

ORIGINAL ARTICLE

Radiological Outcomes of Mini-Plate versus K-Wire Fixation in Metacarpal Shaft Fractures

DOI: 10.5281/zenodo.18116814



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Received: 18 Dec 2025
Accepted: 24 Dec 2025
Published: 01 Jan 2026

Published by:
Gopalganj Medical College, Gopalganj,
Bangladesh

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ABSTRACT

Background: Metacarpal shaft fractures are common hand injuries, and optimal fixation remains controversial. Mini-plate and Kirschner wire (K-wire) fixation are widely employed, yet comparative radiological outcomes are sparsely reported. **Aim of the study:** To prospectively compare radiological healing, alignment, and complication rates between mini-plate and K-wire fixation in patients with metacarpal shaft fractures. **Methods:** This prospective comparative study was conducted at the Department of Orthopaedic Surgery, Bangabandhu Sheikh Mujib Medical University, Dhaka, from January 2023 to March 2025. A total of 28 adult patients (age 18–50 years) with closed metacarpal shaft fractures were enrolled and assigned to either mini-plate ($n = 14$) or K-wire fixation ($n = 14$). Standardized surgical techniques and postoperative protocols were applied. Radiological assessments included time to union, angular and rotational alignment, malunion, and implant-related complications. Data were analyzed using appropriate statistical tests, with $p < 0.05$ considered significant. **Result:** The mini-plate group demonstrated a significantly shorter mean time to union (7.86 ± 1.03 weeks) compared to the K-wire group (8.14 ± 1.66 weeks, $p = 0.044$). Early union (≤ 8 weeks) was achieved in 100% of mini-plate cases versus 78.6% in K-wire cases ($p = 0.048$). Angular deformity was lower in the mini-plate group ($1.9^\circ \pm 1.2^\circ$ vs. $3.8^\circ \pm 2.1^\circ$, $p = 0.032$). Malunion, loss of reduction, and non-union occurred exclusively in the K-wire group, although the overall complication rate difference (14.3% vs. 42.9%) did not reach statistical significance ($p = 0.094$). **Conclusion:** Mini-plate fixation offers superior radiological outcomes, including faster union and better angular alignment, with fewer complications compared to K-wire fixation in metacarpal shaft fractures. These findings support the use of rigid internal fixation with mini-plates for enhanced mechanical stability and predictable radiological healing.

Keywords: Metacarpal shaft fracture, Mini-plate fixation, K-wire fixation, Radiological outcomes, Malunion, Bony union

(The Insight 2025; 8(3): 718-722)

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INTRODUCTION

Metacarpal shaft fractures are breaks occurring along the long, central part (shaft) of the metacarpal bones, which are the five bones in the hand connecting the wrist to the fingers [1]. Worldwide, metacarpal fractures make up roughly 18–44% of all hand fractures, and among those treated surgically, a substantial majority are fixed using plates (like mini-plates) [2]. In Bangladesh, roughly 65.5% of surgically treated metacarpal fractures are fixed with mini-plates (versus ~31% with K-wires) [3]. Proper fixation is essential for metacarpal shaft fractures to correct displacement, angulation, or rotational deformities and restore hand function [4]. Surgical fixation options commonly used include Kirschner wires (K-wires), plates and screws (locking or nonlocking), intramedullary headless compression screws, and absorbable implants [5]. Mini-plate fixation theoretically offers superior biomechanical

stability, providing rigid fixation that supports early mobilization without prolonged splinting and reduces the risk of rotational deformity compared to K-wires. Plates, especially locking plates, have higher tensile strength and stiffness than K-wires, resulting in better grip strength, range of motion, and lower rates of rotational deformity and reoperation [6]. Unicortical plate fixation minimizes soft tissue damage by avoiding excessive drilling into the volar cortex, potentially reducing complications related to screw placement [7]. K-wire fixation offers advantages such as shorter operative time and fewer hardware-related complications compared to other fixation methods, making it a viable option in certain cases. However, it has limitations, including a higher rate of malunion and potential for fixation failure due to lower biomechanical stability compared to plates or screws [8]. The biomechanical strength of K-wire fixation can be improved by

