Mini Plate Versus K-Wire Fixation For The Management Of Metacarpal Shaft Fracture

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ABSTRACT:
Background: Metacarpal (MC) fractures are very common fracture in an orthopaedic trauma unit. Although there are many methods of treatment of metacarpal fracture, no consensus has been established regarding the best fixation technique for metacarpal fractures. **Objective:** Compare the clinical outcome of K-wire and Mini-plate fixation for metacarpal shaft fracture. **Methods:** This prospective comparative study was conducted in the Department of Orthopaedic surgery at BMU, Dhaka, from January 2023 to March 2025. A total of 28 patients were enrolled and randomly assigned to two groups: K- wire fixation (Group A) and Mini-plate fixation (Group B). Evaluations were performed before and at two, four, six, twelve weeks and six months after surgery. Clinical outcomes were measured through Total Active Motion (TAM), Quick Disabilities of the Arm, Shoulder, and Hand (Quick DASH), Visual Analog Scale (VAS) score. Data analysis utilized the 'Statistical Package for Social Science' version 26, with a significance threshold set at p-value <0.05. **Result:** The demographic and pre-operative characteristics were similar between the groups. Group A had a significantly shorter operative duration than Group B (23.57±7.57 vs. 41.79 ±8.23 min, p=0.001). Group B achieved bony union significantly sooner than Group A (7.86 ± 1.03 vs. 8.14 ± 1.66 weeks, p=0.044). Group B consistently showed significantly better VAS scores than Group A (0.71 ±0.73 vs. 1.50 ±0.86, p=0.027). At 12 weeks follow-up, Group B's Quick DASH score was significantly better than that of Group A (7.79 ±3.55 vs. 11.53 ±5.66, p=0.039). Group B's TAM was also significantly better than Group A's at 12 weeks follow-up (246.43 ±14.60° vs. 231.43 ±18.34°, p=0.024). According to the Quick DASH score, an excellent outcome was achieved in 50% of cases in Group A compared to 71.4% in Group B, while a good outcome was observed in 50% of Group A cases and 28.6% in Group B (p=0.053). **Conclusion:** Mini-plate fixation demonstrated superior clinical outcomes compared to K-wire fixation.

INTRODUCTION
Metacarpals are small, elongated bones with a slight arch and concave volar surface with the weakest point behind the head [1]. These bones connect to carpal bones via ellipsoidal joints for fingers and a

saddle joint for the thumb, articulating with the proximal phalanx through condyloid joints [2]. Metacarpal fractures are common, making up about 10% of all fractures and up to 40% of hand fractures [3]. Most fractures occur in active adolescents and young adults. The incidence of hand trauma has also increased, often resulting in metacarpal fractures and dislocations [4]. Injury can stem from direct trauma, like tapping or crushing injury, or indirect trauma, such as traction, angulation, compression and rotation. Metacarpal fractures may impact the base, shaft, neck or head region [5]. Metacarpal fractures are often underestimated, resulting in disability and permanent impairment of fine hand movements. Inadequate treatment can lead to deformities, while excessive treatment may cause stiffness, or both issues may arise from poor care [4]. Hand injuries can cause loss of sensation, strength, and flexibility; so the primary goal of treatment is to prevent disability by maintaining function rather than focusing on appearance [6]. To restore normal function and anatomy, address displacement and neurological or vascular damage through early mobilization with open reduction and internal fixation. Early mobilization also helps to decrease edema, lysis of adhesion, gliding of tendons, and stiffness. Closed reduction and internal fixation are commonly used for closed simple fractures [7]. The approach to treating a metacarpal shaft fracture depends on the fracture's stability and characteristics. An undisplaced fracture, regardless of its configuration, can be treated conservatively using a slab or splint that keeps the wrist in extension and the MP joint flexed more than 70°, which permits early mobilization of the IP joints [6]. Effective treatment depends on whether a fracture is reducible or irreducible and whether the reduction is stable. It should be noted that hand fractures may cause deformity if untreated, stiffness if overtreatment occurs, and both issues from suboptimal treatment [8]. K-wire fixation is a minimally invasive technique that avoids large incisions and general anesthesia, allowing for a quicker procedure and easier removal of wires once bones heal, which can reduce infection risk and speed recovery [9]. The use of K-wire fixation offers several advantages, such as minimal soft tissue disruption, ease of technique, and readily accessible materials but less rigid fixation and reduced stability, it is not suitable for securing unstable fractures [10]. K-wiring allows early mobilization but lacks rotational stability, causes stiffness at the metacarpophalangeal and carpometacarpal joints, and is unsuitable for comminuted fractures [11]. Mini plate fixation is a surgical method for treating multiple metacarpal shaft fractures which uses small metal plates and screws to stabilize the fractured bones, allowing for early mobilization and recovery [9]. Assessing the long-term results of surgical procedures is crucial for evaluating the longevity of techniques such as k-wire and mini-plate fixation for metacarpal fractures. This study aims to compare the clinical outcomes between K-wire fixation and Mini-plate fixation for the management of Metacarpal shaft fracture.

