrome, distal radioulnar joint pain, tendon irritation, eburnation, transient sensory impairment, and nail tip tenderness. Considering that some patients may develop more than one complication, both the total number of complications and the number of patients with complications were calculated separately. Treatment approaches for developing complications were also noted.

Statistical Analysis

The data were analyzed with SPSS 25.0 software. Continuous variables were presented as mean (SD). Compliance with normal distribution was evaluated with the Shapiro-Wilk test. Preoperative and postoperative radiological measurements and range of motion of the affected and healthy sides were compared with paired t-test. The change in VAS score over time was examined at seven time points, and the change in DASH score and grip strength was examined at five time points by repeated-measures ANOVA. Sphericity was assessed using Mauchly's test, and Greenhouse–Geisser correction was applied when the assumption was violated. Bonferroni adjustment was used for pairwise comparisons. Categorical variables were expressed as n and percentages. Chi-square test was used to compare the results according to the AO classification. The relationship between functional and radiological outcomes was evaluated by Spearman correlation analysis. P value below 0.05 was considered statistically significant in all tests.

Ethical Approval

This study was approved by the Ethics Committee. The research followed all principles which the Declaration of Helsinki establishes. Due to the retrospective design, individual patient consent was not required, but patient data was processed anonymously in accordance with the principle of confidentiality.

3. Results

Demographic and Clinical Characteristics

A total of 53 patients were included in our study. The mean age of the patients was calculated as 48.6 years. Female patients constituted the majority and represented approximately two-thirds of all cases. Right-sided involvement was more common than left-sided. In just over half of the patients, the dominant hand was affected. When the mechanism of injury was examined, it was noted that low-energy traumas were significantly prominent. A styloid fracture of the ulna accompanied about two-fifths of the patients. In terms of fracture classification, AO type C2 fractures were determined as the most common type. This was followed by types C1 and C3, respectively. Initially, 68 patients were evaluated for the study, but 15 patients were excluded from the study due to reasons such as open fracture, previous wrist surgery, systemic disease, loss of follow-up and missing data (Table 1).

Table 1

Demographic and Clinical Characteristics of Patients

Parameters	Value
Age (years), Mean ± SD	48.6 ± 12.4
Gender, n (%)	
Male	19 (35.8%)
Female	34 (64.2%)
Affected side, n (%)	
Right	31 (58.5%)
Left	22 (41.5%)
Dominant hand involvement, n (%)	28 (52.8%)
Mechanism of injury, n (%)	
Low-energy trauma	38 (71.7%)
High-energy trauma	15 (28.3%)
Concomitant ulna styloid fracture, n (%)	21 (39.6%)
AO/OTA fracture classification, n (%)	
Type C1 (simple articular, metaphyseal simple)	18 (34.0%)
Type C2 (simple articular, metaphyseal segmented)	24 (45.3%)
Type C3 (segmented articular)	11 (20.8%)
Patient flow	
Assessed for eligibility	68
Excluded (open fracture/previous surgery/systemic disease/loss of follow-up/missing data)	15 (4/3/3/3/2)
Included in the study	53

SD: standard deviation; AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association. Continuous variables are presented as Mean ± SD, categorical variables as n (%).

Radiological Findings

When preoperative and postoperative radiological parameters were compared, significant improvement was found in all measurements. While the radial inclination angle was very low preoperatively, it reached near-normal levels after surgery. This value was

preserved at the final follow-up. A similar improvement was observed in the volar tilt angle. While dorsal angulation was present preoperatively, positive values were reached after surgery. Significant improvements were also obtained in radial height and ulnar variance parameters. The amount of articular step-off was above acceptable limits preoperatively and significantly decreased postoperatively. All these changes were found to be statistically significant (Table 2).

