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Original Article

Management of extra-articular shaft fractures of the non-thumb metacarpals: plate-screw fixation versus K-wire fixation

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Abstract: Metacarpal fractures are common injuries and comprise nearly 36% to 42% of all fractures in the hand. The majority of these can be managed non-surgically. Operative fixation when needed, can be done by a variety of techniques. In this study, we have compared the outcomes of two techniques, plate-screw fixation and K-wire fixation. We have conducted a prospective, non-randomized, comparative study of patients who presented with extra-articular metacarpal shaft fractures of non-thumb metacarpals over a period of 18 months. 30 patients were enrolled according to the inclusion criteria and were alternately allotted to the plate-screw group and the K-wire group. At admission, patient demographics, clinical features, number of fractures, and fracture patterns were recorded, and radiographs were taken. In the plate-screw group, low-profile plates and screws were used, and in the K-wire group, 1 or 2 K-wires were used for fixation after fracture reduction. Hand mobilization exercises were started within one week in the plate-screw group, while in the K-wire group full mobilization was allowed at 4 weeks post-surgery. The Disabilities of Arm, Shoulder and Hand (DASH) score was calculated and compared between the two groups at 6 months and 12 months after surgery. The mean 6-month DASH score in the plate-screw group was 6.3287±2.2453, while it was 17.1627±6.2103 in the K-wire group (p value <0.001). At the end of 1-year follow-up, the mean DASH score in the plate-screw group was 5.1080±1.6637, and in the K-wire group, it was 5.1073±1.9392 (p value =0.848). In conclusion, extra-articular metacarpal shaft fractures of the non-thumb metacarpals treated by plate-screw fixation had significantly better DASH scores and hence better functional outcomes at the end of 6 months. However, at the end of 1 year, the DASH scores in both the groups were almost similar, suggesting similar functional outcomes in the long term.

Keywords: Metacarpal bones, fractures, bone, bone plates, bone screws, range of motion, articular

Introduction

Metacarpal fractures are common injuries, comprising nearly 36% to 42% of all fractures in the hand region [1-3]. Among them, non-thumb metacarpals account for 88% of fractures of which the most common involvement is of the fifth metacarpal [4]. *Xing et al.* reported in their study that 58% of metacarpal fractures were located in the shaft area [5].

The majority of these injuries (70%) occur in the second and third decades of life [6]. Based on the fracture pattern, metacarpal shaft fractures can be classified as transverse, oblique, spiral, or comminuted. As far as the treatment is concerned, the ultimate aim of treatment in any hand and finger fracture is to achieve a full range of wrist and non-scissoring finger motion. Optimal treatment depends on whether the fracture is reducible or irreducible and, whether the reduction achieved is stable or unstable. Swanson had stated that hand fractures can be complicated by deformity without treatment, stiffness from overtreatment, and both deformity and stiffness from suboptimal treatment [7]. In the hand, prolonged immobilization should be avoided since there is a risk of permanent stiffness. At the same time, operative treatments must be used judiciously and only if the final outcome is expected to be better than that of conservative management.

Most of the metacarpal and phalangeal fractures are amenable for non-operative management [8, 9]. However, there are certain indications for surgical treatment. These include rotational deformity of more than 5°, fracture translation above 50%, and shortening of more than 6 mm. Shortening of 2 to 5 mm is a relative indication for surgery, considering the mild loss of grip strength [10]. Degrees of acceptable angulation depend on the involved metacarpal, between 20° and 30° for the fourth and fifth metacarpals, and up to 5° to 10° for the second and third metacarpals [11].

Extra-articular metacarpal fractures with minimal shortening and dorsal angulation do not cause significant functional impairment. Most metacarpal shaft fractures are stable and may not require fixation after closed reduction [12]. In case fixation is needed, the commonly used techniques for fixation are Kirschner wires (K-wire), intramedullary nails, lag screws, plate-screw fixation (including bio-absorbable plates), and external fixators.

