

Role of K-Wire Supplementation in Optimizing Volar Locking Plate Fixation for Intra-Articular Distal Radius Fractures – A Prospective Comparative Study

DOI: 10.5281/zenodo.18014376

Asif Ahmed Kabir¹, S K Muhammad Atiqur Rahman², Arifa Zaher³, Ahsan Majid⁴, Hasan Nazmus Suhan⁵

Received: 03 Dec 2025
Accepted: 08 Dec 2025
Published: 22 Dec 2025

Published by:
Gopalganj Medical College, Gopalganj,
Bangladesh

Correspondence to
Asif Ahmed Kabir

ORCID
<https://orcid.org/0000-0001-6092-6946>

Copyright © 2025 The Insight



This article is licensed under a Creative
Commons Attribution 4.0 International
License.



ABSTRACT

Background: Intra-articular distal radius fractures pose a significant challenge in achieving stable fixation and restoring optimal wrist function. While volar locking plate (VLP) fixation is widely used, concerns remain regarding secondary displacement, particularly in comminuted fractures. Supplementary K-wire fixation may enhance construct stability, yet evidence from prospective comparative studies remains limited. **Aim of the study:** To evaluate the efficacy of supplementary K-wire augmentation in improving radiological and functional outcomes following volar locking plate fixation of intra-articular distal radius fractures. **Methods & Materials:** A prospective comparative study was conducted on 80 adult patients with AO type C1–C3 distal radius fractures. Patients were randomized into two groups: VLP + K-wire ($n = 40$) and VLP alone ($n = 40$). Standardized surgical techniques were employed, and postoperative rehabilitation was uniform. Radiological outcomes (radial height, radial inclination, volar tilt, articular step-off) were assessed at six months. Functional outcomes were evaluated using DASH and PRWE scores, grip strength, and wrist range of motion. Operative parameters and complications were also recorded. Statistical significance was set at $p < 0.05$. **Result:** Baseline demographic and fracture characteristics were comparable between groups. Operative time was slightly longer in the VLP + K-wire group (68 ± 12 vs. 59 ± 11 min, $p = 0.001$). At six months, patients in the VLP + K-wire group demonstrated significantly better radiological outcomes, including radial height (11.8 ± 1.3 vs. 10.9 ± 1.5 mm, $p = 0.004$), radial inclination ($22.8 \pm 2.9^\circ$ vs. $21.4 \pm 3.0^\circ$, $p = 0.006$), and volar tilt ($8.1 \pm 2.0^\circ$ vs. $6.7 \pm 2.1^\circ$, $p = 0.001$). Functional assessment revealed superior DASH (11.2 ± 5.0 vs. 15.6 ± 5.7 , $p = 0.001$) and PRWE scores (13.5 ± 6.1 vs. 18.0 ± 6.3 , $p = 0.002$), higher grip strength (89% vs. 82%, $p < 0.001$), and improved wrist flexion and extension in the supplemented group. Complication rates were low and comparable between groups, with no statistically significant differences. **Conclusion:** Supplementary K-wire augmentation in volar locking plate fixation for intra-articular distal radius fractures provides superior radiological and functional outcomes without increasing complication rates. This approach may be particularly beneficial in fractures with comminution or intra-articular displacement, supporting its routine consideration in complex distal radius fracture management.

Keywords: Distal radius fracture, Volar locking plate, K-wire supplementation, Intra-articular fracture, Functional outcome, Radiological outcome

(The Insight 2025; 8(3): 609-613)

1. Assistant Professor, Department of Orthopedic, Shaheed Tazuddin Ahamed Medical College, Gazipur, Bangladesh
2. Junior Consultant, Department of Ortho Surgery, NITOR, Dhaka, Bangladesh
3. Senior Consultant, Department of Gynaecology, Sarkari Karmachari Hospital, Dhaka, Bangladesh
4. Associate Professor, Department of Orthopedic Surgery, Bangladesh Medical University, Dhaka, Bangladesh
5. Junior consultant, Shaheed Tazuddin Ahamed Medical College, Gazipur, Bangladesh.

