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Original Research Article

COMPARATIVE ANALYSIS OF FUNCTIONAL OUTCOMES BETWEEN K-WIRE FIXATION AND MINI FRAGMENT PLATE FIXATION IN METACARPAL AND METATARSAL FRACTURES

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ABSTRACT

Background: Metacarpal and metatarsal fractures are common orthopaedic injuries. Unstable or displaced fractures are commonly treated with either K-wire fixation or mini fragment plate fixation, but functional superiority remains uncertain. **Objectives:** To compare functional and radiological outcomes of mini fragment plate fixation and K-wire fixation in displaced metacarpal and metatarsal fractures.

Materials and Methods: A prospective comparative interventional study was conducted at the Department of Orthopaedics, Subharti Medical College, Meerut, from 2024 to 2026. Thirty adult patients aged 18–60 years with displaced or comminuted metacarpal or metatarsal fractures were equally divided into two groups: mini fragment plate fixation and K-wire fixation. Outcomes were assessed at 3, 6, and 9 weeks using VAS, TAM, grip strength, QuickDASH score, and radiological union. Data were analysed using Student's t-test, Chi-square test, and Fisher's exact test.

Results: Operative time was significantly longer in the miniplate group than the K-wire group (76.60 ± 9.20 vs 42.40 ± 5.80 minutes; $p < 0.001$). At 6 weeks, the K-wire group showed lower VAS scores and better QuickDASH scores. By 9 weeks, both groups showed comparable TAM, grip strength, QuickDASH score, pain score, and final functional grading. Radiological union was achieved in all patients by 9 weeks, with no significant difference in mean union time. Postoperative stiffness was the only complication.

Conclusion: Both fixation methods provide comparable short-term functional and radiological outcomes. K-wire fixation offers shorter operative time and better early recovery, while mini fragment plating remains useful for unstable fracture patterns.

Keywords: Metacarpal fractures · Metatarsal fractures · K-wire fixation · Mini fragment plate · Functional outcomes · QuickDASH · Total active motion · Orthopaedic trauma · Hand fractures · Foot fractures.

INTRODUCTION

Metacarpal and metatarsal fractures are common appendicular skeletal injuries and represent a significant burden in orthopaedic practice. Metacarpal fractures account for nearly 36% of hand fractures, commonly affecting young, active individuals, while metatarsal fractures often result from road traffic accidents, sports injuries, or crush trauma. Both regions are biomechanically important: metacarpals support grip and fine hand function, whereas metatarsals maintain forefoot stability and weight distribution during gait. Malunion, shortening, or rotational deformity can cause functional impairment, pain, digital scissoring, metatarsalgia, or gait disturbance.

Unstable fractures with angulation, shortening, rotation, intra-articular extension, open injury, or multiple ray involvement usually require surgical fixation. K-wire fixation is minimally invasive,

economical, and simple, while mini fragment plate fixation provides rigid anatomical stability. However, the superiority of either method remains uncertain, especially in combined metacarpal–metatarsal fractures. This study evaluates functional and radiological outcomes at 3, 6, and 9 weeks postoperatively.

2. Review of literature

2.1 Anatomy and Biomechanics

Metacarpals comprise a base, shaft, neck, and head. The second and third rays form a stable central column, while the fourth and fifth provide mobility during grasp. Their dorsal surface is commonly used for plating but lies close to extensor tendons, increasing irritation risk. Metatarsals have similar architecture: the first bears major gait load, the second provides stability, and the fifth is influenced by peroneus brevis insertion. Plate fixation offers greater torsional and bending stability than K-wires.

2.2 K-Wire Fixation: Evidence and Limitations

K-wire fixation using crossed, parallel, or intramedullary wires is simple, economical, minimally invasive, and preserves fracture hematoma. It is suitable for simple transverse or short oblique fractures that remain stable after reduction. However, its limitations include poor rotational control, need for additional immobilisation, risk of pin-tract infection, and possible reduction loss. Higher malunion rates have been reported in comminuted and long oblique fractures, emphasizing the importance of fracture morphology in implant selection.

2.3 Mini Fragment Plate Fixation: Evidence and Limitations

Mini fragment plate fixation provides rigid anatomical stability and allows early mobilisation, helping reduce stiffness and tendon adhesions. Studies have shown better postoperative grip strength and TAM with plating compared to K-wire fixation, although plating requires longer operative time and may involve greater blood loss. Union rates are high with both methods. However, plating may cause implant prominence, extensor tendon irritation, higher cost, and greater surgical complexity, so fracture pattern and patient factors should guide implant selection.

2.4 Evidence Gap and Rationale for This Study

The preponderance of comparative literature focuses exclusively on metacarpal fractures, with limited published data on metatarsal fixation comparisons and virtually no studies evaluating both anatomical regions within a unified prospective cohort using standardised functional scoring (QuickDASH, TAF/TAM) alongside radiological union assessment. Furthermore, the long-term convergence of outcomes—and whether early biomechanical advantages of plating translate to superior final function—remains inadequately characterised. This study addresses these gaps.

