

## Outcome of Displaced Metacarpal and Proximal Phalangeal Fractures Treated with Intramedullary $\kappa$ -Wire and Cross $\kappa$ -wires: A Prospective Study of 105 Patients

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### ABSTRACT

**AIM:** Kirschner wire ( $\kappa$ -wire) fixation is one of the most commonly used methods for fixation of metacarpal and phalangeal fractures. Two commonly used surgical techniques are intramedullary  $\kappa$ -wire fixation and cross  $\kappa$ -wires fixation. The aim of our study was to evaluate and compare the functional results and complications in closed displaced metacarpal and phalangeal fractures treated with  $\kappa$ -wires using above two techniques.

**MATERIALS AND METHODS:** 105 patients of closed displaced metacarpal and phalangeal fractures were randomized to receive fracture fixation with one of the two methods, 54 patients stabilized with intramedullary  $\kappa$ -wires (group A) and rest 51 patients with cross  $\kappa$ -wires (group B). The operative time, pain scale, success of union, time of union, total active range of motion (ROM), total active motion (TAM) and complications were assessed. The Student's *t*-test was used to analyze the difference of mean for different parameters.

**RESULTS:** Both groups showed no statistical difference in term of age ( $p=0.82$ ), gender ( $p=0.64$ ), the time from injury to operation ( $p=0.62$ ). After surgical fixation with above two techniques, there were no significant difference found in terms of postoperative pain, rate of union, union time, total active range of motion (ROM), total

active motion (TAM) and complications except postoperative loss of reduction which was found significantly more common in group A ( $p=0.04$ ). There was insignificant difference found in terms of outcomes and complications between patients of both the groups treated with both techniques.

**CONCLUSION:** Transverse and short oblique closed metacarpal and proximal phalangeal fractures treated with intramedullary  $\kappa$ -wire and cross  $\kappa$ -wires had produced favourable and comparable outcomes in long term.

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**Key words:** Metacarpal fractures; Proximal phalangeal fractures; Kirschner wire

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### INTRODUCTION

Fractures of the metacarpals and phalanges are among the most common fractures of the upper extremity<sup>[1]</sup> and constitute 10% of all fractures<sup>[2]</sup>. The majority of fractures of the metacarpal bones occur at a young age<sup>[3]</sup>. The majority of metacarpal fractures can be treated conservatively, with early mobilization in a brace, early mobilization without external fixation and immobilizing bandages producing functional results that are good to very good<sup>[4,5]</sup>. Unstable metacarpal and phalangeal fractures are difficult to treat, and the results are not always satisfactory<sup>[6]</sup>. In metacarpal fractures, palmar dislocation of  $>30^\circ$  and shortening of  $>5$  mm will significantly affect extension and flexion of the hand<sup>[7]</sup>, so surgical treatment is indicated in these cases. Correct rotation is necessary to prevent digital scissoring. Freeland *et al*<sup>[8]</sup> pointed out that  $10^\circ$  of rotation is equal to 1.5 cm of digit overlap in a clenched fist. Several options are available for surgical fixation of metacarpal and proximal phalangeal fractures: percutaneous  $\kappa$ -wires, intramedullary  $\kappa$ -wires, crossed  $\kappa$ -wires, lag screws, plates

with screws, and external fixation. Several authors<sup>[8,9]</sup> have showed the importance of a rigid fixation to maintain an adequate stability to allow both fracture healing and early active digital motion but still Kirschner wire ( $\kappa$ -wire) fixation is a simple, reliable and cost-effective method of treatment.  $\kappa$ -wire fixation is the most easily available and forgiving technique for the fixation of most fractures and dislocations in the hand and wrist.

With our best of knowledge, no study in the past has elaborated on the comparative results of intramedullary and cross  $\kappa$ -wire fixation treatment for the closed fractures of medial four metacarpals and proximal phalanges of the hand. The objective of this study was to compare outcomes and complications of close displaced metacarpal and proximal phalangeal fractures treated with open reduction and stabilization with single intramedullary  $\kappa$ -wire and two cross  $\kappa$ -wires.

