CLINICO-RADIOLOGICAL RESULTS OF OSTEOSYNTHESIS OF UNSTABLE FRACTURES OF TUBULAR BONES OF HAND USING MINI FRAGMENT PLATE AND SCREW SYSTEM

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ABSTRACT Objective: The hand is a complicated and specialized unit of the body that performs both hard, laborious jobs and delicate fine activities. Deformities or stiffness of the hand from fractures of its bones can hamper these activities and hand function. The behaviour of hand fractures is different from fractures elsewhere in the body, with stiffness resulting from overtreatment and deformity from under treatment. This study aimed to evaluate the outcome of surgical stabilization with mini fragment plates and early rehabilitation in unstable fractures of the metacarpals or phalanges of the hand. **Materials and Methods:** This prospective study was conducted in the Department of Orthopaedics from December 2019 to June 2021 and included 20 patients with unstable metacarpal and phalangeal fractures managed by open reduction and internal fixation using AO mini fragment plates and or screws. The final functional outcome was assessed at six months using a three-criteria scoring system: union, function based on total active movement (TAM) and associated complications. **Results:** The age of the patients ranged from 20 to 74 years, with a mean age of 32.9 ± 14.34 years. Ninety percent of the patients were males, with roadside accidents and blunt trauma being the predominant mode of injury seen in 40% of the patients. Of the 24 fractures in 20 patients, one had a deep infection (osteomyelitis), and one had a loss of fixation. Seventy-five percent of the patients returned to work within 5-6 weeks. 91.6% of fractures had an excellent result, and the remaining 8.4% had a poor score at the final follow-up. **Conclusion:** Open reduction and internal fixation of unstable fractures of the metacarpals and phalanges of the hand with mini-fragment screws and plates provide sufficient stability and strength, allowing early rehabilitation for restoration of the hand function and simultaneous progression of bone union with the least complications.

KEYWORDS hand injuries, metacarpals, phalanges, mini fragment plates

Introduction

It is well said that the hand is the eye of the blind and the tongue of the dumb. The hand is the most delicate part of the locomotor system. It has an extremely important role in sensory perception. Hand injuries are the most common and important because the effect on function is out of proportion to their apparent severity. This is because the hand has to perform very high to discharge all its functions satisfactorily. Although accurate figures of the relative incidence of these injuries are difficult to derive, fractures of metacarpals and phalanges are very common. Phalangeal fractures of the hand are the second most common (23%), and metacarpal fractures are the third most common (18%) below elbow fractures, peaking in the third decade in the males and the second decade in the females [1]. The small finger axis is the most commonly injured, constituting as high as 37% of total hand fractures [2].

Hand injuries may result from crush or compression, blunt trauma, falls, road traffic accidents, machine injuries, and sports and explosive and firearm injuries [3].

Literature regarding these injuries has not been written following any defined classification scheme, and true comparisons are difficult to make. However, fractures of metacarpals as well as phalanges may be classified taking into account the location of the fracture, the fracture pattern, associated soft tissue injury and stability. Most of the fractures are stable and are unlikely to move from their position when they are initially seen even during the rehabilitation process. These include fractures which are not displaced or show minimal displacement (less than 2 mm of translation and less than 10-20 degrees of angulation). These fractures require only a brief period of static or dynamic splinting or even buddy-tapping to an adjacent finger and a short rehabilitation period.

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However, a fracture can be considered unstable if it is irreducible, if acceptable reduction cannot be maintained, or if motion at adjoining joints cannot be started without loss of reduction. Angulation at the fracture is acceptable if there are 10 degrees of angulation in both planes (sagittal and coronal) except in the metaphyseal region in which 20 degrees of angulation in the sagittal plane will be accepted and fifth metacarpal neck where up to 45 degrees of angulation in the sagittal plane is acceptable. The results of the treatment of hand fractures is not universally good, and the incidence of stiffness, mal-union, prolonged functional disability and economic loss is striking. Therefore, the ultimate aim of treatment of any fracture should be a full anatomical and functional restitution of the injured part. This holds true, especially for the fractures of the hand where restoration of mobility is of utmost importance [4].

