ORIGINAL ARTICLE

Intramedullary Crossed K-wire Fixation for the Hand Fractures is a Useful Treatment Modality: A Prospective Observational Study

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Abstract

Background: Various modalities of treatment have been used for the management of metacarpal and phalangeal fractures which include K-wire fixation, mini plates, lag screws fixation, intramedullary screw fixation and external fixator application. The aim of this study was to analyse complications and patient-related functional outcomes after antegrade or retrograde crossed intramedullary K-wire fixation of metacarpal and proximal phalangeal fractures.

Methods: Thirty-one patients (36–fractures, 16–metacarpals, 20–proximal phalanx) meeting the study criteria were included in this prospective study. Fixation of the fractures was done by use of crossed intramedullary K-wire using the principles of 3-point fixation.

Results: The mean preoperative angulation of the fractures noted in this study was 35.8° which was significantly reduced at final follow-up. Union was noted at a mean period of 4.2 ± 6.8 weeks. The mean range of motion at the metacarpophalangeal and proximal interphalangeal joint was 96.4% and 86.3%, respectively as compared to the opposite hand. Stiffness ($n = 3$, 14.2%) and persistent pain ($n = 2$, 9.5%) at the joints were the most common complications noted in this study.

Conclusion: Crossed percutaneous intramedullary fixation of small bone fractures of the hand is a versatile method with advantages such as cost-effectiveness and lesser operative time when compared to other modalities of fixation. Earlier range of motion (ROM) exercises can be started due to preservation of gliding planes, no surgical wound along with good fracture stability and minimal hardware impingement.

Keywords: Crossed intramedullary, Hand, K-wire, Metacarpal, Phalanx.

Strategies in Trauma and Limb Reconstruction (2022): 10.5005/jp-journals-10080-1556

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 and 33% in the metacarpals.[1] These fractures are generally observed in young and active males.[2] They are generally encountered in the emergency department due to multiple causes like road traffic accidents, machine injury, crush injury, assaults and explosion based injury.[3,4] Most often these injuries are neglected as minor injuries and later present with functional limitation and disability. The optimal goal of the treatment of hand injuries is the healing of the wound if any, bony union and most importantly restoration of the function. Surgical treatment is indicated for unstable fractures like dislocations as well as mal-rotations with comminuted fractures.[5]

Various modalities of treatment have been used for their management which includes K-wire fixation, mini plates, lag screws fixation, intramedullary screw fixation and external fixator application.[6–10] An alternative surgical technique is the insertion of one or multiple crossed intramedullary K-wires through a minimally invasive incision in the metacarpal and proximal phalanx. K-wire fixation is a well-established technique for fixing metacarpal and phalangeal fractures.[11–13] The aim of this study was to analyse complications and patient-related functional outcomes after antegrade or retrograde crossed intramedullary K-wire fixation of metacarpal and proximal phalangeal fractures.

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How to cite this article: Ahmad S, Gupta T, Ansari S, *et al*. Intramedullary Crossed K-wire Fixation for the Hand Fractures is a Useful Treatment Modality: A Prospective Observational Study. Strategies Trauma Limb Reconstr 2022;17(2):74–80.

Source of support: Nil

Conflict of interest: None

Materials and Methods

This was a prospective study conducted at a tertiary care teaching hospital from January 2018 to December 2019. Prior institutional ethical approval was obtained and informed consent was taken from all study participants. During the above time period, a total of 36 patients were operated on by the said technique. Five patients were lost to follow-up, hence 31 patients meeting the inclusion criteria were included in the final analysis.

Inclusion criteria were: (1) Adult patients between ages 18 and 60 years, (2) Closed or open fractures without neurovascular injury, (3) Fracture angulation >35° and (4) Displacement >50%. Pathological fractures and fractures with associated injuries in the same limb were excluded from the study.

