Al-Azhar International Medical Journal

Volume 1 | Issue 12 Article 16

12-1-2020

Comparative Study Between Intramedullary K Wires Versus Mini-plates and Screws in Fixation of Metacarpal Shaft Fractures in Adults

mahmoud abdel-hamid
orthopedic surgeon alazhar university, dr.mah_am1991@yahoo.com

Mohamed Abulsoud
Orthopedic Surgery Department, Faculty of Medicine, Al-Azhar University,Cairo, Egypt .,
mamado1978@hotmail.com

Mohamed bissar
Orthopedic Surgery Department, Faculty of Medicine, Al-Azhar University,Cairo, Egypt .,
drmbissar@gmail.com

How to Cite This Article

abdel-hamid, mahmoud; Abulsoud, Mohamed; and bissar, Mohamed (2020) "Comparative Study Between Intramedullary K Wires Versus Mini-plates and Screws in Fixation of Metacarpal Shaft Fractures in Adults," *Al-Azhar International Medical Journal*: Vol. 1: Iss. 12, Article 16.
DOI: https://doi.org/10.21608/aimj.2021.52551.1371

OPEN AIMJ ORIGINAL ARTICLE

Orthopedic

Comparative Study Between Intramedullary K Wires Versus Mini-plates and Screws in Fixation of Metacarpal Shaft Fractures in Adults

Mohamed M Bissar[1] MD, Mohamed I Abulsoud[1] MD, Mahmoud M Abdul-Rahman[1] MBBCh

*Corresponding Author:
Mahmoud M Abdul-Rahman
dr.mah_am1991@yahoo.com

Received *for publication December 14, 2020;* ***Accepted*** *January 25, 2021;* ***Published online*** *February 02, 2021.*

10.21608/aimj.2021.52551.1371

[1]*Orthopedic Surgery Department, Faculty of Medicine, Al-Azhar University.*

Disclosure: *The author has no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the author.*

ABSTRACT

Introduction: Percutaneous intramedullary K. wires fixation and mini-plates fixation are reasonable options for treating unstable metacarpal fractures as they provide anatomical reduction and rigid fixation, which is adequate to permit early mobilization. The aim is to compare between mini-plates and Kirschner wires in management of unstable metacarpal shaft fractures in adults.

Patients and Methods: All patients (n=30) included in this prospective comparative study were managed and followed up at Al-Azhar University Hospital from January 2019 to February 2020. Thirty patients with fracture of shaft metacarpal were divided into 2 groups: group A (n=15) were managed by percutaneous intramedullary K-wires and group B (n=15) were managed by mini-plates.

Results: Twenty-seven patients were males and 3 were females. Dominant hand affection were in 20 patients . All patients had a complete union between 4-8 weeks for group A with average of 6 weeks and 6-10 weeks for group B with average of 8 weeks. The total result according to TAF score, Quick DASH score, and handgrip was excellent in 10 cases, good in 4 cases, and fair in 1 case in group A, while group B was excellent in 10 cases, good in 3 cases, fair in 1 case and poor in 1 case.

Conclusion: Both techniques are highly effective for fixation of metacarpal shaft fractures. Mini-plate fixation provides rapid recovery of hand function and K-wire fixation allows a wide range of hand motion and soft tissue preservation.

Keywords: *K-wire;Mini-plates;metacarpal fractures.*

INTRODUCTION

Metacarpal bone fractures are one of the commonest orthopedic injuries,[1]represent about 10% of all fractures,[2] and the most frequent hand fractures reaching up to 40%.[3] The metacarpals are miniature long bones that are slightly arched in the longituidinal axis and concave at the volar surface. The weakest point is just behind the head.[4, 5]

Metacarpal fractures may be complicated by deformity from neglection of treatment, stiffness from overtreatment, and both deformity and stiffness from mal-treatment.[6]

