Surgery Article

HAND
2018, Vol. 13(2) 184–189

DOI: 10.1177/1558944717695747
hand.sagepub.com

Radiographic and Clinical Assessment of Intramedullary Nail Fixation for the Treatment of Unstable Metacarpal Fractures

Ather Mirza[1], Justin Mirza[2], Chris Healy[3], Vishaaq Mathew[1], and Brian Lee[1]

Abstract

Background: The purpose of the article was to evaluate clinical and radiographic outcomes in a case series of unstable metacarpal fractures treated with flexible intramedullary nail (IMN) fixation. **Methods:** A total of 55 patients with unstable metacarpal fractures between 2003 and 2010 were treated with IMN fixation and followed for a minimum of 1 year. The outcomes were assessed via a radiological study of longitudinal and angular collapse, Disabilities of the Arm, Shoulder, and Hand (DASH) score, total active range of motion (ROM) of the wrist, and grip strength testing. **Results:** In the 55 patients, metacarpal fractures were healed by clinical and radiographic assessment at an average of 12.7 weeks. IMNs were removed in all cases at an average of 13.9 weeks. Patients regained full finger ROM at the final follow-up and were capable of 72.4% of motion at 2 weeks postoperatively. The mean DASH score at the final follow-up was 6.5. Complications included 3 cases of extensor tendon irritation that resolved without functional impairment and 2 cases of "backing out" that required reoperation to replace the pin. In one case, a bony exostosis formed on the affected metacarpal that led to tendon irritation and required operative excision. **Conclusions:** We found that this technique allowed for the stabilization of fractures, early ROM, resumption of usual activities, reduced immobilization, and minimal complications. A removable orthosis, instead of a cast, allowed for earlier mobilization of the wrist, metacarpophalangeal, and proximal interphalangeal joints.

Keywords: closed reduction, early range of motion, intramedullary fixation, metacarpal

Introduction

Fractures of the metacarpals account for nearly 36% of all hand fractures.[8,19] Although many metacarpal fractures can be treated through nonsurgical means, unstable metacarpal fractures cannot be reduced or maintained in an anatomic or near anatomic position without implant fixation when the hand is placed in the safe or functional position.[3] Fractures involving multiple metacarpals may have less surrounding stabilizing forces. This is due to deforming muscle forces, compromise of the anatomic stability provided by the adjacent transverse intercarpal ligaments, and comminution of the volar cortex.[10,19]

Agreement on the optimal surgical treatment modality for unstable metacarpal fractures has yet to be established. Among the current surgical treatment options for unstable or multiple metacarpal fractures are flexible intramedullary nail (IMN) fixation, transverse or cross K-wire pinning, conventional open reduction and internal fixation (ORIF) using screws and mini-fragment, and low-profile plates. Regardless of the method of fixation used, the goals of treatment remain the same. Stable fixation minimizes the extent and period of immobilization allowing for early rehabilitation and effectively facilitating early resumption of usual activities.

Originally, Lord and Pfeiffer performed retrograde intramedullary pinning of metacarpal fractures through a flexed metacarpophalangeal (MCP) joint.[9,16] Although minimally invasive, this involves a period of fixed positioning of the MCP joint and extensor mechanism. Later, Foucher introduced an antegrade method of inserting multiple prebent K-wires into the metacarpal, commonly known as

[1]North Shore Surgi-Center, Smithtown, NY, USA
[2]Stony Brook Orthopedics, East Setauket, NY, USA
[3]North Shore University Plainview Hospital, NY, USA

Corresponding Author:
Ather Mirza, North Shore Surgi-Center, 987 West Jericho Turnpike, Smithtown, NY 11787, USA.
Email: amirza@amsurgical.com

the "bouquet" technique.[2] After several modifications and variations of the "bouquet" technique, a flexible locked or unlocked IMN was described for metacarpal fractures.[6,12] Plate and screw constructs can provide rigid fixation and anatomic reduction of the fracture, but at the expense of soft tissue dissection and resultant extensor tendon adhesions and scarring.[5,15] In an effort to avoid the aforementioned complications, an IMN of metacarpal fractures is minimally invasive, minimizes soft tissue dissection, and provides stable fixation.[12] The aim of this study is to report on the clinical and radiographic outcomes of patients treated with IMNs for unstable metacarpal fractures.