Surgical Technique

All the cases were operated under regional or local anaesthesia. Open fractures were initially treated with copious saline wash and debridement of the non-viable tissues. Under fluoroscopic image control, manual traction and flexion manoeuvres of the metacarpophalangeal joints or interphalangeal joints were done to the reduction of the fractures. Minimally invasive skin stab incisions were done over the epiphysio-metaphyseal area of the bone. The proximal or distal location of the incision was decided by the antegrade or retrograde insertion technique. A cortical window was made initially at the entry point by the use of the smallest size drill bit. The pre-bent 2 K-wires, 1.5–2 mm thick, either over an automated drill or manually over T-handle were passed percutaneously in the metacarpal or phalanx in crossed fashion from the predefined entry point at 5 mm away from the epiphysis over the dorsolateral aspect so that it does not interfere with extensor tendons or ligaments. After insertion of the K-wires, it was checked under fluoroscopy so as not to cross the subchondral bone distally and simultaneously K-wires were rotated in the medullary canal to make the concave side of the wire face the toward canal (Fig. 1). The outer part of the K-wire was bent and cut around 5 mm outside of the skin and the pin-track dressing was done. Immobilization in a functional slab was done in cases of multiple fractures in the hand or associated soft tissue injuries. In such cases, mobilization was started 4 weeks after wire and slab removal.

All patients were followed up postoperatively at 2, 6, 12 weeks and 11 months for clinical and radiological evaluation. Complications like pin-track infections, construct loosening, stiffness or wound infection were noted. K-wire removal was done at 4 weeks. After wire removal, extensive physical therapy was done to prevent stiffness of joints distal to the wrist joint. All the patients had a minimum follow-up of 11 months.

Assessment of functional outcome was done in terms of visual analog scale (VAS) score, quick disability of arm, shoulder and hand (DASH) score, hand grip and ROM at different time points (2, 6, 12 weeks and 6 months). Total active ROM was assessed by the American Society for Surgery of the Hand (ASSH) scale (Table 1, Fig. 2).

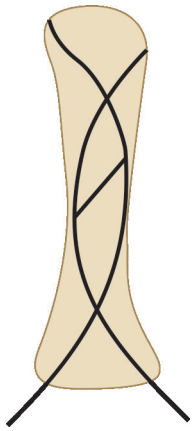


Fig. 1: Schematic diagram showed how the K-wire had inserted in the metacarpal and phalangeal fracture in this study

Table 1: American Society for Surgery of the Hand scale for grading outcome at final follow-up

Degree of ROM		
ROM from MCP to DIP: Digits 2–5	*ROM from MCP to DIP: Thumb*	*Rating*
>220	>120	Excellent
>180–220	>100–120	Good
<180	<100	Fair

Demographics have been depicted in Table 2. Qualitative data were expressed as counts and percentages, quantitative data were expressed by mean ± SD or range. Statistical analysis was performed with SPSS version 18. Results were analysed using paired *t*-test with a significance level set at 0.05.

Results

Thirty-one patients with 36 (16–metacarpals, 20–proximal phalanx) fractures meeting the study criteria were included. The majority of the subjects were right-handed (87%) and males (74.1%). The

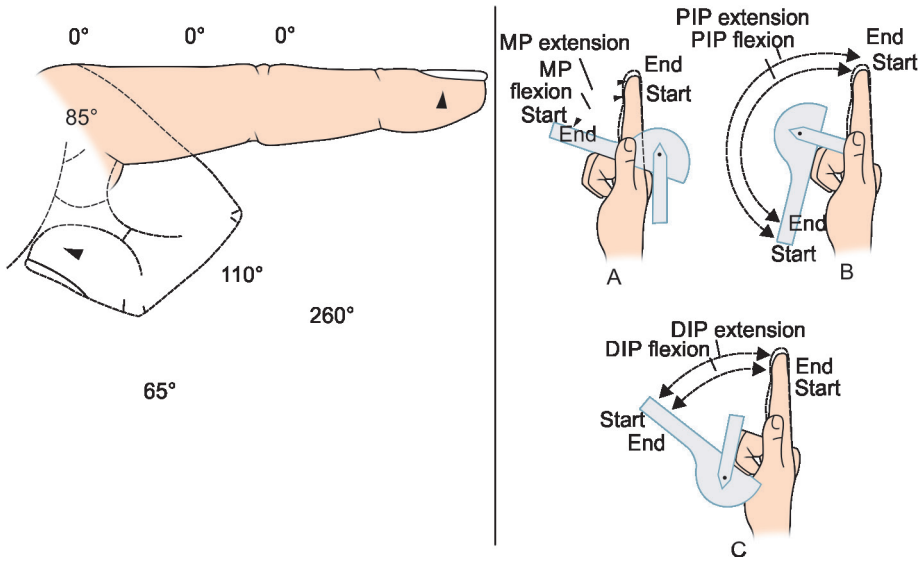


Fig. 2: Schematic diagram showed how to measure ROM at the different joints of the hand

mean preoperative angulation of the fractures noted in this study was 35.8° which was significantly reduced at the final follow-up (p <0.05) (Figs 3 and 4). All the fractures united at a mean period of 4.2 ± 6.8 weeks (Table 3). The mean range of motion at the metacarpophalangeal and proximal interphalangeal joint was 96.4% and 86.3%, respectively as compared to the opposite hand (Fig. 5). The mean grip strength noted at the final follow-up was 96.4% of the contralateral hand. 93.5% (29/31) of patients had excellent to good outcomes according to the ASSH scale at final follow-up.