The goals of treatment include early diagnosis, anatomical reduction correcting the rotational and deformities, preservation of soft tissue, preservation of the longitudinal and transverse arches, and maintaining length of the metacarpus because shortening of more than 3 mm will lead to an imbalance between the extrinsic and intrinsic hand muscles.[7]

Operative fixation of hand fractures has gained increasing popularity [8] due to better materials, implant designs, instrumentation,[9] a better understanding of the biomechanics of internal fixation, availability of subspecialists in hand surgery, ease of anesthesia and improvement of hand physiotherapy methods.[10]

Over the last 25 years, treatment of metacarpal fractures have greatly expanded.[8] It can be treated by closed reduction and splinting [11] which have the disadvantage of difficulty to preserve joint mobility to avoid stiffness,[12] Kirschner wires fixation, intraosseous wiring, and screw fixation with or without plating having the advantage of early active motion but carry the disadvantage of wide surgical exposure and soft tissue injury.[11]

The purpose of this comparative study was to assess Q.DASH score, TAF score, hand grip and union time to determine which fixation method (mini plates or K wires) provides a better functional and radiological outcome for the treatment of metacarpal shaft fractures. Where K wire fixation is a common technique that has the advantages of the subcutaneous nature of hand bones, small size, and their limited loading potential for the stress placed on hardware,[13] While mini-plates produce an anatomical

reduction with good stabilization that is rigid enough to allow rapid mobilization, but rupture of extensor tendons, stripping of periosteum with affection of nutrition, difficult technique, loosening and distraction of the implant and infection are common problems with mini-plates.[8]

Rehabilitation is the most important aspect of treatment. Early motion after fixation of hand fractures is particularly important because tendon gliding and joint mobility are crucial to a well functioning hand.[14]

PATIENTS AND METHODS

All patients included in this prospective comparative randomized study were managed and followed up at Al-Azhar University Hospital. All patients were selected from the orthopedic outpatient clinic of Al-Azhar University Hospitals, Cairo, Egypt. The protocol was discussed and approved for clinical study by the Ethical Research Committee of Al-Azhar University and written informed consent was obtained. All patients were evaluated over the period from January 2019 to February 2020. All patients were followed up for 6 months.

Thirty (n=30) patients with fracture of shaft metacarpal bone were divided into 2 groups: group A (n=15) were managed by closed reduction and percutaneous fixation by antegrade intramedullary K-wires, and group B (n=15) were managed by ORIF by mini-plates and screws.

The inclusion criteria comprised adult patients (≥18 years old) with recent closed fractures of shaft of any medial four metacarpal bones (Transverse, oblique, and spiral fractures) with angulation of more than 30^{o} or with a shorting of more than 2 mm or rotational deformity and we excluded pathological fractures, contaminated compound fractures, fractures with bone loss, thumb metacarpal fractures, stable undisplaced fractures, old fractures and fractures with Intra-articular extension.

Clinical assessment was based on the hisrory taking in the form of the patient's name, age, gender, hand dominance, medical diseases, special habits of medical importance, time and mechanism of trauma and complaints of the patients (Pain. Swelling. Limited range of movement. Paraesthesia). The patient was fully examined systematically for any other associated injuries and locally for checking the initial deformity (angulation, rotational malformation), the rest of the hand skeleton, skin condition, the intensity of the edema and neurovascular examination. Below elbow extended slab was done for all patients. Elevation of the limb with analgesics, anti-edematous measures were recommended until the operation.

Radiographic evaluation: Anteroposterior view, Lateral view, and Oblique view.

Surgical technique:

The operations were done under brachial anesthesia or general anesthesia and the position of the patients was supine with affected limb on side table. Prophylactic intravenous antibiotic was given preoperatively.

