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The Role of Mini-Plate and Screws in Metacarpal Shaft Fracture Fixation: A Clinical and Functional Study

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ABSTRACT

Background: Hand fractures account for 10% of all broken bones, with metacarpal fractures accounting for one-third of all hand breaks. Mini-plates and screws may offer firm fixation, allowing for early joint mobility and hence excellent functional outcomes while preventing the problems associated with Kirschner-wires fixation.

Objectives: To evaluate the clinical and function outcome of mini-plates and screws in the management of isolated, healed, single-digit metacarpal shaft fractures along with long- term functional assessment of the fractured hand by the disabilities of the arm, shoulder and hand (DASH) outcome questionnaire.

Patients and Methods: This is a prospective cohort study that conducted between April 2021 and March 2022 on patients presented with metacarpal shaft fracture. The primary outcomes evaluation includes: Presence of complications related to fixation technique, time of radiographic fracture union, metacarpophalangeal joint's range of motion (ROM) and the Total Active Flexion (TAF) score.

Results: All fractures in all patients (30 cases) had a successful union (100%) ranging between 8-12 weeks with a median of 10 weeks. The mean ROM of the respective MP joint was 74±8.96° at 3 month post-operative, which improved significantly, to 85.6±3.98° (p<0.004) at 6 month follow-up. The total active flexion (TAF) score showed that (73.3%) of our patients have excellent results, while it was good in (20%) patients, and fair in (6.7%) patients. The mean quick DASH score was 8.36±4.86, which significantly decreased to 6.47±4.08 at the end of follow-up period.

Conclusions: Mini-plate and screws is a suitable approach for unstable metacarpal fracture fixation. The employment of mini-plate and screws provide rigid stable fixation which enables early hand movement and achieving good functional outcomes.

Key Words: *Functional-Metacarpal Shaft – Fracture – Mini-plate – Fixation.*

Disclosure: No conflict of interest.

INTRODUCTION

Hand fractures account for 10% of all broken bones, with metacarpal fractures accounting for one-third of all hand breaks **[1]**. The majority of metacarpal fractures happen in people who are actively working, and they have a significant economic effect in terms of treatment costs and probable disability **[2]**. Transverse, short oblique, spiraling, and comminuted fractured of the metacarpal shaft may develop as a consequence of axial stress, twisting, or direct falls **[3]**.

The majority of metacarpal fractures are handled with caution **[4]**. Surgery may be performed to treat displaced shaft fractures if conventional techniques failure to accomplish or sustain reduction and there is angulation, twisting, or shortening. The success of treatment and rehabilitation for metacarpal shaft fractures is determined on the appropriateness of the intervention. For optimal functional results and to limit the risks of increasing stiffness, a correct anatomical reduction and use of the idea of biological, firm fixing that permits early mobility are essential **[5]**.

Although there are many procedures for fixing metacarpal bone fractures, there is no consensual, evidence-based view on the best therapy for several forms of metacarpal fractures, and the operative technique used is mostly dependent on the surgeons **[6]**. Percutaneous pinning using Kirschner wires (K-wires) is a common operative treatment for extra-articular metacarpal breaks; nevertheless, it is not a fully rigid fixation, requiring extensive immobilization and possibly resulting in postoperative stiffness **[7]**. Mini-plates and screws may offer firm fixation, allowing for early joint mobility and hence excellent functional outcomes while preventing the difficulties related to protruding Kirschner-wires **[8]**. Researchers have found that patients with plate fixation needed less time in a cast to heal from a fracture than those with k-wire fixation **[6,9]**. Plating, on the other hand, necessitates

a large dorsal incision and dissecting, which may result in scarring, extensor tendon adhesion, non-union, and delay union, as well as poor outcomes **[10,11]**.

The goal of this research was to evaluate the clinical and function effects of mini-plates and screws in the management of isolated, healed, single-digit metacarpal shaft fractures in a prospective study. The hypothesis was that ORIF with plates and screws allowed for faster mobility without jeopardizing fixation stability, resulting in reduced stiffness, greater patient satisfaction, and improved functional results.