METHODOLOGY & MATERIALS

This prospective comparative study was conducted in the Department of Orthopedic Surgery at Bangladesh Medical University (BMU), Shahbagh, Dhaka, over a period extending from January 2023 to March 2025. Patients diagnosed with metacarpal shaft fractures who presented to either the Emergency Department or the Outpatient Department during the study period were considered for inclusion. The participants were selected using a simple random sampling technique to ensure unbiased allocation. A total of 28 patients with metacarpal shaft fractures were enrolled and randomly allocated into two groups using a computer-generated randomization tool.

Group A (n=14): Patients who underwent K-wire fixation.
Group B (n=14): Patients who received Mini-plate fixation.

Inclusion Criteria:

- Age 18–50 years.
- Closed metacarpal shaft fracture.
- Duration of fracture <7 days.

Exclusion Criteria:

- Pathological fractures.
- Associated fractures of the hand.
- Open fractures or head injury.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki (1964). Patients were provided with detailed information about the study, its objectives, potential risks, and benefits. Written informed consent was obtained from all participants. Anonymity, confidentiality, and the right to withdraw at any time were strictly maintained. The research protocol was reviewed and approved by the Academic Committee of the Department of Orthopaedic Surgery, BMU, and ethical clearance was obtained from the Institutional Review Board (IRB) of BMU, Dhaka.

Data Collection

After obtaining informed written consent, all patients underwent detailed history-taking, physical examination, and radiological assessment with anteroposterior and oblique X-rays of the hand. Necessary preoperative investigations were performed. A structured case record form was used for collecting data preoperatively, intraoperatively, and postoperatively. Postoperative follow-up was carried out at 2, 4, 6, and 12 weeks, and at 6 months; although follow-up continued for upto 12 months, only results upto 6 months were analyzed to maintain homogeneity of follow-up duration. Clinical outcomes were assessed using the Visual Analog Scale (VAS), Quick DASH score, and Total Active Motion (TAM), while radiological union was evaluated based on the presence of bridging callus or bony bridging, obliteration of the fracture line, and cortical continuity on plain radiographs.

Statistical Analysis

Data were analyzed using SPSS version 26 (IBM®, Armonk, USA). Qualitative variables were presented as frequency and percentage and compared using the Chi-square test, while quantitative variables were expressed as mean ± standard deviation (SD) and analyzed using the Student's t-test for parametric data and the Mann-Whitney U test for non-parametric data. A p-value of less than 0.05 was considered statistically significant at a 95% confidence interval.