Fixation by Mini-plates (Figure 1,2):
After inflation of the pneumonic tourniquet and sterilization, a direct skin incision is made at the ulnar border of the 5th MCB and the radial border of the 2nd MCB. A longitudinal incision is made between the 3rd and 4th metacarpal rays for exposure of 3rd and 4th MCB fractures. Then dissection of subcutaneous tissue with identification and preservation of superficial nerves and veins. Then retraction of extensor tendons. The periosteum over the fracture is elevated. Then fixation of the fracture by mini-plates and screws which placed on either the dorsal or the lateral surface of the metacarpal bone. Tourniquet is deflated with proper hemostasis and then skin closure. Then below elbow extended slab is applied dorsally and finger motion exercises were encouraged. Sutures are removed within 14-16 days.

Figure 1: skin incision and exposure of 5th MCB fracture

Fig. 1: show plate fixation of 5th MCB fracture and skin closure

Fixation by Percutaneous K-wires (Figure 3,4):
Skin incision about 1 cm is done over the base of each metacarpal under direct fluoroscopic image then the base of the fractured metacarpal bone is perforated by drilling in a nonarticular area directed to medullary canal. Prepared K-wire is introduced antegrade in the proximal fragment using a T handle. At the fracture site, the reduction done by Jahss maneuver.[15] Then K-wire is inserted in the distal fragment, then rotated 180 degrees to keep the bent distal end of the wire directed volarly to maintain reduction, correct volar angulation, and achieve three-point fixation. The thickness of the K wire is ranged from 1.6 to 2.0 mm. One or Two K wires are used which gave more rotational and angular stability. The proximal part of the wire is bent and keep out to be removed later on. The wound was closed with stitches.

Figure 3: skin incision and penetration of base of 3rd MCB by drill under the image

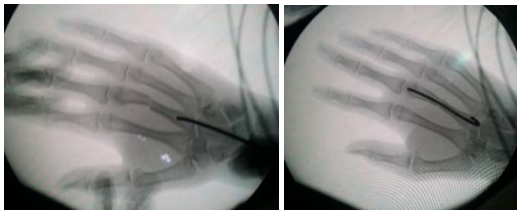

Figure 4: insertion of K wire using T handle

Postoperatively, a below elbow extended slab in the intrinsic-plus position was applied for all the patients and encouraged to start active and passive exercises for fingers within the splint. Five weeks postoperative or when there were radiological signs of bone healing, the wires were removed and patients were advised to do wrist and finger motion exercises without a splint.

Statistical analysis:

Data were analyzed by the Statistical Program for Social Science (SPSS) version 24. Expression of quantitative data was as mean± standard deviation (SD). Qualitative data were expressed as frequency and percentage and The following tests were done:

Independent-samples t-test of significance used when comparing two means, Mann–Whitney U test used when comparing two means (for abnormally distributed data), Chi-square test was used when comparing non-parametric data and probability (P-value): P-value < 0.05 was considered significant and P-value > 0.05 was considered insignificant.

The sample size was calculated using the following formula:

$$N = (Z / \Delta)^2 \times P (100 - P)$$

Z: a percentile of slandered normal distribution determined by 95% confidence level = 1.96.

Δ: the width of the confidence interval = 12

P: the prevalence of disease = 10% of all fractures

$$N = (1.96/12)^2 \times 10 (100 - 10) = 24 \text{ patients}$$

Patients were randomized in blocks of three to receive either K wire fixation or mini-plate fixation. Randomization, data entry, storage, and processing were performed using a web-based electronic data capture (EDC) system.

Figure 5: Male patient 20 yrs old with RT 5th MCB fracture. Images show preoperative facture, k-wire fixation, after healing and range of motion.

Figure 6: Male patient 24 years old with RT 4th MCB fracture. Images show preoperative facture, k-wire fixation, after healing and range of motion.

RESULTS

Fifteen patients were managed K wire, and 15 were managed by mini-plate. All patients had a fracture of a single metacarpal bone. Non-patients involved in the study were diabetic, hypertensive nor having other debilitating diseases. Summary of the demographic data is detailed in Table 1 and assessment was done according to Q. DASH score, TAF score, grip strength (Figures 5 and 6).

