PERCUTANEOUS FIXATION OF UNSTABLE FRACTURE MEDIAL FOUR METACARPALS

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ABSTRACT

Objectives : The objective of this study was to evaluate the clinical outcome of percutaneous fixation of unstable fracture of medial four metacarpls by kirschner wires.

Materials and Methods: In our prospective study we documented twenty cases of unstable fracture medial four metacarpals which we fixed percutaneously by k-wires and evaluated radiographic and functional outcome, with follow up for minimum 4 to 6 months in Elsahil teaching hospital during a 2 year period from january 2011 to january 2013, all patients were men with age from 16 to 58 years old. **Results:** ***Fracture union*** was achieved in19 cases (95%) at a mean of 7 weeks (6 to 8 weeks). One case was malunited and that case required revision through open reduction and internal fixation and united in 6 weeks after revision.

Conclusion: This study suggests that fixation of medial unstable four metacarpal fractures result in predictable satisfactory radiographic and functional outcome. Also, it suggests that percutaneous fixation carries no risk of damage to soft tissues.

Key Words: Metacarpal- Perctaneous-K-wire-Fracture- Fixation.

INTRODUCTION

Trauma to the hand is very common resulting in metacarpal fractures and dislocations. Fractures of the metacarpals and phalanges represent 40% of all upper extremity fractures **(1)**. Most of these injuries can be managed non-operatively, utilizing immobilization or controlled mobilization. For certain intra-articular fractures, displaced and angulated fractures, unstable fracture patterns, combined or open injuries, as well as irreducible and unstable dislocations, surgical intervention may be required for restoration of function and appearance. Intramedullary stabilization of metacarpal shaft and neck fractures is a relatively simple, cost-effective, and safe technique with good published outcomes(2).

Common causes of the fracture are falls, sporting incidents, road accidents and fighting. Any one of the metacarpals can be fractured and sometimes more than one is fractured. The little finger and thumb metacarpals are the most frequently fractured. The bone may be fractured at any point and may involve the joint at either end of the bone. The common sites for a fracture to occur are the neck of the bone (particularly the little finger metacarpal) and the base of the bone particularly the thumb, ring and little fingers (3).Anatomic structures in the hand and wrist lie in close proximity to each other and are critical for precise functioning of the upper extremity. Therefore, minimally invasive surgery (MIS) in this region of the body is of particular interest because of the desire to restore hand function as quickly as possible after a surgical procedure(4). The development of implants and surgical devices specific to minimally invasive techniques for metacarpal and proximal phalangeal shaft fractures as flexible prebent intramedullary nails can be inserted through a small incision at the base of the bone dorsally avoiding the major neurovascular structures in the wrist and hand which are located volarly also avoiding volar tendons of the wrist and hand. Only it needs some surgical skills of the surgeon to avoid injury of dorsal tendons(5).

MATERIALS AND METHODS

In our prospective study we documented twenty cases of unstable fracture medial four metacarpals which we fixed percutaneously by k-wires at Elsahil teaching hospital and evaluated radiographic and functional outcome, with follow up for minimum 4 to 6 months during a 2 year period from january 2011 to January 2013. The youngest patient in this study was 16 years old and the eldest patient was 58 years old. All patients were males. All patients were right handed. Right side was affected in 16 and left side was affected in 4**.** Mode of trauma was fall on hand either during work, daily activity or participating in sports in sexteenth patients, direct trauma as fall of heavy object on the hand in two patients, and road traffic accidents(RTA) in two cases. We do standard lateral and posteroanterior (PA) or anteroposterior (AP) X-rays. If we don't clearly see fracture pattern we do semisupinated view for fourth and fifth metacarpals, semipronated view for second and third metacarpals in 30 degrees**. Associated injuries are,** ipsilateral distal radius fracture was present in 1 case, scaphoid fracture was present in1case, hamate fracture was present in1case._Twenty cases were classified according to site of fracture, two cases at bases(one at base of 5^{th} metacarpal,and the other case at bases of2nd,3rdand 4^{th} metacarpal bones), 12cases at

shaft(1case at shaft of 5th ,2cases at shaft of 2nd,3cases at shaft of 2nd and 3rd,3 cases at shaft of 3rd ,4th,5th,and 3cases at shaft of 4th and5th metacrpals) 6 at neck of 2nd ,3rd and 5th metacarpal bones, and one with fracture-dislocation(scaphoid,distal end radius).

