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Prospective Study of Functional Outcome Analysis of Mini External Fixator in Metacarpal Bone Fractures

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ABSTRACT

Closed or open Metacarpal and phalangeal fractures are the most common type of hand injury. Most metacarpal fractures are closed injuries amenable to conservative treatment, whereas complex soft tissue injuries require external fixation. Improperly treated Hand fractures can also frequently result in complications such as Malunion, Osteomyelitis, Non-union and Stiffness. The ultimate outcome is dependent on the judicious selection of cases for operative fixation, which provides a more favourable outcome than non-operative management. In the management of these difficult fractures, we conducted a study to evaluate the role of external fixation treatment option, that provides minimal surgical trauma, preservation of fracture hematoma, short operative time, minimal anaesthetic complications and simple removal. A total of 11 patients were selected randomly based on some inclusion and exclusion criterias. Patients were called for periodic evaluation at 3weeks, 6 weeks and 3 months on OPD basis to assess: Tenderness at fracture site, Pin tract infections, Residual stiffness, Alignment and Rotation. Patients were also asked to fill out the DASH questionnaire. SPSS software version 25.0 was used for statistical analysis. The mean preoperative DASH scoring was observed to be 38.64 with the standard deviation of 5.104 and standard error of mean to be 1.539. After, 3 weeks, 6 weeks and 12 weeks post operatively, the mean DASH score was 35.36, 21.45 and 10.18, respectively. The DASH scores at these time points were statistically significant when compared to preoperative scores. Most of the patients in the present study showed radiological reunion of the fractured bone within 8-9 weeks. There were no complications in 72.7% of the population. While only 27.3% population experienced minor complications like pin irritation and stiffness. It was concluded in the present study that mini external fixators are an effective and durable treatment of comminuted and open fractures of metacarpals or phalanges of the hand with high functional outcome and union rates. Most of the fractures would heal by 6 weeks on average which is well supported by the radiological investigations also. Additionally, in cases of open fractures, the mini external fixator allows wound inspection and care and avoidance of hardware application at fracture site.

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Key Words
Metacarpal fracture, Mini external fixator, mini JESS

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INTRODUCTION

The human hand has developed into a highly functioning organ that can perform and manipulate intricate actions. The spectrum of uses includes a pinch grasp, a hook function and a firm grip for lifting large objects. The metacarpals and phalanges are involved in 15% of hand injuries[1,2]. The stability of the small articulations, the delicate harmony between the extrinsic and intrinsic motors and the complexity of the tendon mechanism eventually decide the severity of hand skeletal injuries. Due to its orientation in space, it is more prone to various injuries, especially occupational ones. Nowhere else in the body are form and function as tightly related as they are in the hand. In 1963, P. R. Lipscomb stated, "too frequently these fractures are treated as minor injuries and severe disabilities result." Improperly treated Hand fractures can also frequently result in complications such as Malunion-Intraarticular or Extraarticular (with dorsal angulation/malrotation), Osteomyelitis, Non-union and Stiffness[3].

Closed or open Metacarpal and phalangeal fractures are the most common type of hand injury[4]. In the early 20th century, these fractures were all treated without surgery. Depending on the nature of the injury, fracture pattern and fracture stability, these wounds may be treated conservatively or surgically[5]. Most metacarpal fractures are closed injuries amenable to conservative treatment, whereas complex soft tissue injuries require external fixation[6]. As most fractures are functionally stable before and after closed reduction and are effectively managed with a protective splint and early mobilisation, non-operative modalities are used to treat most fractures today. Only a few fractures necessitated surgical fixation, which depended on a variety of factors, including location, Fracture geometry-transverse, oblique, spiral or comminuted, Fracture location-extra articular or intra articular, Fracture with deformity – angular, rotational or shortening, Whether the fracture is open or closed, Associated neurovascular and soft tissue injury ,Intrinsic fracture stability, Additional factors like patient age, occupation, socio economic status, systemic illness and patient compliance[7]. SWANSON claims that "Hand fractures can be complicated by deformity from no treatment, stiffness from overtreatment and both deformity and stiffness from poor treatment" despite the fact that there are many different treatment options"[8].