MATERIALS AND METHODS

3.1 Study Design and Setting

A prospective comparative interventional study was conducted in the Department of Orthopaedics, N.S.C.B. Subharti Medical College, Meerut (Swami Vivekanand Subharti University) over a two-year period (2024–2026), following Institutional Ethics Committee approval. All surgical procedures were performed in institutional operation theatres; postoperative follow-ups were conducted in the orthopaedic outpatient department.

3.2 Participants

Thirty patients (aged 18–60 years) presenting with metacarpal or metatarsal fractures satisfying eligibility criteria were enrolled after written informed consent and allocated equally to two groups:

- **Group 1 (Miniplate, n=15):** Open reduction and internal fixation with 2.0 mm mini fragment plate via dorsal approach.
- **Group 2 (K-wire, n=15):** Percutaneous or limited-open Kirschner wire fixation (1–2 wires as required).

Inclusion Criteria: Displaced/comminuted metacarpal or metatarsal fractures; fractures with rotational deformity; multiple metacarpal/metatarsal fractures; age 18–60 years.

Exclusion Criteria: Age <18 or >60 years; stable undisplaced fractures; pathological fractures; fractures older than 3 weeks.

3.3 Surgical Technique

All procedures were performed under general or regional anaesthesia. The miniplate group underwent open reduction through a dorsal incision, anatomical fracture reduction, plate contouring, and fixation with 2.0 mm cortical screws, followed by 2 weeks of immobilisation and physiotherapy. The K-wire group underwent closed or limited-open reduction with fluoroscopic-guided percutaneous fixation, POP slab immobilisation, wire removal at 4 weeks, and physiotherapy.

3.4 Outcome Measures

Assessments were conducted at 3, 6, and 9 weeks postoperatively. Primary outcomes included:

- **Pain:** Visual Analogue Scale (VAS, 0–10)
- **Range of motion:** Total Active Motion (TAM) in degrees
- **Upper extremity disability:** QuickDASH score (0–100; lower = better)
- **Strength:** Grip strength as percentage of contralateral side
- **Radiological union:** Assessed on serial AP and oblique radiographs
- **Final functional grade:** Excellent / Good / Fair (composite assessment)

3.5 Statistical Analysis

Data were entered in Microsoft Excel and analysed using SPSS. Continuous variables were expressed as mean ± SD, and categorical variables as frequency

and percentage. Student's t-test, Chi-square/Fisher's exact test, and paired t-test were applied. Statistical significance was set at $p < 0.05$.

RESULTS

4.1 Baseline Characteristics

Thirty patients completed the study with no attrition. The groups were comparable at baseline across gender distribution (Miniplate: 86.7% male; K-wire: 60% male; p = 0.215), mode of injury (p = 0.283), and bone involved (metacarpal vs metatarsal; p = 1.000). A statistically significant age difference was noted, with the K-wire group being older (40.67 ± 13.46 years) than the Miniplate group (30.87 ± 9.80 years; p = 0.030), though this did not significantly impact healing or functional outcomes.

Table 1: Baseline demographic and injury characteristics (* p < 0.05)

Variable	Miniplate (n=15)	K-wire (n=15)	Test Statistic	p-value
Age (years)	30.87 ± 9.80	40.67 ± 13.46	t = □2.280	0.030*
Male : Female	13:2 (86.7% : 13.3%)	9:6 (60% : 40%)	□² = 1.534	0.215
Mode of injury	Comparable	Comparable	□² = 3.810	0.283
Bone involved	Comparable	Comparable	□² = 0.000	1.000

4.1 Intraoperative Parameters

Mini fragment plate fixation required significantly more operative time (76.60 ± 9.20 min) compared to K-wire fixation (42.40 ± 5.80 min; t = 12.174, p < 0.001). No intraoperative complications were recorded in either group.

Table 2: Intraoperative parameters (* p < 0.05)

Parameter	Miniplate (n=15)	K-wire (n=15)	t-value	p-value
Duration of surgery (min)	76.60 ± 9.20	42.40 ± 5.80	12.174	<0.001*
Intraoperative complications	0 (0%)	0 (0%)	—	—

4.1 Functional Outcomes

Pain (VAS) scores were comparable between groups at 3 weeks (5.80 ± 0.77 vs 5.60 ± 0.63; p = 0.445) and 9 weeks (0.93 ± 0.88 vs 1.40 ± 0.74; p = 0.128). A transient but statistically significant advantage was observed in the K-wire group at 6 weeks (2.67 ± 0.82 vs 3.40 ± 0.91; p = 0.028). Total Active Motion at 9 weeks (236.27 ± 11.79° vs 242.00 ± 11.62°; p = 0.191) and grip strength recovery (87.13 ± 4.66% vs 88.20 ± 5.73%; p = 0.581) were equivalent between groups.