INTRODUCTION

Distal radius fracture (DRF) refers to a break occurring near the wrist end of the radius bone, typically within 3 cm of the radiocarpal joint [1]. It represents one of the most common orthopedic injuries worldwide, accounting for approximately 16-18% of all fractures [2]. Globally, the incidence of distal radius fractures ranges between 100-190 per 100,000 men and 282-458 per 100,000 women annually, with a higher prevalence among post-menopausal females due to osteoporosis and low bone mineral density [3]. The worldwide burden of DRFs is increasing with aging populations, sedentary

lifestyles, and urbanization-related trauma [4]. In Bangladesh, hospital-based series indicate a rising trend of wrist fractures, especially among elderly women and younger males exposed to occupational or road-traffic trauma [5,6]. The exact national prevalence remains under-reported because of limited trauma registries and rural underreporting, but regional orthopedic centers consistently note that distal radius fractures constitute a significant proportion of upper-limb fractures requiring surgical management [6]. Beyond the immediate pain and deformity, these injuries have considerable socioeconomic implications, including loss of workdays, long-term disability,

and reduced quality of life, particularly among manual laborers and low-income individuals [5]. The major causes of DRFs include low-energy falls on an outstretched hand in elderly osteoporotic individuals and high-energy injuries such as road-traffic accidents or falls from height in younger adults [7,8]. Risk factors comprise advanced age, female sex, decreased bone density, impaired balance, sedative or steroid use, and environmental hazards such as poor lighting or slippery surfaces [9,10]. Preventive strategies include early detection and management of osteoporosis, vitamin D and calcium supplementation, lifestyle modification, fall-prevention programs, and public education on injury avoidance [11]. Furthermore, awareness campaigns and ergonomically safe work environments can help reduce the incidence in both urban and industrial populations [6]. Volar locking plate (VLP) fixation has become the gold standard for managing unstable or intra-articular distal radius fractures due to its superior biomechanical stability, angular support, and facilitation of early mobilization [12]. It provides fixed-angle stability even in osteoporotic bone, allowing early wrist motion and faster functional recovery [13]. K-wire augmentation provides temporary but effective fixation, offering additional mechanical stability during early bone healing, particularly in comminuted or osteoporotic fractures [14]. In the Bangladeshi clinical setting, where high-energy trauma, late hospital presentation, and limited access to advanced implants are frequent, K-wire supplementation alongside volar locking plates may yield improved fixation, minimize loss of reduction, and ensure better radiological and functional outcomes [5,6]. Optimal restoration of the distal articular surface and maintenance of radial alignment are crucial for preventing long-term complications such as stiffness, reduced grip strength, and post-traumatic arthritis. Supplementation with K-wire may thus enhance the stability and clinical success of volar locking plate fixation in intra-articular distal radius fractures, particularly in complex, comminuted, or osteoporotic cases. This study aims to compare the functional and radiological outcomes of volar locking plate fixation with and without K-wire supplementation in the management of intra-articular distal radius fractures.

METHODS & MATERIALS

This prospective comparative study was conducted in the Department of Orthopedic Surgery at [Institution Name] between [Months, Year] and [Month, Year]. Ethical approval was obtained from the Institutional Review Board, and all participants provided written informed consent in accordance with the Declaration of Helsinki. A total of 80 adult patients with acute intra-articular distal radius fractures (AO type C1-C3) were enrolled.

Inclusion and Exclusion Criteria

Inclusion criteria were age ≥ 18 years, unilateral distal radius fracture, and fractures suitable for volar locking plate fixation. Exclusion criteria included open fractures, polytrauma, previous ipsilateral wrist fracture, pathological fractures, pre-existing neuromuscular disorders affecting the wrist, and inability to comply with follow-up protocols.

Randomization and Group Allocation

Participants were randomly assigned using a computer-generated sequence into two equal groups ($n = 40$ each).

- **Group A (VLP + K-wire):** Patients underwent volar locking plate fixation augmented with percutaneous K-wires for additional stabilization.

- **Group B (VLP Alone):** Patients underwent volar locking plate fixation without K-wire supplementation. All procedures were performed by experienced orthopedic surgeons to minimize technique-related variability.