While there have been several favorable reports on the internal fixation of metacarpal fractures [13, 14], there are also studies showing less optimal outcomes and many complications [15-17]. Evidence supporting any single treatment is largely limited to single-center studies. In addition, randomized controlled trials are difficult to perform given the wide spectrum of fracture patterns and mechanisms of injury [18]. Traditionally, pinning has been used in the treatment of unstable metacarpal fractures due to the ease of technique and minimal surgical exposure required. However, there has been an increasing trend towards the use of plates and screws, which provide direct fracture reduction and permit early mobilization. In addition, low-profile plates allow periosteal closure and potentially reduce adhesion formation compared to the earlier designs of plates [6]. But, despite these recent advancements, it is not proven that these techniques lead to improved functional results or more rapid recovery.

In this study, we have attempted to address this issue, by comparing the functional outcome of two techniques, plate-screw fixation and K-wire fixation.

Materials and methods

Study design

We have conducted a prospective, comparative non-randomized study of patients who presented with extra-articular metacarpal shaft fractures of non-thumb metacarpals over a period of 18 months, from July 2013 to December 2014. The study protocol was approved by the Institutional Ethics Committee (approval number NK/1178/DM/14648). All procedures followed were in accordance with the ethical standards of the Institutional Ethics committee and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from each participant before enrolling them into the study.

Inclusion criteria

1. patients with single or multiple, closed fractures. 2. patients with open fractures with adequate soft tissue cover. 3. willing to participate in the study.

Exclusion criteria

1. patients younger than 14 years of age. 2. fractures of the 1st metacarpal. 3. fractures with extensive comminution, segmental bone loss, and soft tissue loss requiring cover. 4. metacarpal fractures associated with other major upper limb injuries.

30 patients were enrolled in the study according to the inclusion criteria and were alternately allotted to the plate-screw group and the K-wire group. This resulted in 15 patients being allotted to each group. At admission, patient demographics, clinical features, number of fractures and fracture patterns were recorded, and radiographs were taken. In the plate-screw group, low-profile plates and screws were used for fixation, and in the K-wire group, 1 or 2 K-wires were used for fixation after achieving fracture reduction.

Procedure

In the plate-screw group, fractures were approached through a dorsal curvilinear skin incision, the extensor tendon was retracted, periosteum over the fracture ends was carefully elevated. The fracture ends were manipulat-

ed into reduction by the Jahss technique, which applies dorsal force to the distal fragment with the metacarpo-phalangeal and proximal interphalangeal joints fully flexed and held with a reduction clamp. Low-profile titanium plates were then applied dorsally or dorso-laterally with the fixation of at least four cortices with screws. Whenever possible, the periosteum was sutured back over the plate to reduce contact and friction with the overlying extensor tendons. A short period of post-operative immobilization was maintained in a temporary splint for 3 to 5 days. Passive and active finger motion was allowed after this period.

In the K-wire group, after reduction, fractures were fixed with 1 or 2 K-wires inserted either antegrade through the base of the metacarpal into the distal fragment or inserted antegrade through a mini-incision at the fracture site into the metacarpal head and then retrograde into the metacarpal base. Wire ends were left protruding from the skin. The operated hand was kept in a volar splint, extending from the middle of the forearm to the middle of the proximal phalanges, with 20° to 30° of wrist extension and metacarpophalangeal joints in 70° flexion. Free motion of interphalangeal joints was allowed. After 4 weeks, the K-wires were removed, the splint was discontinued, and full mobilization of the hand was permitted.

Complications investigated included infection, migration or failure of the implants, mal-union, non-union, adhesions to the extensor tendons, complex regional pain syndrome, cold intolerance, pain requiring removal of the plates, and unaesthetic appearance of the scar.