## MATERIALS AND METHODS

We conducted a randomized, controlled study to compare surgical fixation of closed displaced metacarpal and proximal phalangeal shaft fractures (excluding first ray or thumb fractures) with intramedullary  $\kappa$ -wire and cross  $\kappa$ -wires. This study was approved by the local ethical committee of the Institute and performed in accordance with the ethical standards of the 1964 Declaration of Helsinki as revised in 2000. Between July 2008 and May 2011, a total of 120 patients with closed displaced metacarpal and proximal phalangeal fractures were randomized according to inclusion and exclusion criterias into two equal groups to be treated surgically with either intramedullary  $\kappa$ -wire (group A) or cross  $\kappa$ -wires (group B). All patients gave their informed consent. Patients were randomized into two groups by the concealed envelope technique. In this study, only 105 patients attended last follow-up visit and completed the study. Fifteen patients lost to follow-up. Clinical and radiological parameters of the fracture in every case was observed at each follow-up visit. The characteristics of the patients of both groups (total 105 patients) are shown in Table 1 and 2.

Patients were included in the study if

Age > 16 and < 60 years

Isolated displaced extraarticular metacarpal and proximal phalanx shaft fractures within the last 2 days with no cortical bone contact or shortening of over 5 mm, or if

Fracture fragments were tenting or compromising the skin with palmar dislocation of over 20° and rotation of >10°.

Patients were excluded if they had fracture with marked

comminution, bone loss, intraarticular extension, osteoporosis, fractures older than 2 days, thumb fractures, multiple skeletal injuries (even injuries in ipsilateral hand like multiple metacarpal or phalangeal fractures) that could influence the recovery and the scoring systems, open fractures.

The average age in the group A was 24.6±6.5 (range, 18-58) years and in the group B was 26.4±8.6 (range, 20-55) years. Gender proportions in the two groups were considered to be similar ( $P=0.64$ ). Both groups showed no statistical difference in term of age ( $p=0.82$ ), gender ( $p=0.64$ ), the time from injury to operation ( $p=0.62$ ). Surgeries were performed within 48 hrs of injury time in all cases.

All cases of proximal phalangeal fractures in both the groups were operated upon under digital nerve block with conscious sedation so that the patients could actively flex the digits to assess rotational alignment after reduction. Regional block (wrist block) anaesthesia was used in cases of metacarpal shaft fractures. With patient in supine position and hand to be operated over side arm support, tourniquet is inflated after standard scrubbing, painting, draping and limb exsanguination.

A straight dorsal skin incision was the method for exposure of metacarpal fractures. Fracture site was reached by transposing the extensor tendons ulnarly or radially and occasionally sectioning the juncture tendonum. The periosteal sleeve was also opened longitudinally and the bone was exposed subperiosteally to visualize the fracture. Injured digit was flexed at the MCP joint and a 2-mm  $\kappa$ -wire is passed retrograde from the fracture site through the medullary canal and out the metacarpal head of the flexed MCP joint. The fracture is reduced and the  $\kappa$ -wire is delivered into the proximal medullary canal. In cross  $\kappa$ -wire fixation group, after doing open reduction of fracture as described for intramedullary fixation, two cross  $\kappa$ -wires were placed with an entry point on the dorsal or mid lateral metacarpal surface. The both  $\kappa$ -wires were placed in such-a-way that they crossed each other proximal or distal to the fracture site for maximal stability. Wires were cut and bent at their ends, to be removed later on outpatient basis. In metacarpal fractures, criteria for acceptable reduction was angulation less than 10° in the index and middle fingers, less than 20° in the ring and small fingers and rotation less than 10°<sup>[8]</sup>.