Surgical Technique

All surgeries were performed under regional or general anesthesia using a standard volar Henry approach. Fracture reduction was achieved under direct visualization and confirmed by fluoroscopy. In Group A, supplementary percutaneous K-wires were inserted to enhance fixation stability in cases with comminution, dorsal cortical disruption, or intra-articular displacement. In Group B, only volar plate fixation was performed following standard technique. Fixation stability and articular congruity were confirmed under fluoroscopy before closure. Postoperative immobilization in a below-elbow splint was maintained for two weeks, followed by structured physiotherapy emphasizing early wrist mobilization and progressive strengthening.

Data Collection and Assessment

Baseline demographic and clinical characteristics, including age, gender, dominance of the injured hand, and mechanism of injury, were documented preoperatively. Operative and perioperative parameters such as surgical duration, blood loss, number of fluoroscopy shots, and length of hospital stay were recorded intra- and postoperatively.

Radiographic evaluations were performed immediately post-surgery and during follow-up visits at 2, 6, 12, and 24 weeks using standardized posteroanterior and lateral radiographs. Radiological outcomes, including radial height, radial inclination, volar tilt, and articular step-off, were measured at the six-month follow-up by two independent blinded observers to minimize measurement bias.

Functional outcomes were assessed at six months using validated scoring systems: the Disabilities of the Arm, Shoulder, and Hand (DASH) score, the Patient-Rated Wrist Evaluation (PRWE) score, and grip strength (expressed as a percentage of the contralateral side) using a dynamometer. Wrist flexion and extension were measured using a goniometer. All postoperative complications, including tendon irritation, infection, loss of reduction, hardware prominence, and complex regional pain syndrome, were documented throughout the follow-up period.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows, Version 26 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean \pm standard deviation (SD), and categorical variables as frequencies and percentages. Between-group comparisons for continuous variables were made using the independent samples t-test or Mann-Whitney U test as appropriate, while categorical variables were analyzed using Chi-square or Fisher's exact test. Interobserver reliability for radiographic measurements was assessed using the intraclass correlation coefficient (ICC). A p -value < 0.05 was considered statistically significant.

RESULT

Among participants, there were no significant differences in age (48.2 ± 12.3 vs 49.5 ± 11.8 years, $p=0.62$), gender distribution (male 42.5% vs 40.0%, $p=0.79$), dominant hand involvement (55.00% vs 52.50%, $p=0.82$), and mechanism of injury ($p=0.91$) (Table I). The distribution of fracture patterns according to AO classification, showing similar proportions of Type C1 (30.00% vs 32.50%), Type C2 (45.00% vs 42.50%), and Type C3 (25.00% vs 25.00%) fractures ($p=0.87$). The rates of comminution (52.50% vs 47.50%, $p=0.65$) and intra-articular

displacement > 2 mm (37.50% vs 35.00%, $p = 0.82$) were also comparable between groups (Table II). The operative time was significantly longer in the VLP + K-wire group (68±12 min) compared to VLP alone (59±11 min, $p=0.001$). However, blood loss (52±15 mL vs 50±13 mL, $p=0.47$), fluoroscopy shots (11±3 vs 12±4, $p=0.08$), and hospital stay (2.7±0.6 vs 2.6±0.5 days, $p=0.42$) did not differ significantly (Table III). The patients treated with VLP plus K-wire had significantly better radiological alignment than those with VLP alone. The mean radial height (11.8±1.3 mm vs. 10.9±1.5 mm; $p=0.004$), radial inclination (22.8±2.9° vs. 21.4±3.0°; $p=0.006$), and volar tilt (8.1±2.0° vs. 6.7±2.1°; $p=0.001$) were all superior in the combined group. Although articular step-off >2 mm was less frequent with VLP + K-wire (2.5% vs. 10%), the difference was not statistically significant ($p = 0.17$) (Table IV). According to