Results as regards Quick DASH Score, TAF score, and handgrip

The grip strength measured at third months after fixation using a manual dynamometer and compared to the normal hand. It ranged from 70-95% in group A and 70-98 %. The grip strength was nearly equal in both groups(P=0.713). The TAF score of studied patients ranged from 200 - 260 with no significant difference between the two groups except 1 patient in group B with his score of about 170. There was no statistical significant difference between studied groups as regard hand grip %, quick DASH score & TAM score (P-value: 0.74).

Results as regards union time

Although all fractures eventually healed (except one case in the miniplate group), the plate fixation group had a longer time for radiological union (8 – 12 weeks) when compared with the Kirschner wires group (4 – 8 weeks). There was a statistically significant difference (p-value < 0.05) between studied groups as regard union time (P-value: 0.001).

Result as regards operative time

Percutaneous K. wire fixation under fluoroscopic imaging (despite its radiological hazards) had a shorter operative duration than with ORIF by mini-plates with highly statistically significant difference (p-value < 0.001) between studied groups.

Results as regards complication

There was no statistically significant difference between studied groups as regard complications.

Final Results

It was found that after 6 months of follow up, group A showed 93 % satisfactory results, while group B showed 85 % satisfactory results with a total result of 90% satisfaction for all cases with no statistically significant difference (p-value > 0.05) between studied groups as regard total result.

Table (1): summary of demographic data

		K wire group	Plate screw group
Age , years (range)		19-58	19-55
Sex	**Male**	13	14
	Female	2	1
Occupation	**Manual worker**	7	8
	Student	3	3
	Teacher	1	1
	Housewife	1	0
	Driver	3	3
Hand dominance		RT handed	RT handed
Side of fracture	**RT**	10	11
	LT	5	4
Site of fracture	**Index finger**	5	3
	Middle finger	3	2
	Ring finger	3	5
	Little finger	4	5
Shape of fracture	**Transverse**	9	8
	Oblique	3	5
	Spiral	3	2

Table (2): Comparison between studied groups as regard Quick DASH score, TAF, and handgrip

		Group I (N = 15)	Group II (N = 15)	Stat. test	P-value
Handgrip %	**Median**	92	92	MW = 103.5	0.713 NS
	IQR	85 – 95	85 – 95		
Quick DASH score	**Median**	3	4	MW = 80	0.187 NS
	IQR	2 – 6	3 – 8		
TAF score	**Median**	250	250	MW = 104	0.744 NS
	IQR	240 – 255	235 – 260		

Table (3): comparison between studied groups as regard union time.

		Group I (N = 15)	Group II (N = 15)	Stat. test	P-value
Union time (weeks)	**Median**	6	10	MW = 35.5	0.001 S
	IQR	4 – 8	8 – 12		

Table (4): comparison between studied groups as regard operative time.

		Group I (N = 15)	Group II (N = 15)	Stat. test	P-value
Operative time (min)	**Median**	18	40	MW = 0.0	< 0.001 HS
	IQR	15 – 20	40 – 45		

Table (5): comparison between studied groups as regard complications.

		Group I (N = 15)		Group I (N = 15)		X^2	P-value
Complications	**Infection**	2	13.3%	1	6.7%	0.37	0.542 NS
	Sym. Hardware	0	0%	2	13.3%	2.14	0.143 NS
	Non union	0	0%	1	6.7%	1.03	0.309 NS
	Stiffness	1	6.7%	1	6.7%	0.0	1.0 NS
	Extensor lag	0	0%	1	6.7%	1.03	0.309 NS

Table (6): comparison between studied groups as regard total result

		Group I (N = 15)		Group II (N = 15)		Stat. test	P-value
Total result	**Poor**	0	0%	1	6.7%	X^2 = 1.14	0.767 NS
	Fair	1	6.7%	1	6.7%		
	Good	4	26.7%	3	20%		
	Excellent	10	66.7%	10	66.7%		

DISCUSSION

Undisplaced and impacted fractures of the hand with neither rotation nor angulation are considered stable.[16] On the other hand, fractures that cannot properly be aligned by manipulation and maintained by a cast or splint are unstable.[17,18]

In treating these fractures conservatively, James and Wright [19] reported less good results, while Goodman and Pfenninghaus[20] reported 66% satisfactory results.