Increased popularity of operative treatment at present are due to the following reasons: Improved designs of implants and materials, Availability of self-tapping and miniature screws of 1mm diameter that can be placed percutaneously, Availability of low profile plates which are simple to contour and cut but string enough to withstand sufficient loads, Better understanding of biomechanical principle of internal fixation, Demanding public expectations regarding cosmesis, Availability of improved radiographic imaging by cross section CT permitting multiplanar analysis of fracture, Availability of hand specialists and hand therapists[9]. However, aggressive internal fixation attempts result in tendon adhesion, soft tissue damage, infection and implant removal. Plate fixation of extra-articular metacarpal fractures has been associated with complications in up to 33 percent of patients, including infection, complex regional pain syndrome and plate loosening[3].

The ultimate outcome is dependent on the judicious selection of cases for operative fixation, which provides a more favourable outcome than non-operative management. The primary treatment consists of anatomical reduction and stable fixation, followed by early mobilisation. In general, prolonged immobilisation should be avoided to avoid the risk of permanent stiffness. In the management of these difficult fractures, external fixation is an effective treatment option that involves distraction mobilisation via capsulo-ligamentotaxis External fixation provides minimal surgical trauma, preservation of fracture hematoma, short operative time, minimal anaesthetic complications and simple removal[10,11]. We conducted the study with the following Aims and Objectives:

- To study the functional outcomes of metacarpal shaft fracture treated with extramedullary fixation of pins
- To study the technical difficulties and complications of metacarpal fractures treated by extramedullary pins
- To study the mechanism of injury and natural course of healing in fracture metacarpal in Indian population

MATERIAL AND METHODS

This is a randomized prospective study of 11 patients carried out in the Department of Orthopaedics, NSCB medical college and hospital, Jabalpur, Madhya Pradesh after obtaining informed consent from all the subjects.

Study period: 2019 to 2022

Inclusion criteria:

- Skeletally mature patients
- Closed and open fracture (AO classification type 1, 2 and 3a) of metacarpal
- Intra articular fracture of metacarpal

Exclusion criteria:

- Pathological fracture
- Isolated fracture of distal phalanx, middle and proximal phalanx
- Unwilling patients/refusal to give consent for procedure

Pre-op planning: As soon as patient presented to us, a detailed history was taken from the patient or his relatives and an examination was done and all the details were recorded in a prescribed format. General condition and vital signs were recorded. Local examination was done and care was taken to detect any associated injuries, vascular injuries, compartment syndrome and peripheral nerve injuries. This was followed by physical assessment (Range of motion, grip strength) and standard radiographs of the hand, i.e., antero-posterior and oblique views obtained to confirm the diagnosis and to assess fracture pattern. AO classification was used to classify the fractures. Routine pre anaesthetic checkup like blood investigations, ECG and Chest Xray was also done.

All patients with metacarpal fractures were admitted and temporary immobilization was given in the form of cock-up splint. The operative procedure and its advantages were explained in detail to each patient and an informed consent was obtained. Fitness was taken for surgery and patient was operated as soon as possible between day 1 to day 3 as per availability of Operation theatre.

Intraoperative technique of fixation: Closed reduction was achieved by traction and manipulation. To maintain reduction, external fixator was applied by passing at least two K wires/1.5 mm/2.5 mm shanz pins proximal and two distal to the fracture. These two constructs were connected using connecting rods. Distraction was given if required. Image intensifier was used as a guide for the steps mentioned above.

Post-operative: The patients were taught active mobilization of the unaffected fingers, elbow and shoulder from immediate post-op period. Pin tract dressing were done regularly. Post op X-ray was done for all the patients.

Follow Up: Patients were called for periodic evaluation at 3 weeks, 6 weeks and 3 months on OPD basis to assess: Tenderness at fracture site, Pin tract infections, Residual stiffness, Alignment and Rotation. Patients were also asked to fill out the DASH questionnaire.