Methods

Demographics and Patient Presentation

Between July 29, 2003 and July 2, 2010, 55 patients presented with transverse, spiral, or oblique metacarpal fractures that were deemed unstable following radiographic and clinical assessment. Metacarpal fractures were classified as unstable if acceptable reduction was not maintained at a follow-up visit following index reduction in either the emergency room or clinic. Informed consent was obtained from all participants prior to entry into the study. Exclusion criteria consisted of patients who presented with fractures of the first metacarpal and patients who received additional surgical fixations concurrent to the IMN fixation. There were 39 males and 16 females, with an average age of 33.9 years (range, 15-78 years). Information regarding the type of trauma causing the metacarpal fracture was not recorded. There were no open fractures in this series. This study was not submitted to an institutional review board as it was deemed a therapeutic level IV study.

Surgical Technique

Prior to incision, fluoroscopic guidance confirmed that the metacarpal fracture was amenable to closed reduction. Special attention was paid to the width of the medullary cavity, which in some cases can be narrow and prevent the passage of 1.2-mm or 1.6-mm IMNs. Alternatively, the wider canal of the fifth metacarpal may require more than one IMN for stable fixation. If the medullary cavity was either too narrow or too capacious, alternative fixation methods were considered. A small incision was made in the base of each fractured metacarpal, with blunt dissection carried down to the dorsal cortex. In creating exposure, the surgeon must be cognizant of dorsal sensory branches of the ulnar nerve and superficial branches of the radial nerve, over the fourth/fifth metacarpal and second/third metacarpal, respectively. A 0.062 Kirchner wire was subsequently introduced in the base of the metacarpal to make a fenestration. Next, an internal fixation device (straight, flexible stainless steel nail with a blunt, bent tip, 1.2/1.6 mm; Hand Innovations–Biomet, Warsaw, Indiana) was introduced through the fenestration and threaded through the medullary cavity under fluoroscopic guidance as the fracture is held reduced; the aim is to ensure maintenance of reduction and seating of the IMN tip into the subchondral bone of the metacarpal head to prevent chance of rotational deformity.

In patients with especially large medullary cavities, 2 IMNs were used, either a single 1.6-mm nail or a combination of 1.6- and 1.2-mm IMNs. Alternatively, in narrow medullary cavities, a 1.2-mm IMN was used and if necessary the medullary cavity was predrilled/reamed with a 1.2-mm K-wire; otherwise, an alternate form of fixation was considered. The proximal end of the nail was bent, cut, turned either to the radial or ulnar side, and buried to avoid irritation of the extensor tendons. In our experience, rotating the IMN did not make its fixation less rigid.

Postoperative Management

A removable orthosis was applied and occupational therapy began at a mean of 12 days postoperatively with active range of motion (AROM) exercises. For fractures of the metacarpal base, a short arm orthosis that freed the MCP, proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints was applied; the involved fingers were buddy splinted. For fractures of the metacarpal shaft or neck, a hand-based splint that immobilized the MCP, but freed the wrist, PIP, and DIP joints, was applied. Patients were evaluated for finger and wrist AROM at 2, 4, and 8 weeks postoperatively and at final follow-up with clinical and radiographic evaluation. Early ROM measurement was performed also to assess if early mobilization had any adverse effects on the stability of the surgically treated fractures. Strengthening exercises were commensurate with radiographic healing, typically initiated at 8 to 12 weeks postoperatively. If satisfactory healing occurred, the patients underwent removal of the IMN. Disabilities of the Arm, Shoulder, and Hand (DASH) scores and grip strength measurements were also recorded at the final follow-up.