Table 2

Preoperative, Postoperative and Final Follow-up Values of Radiological Parameters

Parameters	Preoperative	Postoperative	Final Follow-up	p*
Radial inclination (°)	12.4 ± 5.8	21.6 ± 3.2	20.8 ± 3.5	<0.001
Volar tilt (°)	-8.6 ± 7.2	9.4 ± 4.1	8.2 ± 4.6	<0.001
Radial height (mm)	6.8 ± 2.4	11.2 ± 1.8	10.6 ± 2.1	<0.001
Ulnar variance (mm)	+4.2 ± 2.1	+0.8 ± 1.2	+1.2 ± 1.4	<0.001
Articular step (mm)	3.4 ± 1.6	0.8 ± 0.6	1.0 ± 0.7	<0.001

*The data are presented as Mean ± SD. *Paired t-test was applied between preoperative and final follow-up values. Normal values: Radial inclination 22–27°, Volar tilt 11–15°, Radial height 11–13 mm, Ulnar variance −2 to +2 mm.*

Table 3

Treatment Process and Range of Motion Values (n=53)

Parameters	Value
Treatment Process	
Time from injury to surgery (days)	2.4 ± 1.6
Duration of operation (min)	42.6 ± 12.4
External fixator duration (weeks)	7.5 ± 0.8
Time to remove the fixator (weeks)	7.8 ± 0.9
Radiological union time (weeks)	8.2 ± 1.4
Follow-up period (months)	16.4 ± 2.8 (12–24)
Range of Motion – Final Follow-Up	Affected / Intact (% intact)
Flexion (°)	62.4 ± 8.6 / 74.2 ± 6.8 (84.1%)*
Extension (°)	58.6 ± 7.4 / 68.4 ± 5.2 (85.7%)*
Pronation (°)	72.8 ± 6.2 / 78.6 ± 4.8 (92.6%)*
Supination (°)	74.2 ± 7.8 / 82.4 ± 5.4 (90.0%)*
Radial deviation (°)	18.4 ± 4.2 / 22.6 ± 3.8 (81.4%)*
Ulnar deviation (°)	28.6 ± 5.4 / 34.2 ± 4.6 (83.6%)*

*Data are presented as Mean ± SD. *Paired t-test between affected and healthy side p<0.05. min: minutes.*

Treatment Process and Range of Motion

The average time between injury and surgery was about two and a half days. The operation time was recorded as approximately 43 minutes. The external fixator was administered for a mean of seven and a half weeks. The radiological union occurred around eight weeks. The patients were followed for a mean of 16 months. When the range of motion was evaluated at the final follow-up, it was seen that approximately 85 percent improvement was achieved in flexion and extension movements compared to the intact side. This rate exceeded 90 percent in pronation and supination movements. In radial and ulnar deviation angles, approximately 82 percent of the intact side was reached. The differences between the affected and intact side were statistically significant (Table 3).

Pain, Functional Scores, and Grip Strength

The level of pain decreased significantly over time. The VAS score, which was high at baseline, gradually decreased during follow-up and decreased to a minimum level at the final follow-up. The DASH score followed a similar pattern. The disability score, which was quite high at Week 6, decreased to low values at Month 16. Positive results were also obtained in terms of grip strength. Grip strength, which was less than a third of the intact side at Week 6, reached 94 percent at the final follow-up. Changes in all parameters over time were statistically significant (Table 4).

Table 4

Change in VAS, DASH Scores, and Grip Strength Over Time

Time	VAS Score (0–10)	DASH Score (0–100)	Grip Strength (kg)	Grip strength (% of intact side)
Baseline	7.2 ± 1.4	–	–	–
Week 2	5.4 ± 1.2	–	–	–
Week 6	4.2 ± 1.2	48.6 ± 12.4	12.4 ± 4.2	38.5%
Month 3	3.0 ± 1.0	32.4 ± 10.2	18.6 ± 5.4	57.8%
Month 6	2.4 ± 0.8	22.8 ± 8.6	24.2 ± 6.8	75.2%
Month 12	1.8 ± 0.6	14.6 ± 6.4	28.4 ± 7.2	88.2%
Final follow-up (Month 16)	1.5 ± 0.5	12.2 ± 5.8	30.2 ± 6.8	93.8%
p-value*	<0.001	<0.001	<0.001	–

*VAS: Visual Analog Scale (0=no pain, 10=most severe pain); DASH: Disabilities of the Arm, Shoulder and Hand (0=no disability, 100=most severe disability). The data are presented as Mean ± SD. *Repeated-measures ANOVA were applied. Mean grip strength on the intact side: 32.2 ± 7.4 kg.*