PATIENTS AND METHODS

This is a prospective cohort study conducted between April 2021 and March 2022 on patients hospitalized to the Qena University Hospital's Plastic Surgery Department at South Valley University. Informed consent from all participants was taken.

Inclusion criteria: All patients presented with metacarpal shaft fracture whatever the cause.

Exclusion criteria: Patients who are immunocompromised, refuse to participate, have insufficient data, have a concurrent injury, or have had a past hand injury or surgery are all at risk. Data were collected including, patients' demographics, mechanism of injury, hand dominance, fracture characters and presence of associated injuries.

Ethical considerations: All patients who agreed to take part in the study provided informed consent, after explanation in accordance with the local ethical committee regulation.

Surgical technique:

A straight incision was performed on the radial border of the second metacarpal and the ulnar border of the fifth metacarpal to reveal the fractures. With a longitudinal incision across the third and fourth metacarpals, the third and fourth metacarpals were exposed. Fine dissection to expose extensor tendon that is retracted either radially or ulnar followed by periosteal elevation. A low-profile mini-plate was applied to the dorsal portion of the metacarpal after reduction of the fracture. To keep the fracture together, at least two bicortical screws will be placed on each side. Sutures were used to cover the plate with intrinsic muscle fascia. (Fig. 1).

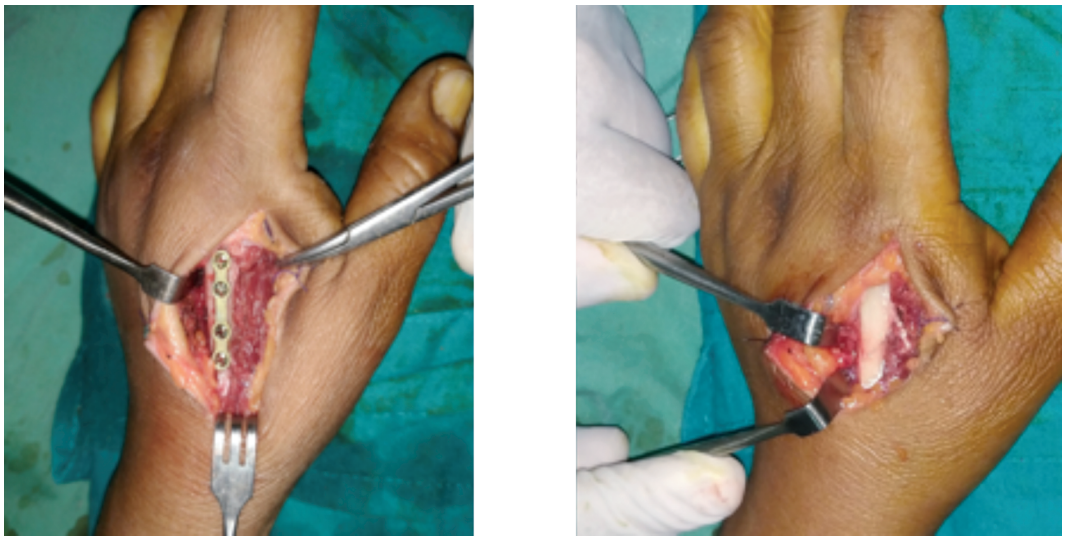

Fig. (1): Intraoperative view showing oblique fracture of the shaft of the 2nd metacarpal bone, left hand, reduction and fixation of the fracture using mini-plate and screws.

Post-operative treatment:

After surgery, a short-arm splint (2nd/3rd finger fracture) or an ulnar gutter short-arm splint (4th/5th finger) was fitted. The wrist was extended 20 degrees, the MP joint was flexed 60 degrees, and the interphalangeal (IP) joint was fully extended in the splint. After two weeks, the splint was removed and replaced with a comfortable wrist brace. All patients were assessed weekly for a month and then monthly for six months in our outpatient clinic. (Fig. 2).