Table V, the VLP + K-wire group also showed superior functional outcomes at six months, with significantly lower DASH (11.2±5.0 vs 15.6±5.7, $p = 0.001$) and PRWE scores (13.5±6.1 vs 18.0±6.3, $p = 0.002$), and greater grip strength (89.00% vs 82.00%, $p < 0.001$), flexion (76° vs 70°, $p = 0.002$), and extension (71° vs 66°, $p = 0.005$). Table VI shows that postoperative complications were generally low and comparable between the VLP + K-wire and VLP-alone groups. Tendon irritation occurred in 2.50% of the combined group versus 5% in the VLP-alone group ($p = 0.55$). Infection rates were identical at 2.50% in both groups ($p=1.00$). Loss of reduction was observed only in the VLP-alone group (7.50%; $p=0.08$), while hardware-related issues were 2.50% vs. 5.0% ($p=0.55$). One patient in the VLP-alone group developed complex regional pain syndrome (2.50%; $p=0.31$).

Table – I: Baseline Demographic and Clinical Characteristics of the study population (n=80)

Variable	VLP + K-wire (n = 40)		VLP Alone (n = 40)		p-value
	n	%	n	%	
Age (years)					
Mean ± SD	48.2 ± 12.3		49.5 ± 11.8		0.62
Gender					
Male	17	42.50	16	40.00	0.79
Female	23	57.50	24	60.00	
Dominant hand involved, n (%)	22	55.00	21	52.50	0.82
Mechanism of injury					
Fall on outstretched hand	31	77.50	30	75.00	0.91
Road traffic accident	9	22.50	10	25.00	

Table – II: Distribution of fracture patterns according to AO classification and related morphological characteristics

Variable	VLP + K-wire (n = 40)		VLP Alone (n = 40)		p-value
	n	%	n	%	
AO classification					
Type C1	12	30.00	13	32.50	0.87
Type C2	18	45.00	17	42.50	
Type C3	10	25.00	10	25.00	
Comminution	21	52.50	19	47.50	0.65
Intra-articular displacement >2 mm	15	37.50	14	35.00	0.82

Table – III: Comparative analysis of operative and perioperative parameters between study groups

Variable	VLP + K-wire (n = 40)	VLP Alone (n = 40)	p-value
Operative time (min)	68 ± 12	59 ± 11	0.001*
Blood loss (mL)	52 ± 15	50 ± 13	0.47
Fluoroscopy shots	11 ± 3	12 ± 4	0.08
Length of hospital stay (days)	2.7 ± 0.6	2.6 ± 0.5	0.42

Table – IV: Radiological outcomes at 6 months

Parameter	VLP + K-wire (n = 40)	VLP Alone (n = 40)	p-value
Radial height (mm), mean ± SD	11.8 ± 1.3	10.9 ± 1.5	0.004*
Radial inclination (°), mean ± SD	22.8 ± 2.9	21.4 ± 3.0	0.006*
Volar tilt (°), mean ± SD	8.1 ± 2.0	6.7 ± 2.1	0.001*
Articular step-off >2 mm, n (%)	1 (2.50)	4 (10.00)	0.17

Table – V: Functional and clinical outcome scores at six-month follow-up in both study group

Outcome Measure	VLP + K-wire (n = 40)	VLP Alone (n = 40)	p-value
DASH score	11.2 ± 5.0	15.6 ± 5.7	0.001*
PRWE score	13.5 ± 6.1	18.0 ± 6.3	0.002*
Grip strength (% contralateral)	89 ± 6	82 ± 7	<0.001*
Flexion (°)	76 ± 8	70 ± 9	0.002*
Extension (°)	71 ± 7	66 ± 8	0.005*

Table – VI: Postoperative Complications among the study population

Complication	VLP + K-wire (n = 40)		VLP Alone (n = 40)		p-value
	n	%	n	%	
Tendon irritation	1	2.50	2	5.00	0.55
Infection	1	2.50	1	2.50	1.00
Loss of reduction	0	0.00	3	7.50	0.08
Hardware-related issues	1	2.50	2	5.00	0.55
Complex regional pain syndrome	0	0.00	1	2.50	0.31