Results

Of the 55 patients treated, 21 patients presented fractures of the metacarpal shaft, 15 patients presented fractures of the metacarpal neck, and 19 patients presented fractures of the proximal metacarpal with diaphyseal extension. Purely proximal metacarpal base fractures were treated with alternative methods of fixation, and thus were not included in this series. Eight patients presented with multiple, concurrent metacarpal fractures of the same hand, and 10 patients required 2 IMNs in the same fractured metacarpal due to the presence of large medullary cavities. Table 1 summarizes patient fracture information. The average time from injury

Table 1. Summary of Operative Results.

Total no. of fractures treated	55
Mean age, y	33.9
Gender	
Male	39
Female	16
Fractured side	
Dominant	35
Nondominant	20
Average angulation	
Preoperative	25.4° ± 16.1
Postoperative	16.3° ± 11.1
Radiographic union	13.9° ± 9.1
Fracture location	
Metacarpal base with diaphyseal extension	19
Metacarpal shaft	21
Metacarpal neck	15
Average time to union, weeks	12.7
Average removal of hardware, weeks	13.9
Postoperative fracture displacement	4

Table 2. Preoperative and Postoperative Metacarpal Lengths.

Average preoperative metacarpal length, mm	60.038
Average postoperative metacarpal length, mm	62.553
Average healed metacarpal length, mm	62.271
Average difference from preoperation to postoperation, mm	2.516
Average difference from postoperation to healed, mm	−0.283

to surgical fixation with the IMN was 7.1 days (range 0-21 days). All fractures were fully healed by radiographic and clinical assessment at an average of 12.7 weeks (range 4.6-35 weeks). Range of patient final follow-up was 7.6 to 47 weeks. The IMNs were removed from all patients at an average of 13.9 weeks. The average preoperative angulation was determined to be 22.1° apex dorsal, the average postoperative angulation was 13.8°, and the average angulation at final follow-up was 14.6°. Preoperatively, 17 patients indicated shortened metacarpals with an average length of 60.038 mm. Following surgery, all 17 patients regained 2.516 mm in metacarpal length, with minimal shortening at final follow-up (Table 2).

Postoperative recovery was assessed through hand and wrist AROM 2 weeks postoperatively and at final follow-up. Patients at 2 weeks postoperatively demonstrated 72.4% wrist ROM compared with the uninjured hand, and achieved full ROM at final follow-up (Table 3). No rotational deformities were encountered. The IMN implant used does have an additional antirotational device; however, it was not used as the bent distal end of the nail gives enough purchase in the distal metaphysis to prevent rotation. The mean DASH score at final follow-up was 6.5. Average grip strength decreased by 23.9% compared with the unaffected hand (Table 4).

Table 3. Postoperative Range of Motion.

	2 Weeks postoperative	Final follow-up	% Increase
DASH score		6.5	
Mean dorsiflexion	55.9° ± 15.9	65.3° ± 11.7	16.8
Mean volar flexion	51.4° ± 17.4	64.1° ± 14.0	24.8
Mean radial deviation	18.1° ± 5.0	22.4° ± 3.4	23.6
Mean ulnar deviation	22.4° ± 7.0	28.3° ± 6.9	26.3
Mean MCP flexion	51.4° ± 19.7	77.49° ± 17.7	50.9
Mean PIP flexion	81.9° ± 18.1	97.87° ± 17.1	31.1
Mean MCP extension	−9.6° ± 10.7	−3.7° ± 10.6	11.5
Mean PIP extension	−11.4° ± 13.8	0.5° ± 9.7	23.2

Note. PIP = proximal interphalangeal; MCP = metacarpophalangeal; DASH = Disabilities of the Arm, Shoulder, and Hand.

Table 4. Average Grip Strength.

Unaffected hand	Affected hand	% Decrease
95.6 ± 35.2	72.7 ± 30.9	23.9

Patient 52 of the study, who had a severe crush injury and considerable soft tissue compromise, presented with 3 unstable fractured metacarpals and a thumb proximal phalanx fracture, and was treated with 5 IMNs (Figure 1). He made a 63° improvement in the total active motion (TAM) of his index finger, 91° in the middle, 24° in the ring, and 52° improvement in the little finger at the final follow-up compared with his initial 2-week postoperative visit. In addition, his wrist extension beyond neutral of 52° improved by 6° and his palmar flexion, originally 44°, improved 20° postoperatively. TAM of his index, middle, ring, and little fingers at final follow-up were 276°, 276°, 254°, and 271°, respectively. Wrist extensions past neutral and palmar flexion at final follow-up were 72° and 78°, respectively (Figure 2).