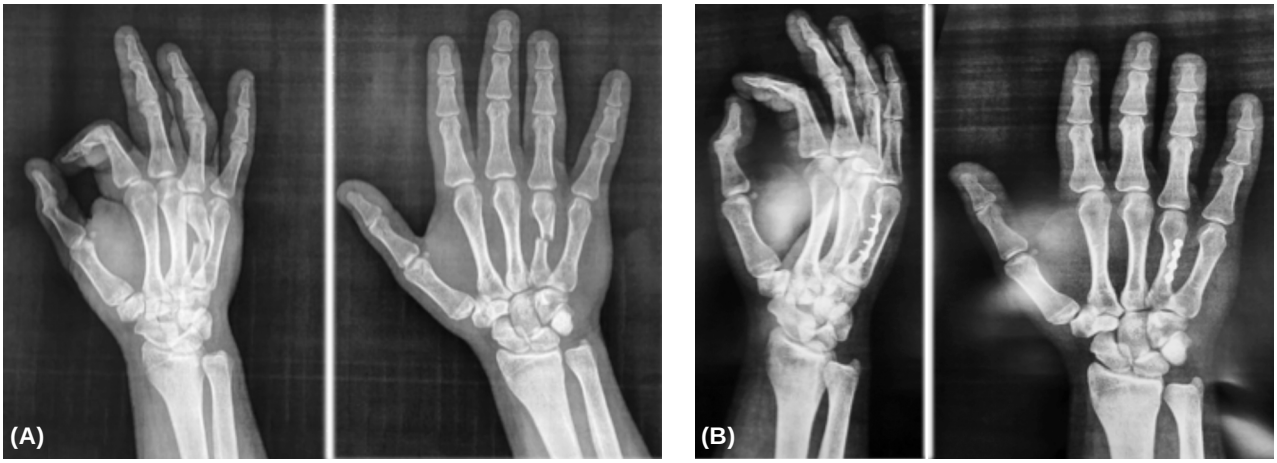

Fig. (2): (A) Preoperative X-ray, AP and oblique view, showing transverse fracture of the shaft of the 4th metacarpal bone, right hand, (B) Postoperative X-ray, AP and oblique views, post-fixation by mini-plate and screws technique.

The primary outcomes evaluation includes: Presence of complications related to fixation technique as wound dehiscence and infection. The time of radiographic fracture union and callus development are considered appropriate when more than three areas of bone bridge between the radial, ulnar, dorsal, and volar cortical aspects of the distal section of the metacarpus as visible on anteroposterior, lateral, and both obliquely forecasts union. The metacarpophalangeal joint's range of motion (ROM) is assessed from extensions to flex. The Total Active Flexion (TAF) score is calculated by adding the flexion degree of the distal interphalangeal (DIP), proximal interphalangeal (PIP), and metacarpophalangeal (MCP) joints and subtracting the total of the extending impairments at each joint. According to degree of flexion:

- Values more than 220 degrees are considered excellent.
- Values from 120-180 degrees are considered good.
- Values less than 120 degrees are considered poor.

This value can then be compared with that of the contralateral hand or a normal value to provide a more accurate assessment of each digit **[12]**. The patient satisfaction is also evaluated.

The secondary result was determined by utilizing the disability of the arm, shoulder, and hand (DASH) outcome questionnaire to measure the long-term functioning status of the broken hand. The Quick DASH questionnaire was used to self-report treatment capacity during an interview done throughout the study's data collecting procedure. The Quick DASH is a self-report questionnaire that assesses symptoms and performance in people with upper extremity diseases. There are many studies in the literature about the creation and validation of the 11-question Quick DASH questionnaire **[13]**. These estimates did not include patients who could not be reached or who declined to participate.

Management and analysis of data: The Statistical Package for Social Sciences (SPSS) software application was employed to conduct the analysis (version 26). The chi-square test was employed to investigate qualitative variables that were reported as frequency and percentage. Student *t*-test was utilized to compare quantitative measures provided as means ± standard deviation (SD). As specified, regression analysis and correlation between various variables were carried out. The significance of *p*-value <.005 was found.

RESULTS

Thirty patients (18 men, 12 women) were enrolled in this study with the age ranged (24-50) yrs. The highest prevalent source of injury was a fall in 46.7% of patients, followed by motor car accidents in 33.3% and a punch injury in 20%. The distribution of fracture categories was transverse (43.3%), followed by oblique pattern (36.7%) and spiral pattern was found in 20% of the patients. The operative time ranges 42-60min (Table 1).