Physiotherapy was instituted by a hand therapist and was supervised by the operating surgeon. This included progressive exercises to regain the range of motion in digital joints, synchronous wrist and digital tenodesis exercises, and individual joint blocking exercises. As pain and swelling decreased and fracture healing progressed, repetitions and the intensity of the exercises were also increased.

When the fracture gap disappeared in the radiograph, it was recognized as the time to union. The primary outcome measure in this study was the Disabilities of Arm, Shoulder and Hand (DASH) score. The DASH score (English version, © Institute for Work & Health, Toronto, ON Canada) is a validated 30-item, self-reported questionnaire designed to measure physical function and symptoms in patients with musculoskeletal disorders of the upper limb. Lower scores indicate a better functional outcome. The total score scale ranges from 0 (no disability) to 100 (most severe disability). In the DASH questionnaire, only the Disability/Symptom section consisting of 30 items, scored on a scale of 1-5 was administered, excluding the optional modules. We assessed the DASH scores at the end of 6 months after surgery. Patients were reviewed again at 12 months post-surgery and the DASH score measurements were repeated. Plate removal was performed when any patient complained of discomfort, pain, or cold intolerance.

Patients in the plate-screw fixation group were contacted again 5 years after the surgery, on the telephone, to enquire regarding the status of the implants and the occurrence of any long-term complications.

Statistical analysis

All the patient data collected was entered into a spreadsheet created in Microsoft Excel™ software 2013 version (©Microsoft Corporation, Redmond, Washington, United States). The data was analyzed in SPSS software Version 22.0 (©IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp). Summary statistics were derived. Nominal variables were statistically described with frequencies and percentages. Continuous variables were described with means and standard deviations. Ordinal variables were also presented in the form of frequencies and percentages. Mann-Whitney test was used to compare the DASH scores of the two groups. A p value <0.05 was considered statistically significant.

Results

Patient characteristics

During the study period, 48 metacarpal shaft fractures were operated in 30 patients. The characteristics of the patients in the plate-screw group and K-wire group are shown in **Tables 1** and **2**, respectively. The age of the patients ranged from 18 to 65 years. There was a male preponderance across the two groups (26 males and 4 females). Manual laborers as

Table 1. Characteristics of the patients in the plate-screw group

Patient (S.no)	Age (years)	Gender	Work status	Injured side	Mechanism of injury	Involved digit(s) and side	6-month DASH score	12-month DASH score
1	18	F	SW	ND	Fall	2, 3, 4 Left	3.33	7.50
2	18	M	SW	D	Punch	4, 5 Right	4.16	4.16
3	35	M	ML	D	RTA	5 Right	5.83	3.33
4	40	M	ML	ND	RTA	2, 3, 4 Left	5.83	8.33
5	60	M	SW	D	RTA	2 Right	6.66	5.83
6	26	M	ML	ND	RTA	3 Left	4.16	5.00
7	23	M	ML	D	Fall	5 Left	3.33	4.16
8	46	M	ML	D	RTA	5 Right	8.33	3.33
9	29	M	ML	ND	RTA	2 Left	7.50	3.33
10	24	M	ML	D	Assault	5 Right	4.16	5.00
11	35	M	ML	D	RTA	5 Right	6.66	3.33
12	26	M	ML	D	RTA	2, 3 Right	8.33	5.83
13	34	M	ML	ND	RTA	5 Left	9.16	4.16
14	23	M	ML	D	RTA	2, 3 Right	10.83	5.83
15	20	M	ML	ND	Machine crush	4 Left	6.66	7.50

M, male; F, female; ML, manual laborer; SW, sedentary work/desk job; D, dominant; ND, non dominant; RTA, road traffic accident.