The improvements in equipment and technique for internal fixation of small fragments have not altered the indication but have made it possible to do the job better when indicated. Once the decision has been made that internal fixation is indicated, the surgeon has an ever-increasing variety of techniques and implants from which to choose, and these include K-wires, intramedullary screws, intra-medullary ender's type nails, cerclage wiring, tension band wiring, bio-absorbable wires or screws, and mini external fixators [5, 6, 7, 8].

With increasing emphasis on rigid internal fixation techniques elsewhere in the skeleton, it is not surprising that these principles have also become more popular and widely used in hand. Biomechanics studies and clinical experience have shown that properly applied AO mini-fragment plates and screws provide the most stable form of internal fixation. Although open reduction internal fixation appears to be an attractive approach to provide rigid stabilization of hand fracture with the early restoration of movement and the best functional outcome, it has limitations. The technique is more difficult than in larger bones, with very little margin for error. On the other hand, when used in properly selected cases, it can provide rigid fixation, allowing early mobilization of the joint and hence good functional results while avoiding problems associated with protruding K-wires and immobilization [9, 10]. The advantage of AO mini fragment screws and plates in achieving the simultaneous goals of reliable and timely fracture healing, operative safety, and functional recovery urged us to undertake this study to improve our results. Our study aimed to assess the results of operative management (open reduction internal fixation) of unstable metacarpal and phalangeal fractures using AO mini fragment screws and plates in 20 hands.

Materials and Methods

This prospective study was conducted in our institute's Department of Orthopaedics from December 2019 to June 2021. The study included 20 patients with unstable metacarpal and phalangeal fractures that were acute (within 2 weeks of injury), involved skeletally mature adult patients of any sex, closed or Swanson type 1 open fracture, involved diaphysis or was periarticular or intra-articular (non- comminuted fracture that constitutes $\geq$ 25% 0f articular surface or an articular step > 1 mm). Fractures in skeletally immature patients, old fractures over two weeks old, stable fractures, Swanson type 2 open fractures, fractures associated with tendon or neurovascular injury and those with a medical contraindication to surgery were excluded.

After properly selecting the cases, the patients were admitted, and a detailed clinical history was taken, followed by a detailed general physical and relevant local examination. Subsequently, standard radiograph projections (AP, lateral and oblique) of metacarpals and phalanges were taken in every patient. All routine investigations were done prior to the anaesthesia assessment.

Surgical procedure and implant

The operative procedure was done under general/regional anaesthesia (axillary block/wrist block/digital block) Moreover, under tourniquet control after taking well-written/informed consent from the patient. Different approaches fixed the fractures of metacarpals & phalanges with lag screws, mini plates or a combination of lag screws and mini plates (Fig 1, Fig 2).

Figure 1 Surgical approaches. A. Longitudinal approach for first MC. B. Radio-palmar curving incision for Bennett fracture. C. Dorsal longitudinal approach for second to fifth MC. D. Straight dorsal incision with split of central slip for proximal phalanx. E, F. Mid axial approach for phalangeal uni-condylar head fracture. G. Dorsal longitudinal approach and interval between lateral band and extensor apparatus for proximal phalanx shaft.

Lag screws were used for unstable long oblique or spiral fractures, displaced intra-articular fractures involving more than 25 percent of the articular surface, with or without communication, including Bennett's fracture and displaced intra-articular condylar fracture, including Rolando fractures. This technique was selected only if the fracture pattern fulfilled the prerequisite that the length of fracture was more than two and a half times the diameter of bone (except in intra-articular fractures). Further, to avoid splintering of the bone, the fragment should exceed at least 3 times the thread diameter of the screw. For metacarpal shaft fracture, 2.0 mm and 2.7 mm screws were used for the metacarpal metaphysis; for phalangeal fracture, 1.5 mm or 2.0 mm screws were used for inter-fragmentary compression.

