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Incidence of postoperative complications in K-wire and mini-plate fixation for metacarpal shoft fractures

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Abstract
Background: Metacarpal fractures are among the most common upper limb injuries and can result in significant functional impairment if not properly managed. Various fixation techniques have been developed to achieve optimal stability and allow early mobilization. Among them, Kirschner wire (K-wire) and mini-plate fixation are widely used, yet the comparative incidence of postoperative complications remains a subject of debate.
Aim of the study: To compare the incidence of postoperative complications and functional outcomes between K-wire and mini-plate fixation in patients with metacarpal shaft fractures.
Methods: This prospective comparative study was conducted at the Department of Orthopedic Surgery, Bangladesh Medical University, Dhaka, from January 2023 to March 2025. Twenty-eight patients with closed metacarpal shaft fractures were randomly allocated into two equal groups: K-wire fixation (N=14) and mini-plate fixation (N=14). Postoperative complications, pain (VAS), hand function (QuickDASH), total active motion (TAM), grip strength, and time to bony union were recorded and compared using appropriate statistical tests in SPSS version 26.
Results: The mean operative duration was significantly shorter for K-wire fixation (23.57±7.57 min) compared to mini-plate fixation (41.79±8.23 min; P=0.001), while bone union occurred earlier in the mini-plate group (7.86±1.03 weeks; P=0.044). The mini-plate group demonstrated lower postoperative pain (VAS at 12 weeks: 0.71±0.73 vs. 1.50±0.86; P=0.027) and better functional recovery (QuickDASH at 12 weeks: 7.79±3.55 vs. 11.53±5.66; P=0.039). Total active motion and grip strength were also superior at 12 weeks in the mini-plate group ($p<0.05$). Postoperative complications were higher in the K-wire group, mainly stiffness (21.4%) and pin tract infection (14.3%), whereas the mini-plate group reported only one case of superficial wound infection. At 6 weeks, excellent outcomes were achieved in 71.4% of the mini-plate group and 50.0% of the K-wire group ($p>0.05$).
Conclusion: Both fixation methods are effective for treating metacarpal shaft fractures. However, mini-plate fixation provides faster recovery, earlier bone union, and fewer complications compared to K-wire fixation, although long-term functional outcomes are comparable.

Keywords: K-wire, metacarpal fracture, mini-plate fixation, postoperative complications, functional outcome.

Introduction
Metacarpal fractures are among the most common injuries of the upper limb and can lead to lasting impairment of hand function and dexterity [1]. The metacarpal bones are tubular and form part of the hand's transverse and longitudinal arches [2]. They are stabilized at their proximal and distal ends by ligamentous attachments and have a concave surface on the palmar side. Mini-plate fixation has been shown to promote a faster and more reliable healing process in metacarpal fractures, with studies reporting bone union times ranging from approximately 4.6 to 10 weeks [3]. Metacarpal fractures account for approximately 36% of all fractures affecting the hand and wrist, with an estimated incidence of 13.6 fractures per 100, 000 person-years [4]. These injuries are not only common but also a significant contributor to healthcare utilization, as metacarpal and phalangeal fractures together are responsible for nearly 40% of visits to emergency departments and urgent care facilities, highlighting their clinical and socioeconomic importance [5, 6]. In comparison, K-wire fixation generally requires a longer period for fracture consolidation, with reported union times varying between 6 and

12.33 weeks [7]. The primary causes of metacarpal fractures are machine-related injuries and road traffic accidents [8]. Most of these fractures are simple, closed, and stable in nature [9]. However, when accompanied by soft tissue damage, joint dislocation, or associated injuries, they can significantly impair hand function recovery of which can often be challenging and incomplete [10]. Metacarpal fractures can lead to various complications deformity may occur if treatment is neglected, stiffness can result from excessive intervention, and a combination of both deformity and stiffness may arise from improper or inadequate treatment [11]. Over the past 25 years, the management of metacarpal fractures has evolved significantly [12]. These fractures can be managed through closed reduction and splinting, though this method often makes it difficult to maintain joint mobility and prevent stiffness [13]. Alternatively, techniques such as Kirschner wire fixation, intraosseous wiring, and screw fixation with or without plating allow for early active movement, but they come with drawbacks such as extensive surgical exposure and a higher risk of soft tissue damage [12]. Failure to achieve radiological or clinical signs of healing within four months after fixation is considered a non-union of a metacarpal fracture. In patients with metacarpal fractures, the incidence of delayed union or non-union can occur in approximately up to 6% of cases [1, 2]. Metacarpal fractures are common upper limb injuries that can significantly affect hand function. Although both K-wire and mini-plate fixation are widely used for their management, each method carries specific advantages and postoperative complications. Comparative evaluation of these techniques is essential to determine which provides better outcomes with fewer complications. The aims of the study to assess and compare the incidence of postoperative complications following K-wire fixation and mini-plate fixation in the management of metacarpal fractures.