For the open reduction of phalangeal fractures, dorsal approach was used. Incision extends from the metacarpophalangeal to the proximal interphalangeal joint in an S curve. Full-thickness subcutaneous tissue and flaps were elevated, the extensor tendon exposed, incised longitudinally in its center; and retracted to either side to expose the fracture site of proximal phalanx. A  $\kappa$ -wire was drilled into the distal fragment under direct vision and after reduction of fracture, it was drilled retrograde. Any rotational deformity was corrected. Periosteum was closed with absorbable suture and the dorsal apparatus over the proximal phalanx was re-approximated with nonabsorbable sutures. In proximal phalangeal fractures,  $\kappa$ -wire of 1.5 mm diameter was used for intramedullary fixation. In patients of group B, a second technique with two cross  $\kappa$ -wires was used. Open reduction of fracture was done as in patients of first group then cross  $\kappa$ -wires were placed with an entry point on the dorsal or mid-lateral surface of phalanges. Wires were cut and bent at their ends, to be removed later on outpatient basis. The criteria for acceptable reduction in proximal phalangeal fractures is no rotational deformity, less than 15° angulation of fracture fragments in the antero-posterior (AP) plane and 10° in the medial lateral plane<sup>[10]</sup>.

Postoperatively, a POP slab was applied in all patients in intrinsic plus (IPP) position and left in place for 4 weeks.  $\kappa$ -wires were removed at 4 weeks follow-up visit and normal motion exercises

**Table 1** Demographic profile of study.

Characteristics	Intramedullary $\kappa$ -wire group (group A)	Cross $\kappa$ -wire group (group B)	p-value
Mean Age (years)	24.6 ± 6.5	26.4 ± 8.6	0.82
Male:Female	40:15	38:13	0.64
Mean Injury time (hr)	20 ± 8 (2-44)	23 ± 9 (1-46)	0.62

**Table 2** Fracture distribution of both groups.

Fracture distribution	Fracture distribution	Intramedullary $\kappa$ -wire group (group A)		Cross $\kappa$ -wire group (group B)		Total
		Metacarpal fractures	Phalangeal fractures	Metacarpal fractures	Phalangeal fractures	
II ray	II ray	4	2	3	3	12
III ray	III ray	6	3	7	9	25
IV ray	IV ray	12	10	9	4	35
V ray	V ray	10	7	11	5	33
Total	Total	32	22	30	21	105

were begun. The standard follow-up protocol for these patients included clinical evaluation at 1 week, 2 weeks, 1, 3 and 6 months. Radiographs were taken to evaluate bony union at 1,3 and 6 months. In followup visits, patients were examined clinically and radiologically to evaluate function of the hand and to record any complication. The X-ray films were taken to ensure that there was no loss of reduction and to evaluate bone healing. The active ROMs of all joints of each finger in the involved hand were measured at 3 months and 6 months followup visit.

Success of union and time to achieve radiographic union was recorded. Radiographic healing was defined as evidence of callus or obliteration of the fracture lines. Clinical union was considered an absence of tenderness at the fracture site. Time to heal was recorded when all of these criteria were fulfilled. Active ROM was determined for each joint and total active motion (TAM) was determined for each digit. The functional outcome after fracture treatment was assessed by calculating total active range of motion (TAM)<sup>[11]</sup>. This was done by adding the active flexion at metacarpophalangeal (MP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints, after subtracting the sum of extension deficit at these three joints. Recovery is calculated as percent-regained motion compared to normal range of digital motion (260°). According to this patients with 85-100% of movement are classified as excellent; 70-84% as good; 50-69% as fair; and <50% as poor. Previously established values for normal AROM were used in the evaluation of the fractured digits: 0-85° at the MP joint, 0-110° at the PIP joint, 0-65° at the DIP joint, and 260° TAM.

Operative time, hospital stay, pain visual analogue scale (0: none to 10: severe) on the first post-operative day were recorded for every patient. Complications such as loss of reduction, delayed and malunion, nonunion,  $\kappa$ -wire migration, wound infection were recorded.