Stiffness (n = 3, 14.2%) and persistent pain (n = 2, 9.5%) at the joints were the most common complications noted in this study (Table 4). The metacarpophalangeal joints were the common joint to have stiffness (n = 2). They were relieved with persistent physical therapy and symptoms had resolved at the final follow-up. In one case each pin-track infection and malunion was noted. Pin-track infection healed by regular dressings. Revision surgery was planned to treat the malunion.

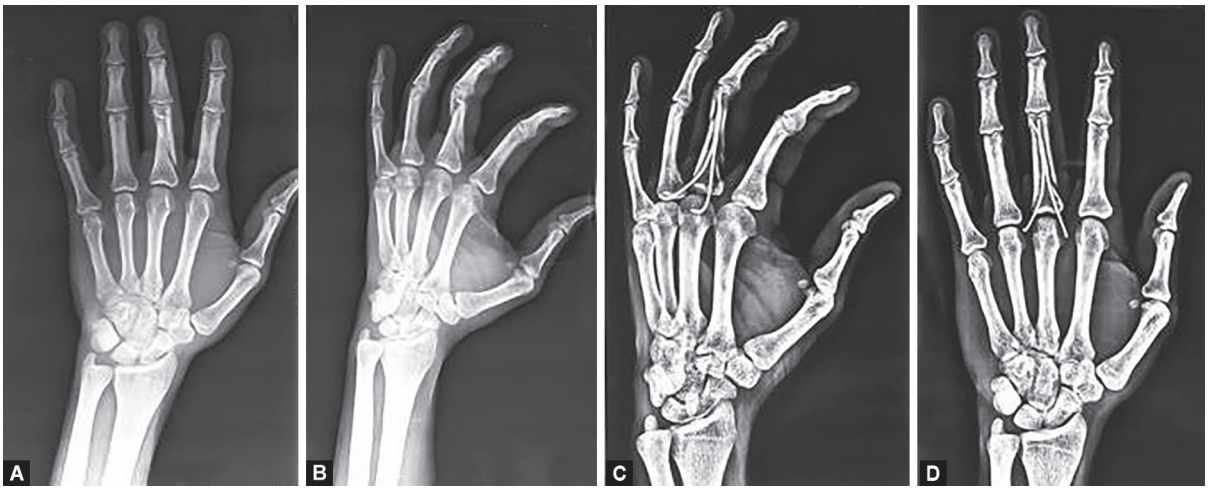
Table 2: Demographic data of the patients included in the study

Age in years: mean (SD)	30.9 ± 11.17
Gender	
Male	23 (74.1%)
Female	8 (25.9%)
Side	
Right	21 (67.7%)
Left	10 (32.3%)
Digit	
Index	14 (38.8%)
Middle	11 (30.5%)
Ring	6 (16.6%)
Small	5 (13.8%)
Bone involved	
Metacarpal	16 (44.4%)
Proximal phalanx	20 (55.6%)
Mechanism of injury	
Crush Injury	6 (19.3%)
RTA	15 (48.3%)
Fall	6 (19.3%)
Assault	2 (6.4%)
Machine injury	2 (6.4%)
Preoperative angulation (mean)	35.8°
Dominance	
Right	27 (87%)
Left	4 (13%)
Open fractures	12 (33.3%)
Closed fractures	24 (66.7%)
Time to surgery (hours): mean (SD)	22.57 ± 25.09