The fixation of long bones fractures has evolved to the point where there is an emphasis on the rigid fixation with early functional use without external cast immobilization. A corresponding shift occurred in the treatment of fractures of the small bones of the hand.[21]

In the present study, percutaneous fixation of metacarpal bones with K. wires had higher satisfactory results than ORIF with mini-plates and screws but without statistical significance, where fixation by mini-plates gave 85% satisfactory results while fixation by K wires yielded 93% satisfactory results with the total result of 90% satisfaction for all cases.

It was also found that percutaneous pinning had a shorter operative time, easier operative techniques, and cosmetically better results. But it had radiological exposure hazards, less rigid fixation.

While open reduction and internal fixation with mini-set plates and screws was a technically demanding operation, higher risk of infection, longer operative time, and a higher risk of soft tissue adhesions.

As regards other author's opinions about closed reduction and percutaneous fixation by intramedullary Kirschner wire, Elmaraghy and coworkers reported 76% of cases with satisfactory results, [22] while Eaton et al. [23] reported satisfactory results in 90% of cases. Gingrass et al, reported 70% satisfactory results after intraosseous wire fixation.[24]

In the treatment of hand fractures with plate and screws, Kilbourne and Paul reported 53.3% satisfactory results,[25] Crawford reported 95.2% excellent results,[26] Segmuller and Weber reported complications in 15.1% of cases,[27] Stern et al, reported 42% complications[28] and Berman et al, reported 25% complications.[29]

Although the time of operation was shorter in the intramedullary K wire group than in the mini-plate group, the incidences of loss of reduction, penetration of metacarpal head were much higher in the K wire group. The same results were found in our study.These clinical findings are similar to those reported by the other authors.[18, 30]

In this study, transverse and spiral metacarpal fractures gave a higher proportion of excellent results than oblique fractures. These findings are similar to those reported by other authors.[31,32,33] Brown concluded that spiral fractures gave satisfactory

results, while oblique fractures had less satisfactory results.[34]

Rigid internal fixation of the metacarpal fractures allowed early active hand motion. Motion after two weeks postoperatively showed a higher incidence of satisfactory results than after one month.

Diwaker and Stothard reported better results after rigid fixation of metacarpal and phalangeal fractures.[35] He concluded that this fixation allowed earlier mobilization.

In treating fractures with open reduction and internal fixation, in addition to the resulting scar, soft tissue injury is increased and the time required for the union of the fracture is prolonged.[36] Non-union of the metacarpal and phalangeal fractures, though unusual, is not rare and their occurrence may cause discomfort or deformity in the hand or even badly impair total hand function.[37]

A non-union rate of 12% was reported by Stern et al in patients treated by plating.[28] In a series of 53 patients treated by internal fixation, Segmuller and Weber reported one case of the nonunion.[27] In the present study, non-union was encountered in one patient that was treated with mini-plate.

According to Stern et al, the major disadvantage of plate fixation is that it is necessary to increase soft tissue dissection because of the size of the plate with further devitalizing the bone on both sides of the fracture and this devitalization may create an even less favorable environment for bone healing.[28]

The main disadvantage of open reduction and internal fixation is the risk of infection.[17,18] Mostafa reported infection in 6.7% of cases.[37] Ford et al reported infection in two patients out of 36 patients.[38] In the present study, there were 3 cases of infection (infection rate 6.6%), two of which were mild pin tract infections and improved by antibiotics. Meticulous surgical technique, prophylactic broad-spectrum antibiotics seemed to be the most important factor in avoiding infection.[17]

Finally, comparative studies recommend minimally invasive techniques, specially intramedullary fixation and intermetacarpal pinning for fixation of metacarpal fractures.[39]

CONCLUSION

Percutaneous intramedullary K. wires and open reduction and internal fixation by mini-plates and are reasonable options for treating unstable metacarpal fractures where mini-plates fixation provides a rigid internal fixation that permits an early active range of motion and early good results but Percutaneous K-wire fixation has the advantages of soft tissue preservation with short operative time and short hospital stay.