Patient complications included three cases of extensor tendon irritation that resolved without functional impairment, and two cases of "backing out" that required reoperation to replace the IMN. In one case, a bony exostosis formed on the affected metacarpal that led to tendon irritation and required operative excision. We had no cases of IMN migration into the MCP joint or postoperative infection. Our overall complication rate was 10.9%, excluding the universal removal of the IMN. The IMNs were removed in the operating room in all cases after radiographic union, with average IMN removal occurring at 13.9 weeks.

Figure 1. Patient 52, presenting with multiple metacarpal fractures, and subsequently requiring multiple fixation.

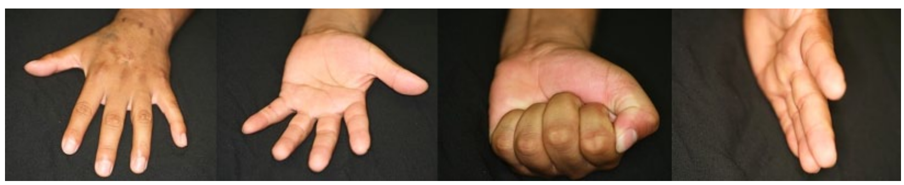

Figure 2. Patient 52's total active range of motion at the final follow-up.

Discussion

Over the years, surgical techniques and instrumentation have evolved to treat fractures. The goals remain the same: reduction followed by stable fixation, minimal soft tissue compromise, early mobilization, and early resumption of usual activities. Fractures of the metacarpal follow the same protocol; however, because the use of hands is essential in daily routines, the aforementioned goals become even more salient. Thus, the extent and period of immobilization is of utmost importance to these patients, and if possible, minimally invasive techniques are preferred with minimal trauma to the soft tissue envelope. Plates achieve higher stability with rigid fixation of metacarpal fractures and early mobilization at the expense of soft tissue compromise and potential for adhesions.[5,15] Despite this stability, the bulk of the implant and screws underlying the extensor tendon mechanism results in difficulty of rehabilitation of these gliding structures; however, this may be more significant in plate-screw (PS) of proximal phalanx fractures versus metacarpal fractures.[5,15] In some instances, it is necessary to remove the hardware, resulting in another invasive surgery and further complications. The "bouquet" wiring technique of Foucher can be used in transverse fractures but not in comminuted or spiral fractures.[2] The rigid intramedullary rod with proximal and distal locking screws, developed by Gonzalez and Hall, needed significant surgical exposure and was mainly indicated for fractures with severe soft tissue injury.[7] Previous studies have established no significant difference in radiographic healing time or clinical outcomes of patients treated with IMN fixation, PS fixation, or K-wire pinning.[4,11]

Flexible IMNs provide stable fixation of metacarpal fractures with minimal soft tissue dissection, which allows for early mobilization of the wrist and fingers with limited and removable external immobilizations. This is supported by the results of this study, as patients regained 72.4% wrist ROM 2 weeks postoperatively and full ROM at final follow-up. IMNs also allowed patients presenting shortened character to regain metacarpal length. Although our average postoperative angulation was 13.8°, we did not think this created any adverse clinical outcome, as evidenced by our postoperative ROM and DASH scores. Patient 52's outcomes demonstrate the advantages of IMN fixation for the treatment of multiple unstable metacarpal fractures. Despite the severity of his multiple metacarpal crush injury, the patient was capable of undergoing occupational therapy on a consistent basis postoperatively. He did not develop any complications. At final follow-up of 1 year, the patient exhibited excellent ROM with marginal web space contracture, in spite of the complications inherent in multiple metacarpal fractures such as adhesions, infections, prolonged recovery, and joint stiffness.