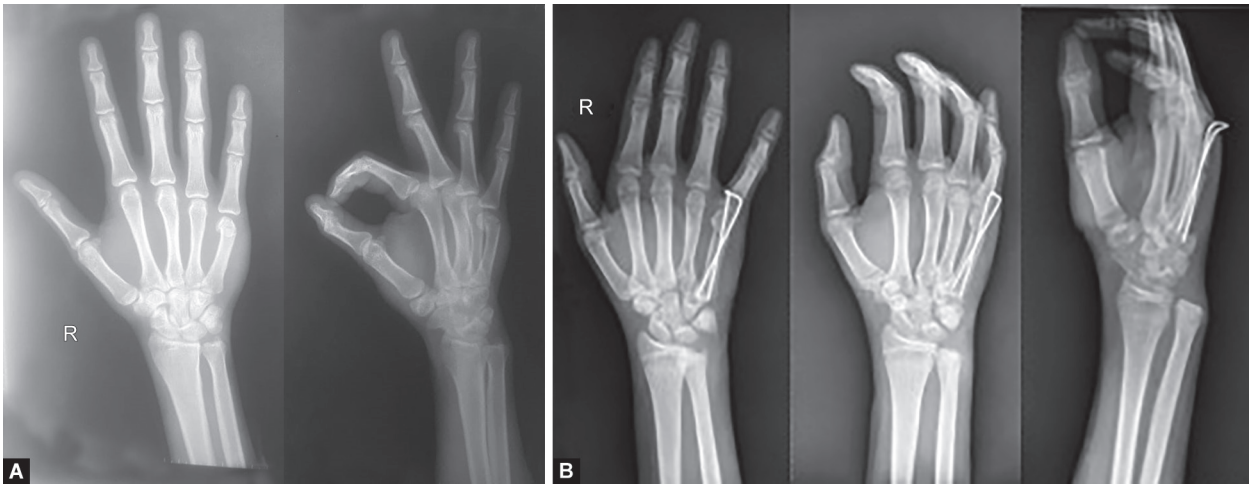
Discussion

Hand fractures are the second most common fractures in the upper extremity after the distal radius, accounting for 20% of fractures in general trauma.[14] Only a few population-based epidemiological studies have been conducted till now with most of the data gathered from the emergency or hospital settings. Hence the studies suggest variable figures when it comes to the distribution of these understudied and often overlooked fractures, with one study showing an incidence of 12.5 and 8.4 per 10,000 person-years for the phalanges and metacarpals, respectively.[15] Another hospital-based study describes the prevalence of this injury subset as fractures of the carpals, metacarpals and phalanges accounting 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] Despite the slight variations in proportions of these fractures, it concurs that hand injuries can significantly affect the functional impairment and quality of life of the patient. These injuries are can cause considerable delay in returning to work if not addressed timely.

The current study describes the clinical and functional outcome of the crossed intramedullary K-wire fixation and early mobilization in hand fractures. Studies on other methods of hardware fixation have been assessed previously in the literature (Table 5). Fixation techniques such as miniplate, lag screws fixation and mini external fixators in the small bone of hand fractures have been widely used and compared. There are no succinct advantages of one procedure over another described in the literature. The indication



Figs 3A to D: Preoperative and immediate postoperative radiograph showed an oblique fracture of the proximal phalanx of the third digit of the left hand and crossed K-wire fixation of it



Figs 4A and B: Preoperative and postoperative radiograph after fracture fixation for fifth metacarpal fracture of the right hand

Figs 5A to C: Showed excellent ROM at MCP and IPJ at 6 weeks after K-wire fixation of third proximal phalangeal fracture of the right hand

Table 3: Postoperative outcome measures of the patients included in the study

Follow-up in months mean (SD)	6.2 ± 12.3
Time of union in weeks mean (SD)	4.2 ± 6.8
Postoperative angulation in (°) mean (SD)	1 ± 1.76
Postoperative ROM at MCP joint in (°) mean (SD)	82 ± 3.45
Postoperative ROM at PIP joint in (°) mean (SD)	95 ± 9.44
Postoperative TAM in the finger in (°) mean (SD)	245 ± 28.88
Postoperative hand grip strength (percentage) mean (SD)	96.4% ± 32.3
Postoperative VAS score mean (SD)	2 ± 2.1
Postoperative quick DASH score mean (SD)	12 ± 4.4
Duration of surgery (minutes) mean (SD)	17 ± 4.63

Table 4: Frequency of complications noted in the study

Complications	*Number*	*Percentage*
Stiffness	3	14.28%
Persistent pain	2	9.5%
Pin-track infection	1	4.7%
Mal-union	1	4.7%

for the alternative methods depends mainly on the availability of the implant and the surgeon's preference. Correction of rotational deformities, angulation and shortening remains the prime objective in the treatment of metacarpal and phalangeal fractures.[16] Shortening at the fracture site can lead to significant loss of power as well as extension lag.