The DASH questionnaire: The DASH consists primarily of a 30-item disability/symptom scale regarding the patient's health status during the previous week. The items inquire about the degree of difficulty in performing different physical activities due to the arm, shoulder, or hand problem (21 items), the severity of each symptom of pain, activity-related pain, tingling, weakness and stiffness (5 items) and the impact of the problem on social activities, work, sleep and self-image (11 items) (4 items). Each item has five possible responses. The sum of all item scores is then used to determine a scale score ranging from 0 (no disability) to 100 (most severe disability). The disability/symptom scale score is known as the DASH score. In this study, the Swedish version of the DASH was utilized.

Statistical analysis: Data was recorded in Microsoft Excel programme and statistical analysis was performed by the SPSS program for Windows, version 25 (SPSS, Chicago, Illinois). Continuous variables were presented as Mean±SD and categorical variables were presented as absolute numbers and percentage. Descriptive analysis was performed to obtain general characteristic of the study population.

Continuous variables were assessed using one sample t-test. $p<0.05$ was considered statistically significant.

RESULTS

The patients with the age less than or equal to 30 years were the majority in the present study and patients with age more than 30 years contributed 36.4% (Table 1). 63.6% patients in the present study were seen to be males whereas 36.4% patients were females. Majority population in this study were either housewife, labourer or students which comprised of 27.3% each. Whereas 9.1% population were either businessmen or professional each.

Patients in the present study were recruited with injury occurred due to various reasons. Most common mode of injury was incurred due to a sudden fall on the ground which comprised of 36.4% population. The next common reasons were assault or road traffic accident. Only 1 patient reported the injury due to sports activities. Almost one third of the patients (63.6%) reported the right sided injury. Which was the dominant hand for the majority whereas 36.4% patients (4) reported left sided injury. Fracture of the fourth metacarpal was observed to be most common, which was found in 36.4% of the population. Whereas the least common site of involvement was fifth metacarpal.

Fracture of third and second were evident in 27.3 and 18.2% of the patient population.

The most common site of the fracture was observed to be shaft of the metacarpal which was the case in 90.9% of the total population of the present study. Only 1 patient in the present study presented with the fracture neck metacarpal (Table 2).

All the patients in the present study were treated with implant surgery. In 72.7% of the cases, the implant was removed after 6 weeks. One patient was

Table 1: Age distribution

Age (years)	Frequency	Percentage
>30	4	36.4
≤30	7	63.6
Total	11	100.0

Table 2: Number of metacarpals and their parts involved

No. of rays	Frequency	Percentage
Multiple	2	18.2
Single	9	81.8
Total	11	100.0
Involved part		
Neck	1	9.1
Shaft	10	90.9
Total	11	100.0

Table 3: Implant removal after weeks

Implant removal (weeks)	Frequency	Percentage
5	1	9.1
6	8	72.7
7	1	9.1
8	1	9.1
Total	11	100.0

Table 4: Comparing dash scores with follow up

DASH score	No.	Mean	Std. Deviation	Error mean	p-value
Pre-operative	11	38.64	5.104	1.539	<0.05
Immediate post, 3 weeks	11	35.36	5.446	1.642	<0.001
Follow up after 6 weeks	11	21.45	5.592	1.686	<0.001
Follow up after 12 weeks	11	10.18	3.710	1.119	<0.001

Table 5: Radiological union

Radiological union (weeks)	Frequency	Percentage
7	1	9.1
8	4	36.4
9	4	36.4
10	2	18.2
Total	11	100.0

Table 6: Complications

Complication	Frequency	Percentage
No complication	8	72.7
Pin irritation	1	9.1
Stiffness	2	18.2
Total	11	100.0

observed to be doing fine and the implant in his hand was removed after 5 weeks. In rest of the two cases implant was removed, respectively after 7 and 8 weeks (Table 3).