Treatment:

Indications for operative treatment include the following:

- Failure to achieve or maintain acceptable reduction using closed techniques
- Open fractures
- Multiple hand fractures
- Complex injuries
- Displaced intra-articular fractures
- Fractures with severe soft-tissue loss requiring a stable skeleton
- Multifragmentary (comminuted) fractures

Short oblique and spiral malrotated fractures **(6).** In our cases metacarpal shaft fractures are fixed with KW due to failure to correct angulation, malrotation or shortening by conservative treatment.Also metacarpal base fracture tends to be unstable and closed reduction and percutaneous pinning can be considered. Also,metacarpal neck fractures especially of the index and middle fingers because residual angulation and volar prominence of the metacarpal head may adversely alter grip patterns, so near anatomic reduction is preferred.

Surgical Technique:

At operation room , the patient lies in supine position with abducted shoulder 90 degrees and the hand on radiolucent table using C-arm image and arm tourniquet in all patients. We used Bier block in 5 patients, wrist block in 10 patients, and general anesthesia in 5 patients.

We manipulate the fracture and check reduction under fluoroscopy. When we achieve fracture reduction, we hold it with the use of fracture reduction forceps over the intact skin. We fix the fracture percutaneously by K-wires with the size of 0.045 inches.

Metacarpal Neck (Boxer's Fracture):

We use JahssS1938(7) maneuver(Fig 1a)to fix the fractured metacarpal head to the next closest intact metacarpal head using one K-wire transversely and two k-wires to fix the metacarpal shaft to the next nearby metacarpal shaft .

Fig. (1a): Jahss maneuver. MP and IP joints flexed to 90°; the proximal phalanx can be used to push the metacarpal head back into position **(8)**.

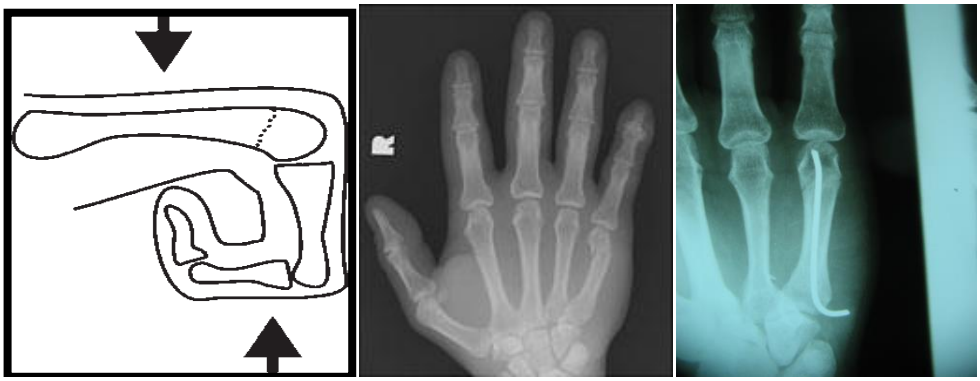

Fig.1 a b preop. b postop.

or use Bouquet technique(9) byinserting k-wire from base of fifth metacarpal through a small incision to pass intramedullary through fracture site reaching the metacarpal head(Fig1b) pre and post operative fixation.

Metacarpal Shaft Fractures:

We achieve fracture reduction by flexing the MP joint to 90 degree to tighten the collateral ligaments and use the proximal phalanx to control the distal fragment as joystick. We use towel clamp to help in rotational reduction. We fixed a case with crossed pins introducing them laterally at the retrocondylar fossa of the metacarpal head and drilling obliquely to the opposite cortex (Fig 2). We fixed another case; by inserting one K wire intramedullary from head and another one transversely from the fractured metacarpal into an adjacent intact metacarpal using the intact metacarpal as a splint(Fig 3-4-5).. The hand is then splinted in the safety position. Then we remove K-wires at three to four weeks.