All fractures in all patients had a successful union (100%) ranging between 8-12 weeks with a median of 10 weeks. The mean ROM of the respective MP joint was 74±8.96° at 3-months post-operative, which improved significantly, to 85.6 ±3.98° (p<0.004) at 6 month follow-up. The total active flexion (TAF) score showed that 22 (73.3%) of our patients have excellent results, while it was

good in 6 (20%) patients, and fair in 2 (6.7%) patients. The mean quick DASH score was 8.36± 4.86, which significantly decreased to 6.47±4.08 at the end of follow-up period (Table 2).

Distribution of post-operative complications of the studied patients were as follow: 2 patients had wound infection, and one patient had finger stiffness. Satisfaction distribution of our patients demonstrated that out of 30 patients, 24 patients were very satisfied, 4 patients were satisfied, one patient was fair, and one patient was unsatisfied with the outcome at 6 month post-operatively.

Table (1): Patient demographics and fracture characteristics.

Item	Value (%)
Total Patients	30
Age, y	42-50
Sex:	
Male	18 (60%)
Female	12 (40%)
Digit involved:	
Index	8 (26%)
Middle	5 (16.6%)
Ring	7 (23.3%)
Small	10 (33.3%)
Side involved:	
Right	24 (80%)
Left	6 (20%)
Mechanism of injury:	
Fall	14 (46.7%)
Punch	6 (20%)
MCA	10 (33.3%)
Fracture configuration:	
Transverse	13 (43.3%)
Spiral	6 (20%)
Oblique	11 (36.7%)
Surgery time (minutes)	42-60
Follow-up period, m	6

Table (2): Post-operative ROM and DASH score.

Variable Mean ± SD Median (Range)	The studied population (N=30)		*p*-value
	3 months	6 months	
ROM	74±8.96 73 (60-88)	85.6±3.98 85 (80-92)	.004
DASH	8.36±4.86 8.45 (0-14.6)	6.47±4.08 7.35 (0-12.2)	.001

DISCUSSION

Metacarpal fractures are the highest prevalent upper-extremity injury, representing 42% of all hand fractures **[14,15]**. Although most of metacarpal breaks are managed non-operatively, closed reduction and percutaneous pinning or open reduction and internal fixation (ORIF) are both acknowledged as viable choices for metacarpal fracture treatment **[16,18]**. Burton and Eudell were the first to record plate fixing in the management of metacarpal breaks in 1958 **[19]**. Since then, the option of stable internal fixation that allow for early movements has grown in popularity **[20,21]**.

When compared to alternative techniques of fixation, a plate placed along the dorsal midline of the metacarpal fracture has proved to give greater biomechanical stability, with much higher strength **[22,24]**. Furthermore, metacarpal plating allows for more vigorous hand physiotherapy sooner in the recovery process, which lowers post-operative stiffness **[16]**. Diwaker and Stothard compare the outcomes of using of K-wires and mini-plate as a fixing approach in the management of metacarpal fractures. They demonstrated that the mini-plates and screws group had a stronger grip power than the other group and reported that this disparity might be attributable to the mini-plates group's good stability and quicker mobilization **[25]**. According to another research, the median load to failure in plating fixation was roughly 10 times higher than crossed K-wire or intramedullary nails. Also, plates fixation was stronger in three-point bending **[26]**.

Low-profile plates have been the standard of therapy for unstable or displaced diaphyseal metacarpal fractures since then **[4,6,18,20,22,27]**. Such implants, on the other hand, may prevent extensor tendon gliding, promote stress shielding of the bone under the plate, and sometimes cause metallosis **[28,29]**. Removing the plates often necessitates further surgery, which may be extremely challenging in certain situations.

In this study, we evaluated 30 metacarpal fractures that were managed with open reduction and internal fixation utilizing a mini-plate and screws. The average period of follow-up was 6 months. The median time to radiographic union was ten weeks, with range between eight to twelve weeks. Proper union was described as more than three regions of bone bridging between the radial, ulnar, dorsal, and volar cortical parts of the distal section of the metacarpus on anteroposterior, lateral, and both angled projecting. The metacarpophalangeal

joint's range of motion is assessed from extension to flexion. Our findings revealed that at three months after surgery, the average and median range of movement were 74 and 73 degrees, respectively, with a substantial improvement at three months. Furthermore, in the post-operative period, the median quick DASH score was 8.36±4.86, which significantly decreased to 6.47±4.08 at the end of follow-up period. Higher scores imply more impairment and severity, whilst lower scores suggest less disability.