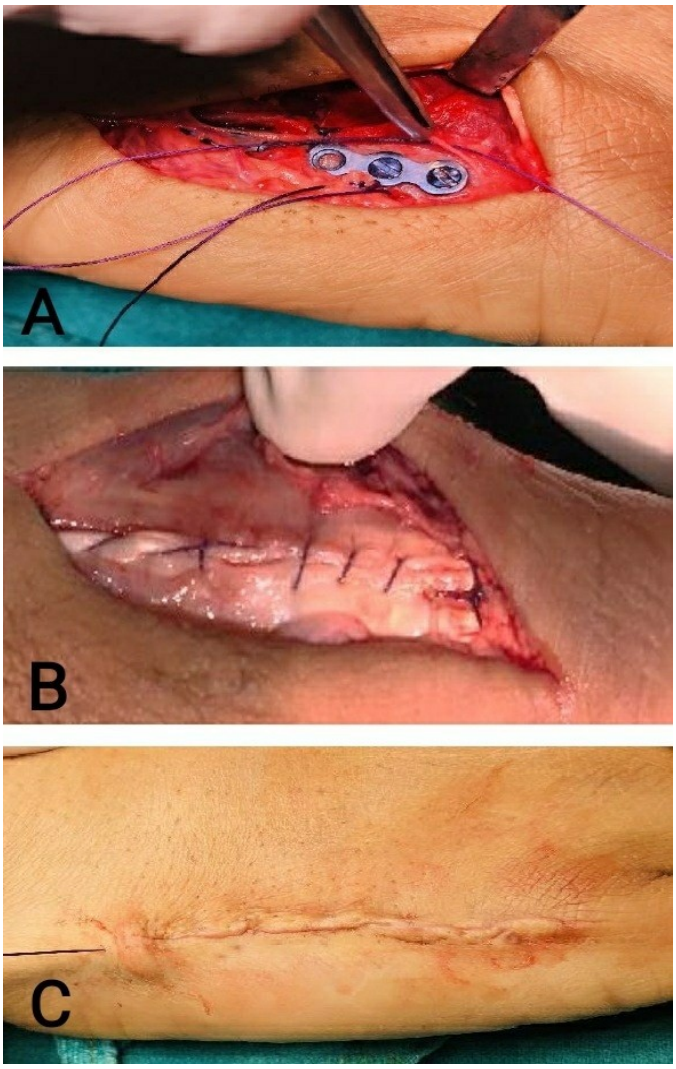

Figure 2 Steps of closure. A. Repair of periosteum. B. Approximation of extensor mechanism. C. Superficial soft tissue closure.

A 2.0 or 2.7 mm straight mini DCP was used for metacarpal shaft fracture (short oblique or transverse fractures). A 2.0 mm T or L condylar plate was used for metacarpal neck or head fractures (metaphyseal fractures). A 1.5 or 2.0 mm T plate was used for fractures involving the base of the first metacarpal, including Rolando fractures. Plate fixation of phalangeal fracture was restricted to the proximal phalanx.

Postoperative protocol

The limb was elevated for the first 48 hours to decrease swelling, and intermittent passive movements were started immediately in the postoperative period. Active movements as tolerated were started after 48 hours. Active movements were progressively increased from the second week, and stitches were removed on the fourteenth day.

Follow up

The patients were followed on an outdoor basis weekly for the first month and then fortnightly till the completion of three months. After that, patients were followed monthly until the final six-month follow-up. At each visit, the clinical and radiological assessment was done for the return of function of the involved digit/ ray, healing of soft tissue, progression of radiological union and picking up complications. At the final follow-up of six months, results were assessed using a 15-point scoring system based on three criteria: union, function and complications. Each criterion was given a maximum score of 5, with a total score of 15. The presence of union carries a score of 5 and non-union scores of 0. The functional assessment of a ray/ digit was done by total active movement (TAM), which is the addition of an active range of movement at metacarpophalangeal (MCP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joint. Excluding the thumb, the normal TAM of a digit is 270 degrees [11]. The function of the digit/ ray was graded and scored as per the American Society for Surgery of the Hand. (Table 1). For assessment of thumb function, the method proposed by Gingras, Fehring and Matlaub was used (Table 2, Table 3) [12]. If there is no complication, it carries a score of 5, and a negative score is allotted to complications (Table 4). Based on the total points scored based on these three criteria, the results were graded as excellent (8 - 10), good (6 – 8)), fair (5 - 6) and poor (< 5) (Fig 3, Fig 4, Fig 5).