Methodology and Materials

This prospective comparative study was carried out in the Department of Orthopedic Surgery, Bangladesh Medical University (BMU), Shahbagh, Dhaka, from January 2023 to March 2025. The objective was to compare the incidence of postoperative complications and functional outcomes between K-wire fixation and mini-plate fixation in patients with metacarpal shaft fractures. Patients presenting with metacarpal shaft fractures to the Emergency or Outpatient Department during the study period were screened for eligibility. A total of 28 patients who met the inclusion criteria were enrolled and divided into two equal groups using a computer-generated simple randomization technique: treated with K-wire fixation (N=14) and treated with mini-plate fixation (N=14).

Inclusion Criteria

- Patients aged 18 to 50 years.
- Diagnosed with closed metacarpal shaft fractures.
- Duration of injury less than 7 days.

Exclusion Criteria

- Pathological or open fractures.
- Associated fractures of the hand.
- Head injury or other major trauma.

Ethical Considerations

The study followed the ethical principles of the Declaration of Helsinki (1964). All participants received detailed information regarding the study purpose, procedure, possible risks, and benefits. Written informed consent was obtained from each patient prior to enrollment. Patient anonymity and confidentiality were strictly maintained throughout the study. The research protocol received approval from the Institutional Review Board (IRB) and the Academic Committee of the Department of Orthopedic Surgery, BMU and Dhaka.

Data Collection

After consent, each patient underwent comprehensive history taking, physical examination, and radiological assessment using anteroposterior and oblique X-rays of the hand. Preoperative investigations were performed as required. Intraoperative and postoperative data were recorded using a structured case record form. Follow-up evaluations were conducted at 2, 4, 6, and 12 weeks, and finally at 6 months post-surgery. Although long-term follow-up continued up to 12 months, data up to 6 months were analyzed to ensure uniformity.

Postoperative complications, including pin tract infection, stiffness, loss of reduction, delayed union, malunion, and superficial wound infection, were meticulously observed throughout the follow-up period. Functional and radiological outcomes were systematically evaluated using multiple validated parameters. Pain intensity was assessed using the Visual Analog Scale (VAS), while overall upper limb function was measured through the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) questionnaire. The range of motion of the affected finger was quantified by calculating the Total Active Motion (TAM), and grip strength was compared as a percentage of the contralateral, uninjured hand. Radiological union was determined by the presence of bridging callus formation, cortical continuity, and obliteration of the fracture line on serial radiographs. Additionally, the time taken for patients to return to their regular work or daily activities was documented as an indicator of overall functional recovery and reintegration.

Statistical Analysis

Statistical analysis was performed using SPSS version 26 (IBM®, Armonk, USA). Quantitative data were presented as Mean ± Standard Deviation (SD) and analyzed using the Student's *t*-test for parametric variables, while the Mann-Whitney U test was applied for non-parametric data. Qualitative variables were expressed as frequencies and percentages and compared using the Chi-square test or Fisher's exact test when applicable. The relationship between postoperative complications and functional outcomes, including QuickDASH, TAM, and VAS scores, was evaluated using the Pearson correlation coefficient (r). A p-value of less than 0.05 was considered statistically significant at a 95% confidence interval.

Results

Table 1 presents the demographic characteristics of the 28 participants, with 14 patients in each fixation group. The mean age was 32.57±6.43 years in the K-wire group and 31.57±6.05 years in the mini-plate group (P=0.769). Males predominated in both groups (85.71% vs. 78.57%, P=0.622). Most participants were manual workers (42.86% K-wire, 35.71% mini-plate) and service holders (35.71% each). All patients were right-hand dominant (100%), with the right limb more commonly affected (64.29% vs. 78.57%, P=0.403). The main causes of injury were blunt trauma (42.86% vs. 35.71%) and fall injuries (35.71% vs. 21.43%). The most frequent