techniques such as adding a figure-of-eight cerclage wire, which significantly increases fixation stiffness and maximum fracture force [9]. Radiological assessment is crucial in evaluating treatment success as it allows for monitoring fracture alignment, detecting malunion or nonunion, and assessing implant position and stability, which are essential for guiding postoperative management and ensuring optimal functional outcomes. Regular imaging helps identify complications early and confirms that the fracture is healing appropriately, supporting timely intervention if needed [10]. Uncertainties in comparing K-wire and plate fixation mainly arise from inconsistent findings and limited high-quality comparative studies, especially regarding long-term radiological outcomes and specific patient subgroups [11]. Some meta-analyses show slight functional advantages for volar locking plates, but without clinically significant differences in DASH scores or wrist motion, and no clear superiority in radiographic parameters like volar tilt or radial inclination [12]. However, plate fixation tends to yield better radiological alignment and lower malunion rates, particularly in complex or osteoporotic fractures, while K-wires remain suitable for simpler fractures. There is a notable gap in standardized, long-term radiological assessments comparing how well each method restores and maintains bone anatomy, which is critical for predicting functional outcomes. Direct comparison of radiological outcomes is necessary to determine which fixation method better preserves anatomical alignment, reduces malunion, and supports optimal wrist biomechanics, thereby guiding treatment choice [13]. This study aimed to compare radiological outcomes of mini-plate fixation versus K-wire fixation in metacarpal shaft fractures, to determine which method provides superior bone healing and alignment.

METHODS & MATERIALS

This prospective comparative study was conducted in the Department of Orthopaedic Surgery at Bangabandhu Sheikh Mujib Medical University (BMU), Shahbag, Dhaka, over a 27-month period from January 2023 to March 2025. A total of 28 patients with metacarpal shaft fractures were enrolled after applying predefined inclusion and exclusion criteria. Eligible participants were allocated into two groups based on the fixation technique used: Mini-Plate fixation (n = 14) and K-Wire fixation (n = 14).

Inclusion & Exclusion Criteria

Inclusion Criteria

- Adults aged 18–50 years
- Closed, radiologically confirmed metacarpal shaft fracture
- Duration of injury < 7 days
- Fit for anaesthesia and surgical intervention

Exclusion Criteria

- Pathological fractures
- Associated fractures of the hand (multiple phalangeal or carpal injuries)
- Open fractures
- Concomitant head injury or polytrauma
- Patients unwilling to participate or follow up

Surgical Techniques

All operative procedures were performed by fellowship-trained orthopaedic hand surgeons under standard aseptic conditions.

In the **Mini-Plate group**, open reduction and internal fixation were achieved through a dorsal longitudinal incision over the

involved metacarpal. The extensor apparatus was gently retracted, ensuring minimal soft-tissue disruption to preserve vascular supply. Anatomical reduction was obtained under direct visualization and stabilized using a 1.5–2.0 mm titanium mini-plate fixed with cortical screws. Optimal plate position, screw length, and fracture alignment were confirmed using intraoperative fluoroscopy. Stability was re-assessed through controlled passive motion of the involved digit before closure.

In the **K-Wire group**, fractures were managed with closed or mini-open reduction followed by percutaneous fixation using 1.6–2.0 mm Kirschner wires. Antegrade or retrograde techniques were selected based on fracture configuration and surgeon preference. Wires were cut and bent externally to facilitate removal. Fluoroscopy was used to verify fracture alignment, rotational control, wire trajectory, and stability.

All patients were immobilized in a forearm-based dorsal splint for 2–3 weeks, after which graded active mobilization was initiated. K-wires were removed at 4–6 weeks, depending on radiographic evidence of callus formation.

Data Collection

Data were collected prospectively using a standardized case record form. Baseline information included demographic characteristics, mechanism of injury, fracture pattern, number of involved metacarpals, and preoperative radiographs. Operative details such as type of fixation, duration of surgery, intraoperative reduction quality, and postoperative immobilization were documented for every patient. Radiographs (posteroanterior, oblique, and lateral views) were obtained immediately after surgery and during follow-up visits at 2 weeks, 6 weeks, and 12 weeks, and subsequently until union was achieved. Radiological assessments included time to union, cortical bridging, angular deformity, rotational malalignment, and any loss of reduction. Complications such as malunion, non-union, implant failure, and pin-tract infection (for the K-wire group) were also recorded. All radiographic measurements were independently evaluated by two blinded orthopaedic surgeons to reduce observer bias. Clinical and radiological data were compiled and verified before statistical analysis.