Table 2. Characteristics of the patients in the K-wire group

Patient (S.no)	Age (years)	Gender	Work status	Injured side	Mechanism of injury	Involved digit(s) and side	6-month DASH score	12-month DASH score
1	53	M	SW	ND	Assault	3 Left	10.00	3.33
2	30	M	ML	D	RTA	2 Right	25.83	3.33
3	40	M	ML	D	Assault	4 Right	10.83	4.16
4	33	M	ML	D	RTA	4 Right	11.66	4.16
5	65	F	SW	D	RTA	2, 3, 4, 5 Right	26.66	8.33
6	60	F	SW	D	Fall	4, 5 Right	11.66	5.83
7	19	M	ML	ND	RTA	2, 3 Left	16.66	8.33
8	20	M	ML	D	Assault	4, 5 Right	14.16	5.83
9	19	M	ML	D	RTA	4 Right	13.33	3.33
10	25	M	SW	ND	RTA	4, 5 Left	15.00	4.16
11	35	M	ML	D	RTA	2, 3 Right	18.33	7.50
12	26	M	ML	D	RTA	2 Right	24.16	3.33
13	24	M	ML	D	RTA	2 Right	22.50	4.16
14	60	F	SW	ND	Fall	5 Left	10.83	3.33
15	50	M	SW	D	Fall	2, 3, 4, 5 Right	25.83	7.50

an occupational group constituted 70% of the study population. The majority of the fractures involved the right hand (right to left ratio was 2:1). There were no cases with bilateral involvement in our study. The dominant hand was involved in the majority of the cases (dominant hand to non-dominant hand ratio was 2:1). The majority of the patients sustained these injuries in road traffic accidents (20). Physical assaults and falls accounted for 4 cases each. One patient sustained 4th and 5th metacarpal shaft fractures in the right hand after punching a brick wall in a fit of anger. Machine crush injury at the worksite was the cause in one case. Fractures most commonly involved the fifth metacarpal (13 fractures) and the second

metacarpal (13 fractures). The mean duration from injury to surgery was 3 days.

Comparison of the plate-screw group and the K-wire group

A comparison of the two groups is given in **Table 3**. The two groups were comparable with each other in age and gender characteristics. The average duration of surgery was 44 minutes in the plate-screw group, while it was 17 minutes in the K-wire group. The average time to bone union was 8 weeks in the plate-screw group and 10 weeks in the K-wire group. There were no cases of fracture non-union in our study. It was observed that patients who underwent plate-screw fixation had better DASH scores when compared to those who underwent K-wire fixation at the end of 6 months. The mean 6-month DASH score in the plate-screw group was 6.3287±2.2453, while it was 17.1627±6.2103 in the K-wire group (Mann-Whitney Asymp. Sig. (2-tailed), *p* value <0.001). At 12 months post-surgery, the mean DASH score was 5.1080±1.6637 in the plate-screw group and 5.1073±1.9392 in the K-wire group (Mann-Whitney Asymp. Sig. (2-tailed), *p* value =0.848).

Complications

At the end of 12 months, there were 7 complications in the plate-screw group. One patient who suffered a fourth metacarpal shaft fracture of the left hand in a machine crush injury developed surgical site infection in the 2nd week after surgery. He responded to conservative management and progressed to bony union after the control of infection, without any significant delay. The rate of surgical site infection in our study population comes out to be 3.33%. One patient had hardware failure and required revision surgery. Further, 3 patients requested the removal of the plates citing pain and cold intolerance; they underwent removal of plates under local anesthesia in the operating room. We did not remove the plates as a routine, otherwise. None of the patients in our study required extensor tenolysis. Two patients were concerned about the aesthetic appearance of the scars.

In the K-wire group, there were 4 cases of accidental extrusion of the K-wires. These cases however, progressed to bony union without any problem. There were no pin tract infections or neurological complications.

Although the most common complications would normally present within a year, other complications such as painful hardware or tendon adhesions or ruptures may present later than a year (19).

We were able to get in touch with 13 out of 15 patients in the plate-screw group at 5 years post-surgery. At this point, 3 more patients reported that they had to undergo plate removal because of cold intolerance and pain. Therefore, in the plate-screw group, 6 out of 15 patients had undergone plate removal by the end of 5 years; the status of 2 patients was not known, while the rest of the 7 patients who had plates *in situ,* did not complain of any problems due to the presence of implants. Two more patients complained about the aesthetic appearance of scars at this point.