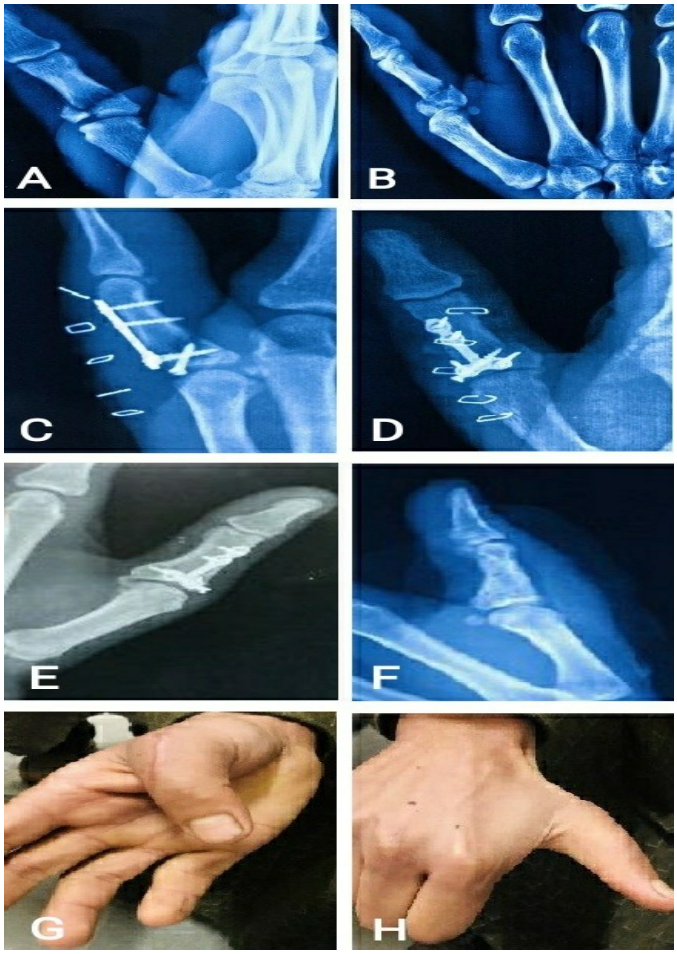

Figure 3 Fracture base of proximal phalanx. A, B. Preoperative radiographs. C, D. Post-operative radiographs. E. Radiograph at six months follow up. F. Radiograph after plate removal. G. Clinical pictures showing range of movement at final follow up.