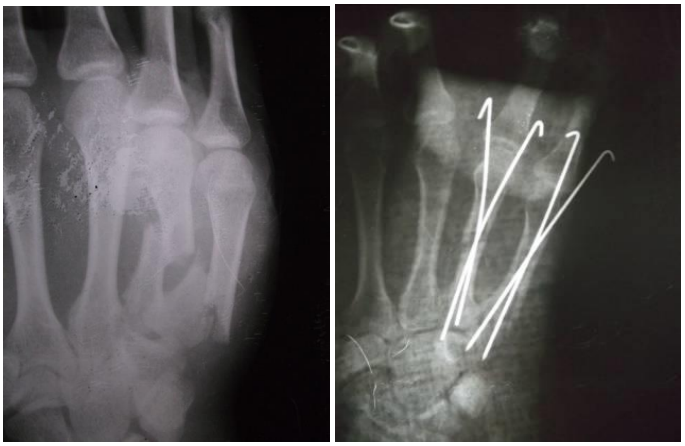

Fig. (2): fracture shaft fourth and fifth metacarpals pre and post- operative.

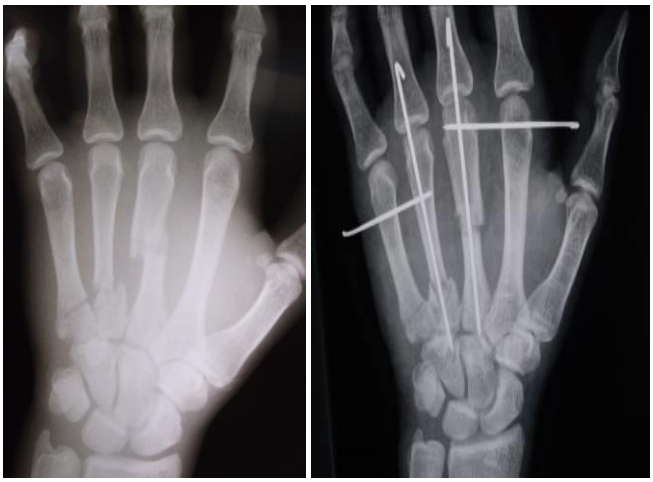

Fig. (3) fracture shaft third and base fourth and fifth metacarpals pre and post- operative.

Fig.(4) fracture shaft 2nd MCB preop, postop,and follow up8 weeks.

Fif,(5) fracture 3rd 4th and 5th MCBs pre,postop,and follow up8 weeks.

Fifth Metacarpal Base Fracture (Baby Bennett's):

We do the reduction by longitudinal traction and medially and volarly directed pressure on the base of the fifth metacarpal. We insert the wires into the fifth metacarpal shaft to the fourth metacarpal shaft. Then we use an obliquely oriented pin to fix the fifth metacarpal base to the hamate. We then place the hand in an ulnar gutter splint for 7 to 10 days. If satisfactory alignment is maintained, protected active ROM can then be initiated. We remove pins at three to four weeks. (Fig6-7).

