ORIGINAL ARTICLE

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Hand function outcome in closed small bone fractures treated by open reduction and internal fixation by mini plate or closed crossed pinning: a randomized controlled trail

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Abstract

Purpose No study in literature clearly gives advantage of one method of surgical fixation of fracture over the other in metacarpal and phalangeal bones of hand comparing wider outcome measures.

Materials and methods A randomized controlled trial between closed reduction and percutaneous Kirschner wire fixation or open reduction and internal fixation with mini fragment plates was conducted. A total of 32 patients with 16 in each group were taken in tertiary-level teaching hospital from 2014 to 2016. Four patients lost to follow-up apart from 32 studied. Inclusion criteria were age group 16–60 years, fresh (3 days) closed shaft fractures of metacarpal and phalanges. Outcome evaluated were time to union of fracture, degree of strength achieved measured with dynamometer, DASH scoring, range of motion of hand and each digit.

Results Both groups were comparable in terms of return to full hand function, union and total range of motion. K wire fixation results were slightly better than plating group in terms of early DASH score and grip strength after fixation.

Conclusion No modality was found to be superior for fixation of small bone fractures of hand. But K wire being cheaper and without inherent complication of plating like scar and tendon irritation, K wire fixation is preferred over plating in shaft fractures of metacarpal and phalanges.

Level of evidence *Level I* Therapeutic study.

Keywords DASH score · Kirshner wire · Metacarpal

Introduction

Fractures of the carpals, metacarpals and phalanges account for approximately 15–19% of fractures in adults, with 59% of these occurring in the phalanges, 33% in the metacarpals and 8% in the carpal bones [1]. The single most common fracture site in the hand is the subcapital region of the fifth metacarpal bone (boxer's fracture) [2], which usually results from a direct blow to the metacarpal head [3]. Most hand fractures are caused by accidental falls or other sports-related injuries [4]. Hand fractures are among the most common fractures of upper extremity [5, 6].

Hand fractures can be treated conservatively or surgically, depending on the severity, location and type of fracture. The main objective of both operative and non-operative treatments is to provide fracture stability for early mobilization [7]. Surgical fixation is mainly indicated for displaced fractures because casts are often not sufficient to maintain reduction [8]. Open reduction with internal fixation (ORIF), using pins or plates, has historically been used to stabilize hand fractures which have rotational deformity or lateral angulation [9].

Open reduction may result in scarring, joint stiffness and tendon adhesion [7]. Closed reduction with internal fixation (CRIF), using percutaneous K wire or screws, is now used to treat the majority of unstable closed simple hand fractures [10]. It is generally considered percutaneous Kirschner wire (K wire) fixation may not provide adequate stabilization to allow for early mobilization [8].

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There are no comparative studies which define clear advantage of one method over the other using wider outcome measures. So our primary objective is to compare clinical and radiological outcomes after treatment of fresh closed small bone fractures in hand and as secondary objectives to study the earliest time duration for return to normal hand function in both groups.

Materials and methods

Randomized controlled trial was conducted between the plating and crossed pinning. Thirty-two patients 16 in each group were included in the study from November 2012 to April 2016. Inclusion criteria were 1—16–60 years, 2—fresh (fixed within 3 days), 3—isolated closed fractures of metacarpals and phalanges. Exclusion criteria were 1—pathological fracture, 2—major systemic illness, malignancy, 3—patient on drugs affecting fracture healing like steroid, anticancer drugs, 4—polytrauma patients, 5—extensive comminution of the metacarpal or phalanx detected pre- or intra-operatively, 6—dislocations at either end of the fractured bone and 7—parents/guardians/patients not willing to participate in study.

The two groups were allocated patients randomly generated by www.randomization.com.

- *Group 1*: open reduction and mini plate (2 mm non locking) fixation by standard techniques (Fig. 1).
- *Group 2*: Close reduction and percutaneous fixation with Kirschner (*K*) wire under image intensifier by standard techniques (Fig. 2).

Group 1 Under regional anesthesia ORIF with mini plate was done using standard operating technique. Metacarpal fractures were exposed by a direct incision made on radial border of the first and second metacarpals and the ulnar border of the fifth metacarpal. The third and fourth metacarpals were exposed by a longitudinal incision between these two bones. Phalangeal fractures were exposed by a mid-lateral incision. The fracture was reduced by means of small bone clamps; then plate was applied on dorsal aspect for metacarpal and lateral aspect of phalanges and thumb with hold of at least four cortices. Closure was done layer by layer.