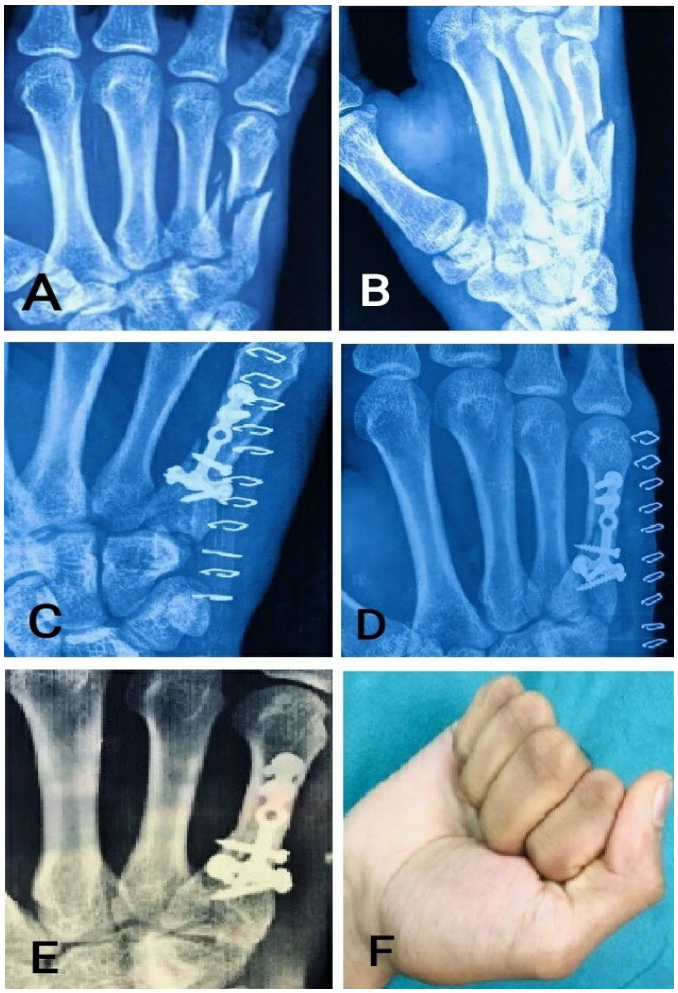

Figure 4 Intra-articular fracture base of fifth MC. A, B. Pre-operative radiographs. C, D. Post-operative radiographs. E. Radiograph at final follow up showing union. F. Clinical photograph at final follow up.

Figure 5 Fracture of fourth proximal phalanx. A, B. Pre-operative radiographs. C. Intra-operative image showing fixation with two lag screws. D, E. Post-operative radiographs. F, G. Radiographs at final follow up showing union.

Statistical analysis

The recorded data was compiled and entered in a spreadsheet (Microsoft Excel) and then exported to the data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). Continuous variables were expressed as Mean ± SD, and categorical variables were summarized as frequencies and percentages.

Results

The age of the patients ranged from 20 to 74 years with a mean of 32.9 ± 14.34 years, with 80% of patients in the age group between 20 to 39 years. Ninety percent of the patients were males. Roadside accidents and blunt trauma was the most common mode of trauma, each involving 40% of the patients. Seventy percent of the patients had involvement of the dominant hand. Seventeen patients had involvement of one bone only, two patients had involvement of two bones, and one patient had involvement of three bones. Of 24 fractures, 14 involved metacarpals and the remaining 10 involved phalanges (Table 5). Intra-articular fracture pattern was seen in 29.2%. Oblique fracture configuration was the most common pattern seen in 33.3%, followed by transverse, spiral and comminuted patterns in 25%, 8.3% and 4.2% patients, respectively. Seventy-five percent of fractures were closed, and the remaining 25% were Swanson's type I open fractures. Ten percent (two) patients had other associated injuries, with a fracture of the contralateral ulna in one patient and an ipsilateral tibial spine fracture in other.

The time interval between injury and surgical intervention ranged from 1 to 11 days, with a mean of 4.3 ± 3.61 days. The duration of surgery ranged from 30 to 120 minutes, with a mean of 59.1 ± 25.57 minutes. Out of 24 fractures, 2 (4.17%) fractures had complications with deep infection (osteomyelitis) in one and re-fracture in another. The majority of the patients (45%) returned to work within 3 to 4 weeks while two patients (10%) who had complications returned to work after 10 weeks. The remaining 45% of patients took 5 to 10 weeks to return to work.

Table 1 Grading of functional results of ray/digit (American Society for Surgery of the Hand).

TAM	Score	Functional Results
>210 degrees	5	Excellent
180 – 210 degrees	3	Good
150 – 180 degrees	1	Fair
<150 degrees	0	Poor

TAM: total active movement

Table 2 Thumb function with palmar abduction more than 45 degrees (Gingrass, Fehring and Matloub).

Functional result	Palmar abduction >45 degree (add flexion at IP and MCP joint)
Excellent	>100 degrees
Good	60 – 100 degrees
Fair	0 – 60 degrees degree
Poor	Lower result by one category if IP joint cannot be flexed beyond 10 degrees.

IP: inter-phalangeal; MCP: metacarpo-phalangeal

Table 3 Thumb function with limitation of thumb abduction (Gingrass, Fehring and Matloub).