RESULT

The baseline characteristics of the study population were summarized in Table 1. A total of 28 patients with metacarpal shaft fractures were enrolled, with 14 patients each in Group A (Mini Plate fixation) and Group B (K-Wire fixation). The mean age was comparable between the groups, with Group A at 32.57±6.43 years and Group B at 31.57±6.05 years (p = 0.769). Age distribution was similar, with most patients aged 31–40 years (50% in both groups), followed by 20–30 years (35.7% in Group A and 42.9% in Group B), and fewer patients aged 41–50 years (14.3% in Group A vs. 7.1% in Group B) (p = 0.809). The majority were male (82.1%), and occupations were mostly manual work (39.3%) and service (35.7%), with no significant differences between groups. All patients were right-hand dominant, and right limb fractures were more common (71.4%) (p = 0.403). The mechanism of injury was blunt trauma in 6 (42.9%) and 5 (35.7%) cases in group A and group B, respectively. Fall injury accounted for 5 (35.7%) and 3 (21.4%) cases, RTA accounted for 2 (14.3%) and 4 (28.6%) cases and Physical assault resulted in 1 (7.1%) and 2 (14.3%) cases respectively (p= 0.661) (Figure 1). The distribution of fracture patterns showed that transverse fractures were most common in both groups, observed in 57.1% of Group A and 42.9% of Group B. Oblique fractures were more frequent in Group B (35.7%) compared to Group A (14.3%). Spiral fractures occurred in 28.6% of Group A and 14.3% of Group B. Comminuted fractures were found only in Group B (7.1%) and absent in Group A (Figure 2). Table 2 was highlighted the distribution of metacarpal fractures and involved bones. Most patients sustained a single fracture (75% overall), with two fractures in 21.4% and three fractures in 3.6%. The 5th metacarpal was most commonly involved (47.2%), followed by the 4th (36.1%), 2nd (11.1%), and 3rd (5.6%), with similar distributions between groups. Operative duration and bony union were summarized in Table 3. The mean operative time was significantly shorter in Group A (23.57±7.57 min) than Group B (41.79±8.23 min; p = 0.001). Most patients achieved bony union by 6–8 weeks. Group A had a slightly longer mean union time (8.14±1.66 weeks) compared to Group B (7.86±1.03 weeks; p = 0.044). Pain assessment using VAS was summarized in Table 4. Preoperatively, both groups reported severe pain (78.6% in Group A, 71.4% in Group B), with no significant difference. At 12 weeks, pain decreased significantly in both groups, with mean VAS scores of 1.50±0.86 in Group A and 0.71±0.73 in Group

B (p = 0.027). Notably, 42.9% of Group B patients reported no pain compared to 7.1% in Group A (p = 0.029). Functional outcomes assessed by QuickDASH were presented in Tables 5 and 6. At 12 weeks, excellent outcomes were observed in 50% of Group A and 71.4% of Group B, with mean scores significantly lower in Group B (7.79±3.55) than Group A (11.53±5.66; p = 0.039). At 6 months, both groups improved with comparable scores (p = 0.311). Analysis by fracture number showed that single fractures recovered faster with K-Wire fixation (p = 0.0106), while multiple fractures showed no significant difference. Overall outcomes, including Total Active Motion and complications, were shown in Table 7. Excellent TAM (>220°) was achieved in 85.7% of Group A and 92.9% of Group B at 12 weeks, with mean TAM significantly higher in Group B (246.43±14.60° vs. 231.43±18.34°; p = 0.024). At 6 months, TAM was near normal in both groups (p = 0.13). Complications were more frequent in Group A (42.9%) than Group B (14.3%; p = 0.094), including stiffness, pin tract infection, and loss of reduction, whereas Group B had one superficial wound infection.

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

Parameter	Group A, n=14 (%)	Group B, n=14 (%)	Total, n=28 (%)	P-value
Age (years)				
20-30	5 (35.7)	6 (42.9)	11 (39.3)	0.809
31-40	7 (50.0)	7 (50.0)	14 (50.0)	
41-50	2 (14.3)	1 (7.1)	3 (10.7)	
Mean± SD	32.57± 6.43	31.57± 6.05	32.07± 6.15	0.769
Gender				
Male	12 (85.7)	11 (78.6)	23 (82.1)	0.622
Female	2 (14.3)	3 (21.4)	5 (17.9)	
Occupation				
Manual workers	6 (42.9)	5 (35.7)	11 (39.3)	0.98
Service holders	5 (35.7)	5 (35.7)	10 (35.7)	
Business owners	1 (7.1)	1 (7.1)	2 (7.1)	
Homemakers	1 (7.1)	1 (7.1)	2 (7.1)	
Students	1 (7.1)	2 (14.3)	3 (10.7)	
Hand Dominancy				
Right	14 (100.0)	14 (100.0)	28 (100.0)	1
Left	0 (0)	0 (0)	0 (0)	
Involved limb				
Right	9 (64.3)	11 (78.6)	20 (71.4)	0.403
Left	5 (35.7)	3 (21.4)	8 (28.6)	