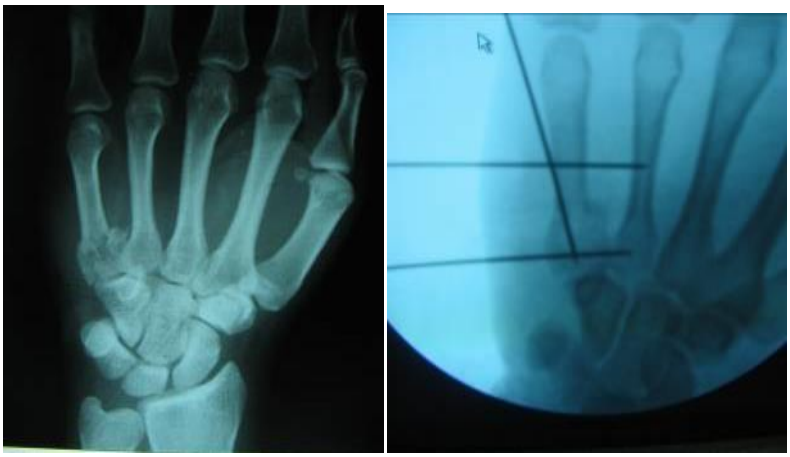

Fig. (6) fracture base fifth metacarpal pre and intra- operative.

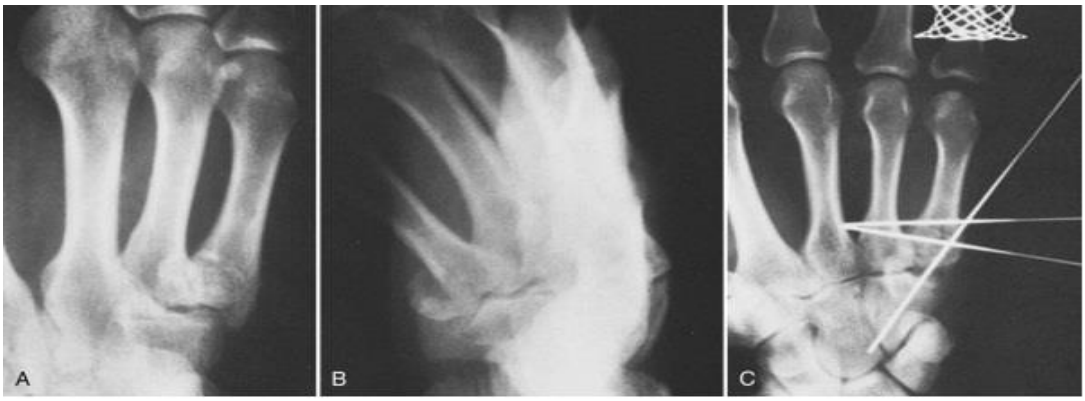

Fig. 7- A) Intra-articular fracture of base of fifth metacarpal with proximal and dorsal subluxation of CMC joint. B) Oblique view taken with hand pronated 30 degrees from fully supinated position shows extent of intra-articular injury. C) Reduction was obtained by longitudinal traction and lateral pressure on displaced bone. Firm fixation with transarticular pin and transfixation pins into adjacent metacarpal allowed early motion **(10).**

Second to Fourth Metacarpal Base Fractures:

Fig. (8): patient presented with RTA producing second,third and fourth metacarpals bases fracture associated with distal radius fracture fixed by percutaneous K wires.

The middle ray is the key to reduction so, we start to reduce first.We do longitudinal traction;followed by palmar translation to reduce the joint,and then we insert a longitudinal wire down the metacarpal throught theMPinto the distal carpal row (Fig8).

Post-operative follow up:

In majority of types of metacarpal fractures we put the hand in an intrinsic plus position splint (80° metacarpophalangeal joint flexion and full interphalangeal joint extension) to avoid tightening of the collateral ligaments and digital stiffness for 7 to 10 days.

In case of satisfactory alignment and stable fixation, we allow the patient for protected active ROM immediate post operative to avoid stiffness of MCP and IP joints.

We need series x ray follow up every two weeks for the first six weeks postoperative then every one month till radiographic union occurs.

We remove pins at four weeks in case of buried pin or non buried pin with pin tract infections.

We continued physiotherapy for two months and till the patient gets satisfactory hand function We assess the hand function three months post operative and when the patient finishes physiotherapy by using **Total Active Motion score** and **Questionnaire** and **Quick Dash score(11).**

RESULTS

In our study we treated twenty cases of unstable fracture medial four metacarpals by percutaneous K wires in Elsahil Teaching Hospital. After obtaining the personal data which included age, sex, occupation, hand dominance, exact address and telephone number for arrangement of the follow up visits; patients were inquired for the mechanism of injury and were clinically assessed and revealed the following: Swelling at the MCP was present in 10 cases, swelling at the dorsal aspect of the hand was present in 9 cases, shortening of the 5th ray and dorsal dislocation of the 5th metacarpophalangeal joint was present in one case.