The Student's *t*-test was used to analyze the difference of mean for different parameters. Mean, standard deviation and standard error of mean for the variables were also calculated. The test was referenced for two-tailed *p*-value and 95% confidence interval was constructed around sensitivity proportion using normal approximation method. A value of <0.05 was considered statistically significant.

## RESULTS

The mean total surgical time was 30±4 minutes (range, 25-50 minutes) for the group A and 35±6minutes (range, 28-55 minutes) for the group B; this difference was insignificant (*P*=0.26). The pain scales on the first post operative day were 3±2 for the group A and 4±2 for the group B, and the difference was statistically insignificant (*P*=0.18). Insignificant difference was found between both the groups regarding mean length of hospital stay (*P*=0.42).

<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3308652/table/T2/>  
The group A achieved union in 52 out of 54 (96%) patients and the group B achieved union in 50 out of 51 (98%) patients, and there was no statistical significant difference found between the two groups (*P*=0.42). The average time to radiographic union was 11±1.8 weeks (range, 9-18 weeks) in the group A and 12±2.6 weeks (range, 8-20 weeks) in the group B, the difference was statistically insignificant (*P*=0.68) (Table 3).

Active ROM was determined for each joint and TAM was determined for each digit. TAM in group B was more than average TAM in group A in all fracture categories, but this difference did not reach significance. Total active ROM in group B was more than total active ROM in group A, but this difference was also not found significant (Table 4).

At the final evaluation, depending on TAM, the overall grading of the results in the group A was 62% excellent, 20% good and 18% fair, while in the group B, there were 64% excellent, 26% good and 10% fair results and there was no statistically significant difference found between two groups (Table 5).

In this series of 105 patients, infection occurred in 9 patients (8.5%), 6 patients had loss of reduction and 7 patients developed finger stiffness (TAM <180°). Among the patients with infection, 4 patients were in group A (7.4%) and 5 patients were in group B (9.8%). This difference was statistically not significant (*p*=0.62). The incidence of postoperative loss of reduction was 9.2% in intramedullary  $\kappa$ -wire fixation group (group A) and 1.9% in cross  $\kappa$ -wires fixation group (group B); and there was significant difference (*p*=0.04) found between both the groups. The finger stiffness rate (TAM<180°) in group A was higher (mean, 7.4%) as compared to group B (mean, 5.8%), but no statistical significant difference was found between both the groups (*P*=0.09). Two patients in group A and group B suffered delayed union but there was no statistically significant difference found (*p*=0.08). The delayed unions were due to poor fracture fragment compression, and satisfactory healing was achieved at 5-6 months without further surgery. There was no significant difference found in terms of malunion (*p*=0.32) and nonunion (*p*=0.12) between both the groups. The complication rate was insignificantly higher in phalangeal fractures (36.5%) than in metacarpal fractures (27.41%); (*p*=0.08) (Table 6).

**Table 3** Comparison of Outcomes of both groups.

Outcome	Intramedullary $\kappa$ -wire group (group A)	Cross $\kappa$ -wire group (group B)	<i>p</i> -value
Surgery time(min.)	30 ± 4 (25-50)	35 ± 6 (28-55)	0.26
Pain (visual analogue scale)	3 ± 2 (2-10)	4 ± 2 (3-9)	0.18
Union rate	52 (96%)	50 (98%)	0.42
Union time(weeks)	11 ± 1.8 (9-18)	12 ± 2.6 (8-20)	0.68

**Table 4** Comparison of TAM (Normal TAM is 260°).

Fractures	Intramedullary $\kappa$ -wire group (group A)	Cross $\kappa$ -wire group (group B)	<i>p</i> -value
Metacarpal fractures	240 ± 12°	252 ± 10°	0.42
Phalangeal fractures	228 ± 12°	242 ± 8°	0.36

**Table 5** Comparison of Results depending on total active motion(TAM) in both groups.

Groups	Total number of patients	Total Active Motion (TAM)			
		Excellent	Good	Fair	Poor
Intramedullary $\kappa$ -wire fixation group (group A)	54	34 (62%)	11 (20%)	9 (18%)	0 (0%)
Cross- K wire fixation group (group B)	51	33 (64%)	13 (26%)	5 (10%)	0 (0%)