The figures below illustrate two cases of plate-screw fixation that were operated during the study period.

Figures 1-**4** show the pre-operative and post-operative radiographs and intra-operative picture of patient 1 in the plate-screw group.

Figures 5-**7** show the pre-operative and post-operative radiographs of patient 2 in the plate-screw group.

Discussion

Metacarpal fractures are common injuries and constitute about one-third of all hand fractures [4]. Many of them present as isolated injuries which are simple, closed, stable, and can be managed conservatively. Operative intervention may be indicated in the rest of the fractures. A variety of techniques are useful for the fixation of these fractures including K-wires, intra-medullary nails, lag screws, plates, and external fixators. In the present study, we have compared the outcomes of two techniques, plate-screw fixation and K-wire fixation.

Our prospective comparative study was not randomized, but we had allocated the consecutive study patients alternately into the two treatment groups. Further, the two groups were comparable to each other in terms of age and

Table 3. Comparison of results between the two groups

Characteristic	Plate-screw group	K-wire group	*p* value
Mean age (SD)	33.1333 (13.4422)	34.60 (15.560)	0.784 Sig. (2-tailed)
Gender (M:F)	14:1	12:3	1.000 Fisher's exact test
Fracture site dominant	66.67%	66.67%	
Digit involved.	No. of Fractures	No. of Fractures	
2nd	6	7	
3rd	5	5	
4th	4	8	
5th	8	5	
Average duration of surgery (minutes)	44	17	
Complications (within one year)	Total-7 Infection (1) Cold intolerance and pain requiring plate removal (3) Hardware failure requiring revision surgery (1) Unaesthetic scars (2)	Total-4 Premature extrusion of K-wires (4)	
Avg. radiographic healing time (weeks)	8	10	
Mean 6-month DASH score (SD)	6.3287 (2.2453)	17.1627 (6.2103)	*p* value <0.001 Mann-Whitney Asymp. Sig. (2-tailed)
Mean 12-month DASH score (SD)	5.1080 (1.6637)	5.1073 (1.9392)	*p* value =0.848 Mann-Whitney Asymp. Sig. (2-tailed)

Figure 1. Fractures of the shafts of metacarpals 2, 3 and 4 in an 18-year-old female patient (patient 1 in the plate-screw group). A: Anteroposterior view radiograph; B: Lateral view radiograph.

Figure 2. Intra-operative picture of plate-screw fixation.

gender characteristics. The follow-up period of 12 months was completed in all the patients.

The DASH score that was used has been extensively studied and validated as a reliable outcome measure of the functional status of the hand [20-22].

Our study highlights many pertinent issues. Earlier studies have shown that metacarpal fractures are most frequent in the 2nd and 3rd decades of life [6]. In our study population, they were most frequently seen in the 3rd decade followed by the 4th decade. Our study population consisted predominantly of young males, the majority of them were manual laborers and were the prime earning members of the family. The treatment modality chosen may have important socio-economic implications; the modality which allows early rehabilitation of the injured hand may help the individuals to return to normalcy quickly and reduce the loss of work hours and income. Road traffic accidents were found to be the most frequent cause of these injuries. In these cases, there is a greater risk of contamination; adequate debridement of the necrotic and contaminated tissues is vital for any form of fixation, but more so for plate-screw fixation.