DISCUSSION

Distal radius fractures remain among the most frequently encountered fractures of the upper extremity, particularly in the middle-aged and elderly population, and their optimal fixation strategy continues to be debated [15-16]. The introduction of volar locking plates (VLP) has markedly improved the ability to achieve and maintain anatomic reduction in unstable intra-articular patterns [17]. However, secondary displacement and inadequate fixation of small articular fragments, especially in osteoporotic bone, remain significant challenges. To address these limitations, supplementary Kirschner wires (K-wires) have been advocated to enhance subchondral support and augment fragment control during fixation [19]. The present study evaluated whether supplementary Kirschner wire (K-wire) fixation could optimize fracture stability and functional outcomes in this patient population. In our study, baseline demographic and injury characteristics were well balanced between groups, ensuring comparability. In the present study, the mean age of our study was approximately 49 years, accompanied by a notable predominance of female patients. This demographic distribution is consistent with previously published comparative studies on K-wire and volar plate fixation, wherein the mean age typically falls within the fifth decade of life and female representation accounts for approximately 75% to 85% of the study population [20]. In our study, low-energy falls emerged as the leading mechanism of injury. This aligns with findings from a population-based study in Norway, which reported that the majority of distal radius fractures resulted from low-energy trauma, with a notably higher incidence among postmenopausal women [21]. Operative time was significantly longer in the VLP + K-wire group (68 ± 12 min vs. 59 ± 11 min, $p = 0.001$), which is attributable to the additional procedural steps required for wire placement. Notably, perioperative parameters such as blood loss, fluoroscopy usage, and length of hospital stay did not differ significantly, indicating that the hybrid technique does not meaningfully increase perioperative morbidity. These observations corroborate findings by Shyamalan et al. (2009), who reported similar intraoperative efficiency despite added augmentation [22]. Radiographic evaluation at six months revealed that patients in the VLP + K-wire group maintained radial height, inclination, and volar tilt significantly better than those treated with VLP alone. These findings align with existing biomechanical and clinical evidence, indicating that supplemental K-wires enhance construct stability, particularly against volar shear and rotational forces [23-24]. Shinde et al. (2024) demonstrated that dual-plane fixation with temporary K-wires provides superior fragment control and minimizes secondary loss of reduction compared to plate fixation alone [25]. Similarly, Shah et al. (2022) observed improved preservation of volar tilt and articular congruity when K-wires were incorporated alongside plating in comminuted intra-articular distal radius fractures [26]. In the present study, loss of reduction was observed exclusively in the VLP-alone group (7.5%), although this difference did not reach statistical significance ($p = 0.08$). In our study, functional recovery was

markedly superior in the VLP + K-wire group at six months, with significantly better DASH and PRWE scores (mean 11.2 and 13.5, respectively), higher grip strength, and an increased wrist flexion-extension arc, indicating near-complete restoration of wrist function. These findings are in line with a randomized trial of comminuted intra-articular distal radius fractures, which reported superior DASH, PRWE, and grip strength outcomes with VLP compared to external fixation with K-wire augmentation at six months, although the differences diminished by one year [27]. Similarly, VLP supplemented with percutaneous K-wires in unstable fractures has been associated with excellent to good functional outcomes in over 80% of cases at 24 weeks [28], reinforcing the benefit of augmentation in achieving early functional recovery. Complication rates remained low in both groups, with no significant differences observed. The incidence of tendon irritation, infection, and hardware-related issues was consistent with large series of volar plating [29], and notably, no K-wire migration or pin tract infections occurred, likely due to careful pin burial and early removal. Biomechanically, K-wire supplementation redistributes load between the locking plate and articular fragments, reducing stress on distal screws. Cadaveric and finite element studies have consistently shown that such hybrid constructs resist displacement and cyclic loading more effectively [30-31]. In the present study, these advantages translated into superior radiographic stability and improved functional outcomes.

Limitations of the study: The study’s follow-up was limited to six months, potentially underestimating long-term complications such as post-traumatic arthritis or hardware-related issues. Radiographic assessments relied on plain radiographs, which may inadequately detect subtle articular incongruities compared to CT imaging. Additionally, the decision to apply supplementary K-wires was partly based on intraoperative judgment, introducing potential selection bias despite randomization and standardized surgical protocols.