Group 2 Under suitable anesthesia and image intensifier control (Fig. 3), closed reduction was performed on a radiolucent table, and stabilization of the fracture was done by percutaneous *K* wire fixation. One or two wires were used to stabilize the fracture crossing the fracture site.

In postoperative follow-up: Oral antibiotics and analgesics were given in both groups. Sutures were removed at 2 weeks. Both groups were given crepe bandage in the immediate postoperative period till first week. The
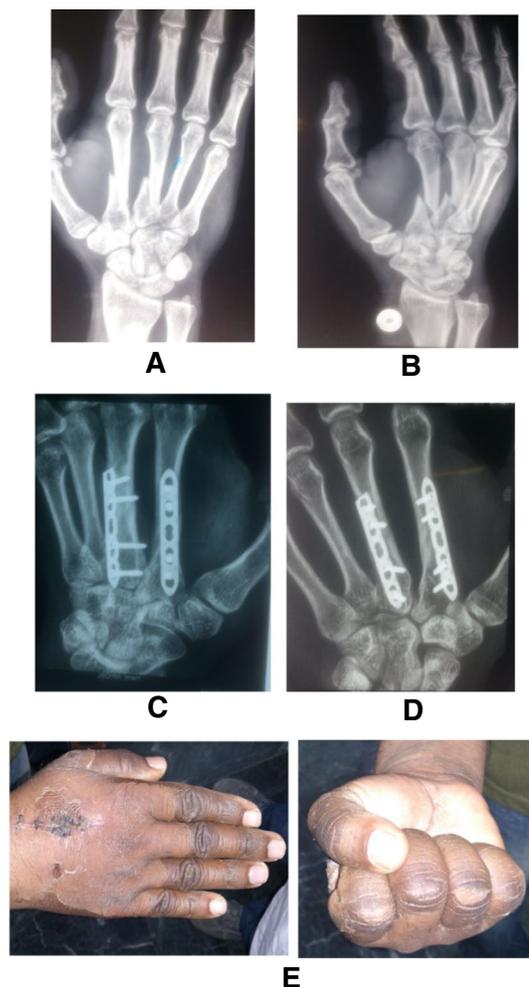

Fig. 1 X ray fracture second and third metacarpal treated with plating at different follow-ups. **a** Preoperative AP view. **b** Preoperative oblique view. **c** Postoperative oblique view at 2 year. **d** Postoperative AP at 2 year. **e** Postoperative return of full hand function

mobilization program was started from day 2. Patients were instructed to elevate the hand to reduce postoperative edema, and self-assisted active and passive exercises for all joints of the hand were taught to the patients and were done under supervision initially. Patients were taught isotonic and isometric exercises, and rigorous physiotherapy was done for initial 4 weeks. Patients were followed at 10 days, 3 week, 3 months and 2 years and assessed on basis of time to union of fracture, degree of strength achieved measured with dynamometer (Fig. 4), DASH scoring, range of motion of each digit and total range of motion hand compared with normal hand.