Previous studies have shown that the fractures of the fifth metacarpal were the most common, followed in frequency by the second metacarpal [4, 23]. In our study, both fifth and second metacarpals were equally frequent sites of fractures. *Ozer et al.* compared intramedullary nailing and plating for metacarpal shaft fractures and reported that there were no significant differences in the range of motion or DASH scores [24]. Further, it was also mentioned that intra-medullary nailing provided less rigid fixation and additionally required hardware removal. *Facca et al.* performed a prospective comparative study between locking plates and intramedullary K-wire fixation in neck fractures of the fifth metacarpal, with an earlier mobilization protocol in the plating group and 6 weeks immobilization in the K-wire group. In this study, range of motion was found to be significantly better in the K-wire group (97.7% mobility of the contralateral side in comparison to 58.7% in

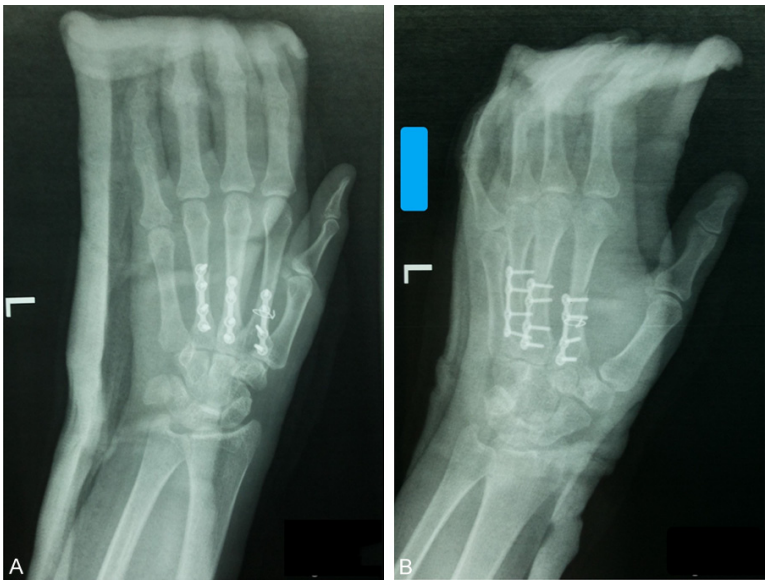

Figure 3. Post-operative picture following plate-screw fixation. A: Anteroposterior view radiograph, note the cerclage in the 2nd metacarpal. B: Oblique view radiograph.

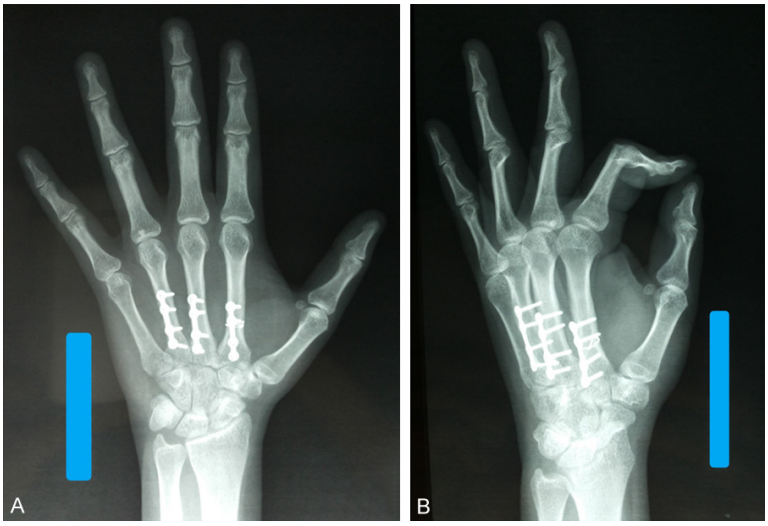

Figure 4. Picture at 1-year post-surgery. A: Anteroposterior view radiograph; B: Oblique view radiograph.

the locking plate group, *p* value =0.001), despite the longer period of immobilization in the K-wire group. The authors mention having a greater number of rehabilitation sessions in the K-wire group; the DASH scores, pain, and complication rates did not differ significantly between the two groups [25].