Although K. wires showed higher satisfactory results than plates and screws (85% and 70% respectively), there were no significant statistical differences in the clinical outcomes using either technique. Prolonged postoperative immobilization should be avoided and patients must start an active movement as early as possible to avoid stiffness.

REFERENCES

1- Avery DM 3rd, Rodner CM, Edgar CM. Sports-related wrist and hand injuries. a review. J Orthop Surg Res. 2016; 11, 1-99 .

2- Rocchi, Lorenzo, Merendi, et al. Antegrade percutaneous intramedullary fixation technique for metacarpal fractures:a prospective study on 150 cases. Techniques in hand & upper extremity surgery. 2018; 22.3, 104-109.

3- Barnett, Richard, Richard Brodsky. Dorsally-Displaced Metacarpal Dislocation-Fracture. Journal of Education and Teaching in Emergency Medicine. 2018; 3.3

4- Kaplan, Emanuel B. Functional and surgical anatomy of the hand. JP Lippincott. 1965.

5- Howard Jr, Lot D. Fractures of the small bones of the hand. Plastic and Reconstructive Surgery. 1962; 29.4, 334-335.

6- Venkatesh, Raghavendra, Shivakumar Kerakkanavar. Functional outcome of closed metacarpal shaft fractures managed by low-profile miniplate osteosynthesis: A prospective clinical study. Journal of Orthopaedics and Spine. 2017; 5.2.

7- Brian J. Sennett. Operative Techniques in Orthopaedics. Vol 7. No 2. April. 1997; 127-33

8- Carreño, Ana, Mohammed Tahir Ansari, Rajesh Malhotra. Management of metacarpal fractures. Journal of Clinical Orthopaedics and Trauma. 2020.

9- Leibovic, S. J. Internal fixation sets for use in the hand. A comparison of available instrumentation. Hand clinics. 1997; 13.4, 531-540.

10- Bryan, B. K., E. N. Kohnke. Therapy after skeletal fixation in the hand and wrist. Hand clinics. 1997; 13.4, 761-776.

11- Pandey, R.,Soni, et al. 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. Musculoskeletal surgery. 2019; 103.1, 99-105.

12- Soni, Ashwani, Gulati, et al. Outcome of closed ipsilateral metacarpal fractures treated with mini fragment plates and screws: a prospective study. Journal of Orthopaedics and Traumatology. 2012; 13.1, 29-33.

13- Langford, Matthew A., Kevin Cheung, et al. Percutaneous distraction pinning for metacarpophalangeal joint stabilization after

blast or crush injuries of the hand. Clinical Orthopaedics and Related Research. 2015; 473.9, 2785-2789.

14- Gupta, Rajat, Krishan Kumar. A prospective study to analyse various methods of surgical fixation of metacarpal & phalangeal fractures. International Journal of Orthopaedics. 2018; 4.2, 658-663 .

15- Jahss, S. A. Fractures of the metacarpals: a new method of reduction and immobilization. JBJS. 1938; 20.1, 178-186.

16- Green DP, Rowland SA. Fractures and dislocation of the hand. In Rockwood CA,Green DP, eds fractures. 6th ed. Philadelphia, Toronto: JB Lippincott Co. 2006; 1, 823-37.

17- Grandizio, Louis C., Speeckaert, et al. Anatomic assessment of K-wire trajectory for transverse percutaneous fixation of small finger metacarpal fractures: a cadaveric study. HAND. 2018; 13.1, 86-89.