Functional result	Palmar abduction	Flexion at IP and MCP
Excellent	>45 degrees	>100 degrees
Good	40 – 45 degrees	>75 degrees
Fair	30 – 40 degrees	>80 degrees
Poor	<30 degrees	<80 degrees

IP: inter-phalangeal; MCP: metacarpo-phalangeal

Table 4 Complications and scoring.

Complications	Score
Angulation >10 degrees	-3
Rotation	-3
Bone infection (osteomyelitis)	-3
Iatrogenic neurovascular complications	-3
Loss of fixation (re-fracture)	-3
Tendon rupture	-3
Skin and soft tissue infection	-1

Table 5 Distribution of fractures.

Fracture Location	Metacarpal		Phalanx		Total	
	No.	Percentage	No.	Percentage	No.	Percentage
Head	0	0	2	20	2	8.3
Neck	2	14.3	1	10	3	12.5
Shaft	7	50.0	6	60	13	54.2
Base	5	35.7	1	10	6	25.0
Total	14	100	10	100	24	100

At the final follow-up of six months, 91.6% of fractures had excellent results and two (10%) fractures with complications had poor results.

Discussion

The patients in our study ranged between 20-74 years, with a mean age of 32.9 years. Most of our study's patients (80%) were aged between 20-39 years. Similar mean age was also reported by Huang CY (2007), Mumtaz U (2010), Wu X (2012), and Ahmad MR (2018) in their study with a mean age of 31.6, 25.8, 32,6 and 32 years, respectively [13, 14, 15, 16]. In our study, 18 (90%) patients were males with a male-to-female ratio of 9:1. Similar results were also observed by Huang CY (2007), Mumtaz MU (2010), Soni A (2012) and Aykut S (2015) with 82.5%, 72.5%, 90.4% and 86.2% of patients being males respectively [14, 17, 18]. Fractures of the metacarpal and phalangeal bones of the hand constitute between 14-28% of all visits to the hospital following trauma by various means like assault, road traffic accidents, industrial accidents, and agricultural accidents [19]. In the present study, the mode of injury was a road traffic accident, and blunt trauma in 8 (40%) patients each, 3 (15%) had been assaulted, and 1 (5%) had fallen from a height. A road traffic accident was the most common mode of injury in other studies as well, with 52.38% and 55% of patients sustaining roadside accidents in studies by Soni A (2012) and Maheswaran J (2019), respectively [17, 20]. Of the 20 patients studied, 17 (85%) patients had one fracture, 2 (10%) patients had 2 fractures, and 1 (5%) had three fractures. Mumtaz MU (2010) conducted a study on 40 patients with 42 fractures, in which 2 (5%) patients had two fractures and 38 (95%) patients had only one fracture [14]. Soni A (2012), in their study on multiple metacarpal fractures, had 11 (52.4%) patients had two fractures, 7 (33.3%) with 3 fractures, and 3 (14.3%) patients had 4 fractures [17].

Maheswaran J (2019), in his study on 20 patients, also observed 14 (70%) patients with 1 metacarpal involvement, 5 (25%) patients had 2 metacarpals involved, and only 1 (5%) patients had 4 metacarpal involvement [20]. In our study of 24 fractures, 14 (58.3%) affected metacarpals and 10 (41.7%) affected phalanges. When correlated with fracture location, the majority of fractures, i.e. 13 (54.2%), were shaft or diaphyseal fractures. Six (25%) fractures were of the base. Agarwal AK (2006) conducted a study on 20 patients in which 11 (55%) were metacarpal fractures, and 9 (45%) were phalangeal fractures [21].

Omokawa S (2008) studied 51 patients, which comprised 39 (76.5%) phalangeal and 12 (23.5%) metacarpal fractures [22].