Reporting guidelines

We have adhered to the consolidated standards of reporting trials (CONSORT) guidelines.
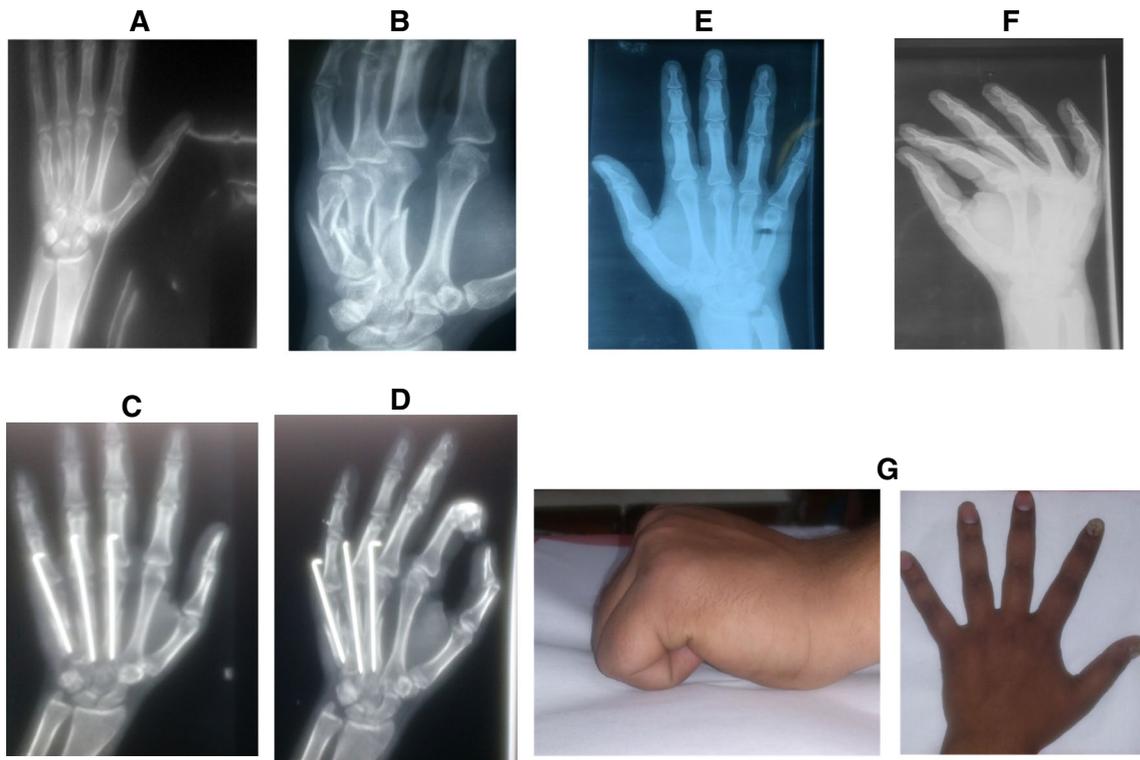
Fig. 2 Case of fracture of third, fourth, fifth, metacarpal fixed with *K* wire at different follow-up. **a** Preoperative AP view. **b** Preoperative oblique view. **c** Immediate postoperative AP view. **d** Immediate Postoperative oblique view. **e** Postoperative AP view at 2 year. **f** Postoperative lateral view at 2 year. **g** Postoperative return of full hand function
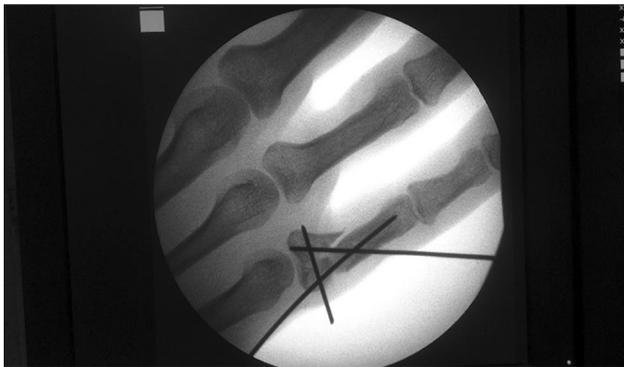

Fig. 3 C-arm images of closed pinning

Fig. 4 Dynamometer to measure grip strength

Statistical tests

Results were compared using Student's *t* test using *p* value and with mean value where sample size was less and inadequate.

Human rights

Approval by the institutional review board was taken, and informed consent was obtained from each patient and where necessary HIPAA consent was taken.

Results

We operated 32 patients. Sixteen in each group. Twenty-eight males (87%), 4 females (13%) with mean age 29.34.18 cases (56.25%) in dominant extremity, 14 (43.75%) in

non-dominant extremity. Males were more may be due to occupational causes, and dominant extremity was involved more in both groups. Four patient lost to follow-up. There is a total 46 fractures (mc—18 and 14, phalanx—5 and 7, thumb—1 and 1, in group 1 and 2, respectively).

1. Total range of motion (TROM) of metacarpal plating was 95.82% as compared to *K* wire 95.34%. In phalangeal plating (83.12%) TROM was less as compared to *K* wire 86.48%. In thumb fractures plating it was 59.25% as compared to *K* wire 96.29% at 2 years (Table 1).
2. DASH score with range 0–100, where 0 = full hand function and 100 = disabled at 3 months in plating, was 42.48 and in *K* wire 37.40 ($p = .022$) and at 2 years in plating 36.76 and in *K* wire 32.98 ($p = .053$) which is significant at 3 months but not at 2 years.
3. Degree of strength with dynamometer with max 25 N/m^2 at 3 months in plating was 16.75 and in *K* wire it was 17.63 ($p = .471$) and at 2 years it was 22.19 in plating as compared to 23.75 ($p = .187$) in *K* wire.
4. TROM at each joint at 2 years (Table 2) as sample size is very small; we were not able to calculate p value at each joint in phalanx and thumb fractures, but by comparing mean we could observe metacarpal fractures mean range of motion at MCP (plating—93.75%, *K* wire—93.56%), IP (plating—95.95%, *K* wire—95.25%) and DIP(plating—97.95%, *K* wire—97.50%). In phalangeal fractures at MCP (plating—82.28%, *K* wire—85.52%), IP (plating—83.6%, *K* wire—81.7%) and DIP(plating—82.28%, *K* wire—92.14%).In thumb fractures at MCP (plating—54.54%, *K* wire—90.9%), IP (plating—62.5%, *K* wire—87.5%).