Table 5

Functional and Radiological Outcomes

Result Category	Functional Result[a] n (%)	Radiological Result[b] n (%)
Excellent	11 (20.8%)	6 (11.3%)
Good	18 (34.0%)	28 (52.8%)
Fair	17 (32.1%)	14 (26.4%)
Poor	7 (13.2%)	5 (9.4%)
Total	53 (100%)	53 (100%)
Good and above result rate	29 (54.7%)	34 (64.2%)
Functional–Radiological Correlation[c]	r = 0.68, p < 0.001	

[a] *Modified Gartland–Werley scoring (Excellent: 0–2, Good: 3–8, Fair: 9–20, Poor: ≥21 points).* [b] *Sarmiento radiological criteria (according to radial shortening and angulation degree).* [c] *Spearman correlation analysis; a moderate-to-strong positive correlation was found between radiological and functional outcomes.*

Functional and Radiological Results

When functional outcomes were evaluated according to the modified Gartland-Werley criteria, very good results were obtained in one-fifth of the patients. The rate of good results exceeded one third. Moderate outcome was seen at a similar rate. Poor results were detected in approximately one-seventh of the patients. The overall rate of good and very good results was just over half. In the evaluation made according to the Sarmiento radiological criteria, the results were slightly better. The rate of good and very good results exceeded two-thirds. There was a statistically significant positive correlation between functional and radiological outcomes (Table 5).

Complications

The most common complication was pinsite infection and occurred in about one-tenth of patients. The vast majority of these infections responded to oral antibiotic therapy. Complex regional pain syndrome and distal radioulnar joint pain were other equally important complications. Tendon irritation, eburnation and transient sensory impairment were found at lower rates. Nail tip tenderness was the rarest complication. A total of 21 complications occurred in 16 patients (30.2%). This proportion corresponded to approximately one-third of all patients (Figure 1).

Figure 1

Distribution and management of complications after external fixation

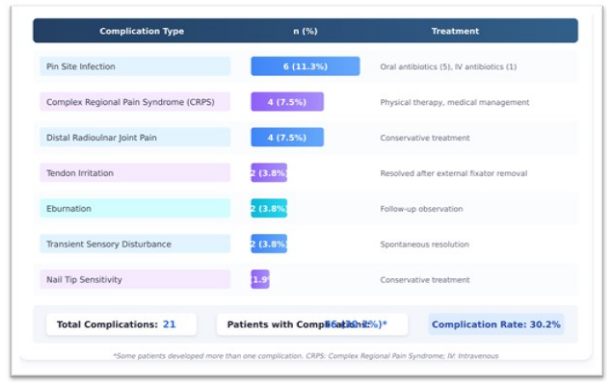
Number and percentage of each complication and corresponding treatment; CRPS = Complex Regional Pain Syndrome, IV = intravenous.

Evaluation of Results by Fracture Type

When the results were examined according to the AO classification, a significant relationship was noted between fracture complexity and results. The rate of functionally good and very good outcomes in type C1 fractures approached three quarters. Radiologically, this rate was even higher. In type C2 fractures, both parameters were slightly above half. In type C3 fractures, the results deteriorated significantly. In this group, the rate of good and above functional outcomes fell below one in four. The relationship between fracture type and functional and radiological outcomes was found to be statistically significant. Complication rates also differed according to the type of fracture. The complication rate in type C3 fractures was approximately twice that of type C1 fractures, but this difference did not reach statistical significance (Figure 2).

Figure 2

Outcomes and complication rates by AO fracture type



Functional and radiological good/excellent outcomes and complication rates across AO/OTA C1–C3 fracture types; AO = Arbeitsgemeinschaft für Osteosynthesefragen, OTA = Orthopaedics Trauma Association.