Table 3: Functional outcome comparison (* p < 0.05)

Outcome Parameter	Miniplate (n=15)	K-wire (n=15)	t-value	p-value
VAS at 3 weeks	5.80 ± 0.77	5.60 ± 0.63	0.775	0.445
VAS at 6 weeks	3.40 ± 0.91	2.67 ± 0.82	2.323	0.028*
VAS at 9 weeks	0.93 ± 0.88	1.40 ± 0.74	□1.571	0.128
TAM at 9 weeks (°)	236.27 ± 11.79	242.00 ± 11.62	□1.341	0.191
Grip strength at 9W (%)	87.13 ± 4.66	88.20 ± 5.73	□0.559	0.581

4.1 QuickDASH Score

At 6 weeks, the K-wire group demonstrated significantly lower disability scores (27.32 ± 3.50 vs 31.15 ± 4.30; t = 2.674, p = 0.012), indicating greater early functional independence. By 9 weeks, QuickDASH scores converged with no significant difference (9.60 ± 2.60 vs 10.70 ± 3.16; t = 0.894, p = 0.382), reflecting equivalent long-term disability profiles.

Table 4: QuickDASH score comparison (* p < 0.05)

Follow-up	Miniplate	K-wire	t-value	p-value
6 weeks	31.15 ± 4.30	27.32 ± 3.50	2.674	0.012*
9 weeks	10.70 ± 3.16	9.60 ± 2.60	0.894	0.382

4.1 Radiological Union

Mean time to radiological union was equivalent between groups: Miniplate 7.80 ± 1.01 weeks; K-wire 7.73 ± 1.16 weeks (t = 0.167, p = 0.868). Union rates at 3 weeks (0% vs 13.3%; p = 0.464) and 6 weeks (13.3% vs 20%; p = 1.000) were statistically comparable. All 30 patients (100%) achieved complete radiological union by 9 weeks regardless of fixation method.

Table 5: Radiological union analysis

Parameter	Miniplate (n=15)	K-wire (n=15)	Test Value	p-value
Time to union (weeks)	7.80 ± 1.01	7.73 ± 1.16	t = 0.167	0.868
Union at 3 weeks	0 (0%)	2 (13.3%)	□² = 0.536	0.464
Union at 6 weeks	2 (13.3%)	3 (20.0%)	□² = 0.000	1.000
Union at 9 weeks	15 (100%)	15 (100%)	□² = 0.000	1.000

4.1 Postoperative Complications

Postoperative stiffness was the sole complication documented—occurring in 5/15 patients (33.3%) in the Miniplate group and 3/15 patients (20.0%) in the K-wire group. This difference was not statistically significant (Fisher's Exact p = 0.682). No cases of wound infection, implant failure, malunion, or non-union were recorded in either group.

Table 6: Postoperative complication profile

Complication	Miniplate (n=15)	K-wire (n=15)	p-value
Postoperative stiffness	5 (33.3%)	3 (20.0%)	0.682
Infection	0 (0%)	0 (0%)	—
Implant failure / malunion / non-union	0 (0%)	0 (0%)	—

4.1 Final Functional Outcome

Composite final functional grading revealed Excellent outcomes in 3 (20%) patients in each group; Good outcomes in 8 (53.3%) Miniplate vs 10 (66.7%) K-wire patients; and Fair outcomes in 4 (26.7%) Miniplate vs 2 (13.3%) K-wire patients. Chi-square analysis demonstrated no statistically significant difference in final outcome distribution ($\chi^2 = 0.889$, p = 0.641).

Table 7: Final functional outcome distribution

Outcome Grade	Miniplate (n=15)	K-wire (n=15)	χ^2 / p-value
Excellent	3 (20.0%)	3 (20.0%)	$\chi^2 = 0.889$
Good	8 (53.3%)	10 (66.7%)	p = 0.641
Fair	4 (26.7%)	2 (13.3%)	

DISCUSSION

5.1 Operative Time and Intraoperative Parameters

The highly significant difference in operative duration (76.60 vs 42.40 min; p < 0.001) is clinically anticipated and reflects the greater technical demands of open reduction with plate application—requiring soft-tissue dissection, fracture exposure, plate contouring, and multi-screw fixation—versus the minimally invasive K-wire technique. This finding aligns with Wang et al. (2020) whose meta-analysis identified longer operative times and greater blood loss as consistent features of mini-plate fixation. Notably, the absence of intraoperative complications in both groups confirms the safety of both techniques when performed under standardised surgical conditions.