5. Union is seen in both *K* wire and plating cases at 3 months.

In one case of proximal phalanx fracture due to poor systemic condition (diabetic) in patient infection occurred and non-compliant physiotherapy, the result was poor ROM (64%) and strength of hand (72%) was also less.

Discussion

Hand fractures are the most common fractures of upper extremity. Mostly due to accidental falls or other sports-related injuries. The presence of loose areolar tissue in hand allows edema fluid to accumulate, leading to early stiffness. Hence, hand needs to be mobilized as quickly as possible. Conventional plaster immobilization leading to stiffness has prompted surgeons to find modalities to fix these fractures. The key factors in the treatment of hand fractures are to allow bony union in good position, soft tissue healing and early rehabilitation.

Present study indicated no significant difference in both groups in terms of return to full hand function. Union was seen in both groups at 3 months as only closed fractures were included; factors causing non-union were automatically eliminated. The complications which could have altered the functional results mainly remained restricted to operating site infection and angulation at the fracture site. This study was that of simpler injuries of hand.

DASH score of both the groups was almost similar at 2 years ($p = .053$). However, at 3 months *K* wire group showed significantly better score as compared to plating. At 3 months, the plating group lagged behind due to residual pain at the surgical site and delayed healing as compared to *K* wire.

Prominence of implant on the dorsum due to minimum soft tissue cover contributed to the stiffness in plating group as compared to the *K* wire group in which implant was removed at 3 weeks. This explains minimal gain of *K* wire group over the plating group at 2 years.

TROM was found to be comparable 96.24 versus 94.98% in case of metacarpal fracture.

Table 1 Total range of motion

Fracture category	Plating Mean	*K* wire Mean	*p* value	Normal
Metacarpal	239.55	238.36	.659 (> .05)	250
Phalynx	207.8	216.21		250
Thumb	80	130		135

Table 2 Range of motion of each digit

Fracture category	MCP			PIP			DIP		
	Plating	*K* wire	*p* value	Plating	*K* wire	*p* value	Plating	*K* wire	*p* value
Normal hand	80			100			70		
Metacarpal	75.02	74.85	.623	95.95	95.25	.501	68.57	68.25	.566
Phalynx	66.6	68.42		83.6	81.7		57.6	64.5	
Normal thumb	55			80					
thumb	30	50		50	70				

In one proximal phalanx fracture treated by plating, TROM was 66.4% indicating poor result. This was probably due to more soft tissue dissected, lesser thickness soft tissue covering the implant and noncompliance of the patient to physiotherapy. Results were poor for plating in comparison with K wire, but more cases are required to reach a consensus.

In K wire group average range of motion (ROM) was 89.58% indicating a good result. ROM decreased in 2 cases. In one case, it was due to poor systemic condition (diabetes) leading to infection requiring implant removal before 3 weeks. The physiotherapy protocol was not followed due to infection.

Movement of each joint in case of metacarpal fractures at MCP, IP and DIP joint was found to be comparable in both plating and K wire. In case of phalangeal fractures, movement was found to be little better in K wire.

In single case of first metacarpal fracture results of plating were poor as compared to K wire maybe due to extensive soft tissue dissection in thenar area and less compliance to physiotherapy.

Infection was encountered in one case of K wire fixation; malunion was seen in one K wire fixation and 5 complained transient numbness in hand 4 in plating and 1 in K wire. there is no vascular damage in any case. Patients of plating had surgical scar and more immediate postoperative pain. Five cases of plating complained of prominent implant, and also implant impingement at terminal range of motion in which plate was applied nearer to the joint.

Somboon [11] found no significant difference between K wire and plating in hand fractures. They studied surgical time, pain visual analogue scale (0, none to 10, severe) on the first postoperative day, success of union, time to achieve radiographic union and complications. The K wire group had significantly shorter operative time ($p < 0.01$). He considered both open and closed fractures. In this study only closed and extra articular fractures were included making groups comparable.

Dabezies and Schutte [12] reported excellent average ROM following plate and screw fixation of 27 metacarpal and 25 phalangeal fractures.

Souer and Mudgal [13] reviewed 19 patients with 43 closed metacarpal fractures treated with 2 mm plates. Eighteen patients (95%) recovered full range of motion. In only two patients implant removal was required due to extensor irritation. His study only considered multiple metacarpal fracture; they have not considered phalangeal fracture or single metacarpal fracture; as compared to their study present study has wider inclusion criteria; also this was a retrospective study, so factor which influences the outcome could not be regulated and measured properly.