Several studies have compared the use of IMN versus transverse or cross K-wire pinning for unstable metacarpal fractures. Complications associated with percutaneous K-wire fixation include pin tract infections, limited ROM, and potential damage to the sagittal bands of the extensor mechanism with distal pin placement.[20] Moon et al examined the clinical outcomes from trans K-wire pinning versus IMN in 41 patients with a distal third metacarpal fracture.[11] In their study, in which 19 and 22 patients were assigned to either IMN or K-wire fixation, respectively, operation time was 14 minutes shorter in the K-wire group, yet the IMN group averaged a 2.3 week earlier return to work. Three of the 22 patients in the K-wire group had associated superficial wound infections, whereas none occurred in the IMN group. At 2 weeks postoperatively, the IMN group reported no discomfort and less pain when compared with the K-wire fixation group. Wong et al also compared transverse K-wire fixation with IMN of the fifth metacarpal, and found no significant difference between the 2 groups for grip strength, ROM, radiographic union, or postoperative pain.[20] However, in the retrospective study by Schadel-Hopfner et al, comparison was made between IMN and retrograde cross K-wire fixation of fifth metacarpal fractures, which resulted in a favorable outcome for IMN in MCP joint ROM, and pain.[17]

Alternatively, ORIF with PS fixation has been used to treat unstable metacarpal fractures. Ozer et al analyzed the outcomes of 52 metacarpal fractures treated with either IMN or PS in a nonrandomized prospective study.[14] Despite much shorter operative time, IMN had a poorer functional outcome than PS, with higher incidences of loss of reduction, nail penetration into the MCP joint, and extensor tendon irritation requiring nail removal. This study reported a higher incidence of complications at 13%, compared with earlier studies that reported a lower incidence rate.[13] Although the IMN group had a higher incidence of tendon irritation compared with the PS group, only patients in the PS group required tenolysis on the secondary procedure. Our complication rate of 10.9% is comparable with others in the recent literature.[18] In a more recent study comparing IMN with PS, at 3 months postoperation, patients in the IMN group were found to have better percent TAM, whereas patients treated with PS had a statistically significant advantage in grip strength.[4] However, at 6- and 12-month postoperative follow-up, no significant difference was seen between PS or IMN groups for grip strength or TAM.

With regard to the future of IMN design to optimize metacarpal fracture fixation, Boonyasirikool and Niempoog studied metacarpal geometry in 50 adult cadavers.[1] Radiographs were taken to study proximal metaphyseal width, distal metaphyseal width, isthmus width, and medullary canal width. The average medullary canal width ranged from 3.05 to 6.74 mm. Given the gradient in the width of the medullary canal and diameter of the IMN, perhaps designing a larger diameter IMN could be of further benefit to maintaining metacarpal fracture reduction. In our study, if one IMN was deemed insufficient to maintain reduction, a second IMN was used.

Patients undergoing IMN fixation commonly complained of prominence and swelling near the metacarpal base. One of the drawbacks of the procedure is the proximally bent IMN frequently causes irritation of the surrounding tissues, including the extensor tendons. If unbearable, the IMN was removed prior to clinical and radiographic fracture union. Once removed, all patients reported relief of symptoms from prominent hardware. A drawback of this procedure is the requirement for patients to undergo successive surgery for the removal of the IMN once the fracture is healed. Possibly a technological advance to avoid extensor tendon irritation at the proximal end of the nail would be the development of IMNs with a predetermined nail length, replacing the normally cut proximal end with a rounded tip which could be buried.

This study has several weaknesses and limitations. Contralateral strength testing was performed but was not used in assessing clinical outcomes. In addition, shortening of the fractured metacarpal was not assessed compared with the contralateral side. Our aim was to evaluate if further shortening occurred once the metacarpal was stabilized with the IMN, that is, was the IMN a stable form of fixation. The study was neither randomized nor blinded. In this single-surgeon case series, only the IMN method of fracture reduction was examined, limiting comparison with other fracture fixation methods such as K-wire or PS fixation.

We found IMN fixation to be a successful treatment option for metacarpal fractures requiring surgical intervention. The IMN fixation's allowance for early recovery of ROM, with minimal complications, enabled patients to optimize and expedite their functional recoveries.