18- Barr, Cameron, Anthony W. Behn, et al. Plating of metacarpal fractures with locked or nonlocked screws: a biomechanical study: how many cortices are really necessary?. Hand. 2013; 8.4, 454-459.

19- Goodman, ml, goodman ml. Closed metacarpal fractures: a retrospective study excluding the thumb. 1980.

20- Oh, Jin Rok,Kim, et al. A comparative study of tensile strength of three operative fixation techniques for metacarpal shaft fractures in adults: a cadaver study. Clinics in orthopedic surgery. 2019; 11.1, 120.

21- Elmaraghy, MW1, Richards, et al. Transmetacarpal intramedullary K-wire fixation of proximal phalangeal fractures. Annals of plastic surgery. 1998; 41.2, 125-130.

22- Saied, A. R., M. Sabet Jahromi. Treatment of proximal phalanx fractures: transarticular pinning the metacarpophalangeal joint or cross pinning from the base of the proximal phalanx: a prospective study. European Journal of Trauma and Emergency Surgery. 2019; 45.4, 737-743.

23- Gingrass, Ruedi P., Bonnie Fehring, , et al. Intraosseous wiring of complex hand fractures. Plastic and Reconstructive Surgery. 1980; 66.3, 383-394.

24- Kilbourne, Burton C., Eudell G. Paul. The use of small bone screws in the treatment of metacarpal, metatarsal, and phalangeal fractures. JBJS. 1958; 40.2, 375-383.

25- Crawford, GARY P. Screw fixation for certain fractures of the phalanges and metacarpals. JBJS. 1976; 58.4, 487-492.

26- Monreal, Ricardo. Reconstructive surgery of the amputated ring finger. International orthopaedics. 2017; 41.8 , 1617-1622.

27- Stern PJ, Wieser MJ, Reilly DG. Complications of plate fixation in the hand skeleton. Clin Orthop Relat Res. 1987; 214, 59-65 .

28- Berman, Keith S., Rothkopf, et al. Internal fixation of phalangeal fractures using titanium miniplates. Annals of plastic surgery. 1999; 42.4, 408-410.

29- Kamath, Jagannath B., Bansal, et al. Current concepts in managing fractures of metacarpal and phalangess. Indian journal of plastic surgery: official publication of the Association of Plastic Surgeons of India. 2011; 44.2, 203.

30- Barton, N. J. Fractures of the shafts of the phalanges of the hand. Hand. 1979; 2, 119-133.

31- Strickland, J. W., JW, et al. Phalangeal fractures: factors influencing digital performance. 1982.

32- Shah, Gyanendra, Bachchu, et al. Functional outcome of Metacarpal Fracture managed with Miniplate and Screws. Janaki Medical College Journal of Medical Science. 2018; 6.1, 43-48.

33- Brown PW. The management of phalangeal and metacarpal fractures. Surg Clin North Am. 1973 Dec 53; 6, 1393-437.

34- Diwaker HN, Stothard J. The role of internal fixation in closed fractures of the proximal phalanges and metacarpals in adults. J Hand Surg Br. 1986 Feb 11; 1, 103-8.

35- Mostafa TA. Comparative study of the results of treatment of unstable shaft fractures of metacarpals and phalanges in adults by open reduction and internal fixation using tension band wiring versus ASI plates and screws. Thesis, DrChOrthAlex. Alexandria: University of Alexandria, Faculty of Medicine. 1991; 1-141 .

36- Ford, D. J., El-Hadidi, et al. Fractures of the phalanges: results of internal fixation using 1.5 mm and 2mm AO screws. The Journal of Hand Surgery: British & European Volume 12.1. 1987; 8-33.

37- Wong VW, Higgins JP. Evidence-Based Medicine: Management of Metacarpal Fractures. Plast Reconstr Surg. 2017; 140, 140e-151e.