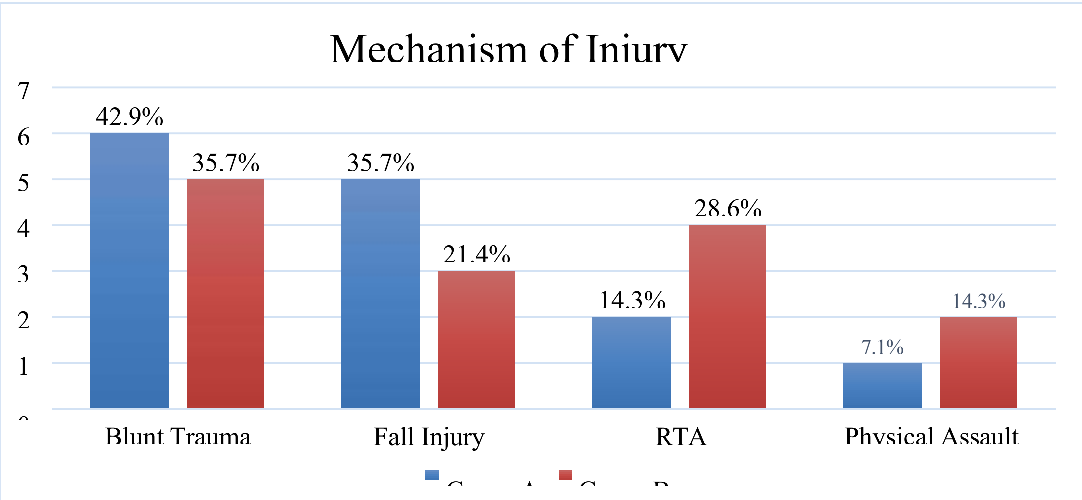

Figure 1: Bar graph showing mechanism of injury (N=28)

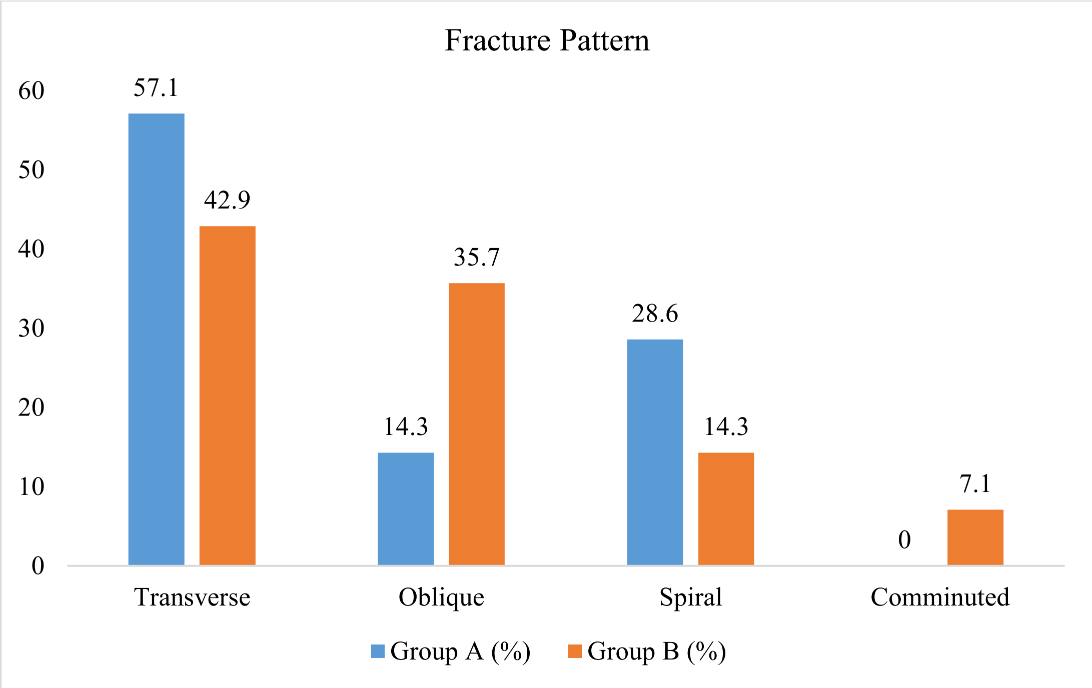

Figure 2: Fracture pattern among study subject (N=28)