There was no muscle wasting or scars of previous operations at both upper limbs. Tenderness at the anatomical snuff box was present in 1 patient due to associated fracture scaphoid.One patient was associated with distal radius fracture, one patient was associated with scaphoid fracture and one patient was associated with hamate fracture they were fixed by percutaneous K wires.

The results are analysed and revealed the following:*Fracture union* was achieved in 19 cases (95%) at a mean of 7 weeks (6 to 8 weeks).One case was malunited and that case required revision through open reduction and internal fixation united in 6 weeks after revision.*We analyzed the patients for the **functional outcome** using.*

Quick DASH DISABILITY score(11):By increasing the score means that the disability increases. One patient was recorded score 50; despite radiographic nonunion and loosening around the k-wire, the patient was asymptomatic with normal function and unrestricted use.One patient was recorded score 75; in spite the sound union of the metacarpal and normal alignment, moderate symptoms and restriction of wrist flexion persisted due to associated distal radius fracture.Two patients were recorded score 25; with sound union normal alignment, normal function and unrestricted use but occasional pain and discomfort without radiographic abnormality.Sixteen patients recorded score 0; with sound union, no deformity normal function, unrestricted use athepatients were asymptomatic.We recorded previous scores at the last visit after finishing physiotherapy.

Table (1): Resume of cases of the study.

Case	Sex	Age	Occupation	Injury	Fracture site	Time to Union (weeks)	Follow up period (months)	TAM	Quick-Dash Disability score	Affected hand (dominance)	Associated injury
1	M	26	Student	RTA	Shaft	8	6	150	50	D	DR
2	M	28	Driver	Fall	Neck	No union	6	80	75	D	
3	M	16	Student	Fall	Neck	6	6	100	0	ND	
4	M	25	Student	Fall	Neck	8	5	120	0	D	
5	M	58	Car technician	Fall	Shaft	8	4	120	0	ND	
6	M	40	Plumber	Fall	Base	8	5	140	0	D	
7	M	40	Car technician	Fall	Shaft	8	6	100	0	D	
8	M	23	Student	Fall	Neck	7	4	90	0	D	
9	M	32	Electrician	Fall	Shaft	8	5	70	0	D	
10	M	21	Car technician	Direct	Shaft	8	6	110	0	D	
11	M	19	Student	Fall	Neck	6	4	150	0	D	
12	M	20	Student	Fall	Shaft	8	5	150	25	ND	
13	M	20	Student	Fall	Shaft	6	5	160	0	D	
14	M	22	Carpenter	Direct	Shaft	8	5	160	0	ND	
15	M	23	Car technician	Fall	Shaft	7	4	150	25	D	
16	M	21	Farmer	RTA	Shaft	7	6	150	0	D	Scaphoid
17	M	24	Carpenter	Fall	Neck	8	5	150	0	D	
18	M	31	Driver	Fall	Shaft	8	4	120	0	D	
19	M	45	Accountant	Fall	Fracture dislocation	8	4	110	0	D	Hamate
20	M	46	Plumber	Fall	shaft	6	5	150	0	D	

M: male; D: dominant; ND: non-dominant; DR: distal radius;
TAM: total active motion.

Table(2)-.(QuickDASH SCORE

QuickDASH

Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new jar.	1	2	3	4	5
2. Do heavy household chores (e.g., wash walls, floors).	1	2	3	4	5
3. Carry a shopping bag or briefcase.	1	2	3	4	5
4. Wash your back.	1	2	3	4	5
5. Use a knife to cut food.	1	2	3	4	5
6. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	1	2	3	4	5

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A BIT	EXTREMELY
7. During the past week, *to what extent* has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups?	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
8. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem?	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. *(circle number)*	NONE	MILD	MODERATE	SEVERE	EXTREME
9. Arm, shoulder or hand pain.	1	2	3	4	5
10. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
11. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? *(circle number)*	1	2	3	4	5

*Quick*DASH DISABILITY/SYMPTOM SCORE = $\left(\left[\frac{\text{(sum of n responses)}}{n}\right] - 1\right) \times 25$, where n is equal to the number of completed responses.