4. Discussion

In this study, the clinical and radiological outcomes of closed reduction and uniplanar external fixator application in the treatment of intra-articular distal radius fractures were evaluated. The findings revealed that this treatment method provided significant improvement in radiological parameters and acceptable functional results were achieved in the majority of patients. The research findings showed that patients achieved substantial pain and disability symptom reduction while their grip strength improved steadily from start to finish of the observation period. However, it was determined as a remarkable finding that the results were negatively affected as the complexity level of the fracture increased.

In our study, ligamentotaxis resulted in significant improvement in all radiological parameters. Our volar tilt value (8.2°) reached at the final follow-up was very close to the 9.6° ± 2.2° value reported by Hassan et al. with Ilizarov ligamentotaxis.[7] Although the anatomical limits of 11-15° were not fully reached in both studies, dorsal angulation was successfully corrected. Our ulnar variance decreased from +4.2 mm to +1.2 mm. The normal value determined by İsmailoğlu et al. in the Anatolian population is -2.0 ± 2.2 mm.[8] Although this comparison shows that complete anatomical restoration could not be achieved in our patients, the improvement achieved is within acceptable limits in terms of distal radioulnar joint compatibility.

The study showed that the volar tilt decreased by 1.2° and the radial height decreased by 0.6 mm throughout the follow-up period. These minor changes do not indicate clinically meaningful loss. Jensen et al. showed that a 10° rotation of the forearm could produce a difference of about 3° in volar tilt measurement.[9] Therefore, our losses may be due to positional differences during measurement. The research by Mittal et al. presents findings which differ from the previous study and emphasized that the success of closed reduction and ligamentotaxis methods depends on maintaining a stable reduction.[10] The fact that 64.2% of the radiologic results were obtained in our study supports that ligamentotaxis is an effective method for anatomical restoration in intra-articular fractures.

In our study, the DASH score decreased from 48.6 at Week 6 to 12.2 at the final follow-up. This value is in line with the year 1 QuickDASH average of 9.8 reported by Ingall et al.[11] The most significant improvement occurred between Week 6 and Month 3; this period

coincided with the beginning of fixator removal and active rehabilitation. Ingall et al. also showed that 82% of the recovery was completed in the first 3-6 months.[11] In the multicenter study of Ludvigsen et al., the QuickDASH score of the external fixation group was reported as 43 at Week 6, but the gap with the volar plate was closed at 1 year.[12] A similar pattern was observed in our series.

Grip strength reached 93.8% of the intact side at the final follow-up. Ludvigsen et al. reported that grip strength equalized at 1 year in both surgical methods.[12] The meta-analysis by Maccagnano et al. also supports that there is no functional difference between techniques in the long run.[13] The range of motion assessment revealed that patients achieved better results with their rotational movements which reached 90-92% compared to their sagittal plane movements which reached 84-85%. Norton et al. described how healthcare providers can monitor complete recovery by using ROM assessment in combination with grip strength measurement and DASH evaluation.[14] The research results indicate that external fixation leads to acceptable functional results which patients can maintain during extended periods.

In our study, the rate of functional good and above results was 54.7% according to Gartland-Werley, while the radiological good and above results were determined as 64.2% according to Sarmiento criteria. This difference of approximately 10% is remarkable. Salama et al. reported a strong positive correlation between radiological and functional scores in the intra-articular fractures they treated with ligamentotaxis.[15] In our series, a moderate-to-strong relationship was found at the level of r=0.68. However, this correlation shows that only 46% of functional outcomes can be explained by radiological parameters.

İpek et al. reported good and excellent functional outcomes in over 80% of patients treated with a volar plate.[16] The fact that this rate remained lower in our external fixation series may reflect the difference between methods. Lee et al. demonstrated that DASH scores depend on the degree of joint surface millimeter mismatch.[17] The study indicates that micro-irregularities that radiography fails to detect may result in decreased functional ability. The research by Diepold et al. reported that function could be preserved in patients over 70 years of age despite the development of radiological malunion.[18] The study shows that radiological–functional mismatch exists as a bidirectional phenomenon.

The overall complication rate in our series was 30.2%. The most common problem was pin-site infection with 11.3%. In the systematic review of Cruciani et al., the infection rate in external fixation was reported as 13.9%, and the majority of these infections consisted of pin-site infections.[19] Our rate is slightly below this value. An important point is that 5 out of 6 infections were controlled with oral antibiotics. Arveladze et al. also emphasized that pin-site infections can often be successfully treated with oral antibiotics.[20] This shows that most of the infections that develop are superficial.