Table 2: Distribution of metacarpal fractures and involved bones among study patients (N=28)

Parameter	Group A, n=14 (%)	Group B, n=14 (%)	Total, n=28 (%)	P-value
Number of Metacarpal fractures				
1	10 (71.4)	11 (78.6)	21 (75)	0.592
2	3 (21.4)	3 (21.4)	6 (21.4)	
3	1 (7.1)	0 (0)	1 (3.6)	
Involved Metacarpal bone				
2nd MC (n=4)	2 (10.5)	2 (11.7)	4 (11.1)	1
3rd MC (n=2)	1 (5.3)	1 (5.9)	2 (5.6)	0.541
4th MC (n=13)	7 (36.8)	6 (35.3)	13 (36.1)	0.705
5th MC (n=17)	9 (47.4)	8 (47.1)	17 (47.2)	0.699

Table 3: Operative duration and bony union time in study patients (N=28)

Parameter	Group A, n=14 (%)	Group B, n=14 (%)	P-value
Operative duration (min)	23.57 ± 7.57	41.79± 8.23	0.001
Bony union (weeks)			
6	3 (21.4)	8 (57.1)	0.135
8	8 (57.1)	6 (42.9)	
10	2 (14.3)	0 (0)	
12	1 (7.1)	0 (0)	
Mean± SD	8.14 ± 1.66	7.86± 1.03	0.044

Table 4: Preoperative and postoperative pain assessment using Visual Analog Scale (VAS) (N=28)

Parameter	Group A, n=14 (%)	Group B, n=14 (%)	P-value
Visual Analog Scale Score (Preoperative)			
Mean± SD	7.21 ±0.89	6.93 ±0.73	0.454
Moderate Pain (4-6)	3 (21.4)	4 (28-6)	0.663
Severe Pain (7-10)	11 (78.6)	10 (71.4)	
12 week Post-op			
Mean± SD	1.50 ±0.86	0.71 ±0.73	0.027
No pain (0)	1 (7.1)	6 (42.9)	0.029
Mild Pain (1-3)	13 (92.9)	8 (57.1)	
P-value	0.001	0.001	--

Table 5: QuickDASH score and fracture pattern at 12 weeks and 6 months follow-up (N=28)

Parameter	Group A, n=14 (%)	Group B, n=14 (%)	P-value
Quick DASH Score			
Excellent (0-10)	7 (50.0)	10 (71.4)	0.246
Good (11-30)	7 (50.0)	4 (28.6)	
12-week follow-up			
Mean± SD	11.53 ±5.66	7.79 ±3.55	0.039
6 months follow up			
Mean± SD	3.39±1.81	2.67±1.88	0.311
Fracture pattern			
Transverse	12.6 ± 6.85	10.6± 1.28	0.95
Oblique	12.1 ±0.57	9.5 ±3.18	0.571
Spiral	12.5±1.18	8.4 ± 1.20	0.133
Comminuted	0	8.3	--

Table 6: QuickDASH score comparison based on number of metacarpal fractures

Quick DASH Score	Group A, n	Group B, n	P-value
For the cases with single MC Fracture	10	11	--
12-week follow-up, Mean± SD	9.9 ±2.67	6.35 ±3.00	0.0106
For the cases with more than one MC Fracture	n=4	n=3	--
12-week follow-up, Mean± SD	15.35±9.52	12.13 ±1.27	0.845
P-value	0.337	0.0008	--

Table 7: Outcome of the study (N=28)