Our study reveals better post-operative DASH scores in patients who underwent plate-screw fixation when compared to those who underwent K-wire fixation, at the end of 6 months follow-up. However, at the end of 12 months follow-up, the DASH scores of the two groups did not differ significantly. It may be inferred from the findings in our study that plate-screw fixation of extra-articular metacarpal shaft fractures may lead to a better functional outcome than K-wire fixation in the short term, but the long-term outcomes are not significantly different.

Plate-screw fixation may be advantageous in many ways. Several investigators have demonstrated that plate fixation yielded more rigid mechanical strength compared to other techniques for hand fracture models [26, 27]. Rigid fixation by plates and screws allows early finger mobilization during the post-operative course, giving the potential of early return to normal activities. It is crucial to start an early rehabilitation program and a careful dynamic splinting protocol in the patients who underwent plate-screw fixation. Prevention of intrinsic muscle atrophy may account for the maintenance of grip strength in patients with plate fixation. Biomechanical studies on hand fractures have shown that internal fixation using plates and screws provides more rigid stabilization in comparison to K-wire fixation [28-30]. *Kodama et al.* showed that patients did not need any plaster because of the rigid fixation when using low-profile plates and were satisfied with the results allowing an early return to work [31]. Early mobilization theoretically results in lesser edema and muscle weakness, and therefore a faster return of the hand function. Similarly, newer generation implants provide a more rigid construct in metacarpal fixation especially for

Figure 5. Fractures of the shafts of metacarpals 4 and 5 in an 18-year-old male patient (patient 2 in the plate-screw group). A: Anteroposterior view radiograph; B: Lateral view radiograph.

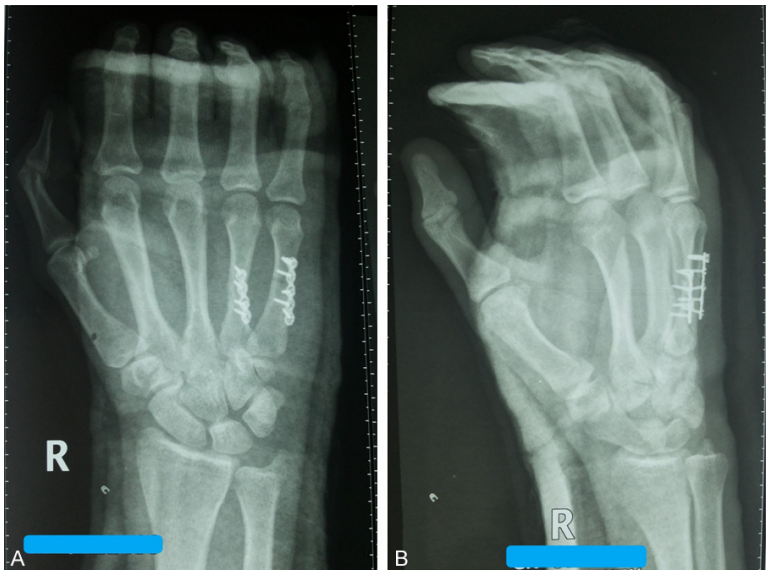

Figure 6. Post-operative picture following plate-screw fixation. A: Anteroposterior view radiograph; B: Oblique view radiograph.

the peri-articular region of the metacarpal and in older patients with osteopenia [32]. These low-profile plate systems are associated with reduced soft tissue irritation and complications [33]. In many of the previous studies, the range of motion following plate osteosynthesis was found to be inferior or equal to percutaneous pinning [24, 34, 35]. However, these studies looked at a heterogeneous group of fractures in the hand and fingers. When specifically dealing with metacarpal shaft fractures, there are several benefits of plating. In these fractures, a plate may be positioned by extensor tendon retraction rather than splitting of the tendon and without disturbing the joint capsule and without risking penetration of screw into the metacarpal head. Careful elevation of periosteum from fracture ends followed by meticulous suturing over the plate allows for early mobilization without the risk of tendon irritation or rupture. All these factors may have accounted for better functional scores among our patients in the plate-screw fixation group at 6-months follow-up.