The mean preoperative DASH scoring was observed to be 38.64 with the standard deviation of 5.104 and standard error of mean to be 1.539. However, 3 weeks after the operation, the mean DASH was observed to decrease to 35.36. This reduction in DASH score was statistically significant when compared to preoperative scoring. Similarly, 6 weeks and 12 weeks post operatively, the mean DASH score was 21.45 and 10.18, respectively. The DASH scores at both the time points were statistically significant when compared to preoperative scores (Table 4).

The post operative recovery and the healing of the patients were also monitored and studied with the means of radiological investigations. Most of the patients in the present study showed radiological reunion of the fractured bone within 8-9 weeks. Two patients took 10 weeks postoperatively for the reunion (Table 5).

There were no complications in 72.7% of the population. While 27.3% population experienced complications like pin irritation and stiffness (Table 6).

DISCUSSIONS

The majority of hand fractures can be effectively treated without surgery. The outcomes of closed treatment for the small percentage of unstable hand fractures are typically unsatisfactory. Treatment in the form of accurate open reduction and internal fixation in hand fractures are uncommon, accounting for less than five percent of all hand fractures. James found that 77% of fingers with unstable phalangeal fractures treated with closed methods lost function[12]. Open reduction and internal fixation of metacarpal fractures with K-wires results in a less rigid and less stable fixation. The protruding ends of the K-wires cause additional issues. Interosseous wiring in conjunction with K-wire provides more rigid stabilisation; however, this technique is only applicable to fractures of the transverse diaphysis.

The fixation of metacarpal fractures with an external fixator has been described in the literature. Shehadi et al. found that total range of motion was restored in 100 percent of metacarpal fractures treated with an external fixator[13]. Tun *et al*.[14] compared the biomechanical properties, clinical versatility, application simplicity and cost of seven mini external fixation systems used to treat unstable metacarpal shaft fractures with segmental bone loss. Due to unacceptable loosening and application challenges, these authors discouraged the routine use of such fixators.

Intramedullary wires may be utilised to splint transverse and short oblique metacarpal fractures. Supporting oblique fractures with flexible intramedullary fascicular bent wires. In a study of 21 metacarpal fractures, a J-shaped nail made from a curved Kirschner wire 2.0 mm in diameter and bent sharply at the proximal end was found to be effective in treating neck or transverse shaft fractures of the metacarpals without concomitant injuries, such as severe soft tissue damage[15]. A recent uncontrolled retrospective consecutive study of 22 metacarpal fractures indicated that transcutaneous intramedullary wire fixation of oblique extra-articular metacarpal shaft fracture wires yields favourable results with few complications[16]. Results of intramedullary nail (IMN) and plate-screw (PS) fixation were evaluated in a study of 52 consecutive closed, displaced, extra-articular metacarpal fractures. The incidences of loss of reduction, penetration to the metacarpal-phalangeal joint and secondary surgery for hardware removal in the operating room were significantly higher in the IMN group but there were no significant differences in clinical outcomes[17].

In this study Eleven patients were recruited. This study included patients with a confirmed diagnosis of fracture of the metacarpal/s of either hand. In this study, the majority of participants had an age of less

than or equal to 30 years. And patients older than 30 contributed 36.4% of the total. In the present study, 63.6% of patients were observed to be male, while 36.4% were female.

In this study, we also investigated the occupations of the patients. The majority of this study's participants were either housewives, labourers, or students, with proportions of 27.3% each. While 9.1% of the population were business or professional individuals. Patients in the present study were recruited with a variety of injury causes. 36.4% of the population sustained injuries as a result of a fall to the ground. The next most common causes were assault and motor vehicle accidents. Only one patient reported the injury as a result of sports participation. Sixty-three percent of the patients reported a right-sided injury. Which was the dominant hand of the majority, as 36.4% of patients (4) reported injuries on the left side.