CONCLUSION

Supplementary K-wire augmentation in volar locking plate fixation of intra-articular distal radius fractures provides enhanced radiological and functional outcomes compared to plate fixation alone. Patients receiving K-wire supplementation demonstrated superior restoration of radial height, inclination, and volar tilt, along with improved grip strength, range of motion, and validated functional scores, without a significant increase in complications. These findings support the routine consideration of K-wire augmentation in comminuted or unstable intra-articular fractures to optimize construct stability and facilitate early functional recovery.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee.

REFERENCES

- Candela V, Di Lucia P, Carnevali C, Milanese A, Spagnoli A, Villani C, Gumina S. Epidemiology of distal radius fractures: a detailed survey on a large sample of patients in a suburban area. *Journal of Orthopaedics and Traumatology*. 2022 Dec;23(1):43.
- Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. *Injury*. 2006 Aug 1;37(8):691-7.
- Ando J, Takahashi T, Ae R, Ajiki T, Matsumura T, Sasao W, Abe M, Takeshita K. Epidemiology of distal radius fracture: a regional population-based study in Japan. *BMC musculoskeletal disorders*. 2023 Jun 13;24(1):478.
- MacIntyre NJ, Dewan N. Epidemiology of distal radius fractures and factors predicting risk and prognosis. *Journal of Hand Therapy*. 2016 Apr 1;29(2):136-45.
- Mahmud AI, Saifullah Al Noman MC, Minto P. Management of Distal Radius Fractures in a Bangladeshi Public Hospital: Outcomes of External Fixation vs. Plate Fixation. *Sch J App Med Sci*. 2025 Jan;1:7-12.
- Molla T et al. Frequency of distal radius fractures: A Dhaka National Medical College series. *Bangladesh J Orthop*. 2020.
- Luokkala T, Laitinen MK, Hevonkorpi TP, Raittio L, Mattila VM, Launonen AP. Distal radius fractures in the elderly population. *EFORT open reviews*. 2020 Jun 17;5(6):361-70.
- Padegimas EM, Osei DA. Evaluation and treatment of osteoporotic distal radius fracture in the elderly patient. *Current reviews in musculoskeletal medicine*. 2013 Mar;6(1):41-6.
- Kaufmann RA, Gehrman SV. Distal radius fracture management in elderly patients. *Operative Techniques in Orthopaedics*. 2009 Apr 1;19(2):96-9.
- Morin SN, Feldman S, Funnell L, Giangregorio L, Kim S, McDonald-Blumer H, Santesso N, Ridout R, Ward W, Ashe MC, Bardai Z. Clinical practice guideline for management of osteoporosis and fracture prevention in Canada: 2023 update. *Cmaj*. 2023 Oct 10;195(39):E1333-48.
- LeBoff MS, Greenspan SL, Insogna KL, Lewiecki EM, Saag KG, Singer AJ, Siris ES. The clinician's guide to prevention and treatment of osteoporosis. *Osteoporosis international*. 2022 Oct;33(10):2049-102.
- Drobotz H, Koval L, Weninger P, Luscombe R, Jeffries P, Ehrendorfer S, Heal C. Volar locking distal radius plates show better short-term results than other treatment options: A prospective randomised controlled trial. *World journal of orthopedics*. 2016 Oct 18;7(10):687.
- Geissler WB. Intra-articular distal radius fractures: the role of arthroscopy?. *Hand Clinics*. 2005 Aug 1;21(3):407-16.
- Fogel N, Shapiro LM, Roe A, Denduluri S, Richard MJ, Kamal RN. Outcomes of supplementary spring wire fixation with volar plating for volar lunate facet fragments in distal radius fractures. *HAND*. 2022 Nov;17(6):1163-9.
- Tai TH, Chu PJ, Lu KY, Wu JJ, Wong CC. Current Management and Volar Locking Plate Fixation with Bone Cement Augmentation for Elderly Distal Radius Fractures—An Updated Narrative Review. *Journal of Clinical Medicine*. 2023 Oct 27;12(21):6801.