Our CRPS rate was determined as 7.5%. Halvachizadeh et al. followed CRPS after distal radius surgery and reported that complication rates ranged from 5.4% to 12.2% in different groups.[21] Our rate fits within this range. When evaluated according to the AO classification, the functional good outcome was 72.2% in C1 fractures and decreased to 27.3% in C3 (p=0.042). Hjelle et al. reported that fracture complexity cannot be explained only by bone quality, and that trauma energy is also decisive.[22] The fact that the difference in complication rates did not reach statistical significance (p=0.284) is probably due to the insufficient number of patients in the C3 group.

The most important limitation of this study is its retrospective design and the absence of a control group; this makes it impossible to directly compare external fixation with other treatment modalities. The study results might not apply to all cases because the research was conducted at a single location with a small number of participants. The study demonstrates two major advantages through its practice of monitoring patients continuously while performing complete assessments of imaging results and operational measurements. The selection of treatment options will become clearer through prospective studies which compare volar locking plates to other alternatives while studying more patients.

5. Conclusions

The treatment of intra-articular distal radius fractures consists of closed reduction which leads to uniplanar external fixator application because this method delivers dependable and successful outcomes. With this method, radiological correction can be achieved, satisfactory functional improvement is achieved in most patients, and pain levels decrease significantly over time. The success of treatment depends on the complexity of fractures but external fixation works as an effective treatment for particular patients who require intra-articular fragmentation repair through proper selection of patients and close medical monitoring.

Statement of ethics

This study was approved by the Adana City Training and Research Hospital Clinical Research Ethics Committee (Approval date: January 18, 2024; Meeting No: 144, Decision No: 3122). All procedures were conducted in accordance with the ethical standards of the institutional research committee and with the principles of the Declaration of Helsinki. As this was a retrospective study, informed consent was waived by the ethics committee.

genAI

No artificial intelligence-based tools or generative AI technologies were used in this study. The entire content of the manuscript was originally prepared, reviewed, and approved by both authors.

Author Contributions:

Conceptualization: İP; Data curation: İP; Formal analysis: İP; Funding acquisition: İP; Investigation: İP, SM; Methodology: İP; Project administration: İP; Resources: İP; Software: İP; Supervision: SM; Validation: SM; Visualization: İP, SM; Writing – original draft: İP; Writing – review & editing: SM

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest statement

The authors declare that they have no conflict of interest.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

References

1. Gouk C, Ng SK, Knight M, Bindra R, Thomas M. Long term outcomes of open reduction internal fixation versus external fixation of distal radius fractures: A meta-analysis. Orthop Rev (Pavia). 2019;11(3):7809. **Crossref**
2. Diaz-Garcia RJ, Oda T, Shauver MJ, Chung KC. A systematic review of outcomes and complications of treating unstable distal radius fractures in the elderly. J Hand Surg Am. 2011;36(5):824-835. **Crossref**
3. Zahed M, Elmesalmi M, El Menawy Z, et al. Volar Locking Plate Versus External Fixation for Distal Radius Fractures: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Cureus. 2026;18(1):e100789. **Crossref**