**Table 6** Comparison of Complications of both groups.

Complications	Intramedullary $\kappa$ -wire group (group A)		Cross $\kappa$ -wire group (group B)		<i>p</i> value
	Metacarpal fractures	Phalangeal fractures	Metacarpal fractures	Phalangeal fractures	
Infection	1	3	1	4	0.62
Loss of reduction	3	2	1	0	0.04
Stiffness(TAM<180°)	2	2	2	1	0.09
Malunion	2	1	2	0	0.32
Delayed Union	1	1	1	0	0.08
Nonunion	1	1	0	1	0.12

## DISCUSSION

Principles of treatment of metacarpal and phalangeal fractures include stable fixation of fractures, elimination of angular or rotational deformity and rapid restoration of mobility and function. In a cadaveric study, Low *et al*<sup>[7]</sup> showed that palmar dislocation of  $>30^\circ$  and shortening of  $>5$  mm results in considerable impairment of flexion and extension and alters the length-tension relationship of the intrinsic sufficiently to affect function this is why, most trauma surgeons consider surgery indicated in these fractures<sup>[12,13,14]</sup>, even though there are reports of very good metacarpal joint functionality after metacarpal fracture healing in extreme false position. Correct rotation is necessary to prevent digital scissoring. Freeland *et al*<sup>[8,11]</sup> pointed out that  $10^\circ$  of rotation is equal to 1.5 cm of digit overlap in a clenched fist. Various methods of internal fixation in metacarpal and phalangeal fractures exist. Longitudinal  $\kappa$ -wires, crossed  $\kappa$ -wires, tension band wiring that uses a figure-of-eight dorsal loop, interosseous wiring, intramedullary rod fixation, or plate fixation can all give satisfactory results. Each has its advantages and disadvantages. The Kirschner wire can be safely used to reduce and stabilise metacarpal fractures. Percutaneous  $\kappa$ -wiring is done when closed reduction of fracture is possible. Open reduction is recommended in cases of irreducible and multiple metacarpal fractures when the support of the intermetacarpal ligaments has been lost. Significant exposure is required for screws and plate fixation of these fractures but these fixation methods produce rigid constructs to facilitate early motion<sup>[15,16,17]</sup>. External fixation is reserved for open fractures, fractures with segmental bone loss or exposed dorsal structures requiring access for wound care<sup>[18]</sup>. Compared with the other available surgical methods (open reduction with subsequent screw or plate osteosynthesis; closed reduction with external fixator), intramedullary splinting of metacarpals and phalanges is characterized by its simplicity and forgiving nature and the fact that fracture treatment does not harm the sliding tissue<sup>[12,14]</sup>. Open reduction with retrograde Kirschner wire fixation with transfixation of joint was first advocated by Vomsaal<sup>[19]</sup>.

Our study compares the outcomes and complications of a series of extraarticular, closed metacarpal and phalangeal fractures treated by open reduction and internal fixation with 2 different technique of  $\kappa$ -wires. In both the groups, outcomes and complications were comparable except one parameter (postoperative loss of reduction that could be result of pin tract infection and pin migration). The radiographic assessment confirmed the good results, with an anatomic reduction in most of the cases in both groups. We did not record a higher rate of soft-tissue adhesion or limitation in tendon gliding with phalangeal fractures, so that the average ROM and subjective impairment score at the final follow-up were not significantly different between metacarpal and phalangeal fractures.