In accordance with our study, Faisal et al., **[20]** showed that union of metacarpal fractures was seen in all patients (100%) ranging between 8-12 weeks with a median of 10 weeks. Only one patient had stiffness of metacarpophalangeal and his total active flexion score was 150 º (fair). Mahmoud et al., **[23]** demonstrated a bony union following mini plate fixation ranged from 6 weeks in young age patients to 10 weeks in old patients and there were no cases reported with nonunion or malunion.

Also, Köse et al., **[17]** and Kandasamy et al., **[31]** revealed that radiological union was accomplished in a median of 4.5 and 6 weeks, respectively, and one patient had a postponed union that was completed at the last follow-up. On the other hand, with mini-plate fixation, multiple investigations have shown a significant rate of delayed union and nonunion. Page et al., **[32]** showed that the frequency of delayed union is 4%, while the rate of nonunion is 2%. However, Pukett et al., **[33]** stated there is a 4% frequency of delayed union and an 8% nonunion rate owing to significant periosteal stripping, which does not match our findings.

Consistent with our findings, Aykut et al., **[27]** revealed that the median quick DASH score was 3.6 (0-11.4) and overall motion was 271.1 (245-275) degrees. Kandasamy et al., **[31]** revealed that the range of motion (ROM) was improved at 6 months follow-up and the mean ROM reached 87.8 degrees. DASH scores in our study population were similar to other studies. Soni et al., **[34]** showed that the median DASH score was 8.47 (range 1-26). Furthermore, Mahmoud et al., **[23]** assessed the hand function 3 months postoperatively using Quick DASH score with a mean score of 3.184. Neagu et al., **[35]** study demonstrated an excellent DASH score with 95% function recovery at twelve months, which also aligns with our results.

The total active flexion (TAF) score of our patients showed that 22 (73.3%) of our patients have excellent outcomes, while it was good in 6 (20%) patients, and fair in 2 (6.7%) patients. Similarly, Puckett et al., repaired 50 metacarpal shaft fractures using open reduction and internal fixation with plate and screws, demonstrating that the TAM of the affected finger restored normal or near-normal mobility in all patients **[33]**. In contrast, only 54 percent of Ford et al's patients restored full TAM mobility after internal treatment with screws and plates on 26 fractured metacarpal bones **[36]**.

At 6 months post-operatively, 24 patients in our research were very satisfied with the result, 4 patients were satisfied, one patient was fair, and one patient was dissatisfied. The solid bone build and aggressive mobilization at an early stage, which limit edema, fibrosis, and development of scars and increase tendon gliding, may account for the favorable outcomes reported in our research (80%). Crawford also found positive outcomes with younger individuals **[37]**.

As regard post-operative complications of our patients, 2 patients had wound infection, and one patient had finger stiffness due to delayed time of operative intervention as the patient had marked edema, which is in line with other previous studies **[23,30]**. While Kandasamy et al., **[31]** demonstrated that there were complications in 5 of the 32 cases (15.6 percent), 2 patients had superficial infection with metacarpophalangeal joint tightness, 2 patients had isolated metacarpophalangeal joint rigidity, and 1 patient had delayed union.

Mini-plates are recommended for the management of certain metacarpal shaft fractures. It provides robust rigid fixation of metacarpal fractures, allowing early mobility, reducing joint stiffness and tendon adhesion, and maximizing hand performance.

The limitations of this study are the small number of patients and short follow-up period. More cases are required, and long period follow-up period is needed to ensure the efficiency of mini-plate and screws technique in metacarpal shaft fracture fixation.

Conclusion:

Mini-plate and screws is a suitable approach for unstable metacarpal fracture fixation. The employment of mini-plate and screws provide rigid stable fixation which enables initial hand movement and achieving good functional outcomes.

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