fracture pattern was transverse (57.14% in K-wire vs. 42.86% in mini-plate). No statistically significant differences were observed between groups (p>0.05). Figure 1 illustrates the distribution of the number of metacarpals involved in both fixation groups. In the K-wire group, 71.43% of patients had single metacarpal fractures, while 28.57% had multiple metacarpal involvement. In comparison, the mini-plate group showed 78.57% single metacarpal and 21.43% multiple metacarpal fractures. Table 2 shows that mean operative duration was significantly longer in the mini-plate group (41.79±8.23 min) than in the K-wire group (23.57±7.57 min, P=0.001). Bony union occurred slightly earlier with mini-plate fixation (7.86±1.03 weeks, P=0.044). Mean preoperative VAS was 7.21±0.89 in the K-wire group and 6.93±0.73 in the mini-plate group (P=0.454). At 12 weeks, VAS was 1.50±0.86 vs 0.71±0.73 (P=0.027). QuickDASH at 12 weeks was 11.53±5.66 vs 7.79±3.55 (P=0.039) represents in Table 3. Table 4 shows that total active motion at 12 weeks was 231.43°±18.34 in the K-wire group and 246.43°±14.60 in the mini-plate group (P=0.024). Grip strength at 12 weeks was 75.4%±9.8 vs 82.6%±8.5 (P=0.048). Table 5 shows postoperative complications: stiffness (21.43% vs 7.14%), pin tract infection (14.29%), and superficial wound infection (7.14%). Table 6 shows significant correlations: complication rate vs. QuickDASH (r=0.512, P=0.008), complication rate vs. TAM (r=-0.468, P=0.015), grip strength vs. TAM (r=0.573, P=0.003), and return-to-work time vs. VAS (r=0.391, P=0.034). Table 7 shows outcome grading at six months: excellent (50.00% K-wire, 71.43% mini-plate, total 60.71%), good (42.86% vs. 21.43%, total 32.14%), fair (7.14% each group), and poor (0%). Differences were not statistically significant (p>0.05).

Table 1: Demographic characteristics of the study population (N=28)

Parameter	K-Wire (N=14)		Mini-Plate (N=14)		P-Value
	N	%	N	%	
Age (years), Mean ± SD	32.57±6.43		31.57±6.05		0.769
Gender					
Male	12	85.71	11	78.57	0.622
Female	2	14.29	3	21.43	
Occupation					
Manual workers	6	42.86	5	35.71	0.98
Service holders	5	35.71	5	35.71	
Business owners	1	7.14	1	7.14	
Homemakers	1	7.14	1	7.14	
Students	1	7.14	2	14.29	
Hand Dominancy					
Right	14	100.00	14	100.00	1
Left	0	0.00	0	0.00	
Involved limb					
Right	9	64.29	11	78.57	0.403
Left	5	35.71	3	21.43	
Mechanism of injury					
Blunt trauma	6	42.86	5	35.71	0.661
Fall injury	5	35.71	3	21.43	
Road traffic accident	2	14.29	4	28.57	
Physical assault	1	7.14	2	14.29	
Fracture Pattern					
Transverse	8	57.14	6	42.86	0.71
Oblique	2	14.29	5	35.71	
Spiral	4	28.57	2	14.29	
Comminuted	0	0.00	1	7.14	