Cross  $\kappa$ -wires fixation is biomechanically more effective than intramedullary  $\kappa$ -wire fixation<sup>[20,21]</sup>. It can resist rotational malalignment and it is also more rigid fixation as compared to intramedullary  $\kappa$ -wire fixation. The advantage of Cross  $\kappa$ -wire fixation was that it does not permit rotation of fracture fragments, thus making early mobilization possible, as compared to the technique of intramedullary fixation where chances of rotation of fragments do exist. The pins should cross each other proximal or distal to the fracture site for maximal stability. Several biomechanical studies have shown crossed pins to be inferior to other pin, wire, and plate constructs<sup>[15,22,23]</sup>. Vanik *et al*<sup>[22]</sup> concluded that techniques that used two interosseous wires were superior to a single interosseous wire or to  $\kappa$ -wire techniques, with two right-angle interosseous wires

producing the best results. Ikuta and Tsug<sup>[24]</sup> reportedly observed distraction with crossed  $\kappa$ -wire fixation using two wires, thereby holding it responsible for delayed union and nonunion. In our study, one case of nonunion of phalangeal fracture and one case of delayed union of metacarpal fracture was observed in cross  $\kappa$ -wires fixation group. It is desirable that while using cross  $\kappa$ -wire fixation crossing point of the wires should not be located at the fracture site to avoid distraction.

Fyfe *et al* and Mason *et al*<sup>[17,25]</sup> concluded that 2 crossed  $\kappa$ -wires provided adequate rigidity to withstand the forces involved in various hand functions. In cyclic loading testing, Firooz-bakhsh *et al*<sup>[21]</sup> found that dorsal plating with multiple screws was superior to crossed  $\kappa$ -wires, tension banding with wires, and intramedullary  $\kappa$ -wire fixation. Black *et al*<sup>[26]</sup> found that dorsal plating with or without interfragmentary screws provided significantly more stability than wire techniques-crossed  $\kappa$ -wires, an interosseous wire that was combined with an oblique  $\kappa$ -wire, or an interosseous wire alone.

Ahmad *et al*<sup>[27]</sup> reported their series of 20 metacarpal shaft fractures treated with closed reduction and percutaneous elastic intramedullary nail using single 1.6-mm  $\kappa$ -wire, prebent into a "lazy-S" shape. They had reported similar results as in our study with eventual union of all the fractures except one case, who underwent revision intramedullary fixation at 8 weeks for a delayed union. James<sup>[28]</sup> reported that with closed treatment of unstable phalangeal fractures, 77% of fingers lost function and results were considered unsatisfactory, primarily because of loss of active ROM at the PIP joint. With open treatment with  $\kappa$ -wire, 8% regained full function. Green and Anderson<sup>[29]</sup> reported satisfactory results of 69% with closed reduction and percutaneous pin fixation of fractures of the proximal phalanges. They recommended that technique be used only for long oblique fractures of the proximal phalanx and that comminution was a contraindication for this percutaneous pinning technique. Huffaker *et al*<sup>[30]</sup> studied the factors influencing final ROM in 150 finger fractures and find satisfactory results of 67% regardless of the method of treatment and 20% patients had decreased ROM in unfractured fingers in the same hand. Strickland *et al*<sup>[31]</sup> studied and said that 25% percent of their midshaft phalangeal fractures treated by open reduction and internal fixation with  $\kappa$ -wire fixation produced an average TAM of  $142^\circ$ . In a study, Lister<sup>[32]</sup> showed that  $\kappa$ -wire fixation with immobilization for 3 weeks produced a TAM of  $157^\circ$ . He recommended  $\kappa$ -wire fixation for phalangeal fractures, which in his group achieved a TAM of  $199^\circ$ . In our study TAM of metacarpal fractures was  $240^\circ$  in intramedullary  $\kappa$ -wire fixation group and  $252^\circ$  in cross  $\kappa$ -wire fixation group. In proximal phalangeal fractures, TAM was  $228^\circ$  in intramedullary  $\kappa$ -wire fixation group while in cross  $\kappa$ -wire fixation group it was  $242^\circ$ . TAM reported in our study was higher as compared to other studies<sup>[31,32]</sup>. Our study reported favourable functional outcomes in both the groups as mentioned earlier in result section. Belsky *et al*<sup>[33]</sup>, who used an alternate technique of closed reduction, intramedullary fixation, and 3 weeks of immobilization, reported 69% excellent, 29% good, and 10% poor results. Similar results were reported by various authors for intramedullary  $\kappa$ -wire fixation in metacarpal and proximal phalangeal shaft fractures<sup>[34,35,36]</sup>.