A *Quick*DASH score may not be calculated if there is greater than 1 missing item.

DISCUSSION

Hand fractures can be complicated by deformity from no treatment, stiffness from overtreatment, and both deformity and stiffness from poor treatment. **(12)**. Today, most of these fractures can be successfully managed by nonoperative techniques**.** Certain fractures require operative fixation. Selection of the optimal treatment depends on many factors, including fracture location (intra-articular versus extra-articular), fracture geometry (transverse, spiral or oblique, comminuted), deformity (angular, rotational, shortening), whether the fracture is open or closed, whether osseous and soft tissue injuries are associated, and intrinsic fracture stability. Additional considerations include the patient's age, occupation, and socioeconomic status; the presence of systemic illnesses; the surgeon's skill; and the patient's compliance.

Percutaneous pinning of metacarpal fractures is a useful technique for injuries those are unsuitable for closed reduction and cast immobilization and that do not demand open reduction. Soft tissue dissection and swelling is minimized with percutaneous pinning. One limitation is that motion exercises are often delayed due to immobilization and sometimes cannot be started until the K-wires are removed. However, for many patients, percutaneous pinning can minimize complications and provide excellent results **(13).**

In several reports, plate and screw fixation of metacarpal shaft fractures have shown satisfactory results. (**14)** reported multiple complications of metacarpal fracture plating, however, including malunion, nonunion, and stiffness (articular and tendon adhesions). Complications were more frequent when there was associated bone loss, soft tissue injury, and open fractures. Fusetti and colleagues assessed 81 patients treated with plate fixation and reported complications in 28 (35%). Complications included difficulty with fracture healing (15%), stiffness (10%), plate loosening or breakage (8%), complex regional pain syndrome, and infection. In another study, Fusetti and Santa reported significant correlation between a transverse fracture pattern and nonunion when treated with plate fixation **(15).**

The Kirschner wire(Foucher "bouquet" osteosynthesis 1995)can be safely used to reduce and stabilize metacarpal fracturesand is based on Ender's flexible intramedullary pinning **(16).** In the metacarpal, it combines the known benefits of intramedullary implants with minimal iatrogenic soft tissue trauma. They have modified this technique using a single wire of adequate diameter which is pre-bent to act as an elastic support. With the elastic pre-bent wire acting as a three point fixation, adequate stability is achieved to commence early mobilization. With minimal soft tissue dissection, avoidance of periosteal stripping and flexible fixation as opposed to rigid fixation; abundant periosteal callus is generated encouraging fracture healing **.** In addition this procedure is relatively simple, with reduced operating times, minimal radiation exposure and can be performed as day case surgery thereby reducing hospital costs **(17).**

Foucher reported excellent results with the use of "bouquet" osteosynthesis in the management of displaced small finger metacarpal neck fractures. The fracture is reduced in closed fashion; a hole is made in the proximal ulnar metaphysis of the metacarpal; and three blunt pre-bent Kirschner pins are passed antegrade down the medullary canal, across the fracture, and into the subchondral bone of the metacarpal head. This antegrade fixation technique has the advantage of avoiding the fracture site, but it can be technically difficult, and pins can migrate either proximally or distally **(9)**. Using a similar antegrade intramedullary Kirschner wire fixation technique, Kelsch and Ulric reported satisfactory 1-year radiographic and functional results in 35 patients. The fractures were immobilized for 2 to 6 weeks, depending on patient compliance (18).