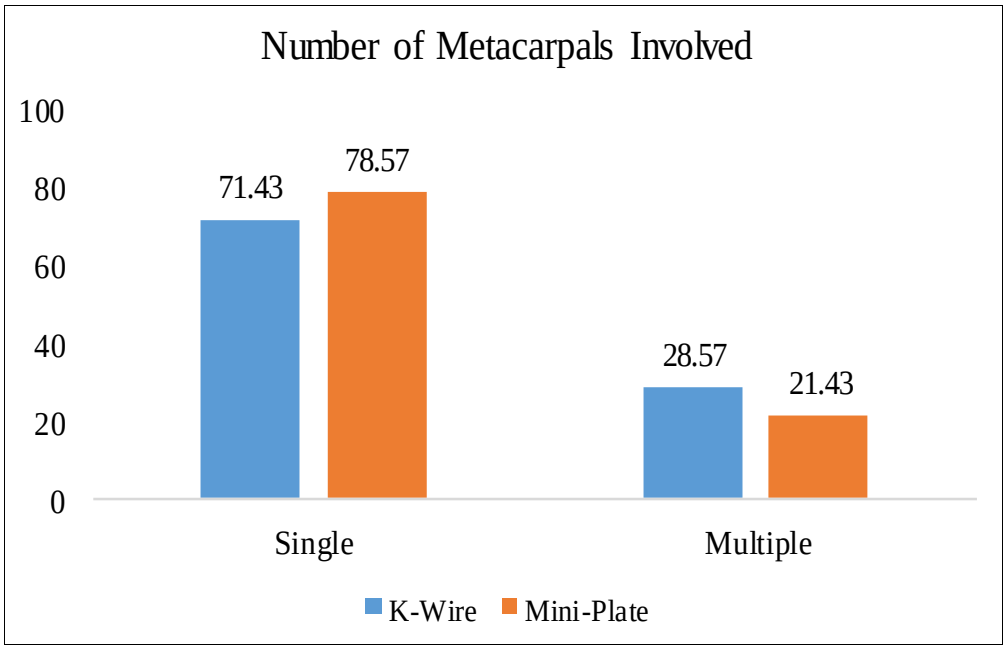

Fig 1: Number of metacarpals of study subjects (N=28)

Table 2: Operative and radiological parameters (N=28)

Parameter	K-Wire (N=14)		Mini-Plate (N=14)		P-Value
	N	%	N	%	
Operative Duration (min, Mean ± SD)	23.57±7.57		41.79±8.23		0.001
Time to Bony Union (weeks, Mean ± SD)	8.14±1.66		7.86±1.03		0.044
Delayed Union (>10 weeks)	2	14.29	0	0.00	0.147
Malunion	1	7.14	0	0.00	0.309
Early Postoperative Edema (Yes/No)	6	42.86	3	21.43	0.182

Table 3: Postoperative pain and functional recovery (VAS & QuickDASH)

Parameter	K-Wire (Mean ± SD)	Mini-Plate (Mean ± SD)	P-Value
Pre-op VAS (Mean ± SD)	7.21±0.89	6.93±0.73	0.454
12-week VAS (Mean ± SD)	1.50±0.86	0.71±0.73	0.027
6-month VAS (Mean ± SD)	0.36±0.48	0.14±0.36	0.118
QuickDASH 12 weeks (Mean ± SD)	11.53±5.66	7.79±3.55	0.039
QuickDASH 6 months (Mean ± SD)	3.39±1.81	2.67±1.88	0.311
Return to Work (weeks, Mean ± SD)	8.93±2.07	7.21±1.56	0.036

Table 4: Range of motion and grip strength of study population

Parameter	K-Wire (Mean ± SD)	Mini-Plate (Mean ± SD)	P-Value
Total Active Motion (°) at 12 weeks (Mean ± SD)	231.43±18.34	246.43±14.60	0.024
Total Active Motion at 6 months (Mean ± SD)	245.36±12.74	251.79±8.23	0.13
Grip Strength (% of contralateral hand at 12 weeks)	75.4±9.8	82.6±8.5	0.048
Grip Strength (% at 6 months)	89.7±5.3	93.2±4.8	0.07

Table 5: Incidence and type of postoperative complications among patients (N=28)

Complications type	K-Wire (N=14)		Mini-Plate (N=14)		P-Value
	N	%	N	%	
Stiffness	3	21.43	1	7.14	0.215
Pin tract infection	2	14.29	0	0.00	
Loss of reduction	1	7.14	0	0.00	
Superficial wound infection	0	0.00	1	7.14	

Table 6: Correlation between functional outcome and complications (N=28)

Variable	Correlation Coefficient (r)	P-Value
Complication rate vs. QuickDASH score	0.512	0.008
Complication rate vs. TAM	-0.468	0.015
Grip strength vs. TAM	0.573	0.003
Return-to-work time vs. VAS	0.391	0.034

Table 7: Overall outcome grading of participants at 6 weeks (N=28)

Outcome Category	K-Wire, n (%)	Mini-Plate, N (%)	Total, N (%)	P-Value
Excellent	7 (50.00)	10 (71.43)	17 (60.71)	0.25
Good	6 (42.86)	3 (21.43)	9 (32.14)	0.19
Fair	1 (7.14)	1 (7.14)	2 (7.14)	1
Poor	0 (0.00)	0 (0.00)	0 (0.00)	—