The fourth metacarpal fracture was observed to be the most prevalent, occurring in 36.4% of the population. whereas fifth metacarpal involvement was the least common site. Fractures of the third and second ribs were observed in 27.3 and 18.2% of the patient population, respectively. In this study, we also recorded the location of the metacarpal fracture. The shaft of the metacarpal was observed to be the most common site of fracture, occurring in 90.9% of the study's total population. In the present study, only one patient presented with a metacarpal neck fracture.

In terms of fracture union and active range of motion, Yaseen *et al*.[18] evaluated the role of an external fixator in the treatment of a soft tissue condition along with a metacarpal and phalangeal fracture. Ages ranged from 20 to 60, with a mean (SD) of 36.31 8.79 years. 41 (73.21%) of the 56 were males, while 15 (26.79%) were females, for a male to female ratio of 2.73:1.

The leading cause of fractures was motor vehicle accidents (36, 64.29%), followed by blunt trauma and falls. In 43 (76.79%) patients, only one digit was fractured, while in 9 (16.07%) and 4 (7.14%) patients, two and three digits were fractured. In 39 (69.64%) patients, phalangeal bones were fractured, while in the remaining patients, metacarpal bones were fractured.

Venkatesh and Maruti[19] reported a male preponderance of fracture incidence of (10) 58%, with the remaining female population comprising (7) 42%. The majority of fractures were open fractures as a result of agricultural workers handling sharp objects. There were 65% open fractures and 35% closed fractures. According to the preceding table, the proximal phalanx (41%), middle phalanx (23%) and metacarpals (35%) are the most common types of phalanges. The proximal phalanx occurs more frequently, followed by the metacarpals.

In the present study, all patients were treated with implant surgery. After six weeks, the implant was removed in 72.7% of cases. After observing that a patient was doing well, the implant in his hand was removed after five weeks. In the remaining two cases, the implant was removed after 7 and 8 weeks, respectively. We calculated and utilised the DASH score to assess patient outcomes. It was determined that the mean preoperative DASH score was 38.64, with a standard deviation of 5.104 and a standard error of mean of 1.539. However, the mean DASH was observed to decrease to 35.36 weeks after surgery.

This reduction in DASH score compared to preoperative scoring was statistically significant. Similarly, the mean DASH score at 6 weeks and 12 weeks after surgery was 21.45 and 10.18, respectively. When compared to preoperative scores, the DASH scores were statistically significant at both time points (Fig. 1-3).

In their study, Dailiana *et al*.[20] reported that based on subjective measurements, the DASH score reached a mean of 7.9 in the intra-articular fracture group of patients but remained below 1.5 in all other groups. On a scale from 0-10 ranging from better to worse, patient satisfaction ranged from 8-10. The maximum score on the visual analogue scale for everyday pain in the previous month (0-10 from better to worse) was 0.50 across all fracture groups. Soni *et al*.[21] reported that the average DASH score was 8.47 (Range 1-26).

The patients' post-operative recovery and healing were also monitored and studied with the aid of radiological examinations. Most patients in this study had radiographic evidence of bone union within 8 to 9 weeks. Two patients showed union 10 weeks following surgery.

The study by Ahmed *et al*.[22] found that the distribution of union duration was 8.33 2.1 weeks, with a minimum of 6 weeks and a maximum of 13 weeks (one delayed case >12 weeks). According to Yaseen *et al*.[18] the overall results were excellent in 66.07% of cases, good in 16.07%, acceptable in 10.71% and poor in 7.14% of instances. A higher TAM was observed in fractures involving a single digit (n = 43) compared to fractures involving multiple digits (n = 13). At the end of 6 months, fracture union was observed in 51 (91.07%) of 52 patients, while non-union was observed in 5 (8.93%) patients.

Throughout the study period, we also monitored the incidence of complications associated with the external fixation of the metacarpal bones. No complications were reported in 72.7% of the population. While 27.3% of the population experienced pin irritation and stiffness.