In a retrospective study, Diwaker and Stothard<sup>[37]</sup> compared  $\kappa$ -wire synthesis with miniscrews and miniplate fixation in metacarpal and phalangeal fractures, evaluating deformity, ROM and grip. The percentage of good results (no deformity, total active movement  $>210^\circ$ , strong grip) was 50% in the  $\kappa$ -wire fixation group and 79% in the miniplates and screws group. In our study, excellent to good results were reported in  $>80\%$  cases in both the groups. Takigami *et al*<sup>[38]</sup> reported comparable outcomes and complications in a series



of 71 patients with 78 metacarpal or phalangeal fractures treated with one of two different methods of fixation. Thirty-nine fingers were treated using a low profile plate and screw system (LPP group) whereas 39 fingers were treated using Kirschner wire ( $\kappa$ -wire group).

Aseptic loosening, pin tract infections, and nonunion are the most frequent complications of  $\kappa$ -wire fixation. Metacarpal shortening, rotation, and pin migration are reported complications for intramedullary  $\kappa$ -wire fixation<sup>[39]</sup>. One complication may lead to the other. Laboratory studies, which identify the failure mode of  $\kappa$ -wires, noted that loosening at the bone-wire interface allowed the pin to slide and distract the fracture fragments<sup>[15]</sup>.  $\kappa$ -wire loosening is prevented by using trocar-tipped pins, delivered at low rpm, and avoiding repeat passes in and out of the same drill hole. Malunion primarily manifests as malrotation or dorsal angulation. At each visit the surgeon should confirm that the patient's fingertips point toward the scaphoid tuberosity in composite flexion. Prominent palmar metacarpal heads from an apex dorsal malunion also can produce pain and secondary weakness. Gupta *et al.*<sup>[40]</sup> had used three techniques of open reduction with  $\kappa$ -wire fixation of 26 metacarpal and phalangeal fractures using three different techniques. In 16 cases, retrograde insertion of  $\kappa$ -wire with transfixation of joint was done. No significant stiffness was observed in cases of metacarpal fractures treated by this technique, while one proximal phalangeal fracture developed extension lag. Intramedullary  $\kappa$ -wire without transfixing the joint was done in 6 cases. No stiffness was observed in any of the cases treated by this method and Cross  $\kappa$ -wire fixation using two  $\kappa$ -wires was done for stabilization of four fractures. No nonunion or delayed union was observed in the group treated with cross wire fixation with two Kirschner wires. In our study 2 cases of nonunion in intramedullary  $\kappa$ -wire fixation group and 1 case of nonunion in cross  $\kappa$ -wire fixation group was reported.

The weaknesses and limitations in this study were recognized. There was an unequal distribution of patients in both the groups, with 54 patients in the intramedullary  $\kappa$ -wire fixation group and 51 patients in cross  $\kappa$ -wire fixation group. 12.5% (15 cases) patients in this series were lost to follow-up so they were excluded from this study leading to unequal number of patients in both the groups. Another limitation of our study was that this study was a small prospective study. A randomized controlled trial with a larger sample size is required in future to confirm the outcome achieved in our study.

We can conclude from our study that both these techniques represent a safe and effective treatment option for unstable metacarpal and proximal phalangeal shaft fractures of hand. It provides good functional recovery with acceptable complication rate. Insignificant differences were observed in terms of outcomes and complications of proximal phalangeal and metacarpal fractures treated with both techniques of  $\kappa$ -wire fixation. Implant removal at the outpatient department is a further advantage in both the techniques.

## CONFLICT OF INTERESTS

There are no conflicts of interest with regard to the present study.

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