In our study, the oblique configuration of the fracture was most common, seen in 33.3% of the fractures, which is almost comparable to 40% seen in the study of Zayed FH (2020) [23]. The spiral configuration was seen in 8.3% of fractures in our study and 7.14% in a study by Mumtaz MU (2010) [14]. Transverse configuration, seen in 25% of cases in our study, was also comparable to 23.8% of fractures in a study by Mumtaz MU (2010) [14]. Our study and Mumtaz MU (2010) had a comparable incidence of comminuted fractures seen in 4.2% and 4.76% fractures, respectively [14]. In our study, 75% of the fractures were closed, while in a study by Gupta R (2007), 57.8% of patients had closed fractures [19]. The duration between injury and surgery was 1-11 days, with a mean of 4.3 days in our study. In studies by Omokawa S (2008) and Aykut S (2015), the mean injury to surgery time interval was 6 days and 8.48 days, respectively [18, 22]. In our study, the duration of surgery ranged between 30-120 minutes with a mean time of 59.1 minutes. Jeong YJ (2019), in a study on 37 patients, divided patients into two groups, namely group I (conventional open reduction group) and group II (minimal invasive group). In their study, the mean operative time was 41 minutes in group I and 24 minutes in group II [24].

Both conservative and surgical approaches to hand fractures are plagued with complications. With conservative treatment, mal-union, complex regional pain syndrome (CRPS), and stiffness are common complications. In contrast, with surgical approach, extensor lag, infection, hardware-related problems and soft tissue complications are more likely [25]. A complication rate as high as 36% has been reported by Page SM (1998) with plate fixation of these fractures. However, a low incidence of complications (10%) was observed in our study [26]. Varitimidis S (2021), in their study on 90 patients with 114 hand fractures, had a complication rate of 13.33%, almost comparable to that seen in our study [27]. A hand fracture is not only an injury of the bone. The hand is a delicate structure and associated injury to the soft tissue component will have a bearing on the functional outcome as well as the occurrence of the complications. Severe crush injuries of the digit(s), associated neurovascular injury and higher grades of compounding injuries will have a higher incidence of complications. Besides, the availability of low profile mini fragment plates and screws has reduced the incidence of soft tissues related and hardware-related complications. Maheswaran J (2019), in his study, had complications in 20% of his patients, with infection seen in 10% and stiffness in 10% of patients [20].

In our study, functional outcome was excellent in 18 (90%) patients and poor in 2 (10%). The results, as judged according to American society's criteria for hand surgery, were good in 46.3%, fair in 32.2% and poor in 21.5% in a study done by Chen SH (1994) [28]. The overall functional results (all digits including thumb) were good in 78.5% of cases, fair in 19% and poor in 2.5% in another study by Mumtaz MU (2010) [14]. Soni A (2012), in his study, had excellent functional outcomes in 85.71% and good in 9% of his patients [17]. Functional outcome, assessed by ASSH (American Society for Surgery of the Hand) and TAF (Total Active Flexion) score, was excellent in 16 patients (80%), good in 2 patients (10%), fair in one patient (5%), and poor in one patient (5%) in a study by Maheswaran J (2014) [20].

The advantage of fixation of unstable metacarpal and phalangeal fractures using mini fragment plates is achieving compression at the fracture with stable and anatomical fixation, allowing early rehabilitation and early return to work [14, 29]. In addition, early rehabilitation for hand injuries prevents stiffness and CRPS. However, the hand is a delicate structure, and complications are common. Therefore, careful handling of soft tissues during the surgical intervention and debridement of the devitalized and contaminated tissue in compound fractures is important to prevent soft tissue-related complications and infection [30]. The main disadvantage of this study is the small sample size and the absence of a control group like a conservatively managed group or a group where minimally invasive intervention has been done, or some other hardware has been used for fixation of these fractures.

Conclusion

Like intra-articular fractures, the goal of management of metacarpal and phalangeal fractures is to obtain an anatomical and stable fixation so that early mobilization can be started to regain the pre-injury level functional status of the hand without

jeopardizing the progression of the bone union. Mini fragment plates and screws have sufficient strength to give stable fixation to fractured metacarpals and phalanges to allow early rehabilitation and achieve excellent hand function, which makes open reduction and internal fixation of unstable metacarpal and phalangeal fractures with mini fragment plates and screws an ideal treatment modality.

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Conflict of interest

There are no conflicts of interest by any of the authors of this research article.

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