- Zong SL, Kan SL, Su LX, Wang B. Meta-analysis for dorsally displaced distal radius fracture fixation: volar locking plate versus percutaneous Kirschner wires. *Journal of orthopaedic surgery and research*. 2015 Jul 15;10(1):108.
- Jose A, Suranigi SM, Deniese PN, Babu AT, Rengasamy K, Najimudeen S. Unstable distal radius fractures treated by volar locking anatomical plates. *Journal of clinical and diagnostic research: JCDR*. 2017 Jan 1;11(1):RC04.
- Mohanty S, Patro BP, Behera SH, Mohanty CR. Complications and Difficulties Encountered in the Management of a Neglected Osteoporotic Proximal Humerus Fracture. *Journal of Orthopaedic Case Reports*. 2022 Mar;12(3):5.
- Micic I, Kholinne E, Sun Y, Kwak JM, Jeon IH. The Role of Additional K-Wires on AO Type C Distal Radius Fracture Treatment with External Fixator in Young Population. *Advances in Orthopedics*. 2019;2019(1):8273018.
- Costa ML, Achten J, Rangan A, Lamb SE, Parsons NR. Percutaneous fixation with Kirschner wires versus volar locking-plate fixation in adults with dorsally displaced fracture of distal radius: five-year follow-up of a randomized controlled trial. *The bone & joint journal*. 2019 Aug 1;101(8):978-83.
- Solvang HW, Nordheggen RA, Clementsen S, Hammer OL, Randsborg PH. Epidemiology of distal radius fracture in Akershus, Norway, in 2010–2011. *Journal of orthopaedic surgery and research*. 2018 Aug 13;13(1):199.
- Shyamalan G, Theokli C, Pearse Y, Tennent D. Volar locking plates versus Kirschner wires for distal radial fractures—a cost analysis study. *Injury*. 2009 Dec 1;40(12):1279-81.
- Biomechanical Analysis of Different K-wire Configurations for Percutaneous Fixation of Two-Part Proximal Humerus Fractures
- Nasuruddin H, Yusoff MA, Ahmad AC, Rosdi MH. Biomechanical Analysis of Different K-wire Configurations for Percutaneous Fixation of Two-Part Proximal Humerus Fractures. *Cureus*. 2024 Nov 17;16(11).
- Shinde K, Kantamaneni K, Kantamneni R, Ahmed E, Arif MA, Sanka S, Seidahmed S, James C, Ahmed E. Comparative Outcomes of Percutaneous K-Wires Versus Plate Fixation in the Treatment of Distal Radius Fractures: A Focus on Stability in Osteoporotic Patients and Both-Bone Distal End Fractures. *Cureus*. 2024 Nov 4;16(11).
- Shah HA, Martin AR, Geller JS, Iyer H, Dodds SD. Radiographic outcomes following K-wire augmentation of dorsal spanning plate fixation for intra-articular fractures of the distal radius. *Journal of wrist surgery*. 2022 Oct;11(05):388-94.
- Mishra RK, Prasad Sharma B, Kumar A, Sherawat R. A comparative study of variable angle volar plate and bridging external fixator with K-wire augmentation in comminuted distal radius fractures. *Chinese Journal of Traumatology*. 2021 Sep 1;24(05):301-5.
- Mahajan N, Mhatre JA, Talukder P. Augmentation of Volar Locking Plate with Percutaneous Kirschner Wires in Management of Unstable Distal Radius Fractures.
- Alter TH, Sandrowski K, Gallant G, Kwok M, Ilyas AM. Complications of volar plating of distal radius fractures: a systematic review. *Journal of wrist surgery*. 2019 Jun;8(03):255-62.
- Wolfe SW, Austin G, Lorenze M, Swigart CR, Panjabi MM. A biomechanical comparison of different wrist external fixators with and without K-wire augmentation. *The Journal of hand surgery*. 1999 May 1;24(3):516-24.
- Sokol SC, Amanatullah DF, Curtiss S, Szabo RM. Biomechanical properties of volar hybrid and locked plate fixation in distal radius fractures. *The Journal of hand surgery*. 2011 Apr 1;36(4):591-7.