We had 7 complications in the 15 patients in the plate-screw group in 12 months duration. According to several studies, the rate of complications for plating is reported to be between 32-36% [15, 16]. These include infection, stiffness, malunion, non-union, extensor lag, contractures, tendon ruptures, and hardware failure requiring revision surgery. The rate of infection in open metacarpal fractures is reported to be between 2-11%, and it correlates directly with the degree of injury to the soft tissues and the degree of contamination [36, 37]. We had one case of a surgical site infection in the plate-screw fixation group (rate of infection 3.33%). Cold intolerance and pain requiring plate removal, hardware failure requiring revision surgery and unaesthetic scars were some of the other complications reported in the plate-screw group. The high cost of the implants was also an important concern for the patients in this group.

Although K-wire fixation involved lesser cost, a longer period of immobilization was required in

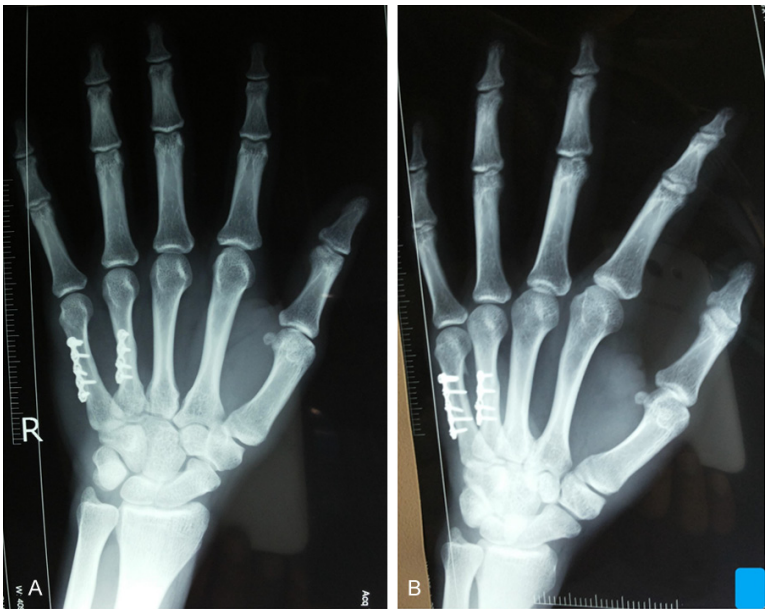

Figure 7. Picture at 1-year post-surgery. A: Anteroposterior view radiograph; B: Oblique view radiograph.

this group. This is because K-wires do not provide truly rigid fixation and immobilization was necessary to avoid loss of reduction. This was followed by implant removal and mobilization. The longer period of immobilization may lead to an increased risk of development of stiffness. This may have led to the lesser DASH scores in the K-wire fixation group at 6 months follow-up. The hand function gradually improved, and the DASH scores became more or less similar to the plate-screw group at 12 months follow-up.

Although the most common complications would normally present within a year, other complications such as painful hardware or tendon adhesions or ruptures may present later [19]. Therefore, we have contacted the plate-screw group patients 5 years after surgery to enquire regarding the status of the implants and the occurrence of any long-term complications.

The strengths of the study are its prospective design and the use of a widely accepted and validated outcome measure (DASH score). The weakness of the study is the lack of true randomization between the two treatment groups. The findings of our study are to be interpreted cautiously considering the small sample size.

In conclusion, extra-articular metacarpal shaft fractures of the non-thumb metacarpals treated by plate-screw fixation had significantly better DASH scores and hence better functional outcomes when compared to those treated by K-wire fixation, at the end of 6 months. However, at the end of 1 year, the DASH scores in both the groups were almost similar, suggesting similar functional outcomes in the long term. Therefore, occupational and socio-economic factors of the patient should be given due consideration when deciding on the treatment option, in addition to other fracture and patient-related factors.

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Disclosure of conflict of interest

None.

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