Miniplate fixation is a method of rigid fixation which addresses the fracture deformity in particular but it needs extensive exposure to the fracture site. Hence, as compared to K-wires it is associated with increased operative time and extensive surgery leading to local soft tissue damage, loss of gliding planes, delayed postoperative physiotherapy, increased stiffness and surgical site pain.[17,18] Another disadvantage with miniplates is the lack of design versatility, making it a bulky implant for hand fractures, with implant impingement a frequent complication. This further limits the use of implants on hand and often requires subsequent additional procedures for implant removal.[19]

Lag screw fixation provides a biomechanically stable fixation for simple oblique and spiral fractures. Studies have demonstrated comparable functional outcomes with the use of lag screw in terms of the range of motion, DASH score and grasping strength, although the time to return to work was longer as compared to fixation with miniplate.[20,21] Despite good clinical outcomes, the use of lag screws is limited to a subset of hand fractures with a particular fracture pattern. In addition, minor drilling errors may lead to implant loosening with little scope for correction due to limited bone stock in small bones of the hand, making the loss of fixation a common complication.[22]

The use of intramedullary screws has also been reported in the literature.[9,10] It was initially reported for comminuted subcapital metacarpal fracture.[23] The rationale for use of a headless screw is

Table 5: Studies comparing the other modalities of fixation (like a lag screw, mini plate, JESS fixator) with K-wire fixation of metacarpal and phalangeal fracture of the hand

Study, method	*Sample size*	*Results*	*Complications*
Reformat et al.[17] (plate and screw vs K-wire) in hand fractures	158 patients (192 fractures out of which 90 metacarpal and 102 phalangeal fractures)	Mini plate and lag screw group (A): Operative time (minutes)–149, period of immobilization (days) 18, active ROM (°)–145. K-wire group (B): Operative time (min)–84, period of immobilization (days)–33, active ROM (°)–149.	Group (A): Adhesion and persistent pain. Group (B): Infection (pin-track site), mal-union, non-union, persistent pain.
Pandey et al.[18] (mini plate vs closed crossed pinning of metacarpal and phalangeal fractures)	32 patients (46 fractures in which 32 metacarpal, 12 phalanges and 2 thumbs involved)	Mini plate group (A): Total active ROM: 239.55, DASH (range 0–100): 42.48, Hand grip (max 25 N/m^2): 16.75. K-wire group (B): Total active ROM: 238.36, DASH (range 0–100): 37.40, Hand grip (N/m^2): 17.63.	Group (A): None Group (B): Pin-track infection
Kootstra et al.[22] (K-wire vs lag screw and mini plate)	159 patients (159 proximal phalangeal fractures)	K-wire group (A): DASH, SD (range) 6.0, SD 8.6 (0–38), PRHWE, SD (range) 9.4, SD 15 (0–58). Mini plate (B): DASH, SD (range) 4.6, SD 6.9 (0–35), PRHWE, SD (range) 8.6, SD 13 (0–52). Lag screw (C): DASH, SD (range) 3.9, SD 9.1 (0–51), PRHWE, SD (range) 5.6, SD 14 (0–82).	Group (A): Mal-union, non-union, infection Group (B): Mal-union, non-union, infection and loss of fixation (max) complications) Group (C): Loss of fixation, infection
Mishra et al.[25] (JESS-Joshi External Stabilizing System)	38 patients (21 MC and 17 phalangeal fractures)	73.70% excellent and 26.30% has good active ROM, no poor results.	Pin-track infection in 7 patients, 2 had loosening of K-wire (23.70%)

Table 6: Summary of results of different studies fixing the metacarpal and phalangeal fractures with K-wire (different methods) and their results