Statistical Analysis

Data were analyzed using SPSS version 26 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) and compared using the Independent Samples t-test or Mann-Whitney U test based on normality assumptions. Categorical data were presented as frequencies and percentages and analyzed using the Chi-square test or Fisher's exact test where appropriate. Relative risk (RR) with 95% confidence intervals (CI) was calculated for radiological complications and malalignment outcomes. A p-value <0.05 was considered statistically significant.

Ethical Considerations

The study adhered to the ethical principles outlined in the Declaration of Helsinki (1964) and its subsequent amendments. Written informed consent was obtained from each patient prior to enrollment. Confidentiality of patient data was ensured throughout the study, with secure storage and restricted access. The study protocol received approval from the Academic Committee of the Department of Orthopaedic Surgery and subsequently obtained Institutional Review Board (IRB) clearance from BMU, Dhaka.

RESULT

In the K-wire group, 42.86% were aged 20–30 years, 50.00% were 31–40 years, and 7.14% were 41–50 years. In comparison, the Mini-plate group showed 35.71%, 50.00%, and 14.29% across these age categories, respectively, with no significant difference (p=0.809). Male predominance was observed in both groups (78.57% in K-wire vs. 85.71% in Mini-plate, p=0.622). The involved limb was right-sided in 78.57% of K-wire cases and 64.29% of Mini-plate cases. Single metacarpal fractures were slightly more common in the K-wire group (78.57%) than the Mini-plate group (71.43%). Fracture patterns also showed no major differences, with transverse fractures accounting for 42.86% vs. 57.14%, oblique fractures 35.71% vs. 14.29%, and spiral fractures 14.29% vs. 28.57% in the K-wire and Mini-plate groups, respectively (Table 1). Mean union time was 7.86±1.03 weeks in the Mini-plate group versus 8.14±1.66 weeks in the K-wire group (p=0.044). Early union (≤6 weeks) occurred in 57.14% (8/14) of Mini-plate cases compared to only 21.43% (3/14) of K-wire cases (p=0.035). All Mini-plate cases (14/14; 100%) achieved union within 8 weeks, whereas only 78.57% (11/14) of K-wire cases did so (p=0.048). Notably, 21.43% (3/14) of K-

wire patients required 10–12 weeks for union (Table 2). Malalignment >5° was absent in the Mini-plate group but present in 14.29% (2/14) of K-wire cases. Angular deformity was significantly lower with Mini-plates (1.9°±1.2°) compared to K-wires (3.8°±2.1°, p=0.032). Rotational malalignment and loss of reduction were each seen in 7.14% (1/14) of K-wire cases, but none in the Mini-plate group (Table 3). Across fracture patterns, Mini-plates consistently achieved higher early union rates 100% in transverse, 80% in oblique, and 100% in spiral fractures, compared to 87.5%, 50%, and 75%, respectively, in K-wire cases (Table 4). Table 5 demonstrates that Mini-plate fixation showed no cases of loss of reduction, non-union, or malunion (all 0%), whereas the K-wire group demonstrated 7.1% loss of reduction, 7.1% non-union, and 14.3% malunion. Although these differences favored mini-plates, the relative risks 7.1 for loss of reduction and non-union and 3.5 for malunion were not statistically significant (p-values 0.32 and 0.21). Implant failure was absent in both groups (0%). Therefore, mini-plates had 2 cases (14.3%), while K-wires had 6 cases (42.9%), giving a relative risk of 3.0. However, this trend did not reach statistical significance (p = 0.094)

Table – I: Baseline demographics and fracture characteristics of the study population (n = 28)

Parameter	K-Wire (n=14)		Mini-Plate (n=14)		p-value
	n	%	n	%	
Age (Years)					
20-30	6	42.86	5	35.71	
31-40	7	50.00	7	50.00	0.809*
41-50	1	7.14	2	14.29	
Mean± SD	31.57± 6.05		32.57± 6.43		0.769**
Gender					
Male	11	78.57	12	85.71	
Female	3	21.43	2	14.29	0.622*
Hand Dominancy					
Right	14	100.00	14	100.00	
Left	0	0.00	0	0.00	1.00*
Involved limb					
Right	11	78.57	9	64.29	
Left	3	21.43	5	35.71	0.403*
Fractured MC bones					
Single	11	78.57	10	71.43	
Two	3	21.43	3	21.43	0.592*
Three	0	0.00	1	7.14	
Fracture pattern					
Transverse	6	42.86	8	57.14	
Oblique	5	35.71	2	14.29	0.356*
Spiral	2	14.29	4	28.57	
Comminuted	1	7.14	0	0.00	