Parameter	Group A, n=14 (%)	Group B, n=14 (%)	P-value
Total Active Motion			
Excellent (>220)	12 (85.7)	13 (92.9)	0.541
Good (180-219)	2 (14.3)	1 (7.1)	
12-week follow-up (°), Mean± SD	231.43 ± 18.34	246.43 ±14.60	0.024
6 months follow-up (°), Mean± SD	245.36 ± 12.74	251.79 ±8.23	0.13
Complication			
Present	6 (42.9)	2 (14.3)	0.094
Absent	8 (57.1)	12 (85.7)	
Complications type			
Stiffness	3 (50.0)	1 (50.0)	0.215
Pin tract infection	2 (33.3)	0 (0)	

Loss of reduction	1 (16.7)	0 (0)	
Superficial wound infection	0 (0)	1 (50.0)	

DISCUSSION

In this study, the average age of participants was 32.1 ± 6.2 years. 89.3% of cases were aged ≤40 years. No significant age difference existed between groups (p = 0.769). The results were comparable to the study of Bayder et al and Kumar et al where the authors have reported the mean age of 31.2 and 32.4 years [12,13]. Male patients predominated, comprising 85.7% in Group A and 78.6% in Group B, with no significant difference between the groups (p = 0.622). Studies indicate that metacarpal bone fractures were more common in men than in women [1,5,14]. Young people, particularly males, experience a higher rate of metacarpal fractures largely due to their involvement in sports, recreational activities, and physically strenuous jobs, all of which raise the likelihood of hand injuries. Manual workers were 42.9% in Group A and 35.7% in Group B; service holders 35.7% in both. Students comprised 7.1% in Group A and 14.3% in Group B, while business owners and homemakers each accounted for 7.1% in both groups. No significant difference was found (p=0.980). Manual worker has high incidence of hand injury because of increasing use of machinery tools. Similarly, a study from Bangladesh by Barua et al reported service holders (35%) and manual workers (31%) as the predominant groups [15]. All patients were right-handed and twenty (71.4%) cases involved the dominant hand in our study. Similar to Kumar et al and Lv et al who reported 76.66% and 70% dominant-hand injuries [13,16], our findings suggest higher risk due to greater use of the dominant hand in daily activities, work, and sports. In Group A, fractures were caused by blunt trauma in 6 (42.9%) cases, falls in 5 (35.7%), RTA in 2 (14.3%), and assault in 1 (7.1%). In Group B, blunt trauma caused 5 (35.7%), falls 3 (21.4%), RTA 4 (28.6%), and assault 2 (14.3%) (p=0.661). Metacarpal fractures commonly result from blunt trauma due to their slender structure, minimal soft tissue cover, and frequent exposure during falls, accidents, or assaults. The most common fracture pattern in Group A was transverse (57.1%), followed by spiral (28.6%) and oblique (14.3%). In Group B, oblique fractures were most frequent (35.7%), followed by transverse (42.9%), spiral (14.3%), and comminuted (7.1%). There was no significance differences between groups (p = 0.356). Other studies found similar findings [1,3,15]. Twenty-one (75%) had single metacarpal fractures, six (21.4%) had two, and one (3.6%) had three with no significant difference between groups (p = 0.592). The findings align closely with Barua et al and Lv et al [15,16]. Out of 36 metacarpal fractures, 17 (47.2%) were 5th MC, 13 (36.1%) were 4th MC, 4 (11.1%) were 2nd MC, and 2 (5.6%) were 3rd MC. However, there was no significant difference. Likewise, a study by Lv et al reported that the most frequently injured metacarpal was the 5th metacarpal (47.7%), followed by the 4th metacarpal (28.9%) [16]. The 5th metacarpal is more prone to fracture as it lies on the ulnar side of the hand with less protection from surrounding bones and soft tissues, making it more vulnerable to direct trauma. The mean operative time was significantly shorter with K-wire (23.57 ± 7.57 min) than with the Mini-plate (41.79 ± 8.23 min; p=0.001). Research indicates that patients receiving Percutaneous K-wire fixation experienced significantly shorter surgical times compared to those who had Mini-plate fixation [17-19]. K-wire fixation showed an average bony union time of 8.14 ± 1.66 weeks (range 6–12), while the Mini-plate group averaged 7.86 ± 1.03 weeks (range 6–8). Union occurred significantly earlier with Mini-plates (p=0.044). By 8 weeks, 78.5% of K-wire cases and 100% of Mini-plate cases had achieved union. In comparison, OMER reported 28% vs. 80% union at 8 weeks [20], while Mahmoud et al found 90% in both groups [5]. K-wire Group's average preoperative VAS score was 7.21 ± 0.89 and Mini-plate Group's was 6.93 ±0.73 (p = 0.384). At the 12-week follow-up, K-wire Group's VAS score improved to 1.50 ±0.86 compared to Mini-plate Group's 0.71 ±0.73. Mini-plate Group showed significantly better VAS scores than K-wire Group at 12-week follow-up (p = 0.027). The results aligned with studies conducted by Baydar et al and Kumar et al [12,13]. At 12 weeks, the mean QuickDASH score was 11.53 ± 5.66 in the Group A and 7.79 ± 3.55 in the Group B, with significantly better outcomes in the latter (p = 0.039). Similar findings were reported by Elmalt et al, showing lower scores in the Mini-plate group [14]. At 12 weeks, mean TAM was 231.43 ± 18.34° (190–260°) in the K-wire group and 246.43 ± 14.60° (210–260°) in the Mini-plate group, with significantly better outcomes for Mini-plates (p=0.024). Comparable results were reported by Kumar et al and Ahmed et al, all showing superior TAM with Mini-plate fixation [13,17]. According to QuickDASH, excellent outcomes were observed in 50% of K-wire cases and 71.4% of Mini-plate cases, while good outcomes occurred in 50% and 28.6%, respectively (p = 0.246). Noor et al reported excellent outcomes in 42.9% vs. 57.1% and good in 46.4% vs. 39.4% for K-wire and Mini-plate groups, respectively, with a few fair and poor results [3]. Rashid et al similarly found 65% excellent and 25% good outcomes in Mini-plate cases versus 35% excellent and 35% good in K-wire cases [21]. At 6 months, Mini-plates showed slightly better QuickDASH (2.67 vs. 3.39) and TAM (251.79° vs. 245.36°) scores, though differences were not significant (p=0.311, p=0.13). Complications included stiffness (21.4% vs. 7.1%), pin tract infection (14.3%), and loss of reduction (7.1%) in the K-wire group, while Mini-plates had 7.1% superficial wound infection (p=0.215). These findings are consistent with Noor et al and Ahmad et al [3,22], where pin tract infection and stiffness were common after K-wire, while wound infection was more frequent with Mini-plates.