Authors	*Technique*	*Patients*	*Results*	*Complications*
Green and Anderson[26]	Closed reduction and extra-articular pinning; early mobilization	26 fractures in 21 patients; mixed fracture patterns	18 fractures regained full movement	No breakdown for fracture pattern described
Belsky et al.[27]	Trans-articular, intramedullary Pinning with rigid postoperative Casting	31 base fractures (in cohort of 100 proximal phalanx shaft)	61 excellent; 29 good; 10 poor	Pin-track infection and mal-union
Joshi[28]	Wire inserted into phalangeal base using awl; immobilized in moulded cast with PIP joint movements	15 proximal third fractures (in larger cohort of 61 fractures)	90% satisfactory	Complications: tendon rupture, loss of fixation, wire protrusion
Hornbach and Cohen[29]	Trans-articular pinning with 2 wires; thermoplastic splint immobilization	9 base fractures in cohort of 12 proximal phalanx fractures failing conservative management	Mean TAM 265°	3 patients had significant complications; 4 patients had rotational mal-union
Faruqui et al.[30]	Trans-articular wiring (25) Extra-articular pinning with 2 wires (25)	50 unstable displaced fractures of proximal third of phalanx	Trans-articular mean TAM 201° Extra-articular mean TAM 198°	Complications 54% trans-articular; 48% extra-articular cross pinning; 16% reoperation rate
Van Bussel et al.[31]	A pre-bended 0.8–1.5 mm K-wire was then intramedullary inserted in the metacarpal bone passing the fracture under fluoroscopy	34 fractures of 27 patients	Functional outcome was excellent with mean PRWHE and DASH Scores of 7 and 5 points, respectively.	In the form of persistent pain, dysaesthesia and decrease ROM.

that it holds reduction as well as provides stability by distal hold in the subchondral bone and proximal fixation in the endosteal isthmus of the medullary canal. Also, the buried location of the screw removes the need for future removal. The rotational stability as well as the lack of hardware removal are the advantages of this technique over intramedullary K wiring. Biomechanically, the strength of intramedullary devices is comparable to multiple intramedullary K wiring.[24]

The mini external fixator is another popular method for the fixation of hand fractures as it provides the option for dynamic stability. The fixator is based on the principle of ligamentotaxis and provides near excellent reduction of the fracture without opening of fracture site and minimal handling of soft tissue but may prove to be technically challenging. Though this procedure provides a good functional outcome, pin-track infection is seen in almost one-fourth of the patients.[25] The simplicity and cost-effectiveness of the device and fixation technique is countered by the fact that the patient has to carry the fixator which is physically discerned and may be uncomfortable for a few. Hence, this method of treatment is mostly reserved for comminuted and open injuries with bone loss.

Intramedullary K-wire fixation needs less soft tissue manipulation and can be complemented with earlier physiotherapy leading to good ROM at metacarpophalangeal joints. The advantages of using this method are its cost-effectiveness, a lesser operative time when compared to miniplate, lag screws and external fixators, early ROM exercises that can be started due to preservation of gliding planes, and no surgical wound along with good fracture stability and minimal hardware impingement. The procedure is short and can be performed on a daycare basis under local or regional anaesthesia with established excellent functional results as compared to other modalities. There are multiple methods of K-wire fixation like single K-wire fixation and double K-wire fixation (percutaneous intramedullary/percutaneous crossed K-wire fixation) (Table 6). In this study two pre-bent K-wires, 1.5–2 mm in size, either over an automated drill or manually over T-handle were passed percutaneously in the metacarpal or phalanx in crossed fashion from a predefined entry point at 5 mm away from epiphysis over the dorsolateral aspect, and then turned inside the canal making its concave side toward the medullary canal cresting a 3-point fixation. In the present study all the fractures united at a mean period of 4.2 ± 6.8 weeks, which is the shortest duration as compared to other studies.[17,18,22,25] In addition, most of the patients were started with physiotherapy in immediate postoperative period. This can be attributed to extra stability after fixation of fracture with crossed percutaneous intramedullary K-wire. The mean range of motion at the metacarpophalangeal and proximal interphalangeal joint was 96.4% and 86.3% respectively as compared to the opposite hand (Fig. 5). The mean grip strength noted at final follow-up was 96.4% of the contralateral hand. 95.2% (20/21) patients had excellent to good outcome according to ASSH scale at final follow-up.

As with any study, this study also has some limitations like small sample size, short follow-up and lack of articular fractures in the study group. But the strength of this study is that it is a prospective study and very few studies in the literature have explored or studied this modality of crossed intramedullary K-wires in metacarpal and proximal phalangeal fractures.

Conclusion

Crossed percutaneous intramedullary fixation of small bone fractures of the hand is a versatile method with advantages such as cost-effectiveness and lesser operative time when compared to other modalities of fixation. Earlier ROM exercises can be started due to preservation of gliding planes, no surgical wound along with good fracture stability and minimal hardware impingement. The procedure is short and can be performed on an office basis under local or regional anaesthesia with excellent functional results.

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