5.2 Early Functional Recovery (6 Weeks)

The K-wire group demonstrated superior early outcomes at 6 weeks in both pain (VAS 2.67 vs 3.40; p = 0.028) and functional disability (QuickDASH 27.32 vs 31.15; p = 0.012). This finding—seemingly counterintuitive given plating's biomechanical superiority—likely reflects the greater soft-tissue trauma inherent to open reduction: periosteal stripping, dorsal tissue dissection, and implant prominence may temporarily exacerbate pain and restrict early functional recovery. Similar patterns of intermediate postoperative discomfort in plating cohorts were reported by Elhomy et al. (2023) and Mahmoud et al. (2024). The K-wire technique's percutaneous nature preserves soft-tissue envelope integrity and may create a more comfortable early rehabilitation milieu despite relatively weaker mechanical fixation.

5.3 Long-Term Functional Equivalence (9 Weeks)

The main finding of this study was the convergence of functional outcomes at 9 weeks. TAM, grip strength, QuickDASH score, pain score, and final functional grading were statistically comparable between mini fragment plate and K-wire fixation groups. This suggests that once adequate fracture stability is achieved, final recovery depends more on biological healing, anatomical reduction, and rehabilitation than implant rigidity alone. Structured physiotherapy may compensate for the early mobilisation advantage of plating, resulting in similar final motion and strength. Unlike studies showing better early results with plating, this study included both metacarpal and metatarsal fractures with 9-week follow-up.

5.4 Radiological Union

Both fixation methods achieved 100% union at 9 weeks, with similar mean union times (7.80 vs 7.73 weeks; p = 0.868). This shows that small bone fractures heal reliably once adequate stability is achieved, whether by plating or K-wire fixation. A minor trend toward earlier union with K-wires may reflect better periosteal preservation, though it was not statistically significant.

5.5 Complications

Postoperative stiffness was the only complication documented, with a numerically higher but statistically non-significant incidence in the Miniplate group (33.3% vs 20%; p = 0.682). The higher stiffness rate in the plating cohort is consistent with greater soft-tissue dissection and potential extensor tendon adhesions from dorsal plating. The absence of pin-tract infection in the K-wire group—contrary to published rates of 3–12%—likely reflects stringent aseptic technique and pin care protocols. Similarly, no hardware irritation requiring implant removal was recorded in the plating group, which may reflect a shorter follow-up period (9 weeks)

relative to studies reporting hardware complications at 6–12 months.

5.6 Biomechanical Considerations and Implications

Mini fragment plates provide superior mechanical stability against bending, torsional, and axial forces; however, this did not translate into better long-term functional outcomes in routine displaced fractures. K-wire fixation may be preferred when adequate reduction and stability are achievable, especially in resource-limited settings. Plate fixation remains useful for comminuted, long-oblique, or rotationally unstable fractures requiring rigid control and early mobilisation.

CONCLUSION

Both mini fragment plate fixation and K-wire fixation are safe and effective for displaced or comminuted metacarpal and metatarsal fractures in adults. Mini fragment plating requires longer operative time and may cause slightly greater early pain and disability, but these differences resolve by 9 weeks. Final outcomes, including total active motion, grip strength, QuickDASH score, radiological union, and functional grading, are comparable between both methods. K-wire fixation is a cost-effective alternative with shorter operative time and similar long-term results. Fixation choice should depend on fracture pattern, patient factors, cost, surgeon expertise, and structured postoperative.

Key Messages for Clinical Practice

Both K-wire and mini fragment plate fixation achieve 100% radiological union by 9 weeks in displaced metacarpal and metatarsal fractures.

- Mini fragment plate fixation requires ~34 additional minutes of operative time with no benefit in final functional outcomes.
- K-wire fixation offers superior early functional comfort at 6 weeks (lower VAS and QuickDASH), with convergence by 9 weeks.
- Final TAM, grip strength, union time, and composite functional grading are statistically equivalent between fixation methods.
- In resource-limited settings, K-wire fixation is a cost-effective alternative without sacrifice of long-term patient outcomes.
- Fracture morphology (comminution, rotational instability) should guide implant selection; rigid plating remains preferable for highly unstable patterns.
- Structured physiotherapy is an indispensable component of recovery, capable of compensating for early mobilisation differences between fixation techniques.

Study Limitations

- Relatively small sample size (n=30) limits statistical power to detect modest differences in subgroup analyses.
- Significant age difference between groups (p=0.030) may confound results despite clinical equivalence in outcomes.
- Follow-up limited to 9 weeks; longer-term assessment (6–12 months) is needed to capture hardware-related complications and implant removal rates.
- Absence of fracture-pattern stratification (transverse, oblique, comminuted) precludes subgroup functional comparison.
- No blinding was possible given the nature of the interventions; radiological assessors were not independently blinded.
- Generalisation may be limited to tertiary care institutional settings with standardised physiotherapy protocols.

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