Limitations of the study:

- The research took place at a single center, which also constrains the generalizability of the findings.
- The follow-up period may not suffice to thoroughly evaluate long-term results and complications linked to the two treatment approaches.
- There is the risk of bias during the post-operative assessments and measurements that could affect the outcomes.

CONCLUSION AND RECOMMENDATIONS

The study demonstrates that mini-plate fixation is superior to K-wire fixation in the treatment of metacarpal shaft fractures. The findings indicate that all cases in the mini-plate group achieved early radiological union (assessed by the presence of bridging callus or bony bridging, obliteration of the fracture line and appearance of cortical continuity) compared to the K-wire group, and the complication rates were also lower in the mini-plate group. Additionally, the functional outcomes, evaluated using the Quick Disability of Arm, Shoulder and Hand (Quick DASH) score, Total Active Motion (TAM), and Visual Analog Scale (VAS) score, revealed significantly lower levels of disability in the Mini-plate group compared to the K-wire group, suggesting a superior overall functional recovery following mini-plate fixation.

Recommendations:

- Longer Follow-Up Periods: Extending the follow-up duration beyond 3 months would help assess long-term outcomes, including complications and functional recovery.
- Multi-Center Trials: Conducting multi-center trials would allow for a more diverse patient population and different clinical settings, increasing the applicability of the findings.
- Randomized Controlled Trials (RCTs): Future studies should employ randomization to minimize selection bias and enhance the reliability of comparisons between different treatment methods.
- Blinding of Assessors: Implementing blinding for researchers assessing the outcomes will help reduce observer bias and strengthen the integrity of the study results.

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