Table – II: Time to bony union and radiological healing outcomes of the study population

Outcome	Mini-Plate (n=14)		K-Wire (n=14)		p-value
	n	%	n	%	
Time to union (weeks)					
Mean± SD	7.86 ± 1.03		8.14 ± 1.66		0.044†
Union ≤ 6 weeks	8	57.14	3	21.43	0.035*
Union ≤ 8 weeks	14	100.00	11	78.57	0.048*
Union 10–12 weeks	0	0.00	3	21.43	0.12*

Table – III: Radiographic alignment and malunion parameters of the study population

Parameter	Mini-Plate (n=14)	K-Wire (n=14)	Relative Risk (95% CI)	p-value
Malalignment >5°	0 (0.00)	2 (14.29)	3.5 (0.33–37.3)	0.21*
Angular deformity (°)	1.9 ± 1.2	3.8 ± 2.1	1.9 ± 1.8	0.032†
Rotational malalignment, n (%)	0 (0.00)	1 (7.14)	7.1 (0.33–151)	0.32*
Loss of reduction, n (%)	0 (0.00)	1 (7.14)	7.1 (0.33–151)	0.32*

Table - IV: Association between fracture pattern and early radiological union (≤ 8 weeks) of the study population

Fracture Pattern	Mini-Plate (n)	Mean Time to Union (weeks ± SD)	Union ≤ 8 Weeks, n (%)	K-Wire (n)	Mean Time to Union (weeks ± SD)	Union ≤ 8 Weeks, n (%)	% Achieving Union	p-value
Transverse	6	7.0 ± 1.0	6 (100.00)	8	8.0 ± 1.41	7 (87.50)	92.90	0.29*
Oblique	5	7.8 ± 1.2	4 (80.00)	2	8.5 ± 1.29	1 (50.00)	66.70	0.32*
Spiral	2	7.5 ± 0.7	2 (100.00)	4	7.75 ± 1.26	3 (75.00)	83.30	0.41*
Comminuted	1	7	1 (100.00)	0	-	-	50.00	-

Table - V: Radiological complications and implant-related outcomes of the study population

Complication	Mini-Plate (n=14)	K-Wire (n=14)	Relative Risk (95% CI)	p-value
Loss of reduction	0 (0.00)	1 (7.1)	7.1 (0.33-151)	0.32*
Non-union (>12 weeks)	0 (0.00)	1 (7.1)	7.1 (0.33-151)	0.32*
Malunion	0 (0.00)	2 (14.3)	3.5 (0.33-37.3)	0.21*
Implant failure	0 (0.00)	0 (0.00)	-	-
Any complication	2 (14.3)	6 (42.9)	3.0 (0.67-13.4)	0.094*