Multiple CMC dislocations are high-energy injuries that nearly always require ORIF. Lawlis and Gunther reported on 20 patients, reduction with Kirschner pin fixation was recommended,but open reduction is necessary only if closed reduction is unsuccessful**(19).**

Bora and Didizian called attention to a potentially disabling intra articular fracture at the base of the fifth metacarpal. If the injury is not reduced properly, a malunion may result in weakness of grip and a painful joint. The joint consists of the base of the fifth metacarpal articulating with the hamate and the adjoining fourth metacarpal. The extensor carpi ulnaris tendon attaches proximally to the fifth metacarpal dorsal base. The joint permits approximately 30 degrees of normal flexion and extension and the rotation necessary in grasp and in palmar cupping. This displaced intraarticular fracture might be compared with a Bennett fracture because the pull of the extensor carpi ulnaris has a great tendency to displace the metacarpal shaft proximally, similar to the thumb metacarpal displacement in a Bennett fracture by the abductor pollicis longus. In addition to the routine anteroposterior and lateral views, a radiograph should be made with 30 degrees of pronation to give a better view of the articular surface for accurate diagnosis. This

fracture often can be reduced by traction and percutaneous pinning and is then protected by a cast. Fractures that are not recognized early and are healing in a displaced position should have a correction osteotomy of the malunion or resection arthroplasty (**20).**

In our study, 20 patients within14 after trauma were fixed percutaneously by K wires and followed up for a within 4-10 months (average, 7months). All patients were men with an average age of 30 years. According to site of fracture one at base 12 shaft 6 neck and 1 fracture dislocation CMC .Mostofthefracturesoccurred inyoungmenwhowantedtousetheir handsearly.Thestudentsinthisstudyhadtooperateco mputers ordesiredto participateintheirexams.Patientsrefused toimmobilizethewristforlong periodsbecause oftheeconomic impact.Inthisstudynoimmobilizationwas usedforisolatedmetacarpalfractures,whichenabledt hepatienttoreturnto workearlier.Thisstudyhasshown thattherewerenocomplications relatedto soft tissue estripping and instability at aminimum ofa4-monthfollow-up period. Even withacuteunstable fractures, thismethodisconsideredan effectivealternativetoopentechniques.Closedreduct ion underimage intensifierwasanexcellenttechniqueforanatomicred uctionwithoutsoft tissuedissection. Theaveragetimeforreturntoschoolorworkinisolated metacarpalfracturesinourserieswas7daysandtheave ragetimefor clinical unionwas 5 weeks. Percutaneousfixationusinga k wiresisareliablemethodforunstable medial four metacarpalfractures, whichenables patientstousetheirhandsearlierwithhighsatisfaction and minimumcomplications. Minimal invasive surgerywith minimalsurgical traumatosofttissueis consideredtobethe keytoa successfuloutcome, as in the study of Galanakis et al **(13).** In majority of our cases no residual stiffness was found after full rehabilitation as the patient start early active and passive ROM, especially in manual hand workers.

The study does not focus on a special type of fracture or compare between specific methods of fixation. Majority of our study cases were fixed by intramedullary wires through MCP based on the work of Hopfner et al **(21),** resulted in temporary stiff MCP (and delay of the patient return to work) but this problem disappear completely after rehabilitation.

Although transfixing method produce minimal stiffness post operative, but it may result in shortening of metacarpal as reported in the study of Hopfner et al **(21),** so that combined intramedullary and transfixing may be better than transfixing method.

Although majority of metacarpal fracturescouldbefixedthroughtheMCP jointthe our studyrecommends touseany technique of wire fixation but to be away from MCP joint to allow fracture fixation with free MCP joint, extensor expansion and wide ROM for MCP and interphalangeal joint immediate post operative thus avoiding their stiffness.

CONCLUSION

The purpose of this prospective study is to document that the percutaneous fixation technique of medial unstable four metacarpal fractures result in predictable satisfactory radiographic and functional outcome. Also, it suggests that percutaneous fixation carries no risk of damage to soft tissues.