Fusetti et al. [14] reported excellent to good results in 76% of fractures in plating, and they speculated that the higher incidence of complications in their series with multiple metacarpal fractures was due to higher-energy trauma. They concluded despite technical advances in implant material, design and instrumentation, plate fixation of metacarpal fractures remains fraught with complications and unsatisfactory results. This is also retrospective study criteria for inclusion which couldn't be varied, and randomization was not possible. Present study has found no infection in plating cases, and one case of infection in K wire over complication was insignificant in both the groups. Stiffness was more in one case of phalangeal plating in present study. But in general plating did not have more complication.

Page and Stern [15] reported excellent results in only 62% of 66 metacarpal fractures treated with miniplates. Despite stable fixation and early mobilization, major complications were encountered in 36% cases, mostly with phalangeal and open fractures. Complications included stiffness, non-union, plate prominence, infection and tendon rupture. They reviewed data retrospectively in operated cases compared to present study in which cases were operated and then reviewed which eliminates criteria like surgeon skill, proper follow-up and postoperative rehabilitation which makes present study sounder. We also had more complication in phalangeal plating and first mc fractures.

Ozer et al. [16] performed a prospective comparative study of plates and intramedullary nails for metacarpal fractures and found no differences. Incidence of loss of reduction, penetration to the metacarpophalangeal joint and secondary surgeries for hardware removal were higher in the intramedullary nail group. They have not followed true randomization which makes fracture treatment dependent on surgeon's preference which may alter results.

Few recent studies have agreed with us in use of percutaneous pinning of metacarpal fracture, they have specially seen the cost effectiveness in procedure room vs operating room, and they concluded that these procedures can be done in procedure room with no significant difference in complication rates and with less cost [17].

More and more percutaneous technique using elastic nailing system is in vogue, and different techniques are being used to avoid iatrogenic injuries, as well as multiple methods are used to reduce displaced fractures. Further research is required in this field to develop a proper protocol with minimal invasiveness to fix these fractures [18, 19].

In present study randomization was done for number of patients; however it did not take into consideration the number of fractures in each hand, whether the patient had bilateral or unilateral fractures and the type of fractures; thus there was mismatch between the number of bones undergoing each procedure. The outcome would naturally be different in patient having single or multiple bone fractures treated with either modality. The thumb metacarpal being anatomically different in its proximal articulation

Table 3 Comparison of total active range of motion and complications in different studies

Series	Excellent (%)	Good (%)	Fair (%)	Poor (%)	Major complications (%)	Minor complications (%)
Stern et al. [20]	50	37.5	–	12.5	29	–
Page and Stern [15]	62	14	13	11	23	26
Bosscha and Snellen [21]	92	–	–	8	–	–
Fusetti et al. [22]	76		–	–	19	16
Souer and Mudgal [13]	94.7	–	–	–	10.5	–
Present study	43.33	46.66	3.33	6.6	6.25	–

should be given a special consideration when assessing final hand function. It would be prudent not to compare fracture of first metacarpal with other metacarpals.

K wire gives advantage of being economical and tissue friendly with good results. Further studies should identify specific patterns of small bone fractures that can be fixed by plating as it is a technically demanding procedure with its share of complications. In planning prospective studies, fracture pattern should be considered while randomizing rather than number of cases. Multiple fracture and open injuries should be considered separately. There should be more studies having larger sample size comparing identical fractures in each group.

Strict postoperative instructions to prevent gravitational edema in hand are necessary for good results. Absolute patient compliance with physiotherapy program is mandatory for return of full hand function; some of the results of present study prove this fact.

The pattern of fracture in same hand may differ and require both the modalities as the combination of treatment. Retrospectively, it can be suggested that a true comparative study of *K* wire v/s plating may be feasible in identical isolated fracture of either metacarpal or phalanges in age and dominant matched groups of patient. However, the fact cannot be denied that use of both the modality does not change the outcome significantly as seen from current study. Result of present study is comparable to other studies in term of gain in range of motion (Table 3).

Hand function outcome was comparable in both the groups. No modality was found to be superior to other for fixation of small bone fractures of hand. However, *K* wire was cheaper and fixation results were slightly better than plating in early DASH score, grip strength after fixation. Patient's compliance to physiotherapy was also a decisive factor in the outcome. Plating has its inherent complications like damage to soft tissue, surgical scar and implant impingement. Overall, use of *K* wire in fracture fixation in preference to plating can be recommended from the current study.

Compliance with ethical standards

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