4. Gou Q, Xiong X, Cao D, He Y, Li X. Volar locking plate versus external fixation for unstable distal radius fractures: a systematic review and meta-analysis based on randomized controlled trials. BMC Musculoskelet Disord. 2021;22:433. **Crossref**
5. Van Oijen GW, Van Lieshout EMM, Reijnders MRL, et al. Treatment options in extra-articular distal radius fractures: a systematic review and meta-analysis. Eur J Trauma Emerg Surg. 2022;48(10):4333-4348. **Crossref**
6. Cui Z, Pan J, Yu B, Zhang K, Xiong X. Internal versus external fixation for unstable distal radius fractures: an up-to-date meta-analysis. Int Orthop. 2011;35(9):1333-1341. **Crossref**
7. Hassan SMT, Meeran G, Raza T, Akmal U, Ullah Z, Kakar AUK, et al. Evaluating Clinical and Radiological Outcomes of Ilizarov Ligamentotaxis and Volar Locked Plating in AO Type C2 and C3 Distal Radius Fractures: A Two-Year Prospective Observational Study. Cureus. 2025;17(9):e91663. **Crossref**
8. İsmailoğlu P, Nalbantoğlu U, Tok O, Bayramoğlu A, İsmailoğlu AV, Yıldırım FG. Distal radius morphometry of volar curvature along with scaphoid and lunate facet inclinations and ulnar variance in the Anatolian population. Sci Rep. 2026;16(1):35123. **Crossref**
9. Jensen J, Tromborg HB, Rasmussen SBSB, Gerke O, Torfing T, Precht H, et al. Dorsal Tilt of the Distal Radius Fracture Changes With Forearm Rotation When Measured on Radiographs. J Hand Surg Glob Online. 2021;3(4):182-189. **Crossref**
10. Mittal S, Agrawal AC, Sakale H, Kar BK. Distal radial fractures: Conservative treatment. J Orthop Dis Traumatol. 2020;3(2):41-44. **Crossref**
11. Ingall EM, Harper CM, Bernstein DN, Shoji MM, Merchan N, Rozental TD. Using the QuickDASH to Model Clinical Recovery Trajectory After Operative Management of Distal Radius Fracture. J Hand Surg Glob Online. 2021;3(1):1-6. **Crossref**
12. 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. **Crossref**
13. Maccagnano G, Noia G, Vicenti G, et al. Volar locking plate versus external fixation in distal radius fractures: A meta-analysis. Orthop Rev (Pavia). 2022;14(3):37050. **Crossref**
14. Norton B, Bugden B, Liu KPY. Functional outcome measures for distal radius fractures: A systematic review. Hong Kong J Occup Ther. 2022;35(2):115-124. **Crossref**
15. Salama AM, El-Adawy AM, Mashhour A, Bentaher MR. Results of ligamentotaxis technique in treatment of intra-articular distal radius fracture. Zagazig Univ Med J. 2022;28(6):152-157. **Crossref**
16. İpek E, Balkanlı B, Altuntaş Y, Cam N. Comparison of plate applications for distal radius fractures in semi-prone and supination. Hand Microsurg. 2025;14(1):33-40. **Crossref**
17. Lee CH, Kwon Y, Jung IY, Lee BG, Kim SJ. Effect of the Articular Surface Incongruency on Surgical Outcome of the Distal Radius Fracture. Biomed Res Int. 2022;2022:8357675. **Crossref**
18. Diepold J, Filipp S, Dussing F, Steiner G, Deininger C, Gotterbarm T, Wichlas F. Poor fracture alignment equals poor outcome? Analysis of conservatively managed distal radius fractures. Arch Orthop Trauma Surg. 2025;145:442. **Crossref**
19. Cruciani A, Giuli C, Di Pietro G, Cianni L, Fulchignoni C, Del Vecchio P, Maccauro G, Vitiello R. Epidemiology and treatment of surgical infections after distal radius fractures: a systematic review. Arch Orthop Trauma Surg. 2025;145:483. **Crossref**
20. Arveladze S, Moriarty F, Jennison T. The influence of pin material and coatings on the incidence of pin site infection after external fixation. J Limb Lengthen Reconstr. 2022;8(Suppl 1):S16-S23. **Crossref**
21. Halvachizadeh S, Dreifuss M, Rauer T, Kaiser A, Ubmann D, Pape HC, Allemann F. Does the AO/OTA fracture classification dictate the anesthesia modality for the surgical management of unstable distal radius fractures? A retrospective cohort study in 127 patients managed by general vs. regional anesthesia. Patient Saf Surg. 2025;19:2. **Crossref**
22. Hjelle AM, Gjertsen JE, Apalset EM, Nilsen RM, Lober A, Tell GS, Mielnik P. No association between osteoporosis and AO classification of distal radius fractures: an observational study of 289 patients. BMC Musculoskelet Disord. 2020;21:811. **Crossref**