Fig. 1(a-d): CASE 1 (a) Intra OP PIC after mini jess application, (b) Clinical assessment compared with normal side (at 4 weeks follow-up) (c) Clinical assessment showing flexion at MCP joint at 6 weeks follow-up) and (d) Clinical assessment of flexion at mcp joint and rotation compared with normal side (at 6 weeks follow up)

Fig. 2(a-c): CASE 2 (a) Pre-operative PIC showing swelling over dorsum of right hand (b) Clinical assessment showing flexion at MCP joint compared with normal side (at 6 weeks follow-up) and (c) Clinical assessment of rotation compared with normal side (at 6 weeks follow up)

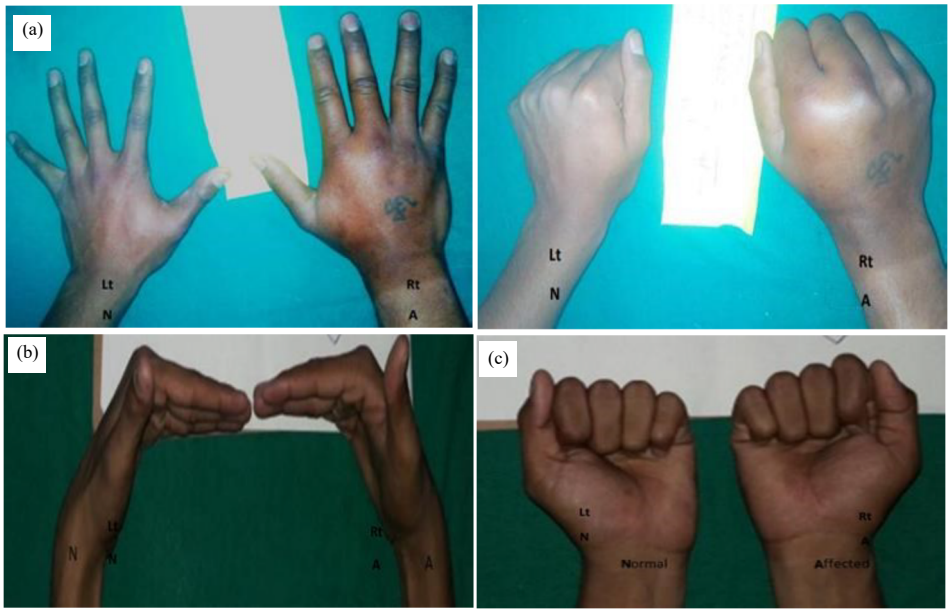

Fig. 3(a-c): CASE 3 (a) Pre-operative pic showing swelling over dorsum of right hand, (b) Clinical assessment showing flexion at mcp joint compared with normal side (at 6 weeks follow-up) and (c) Clinical assessment of rotation compared with normal side (at 6 weeks follow up)

Allah *et al*.[22] reported that only one case (8.3%) had pin tract infection and one case (8.3%) had delayed union >12 weeks, mal union was discovered in two cases (16.7%) and stiffness was discovered in three cases (25%). Two patients (16.7%) had malunion deformities at the conclusion of the follow-up period, one patient (8.35%) had rotational deformity and another (8.35%) had angular malunion.

Soni *et al*.[21] reported that two patients presented with a deep infection that was treated with daily dressings and antibiotics. One of these two patients had four metacarpal fractures, while the other patient had three. Three patients presented with a superficial infection, which was treated with daily dressings and antibiotics. There were no instances of rotational or angular displacement. No instances of implant failure were reported. No patient in our study experienced tendon irritation. None of the patients required implant removal.

CONCLUSION

Metacarpal fractures are relatively common in younger males. It is more frequently associated with accidental fall on the ground. As right-handed people are more as compared to left and during a fall people invariably take support of their dominant hand, such fractures were commonly seen in the right hand. Mini external fixators were found to be a successful and long-lasting treatment for comminuted and open fractures of the hand's metacarpal or phalangeal bones fractures, with good functional outcomes and union rates. The majority of fractures would typically heal within 6 weeks, which is also strongly supported by radiological tests. The mini external fixator also enables wound care and examination in open fracture cases while preventing the placement of hardware at the fracture site.

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