Acknowledgment

The authors acknowledge Patricia Meyer for her assistance with range of motion data collection, and Alexander Pankratov and Shawn Adhya for their assistance with writing the manuscript.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 and 2008.

Statement of Informed Consent

Informed consent was obtained from all participants of the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Boonyasirikool C, Niempoog S. Locked intramedullary nail: metacarpal geometry study in adults. *J Med Assoc Thai*. 2014;97(suppl 8):S194-198.
2. Foucher G. "Bouquet" osteosynthesis in metacarpal neck fractures: a series of 66 patients. *J Hand Surg Am*. 1995;20(3, pt 2):S86-S90.
3. Freeland AE. *Hand Fractures Repair, Reconstruction and Rehabilitation*. Philadelphia, PA: Churchill Livingstone; 2000.
4. Fujitani R, Omokawa S, Shigematsu K, et al. Comparison of intramedullary nail and low-profile plate for unable metacarpal neck fractures. *J Orthop Sci*. 2012;17(4):450-456.
5. Fusetti C, Meyer H, Borisch N, et al. Complications of plate fixation in metacarpal fractures. *J Trauma*. 2002;52(3):535-539.
6. Gonzalez MH, Hall RF Jr. Intramedullary fixation of metacarpal and proximal phalangeal fractures of the hand. *Clin Orthop Relat Res*. 1996;327:47-54.
7. Gonzalez MH, Igram CM, Hall RF. Flexible intramedullary nailing for metacarpal fractures. *J Hand Surg Am*. 1995;20(3):382-87.
8. Greene TL. Metacarpal fractures. In: American Society for the Surgery of the Hand, ed. *Hand Surgery Update*. Rosemont, IL: American Academy of Orthopaedic Surgery; 1996:11-15.
9. Lord RE. Intramedullary fixation of metacarpal fractures. *JAMA*. 1957;164(16):1746-1749.
10. Low CK, Wong HC, Low YP, et al. A cadaver study of the effects of dorsal angulation and shortening of the metacarpal shaft on the extension and flexion force ratios of the index and little fingers. *J Hand Surg Br*. 1995;20(5):609-613.
11. Moon SJ, Yang JW, Roh SY, et al. Comparison between intramedullary nailing and percutaneous K-wire fixation for fractures in the distal third of the metacarpal bone. *Arch Plast Surg*. 2014;41(6):768-772.
12. Orbay JL. Intramedullary nailing of metacarpal shaft fractures. *Tech Hand Up Extrem Surg*. 2005;9(2):69-73.
13. Orbay JL, Touhami A. The treatment of unstable metacarpal and phalangeal shaft fractures with flexible nonlocking and locking intramedullary nails. *J Hand Clin*. 2006;22(3):279-286.
14. Ozer K, Gillani S, Williams A, et al. Comparison of intramedullary nailing versus plate-screw fixation of extra-articular metacarpal fractures. *J Hand Surg Am*. 2008;33(10):1724-1731.
15. Page SM, Stern PJ. Complications and range of motion following plate fixation of metacarpal and phalangeal fractures. *J Hand Surg Am*. 1998;23(5):827-832.
16. Pfeiffer KM. Advances in osteosynthesis of hand fractures. *Handchirurgie*. 1976;8(1):17-22.
17. Schadel-Hopfner M, Wild M, Windolf J, et al. Antegrade intramedullary splinting or percutaneous retrograde crossed pinning for displaced neck fractures of the fifth metacarpal? *Arch Orthop Trauma Surg*. 2007;127(6);435-440.
18. Venkatachalam S, Harrison J. Results of locked flexible intramedullary nailing of metacarpal fractures: a case series. *J Trauma Emerg Surg Eur*. 2011;37(5):519-524.
19. Wolfe SW, Elliot AJ. Metacarpal and carpometacarpal trauma. In: Peimer CA, ed. *Surgery of the Hand and Upper Extremity*. New York, NY: McGraw-Hill; 1996:883-920.
20. 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):61-65.