Discussion

In this study, the mean age of participants was 32.1±6.2 years, with 89.3% aged ≤ 40 years and no significant intergroup difference (P=0.769), consistent with Bayder *et al.* and Kumar *et al.*, who reported mean ages of 31.2 and 32.4 years, respectively [14, 15]. Males predominated in both groups (85.7% vs. 78.6%, P=0.622), aligning with previous reports that metacarpal fractures occur more frequently in young men due to sports, manual labor, and physical activities [16, 17]. Occupational distribution was similar across groups (P=0.980), with manual workers and service holders being most affected, as also noted by Barua *et al.* [18]. Dominant-hand involvement was seen in 71.4% of cases, comparable to Kumar *et al.* and Lv *et al.* [19, 20]. Blunt trauma and falls were the leading causes (P=0.661). Transverse and oblique fractures were most frequent, with no significant difference between fixation groups (P=0.356), consistent with prior studies [16, 18]. Single metacarpal fractures were more frequent in both groups, accounting for 71.43% in the K-Wire group and 78.57% in the Mini-Plate group, while multiple metacarpal fractures occurred in 28.57% and 21.43%, respectively. This is consistent with the result of other studies [18, 20]. Operative time in our study was significantly shorter for percutaneous K-wire fixation (23.6±7.6 min) than for mini-plate fixation (41.8±8.2 min; P=0.001). There is shorter operating times for closed/percutaneous K-wire techniques versus open reduction internal fixation (ORIF) with plates, which require exposure, contouring and screw fixation. Shorter theatre time for K-wire fixation has been emphasized in other study as an advantage of the technique [21]. Time to union in our series favored mini-plate fixation (7.86±1.03 weeks) over K-wire (8.14±1.66 weeks), with a statistically significant difference (P=0.044). Our finding of earlier union with plates is in line with report that emphasize the stable fixation and consistent anatomic reduction achievable with plates and screws [20]. Pain and early functional recovery also favored mini-plates at intermediate follow-up: 12-week VAS (0.71 vs 1.50; P=0.027) and QuickDASH at 12 weeks (7.79 vs 11.53; P=0.039) were significantly better in the mini-plate group. Similarly, Total Active Motion (TAM) at 12 weeks was higher in the mini-plate group (246.4° vs 231.4°; P=0.024) and grip strength at 12 weeks (82.6% vs 75.4%; P=0.048). By 6 months these differences narrowed and were no longer statistically significant for most measures (QuickDASH P=0.311; TAM P=0.13), indicating convergent long-term outcomes. These patterns faster early recovery with plating and similar final outcomes have been repeatedly described in other study: mini-plate fixation often permits more rigid fixation and earlier active mobilization producing earlier gains in range and pain, while end-point function at mid to long-term follow-up becomes similar between the two methods in report [22]. Return-to-work time was shorter in the mini-plate group (7.21±1.56 vs 8.93±2.07 weeks; P=0.036), which indicates the earlier functional recovery. This may

reflect the combined effect of more stable fixation, less need for prolonged external immobilization, and earlier confidence in load bearing after ORIF with a plate. This is comparable with the study of Elhomy *et al.* [21]. Complication patterns in the present study differed by technique: the K-wire group experienced stiffness (21.4%), pin-tract infection (14.3%), and single loss of reduction (7.1%), whereas the mini-plate group had one superficial wound infection (7.1%). Evidence indicates that while plates may be associated with slightly higher wound-related events, K-wire fixation carries unique pin-site and fixation-stability related complications; overall complication rates may be similar but the type differs [19]. Correlation analysis in our data showed that higher complication rates were associated with worse QuickDASH scores (r=0.512; P=0.008) and lower TAM (r=-0.468; P=0.015), and grip strength correlated positively with TAM (r=0.573; P=0.003). These internal correlations reinforce the clinical importance of minimizing complications (infection, stiffness, loss of reduction) to preserve motion and function. At six weeks, the proportion of "excellent" outcomes favored mini-plates (71.4% vs 50%), though this difference did not reach statistical significance in our small sample (P=0.25). This pattern better early and midterm patient-reported and objective functional indices with plating that become less distinct later is in concordance with comparative study that report faster return to work and earlier functional recovery with plates but often similar long-term outcomes [22].

Limitations of the study

- The study did not include radiological scoring systems or detailed cost-effectiveness analysis between fixation methods.
- Blinding was not possible due to the nature of surgical procedures, which may introduce observer bias during outcome assessment.

Conclusion and Recommendations

This comparative study demonstrates that both K-wire and mini-plate fixation methods are viable options for managing metacarpal shaft fractures. Mini-plate fixation, however, offers the advantages of earlier pain relief, faster functional recovery, and fewer postoperative complications, though it requires longer operative time and surgical exposure. Despite these benefits, long-term outcomes at six months were similar for both groups. Larger multicenter trials with longer follow-up and cost-benefit analysis are recommended to further validate these findings and guide clinical decision-making.

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