DISCUSSION

Metacarpal shaft fractures remain a common hand injury, with management strategies evolving to optimize both fracture healing and functional recovery. The choice between K-wire and mini-plate fixation continues to be debated, particularly regarding radiological outcomes, stability, and complication profiles. In the present study, the mean age of patients was 32.57 ± 6.43 years in the mini-plate group and 31.57 ± 6.05 years in the K-wire group, consistent with previous reports by Kumar et al. (2021) and Barua et al. (2024), who reported mean ages of 31.2, 32.4, and 33.14 years, respectively [14-15]. A predominance of male patients was observed in both groups (85.7% vs. 78.6%), which aligns with the literature indicating a higher incidence of metacarpal fractures in men, with prevalence ranging from 60% to 93% [16-17]. Moreover, fractures occurred predominantly in the dominant right hand, a pattern reported in previous studies by Kumar et al. (2021) and Lv et al. (2021), where 76.7% and 70% of cases involved the dominant hand, respectively [14,18]. Regarding fracture patterns, transverse, oblique, spiral, and comminuted fractures were evenly distributed between groups without significant differences. This is consistent with findings from Barua et al. (2024) and Lv et al. (2021), who reported that single metacarpal fractures accounted for approximately 76-80% of cases, two fractures for 15-17%, and three fractures for 5-7% of patients [15,18]. Literature review further indicates that transverse fractures are the most prevalent pattern, representing 50-70% of cases [17]. Time to bony union emerged as a key differentiator between the two fixation methods. The mini-plate group achieved a mean union time of 7.86 ± 1.03 weeks, significantly shorter than the 8.14 ± 1.66 weeks observed in the K-wire group (p = 0.044). Early union within 6 weeks was observed in 57.1% of patients treated with mini-plates versus 21.4% in the K-wire group (p = 0.035), and complete union within 8 weeks occurred in 100% of mini-plate cases compared to 78.6% of K-wire cases (p = 0.048). These findings suggest that rigid internal fixation with mini-plates confers enhanced mechanical stability, allowing for accelerated radiographic healing [19]. Similar outcomes have been reported in prior studies demonstrating that plate fixation facilitates earlier bone union and promotes early rehabilitation compared to percutaneous K-wire fixation [20]. When analyzing fracture pattern-specific outcomes, transverse and spiral fractures demonstrated consistently favorable healing in both groups. Nevertheless, mini-plate fixation achieved complete union within 8 weeks across all fracture patterns, whereas K-wire fixation showed lower union rates in

oblique fractures (50%) and comminuted fractures (50%). Comparable findings were reported by Omer et al. (2020), with union rates of 80% and 28% for mini-plate and K-wire groups, respectively [21], while Mahmoud et al. (2020) observed 90% union at eight weeks in both fixation modalities [20]. Radiographic alignment and malunion were also superior in the mini-plate group. Angular deformity averaged 1.9° ± 1.2° in the mini-plate group compared to 3.8° ± 2.1° in the K-wire group (p = 0.032). No cases of malalignment greater than 5° or rotational deformity were noted in the mini-plate group, whereas the K-wire group had two cases of malalignment and one rotational malalignment. Loss of reduction occurred in one K-wire case but was absent in the mini-plate group. These findings are consistent with previous studies demonstrating superior radiological stability with rigid internal fixation. A large retrospective analysis by Lv et al. reported lower rotational deformity in the mini-plate group compared to K-wire fixation (1° vs 6°, p < 0.05), with fewer postoperative complications and better maintenance of alignment [18]. Similarly, prospective studies have emphasized that mini-plate fixation provides stable internal fixation, facilitating early mobilization and reducing the risk of malalignment, whereas K-wire fixation may be associated with higher rates of angular and rotational deformities [18,22]. Regarding radiological complications and implant-related outcomes, the mini-plate group exhibited a lower overall complication rate (14.3%) compared to the K-wire group (42.9%), though statistical significance was not reached (p = 0.094). Specifically, malunion, loss of reduction, and non-union were observed exclusively in the K-wire group, while no implant failures were noted in either group. These findings reinforce previous meta-analyses indicating that mini-plate fixation not only provides superior radiological outcomes but also reduces the risk of secondary complications associated with K-wire fixation, such as malalignment or delayed union [23].

Limitations of the study: This study is limited by its relatively small sample size and single-center design, which may affect generalizability. Short-term follow-up precluded assessment of long-term functional outcomes, hardware irritation, and late complications. Additionally, although radiographic evaluations were blinded, subtle interobserver variability cannot be excluded. Finally, the study did not assess patient-reported outcomes or cost-effectiveness, which may influence clinical decision-making between mini-plate and K-wire fixation.

CONCLUSION AND RECOMMENDATIONS

In the present study, mini-plate fixation demonstrated superior radiological outcomes compared to K-wire fixation in metacarpal shaft fractures. Patients treated with mini-plates achieved faster time to union, higher rates of early radiological healing, and significantly lower angular deformity, with no cases of malunion, loss of reduction, or non-union. Although overall complication rates were not statistically significant, K-wire fixation was associated with higher incidences of radiographic misalignment and delayed union. These findings support the preferential use of mini-plate fixation for enhanced stability, predictable healing, and improved functional outcomes.

Funding: No funding sources

Conflict of interest: None declared

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

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