REFERENCES

1- Downing ND; Davis TR Department of Trauma and Orthopaedic Surgery, Queen's Medical Centre, University Hospital, Nottingham NG7 2UH, United Kingdom. nicholas.downing@qmc.nhs.uk Hand Clin. 2010; 26(2):169-77 (ISSN: 1558-1969)

2 Balaram AK; Bednar MS Department of Orthopaedic Surgery and Rehabilitation, Stritch School of Medicine, Loyola University - Chicago, Maguire Center, Suite 1700, 2160 South, 1st Avenue, Maywood, IL 60153, USA. Hand Clin. 2010; 26(2):169-77 (ISSN: 1558-1969)

3 Orbay J. Intramedullary nailing of metacarpal shaft fractures. Tech Hand Up ExtremSurg 2005; 9(2):69–73.

4 Lorgelly PK, Dias JJ, Bradley MJ, Burke FD: Carpal tunnel syndrome, the searchfor acost-effective surgical intervention: arandomised controlled trial. Ann RColl Surg Eng 2005; 87(1):36–40.

5- Vella JC, Hartigan BJ, Stern PJ. Kaplan's cardinal line. Hand Surg [Am] 2006; 31(6):912–8.

6- Jesse B. Jupiter, Terry S.: Axelrod, Mark R. Belsky, Skeletal Trauma, 4th ed. W. B. Saunders Company 2008.

7- Jahss S.: Fractures of the metacarpals: a new method of reduction and immobilization. J Bone Joint Surg Am 1938;20A:178-186.

8- John T. Capo, Virak Tan.: Atlas Of Minimally Invasive Hand And Wrist Surgery, 2008.

9- Foucher G: "Bouquet" osteosynthesis in metacarpal neck fractures: a series of 66 patients. J Hand Surg Am 1995, 20(3 Pt 2):S86-90.

10- Wolfe Scott W, A. Bobby Chhabra, Brian D. Adams, Julie E. Adams, David A.: Green's Operative Hand Surgery, 6th ed 2010 Churchill Livingstone, An Imprint ofElsevier

11-Quickdashscore.www.orthopaedic-score.com/scorepages/disabilities_of_arm_schoul

der_hand-score_quickdash.htm .
12- Swanson AB: Fractures involving the digits of the hand. Orthop Clin North Am 1970; 1:261-274.
13-Wong TC, Ip FK, Yeung SH.: Comparison between percutaneous transverse fixation and intramedullary K-wires in treating closed fractures of the metacarpal neck of the little finger. J Hand Surg [Br] 2006; 31(1):61–5.
14- Page SM, Stern PJ: Complications and range of motion following plate fixation of metacarpal and phalangeal fractures. J Hand Surg Am 1998, 23(5):827-32.
15- Fusetti C, Meyer H, Borisch N, Stern R, Santa DD, Papaloïzos M.: Complications of plate fixation in metacarpal fractures. J Trauma 2002; 52(3):535-539 .
16- Liew KH, Chan BK, Low CO: Metacarpal and proximal phalangeal fractures–fixation with multiple intramedullary Kirschner wires. Hand Surg 2000, 5(2):125-30.
17- Galanakis I, Aligizakis A, Katonis P, Papadokostakis G, Stergiopoulos K, Hadjipavlou A.: Treatment of closed unstable metacarpal fractures using percutaneous transverse fixation with Kirschner wires. J Trauma 2003; 55(3):509–13.
18- Kelsch G, Ulrich C: Intramedullary K-wire fixation of metacarpal fractures. Arch Orthop Trauma Surg 2004; 124:523-526.
19- Lawlis JF and Gunther SF.: Carpometacarpal dislocations. Long-term follow-up. J Bone Joint Surg Am 1991;73A:52- 59.
20- Chung KC, SpilsonSV.The frequency and epidemiology of hand and forearm fractures in the United States. J Hand Surg 2001;26:908-915.
21- McKerrell J, Bowen V, Johnston G.: Boxer's fractures—conservative or operative management?. J Trauma 1987; 27:486-490

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