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# Clinical Outcomes of Limited Open Intramedullary Headless Screw Fixation of Metacarpal Fractures in 91 Consecutive Patients

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**Abstract**

**Background:** The objective of the study is to evaluate clinical and radiographic outcomes in patients treated with limited-open retrograde intramedullary headless screw (IMHS) fixation for metacarpal neck and shaft fractures. **Methods:** Retrospective review of 91 consecutive patients (79 men; 12 women), mean age 28 (range =15-69) years, treated with IMHS fixation for acute displaced metacarpal neck (N = 56) and shaft (N = 35) fractures at a single institution. Mean follow-up was 10 (range = 1-71, median = 3) months. Preoperative mean magnitude of metacarpal neck angulation was 48° (range = 0°-90°), and mean shaft angulation was 42° (range = 0°-70°). Active motion was initiated within 5 days postoperatively. Clinical outcomes were assessed with digital goniometry, grip strength, and return to full activity. The time to radiographic union and radiographic arthrosis was assessed. **Results:** All 91 patients achieved full functional arc of metacarpophalangeal (MCP) motion, and all achieved full active MCP extension or hyperextension. At mean follow-up of 10 months, postoperative mean MCP joint flexion-extension arc was 88° (range = 55°-110°). Grip strength was available for 52 patients and measured 104.1% of the contralateral hand (range = 58%-230%). Radiographic union data were available for 86 patients. Seventy-six percent (65/86) achieved radiographic union by the end of week 6 (range = 2-10 weeks). Early arthrosis was noted in 1 patient at the MCP. There were 3 cases of shaft refracture after recurrent blunt trauma, following prior evidence of full osseous union. **Conclusions:** The IMHS fixation is safe, reliable, and durable for metacarpal neck/subcapital, axially stable shaft fractures, and select delayed unions or malunions. It allows for early postoperative motion without affecting union rates and obviates immobilization. This technique offers distinct advantages over formal open reduction and percutaneous Kirschner wire techniques.

**Keywords:** metacarpal fracture, hand trauma, headless screw, intramedullary fixation, minimally invasive surgery, clinical outcome

## Introduction

Metacarpal and phalanx fractures account for 41% of all fractures in the hand and forearm.[1] Multiple approaches have been described for the treatment of displaced and unstable fractures.[2-4] Displaced metacarpal and phalangeal fractures with clinical deformity are commonly treated operatively with reduction and stabilization. The techniques described in the literature are percutaneous and limited-open antegrade (ie, bouquet pinning),[4-6] retrograde (ie, longitudinal intramedullary fixation),[7] plate fixation,[6,8-10] or transmetacarpal Kirschner wire (K-wire) pinning.[11-13] More recently, centers have described the use of limited-open retrograde intramedullary headless screw for the fixation of select metacarpal neck and shaft fractures.[13-17]

There is no consensus on ideal fixation technique for metacarpal shaft and neck fractures.[2,3,7,8,18] Fixation of these fractures with K-wires offers the advantage of limiting surgical dissection, but requires formal postoperative immobilization

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**Table 1.** Metacarpal Neck and Shaft Fractures Angulation Distribution.

| Fracture Location | Thumb | Index | Middle | Ring | Small | Total |
|---|---|---|---|---|---|---|
| Neck fractures, n | 0 | 2 | 2 | 2 | 50 | 56 |
| Mean angulation, deg (range) | NA | 40 (15-65) | 5 (0-10) | 49 (45-53) | 50 (0-90) | 48 (0-90) |
| Shaft fractures, n | 0 | 1 | 0 | 4 | 30 | 35 |
| Mean angulation, deg (range) | NA | 12 | NA | 38 (30-45) | 44 (0-70) | 42 (0-70) |

and delayed functional rehabilitation.[19-21] Open reduction with internal fixation (ORIF) aims to achieve rigid internal fixation and early postoperative rehabilitation, but complications are increasingly recognized.[5,6,9,10]

Limited-open intramedullary headless screw (IMHS) fixation of metacarpal fractures represents a hybrid solution between K-wire fixation and formal open techniques.[15] This technique has since been studied in both clinical and anatomical studies.[13,17,22] We hypothesized that IMHS fixation of metacarpal fractures allows for early mobilization without negatively affecting union rates. Here, we present the largest consecutive series of 91 metacarpal neck and shaft fractures treated with IMHS fixation with analysis of the clinical and radiographic outcomes.

## Methods

Following institutional review board approval, a retrospective review was conducted to identify all consecutive patients who underwent IMHS fixation for metacarpal neck or shaft fractures. A database was created to record sex, age, handedness, fracture location, dorsal/volar angulation, sagittal plane deformity, radiographic characteristics (fracture union, metacarpophalangeal [MCP] joint narrowing, arthrosis, and chondrolysis), postoperative active digital range of motion, grip strength, return to full daily activities, and complications.

All patients were treated with an identical surgical procedure and postoperative protocol. This was previously described in detail by Ruchelsman and colleagues in 2014. The operation was performed using a small extensor split over the MCP joint followed by limited dorsal arthrotomy. Closed reduction without disruption of the fracture site was confirmed under fluoroscopic guidance, and a 1.1-mm K-wire was then inserted under direct visualization through the dorsal corridor of the metacarpal head in line with the medullary canal to achieve provisional fixation. The dorsal-central starting point was well visualized following fracture reduction, dorsal capsulotomy, and passive MCP joint flexion. The K-wire was then overdrilled and replaced with a 2.4-mm or 3.0-mm cannulated IMHS (Synthes, Paoli, Pennsylvania) based upon preoperative templating of the dimensions of the isthmus of the intramedullary canal.

Subchondral intramedullary fixation with isthmal purchase allowed active and active-assisted motion within the first postoperative week. A removable hand-based ulnar gutter orthosis with the MCP joints in intrinsic plus position and the interphalangeal joints free was worn when not performing range of motion exercises until suture removal, and then was gradually weaned. With neck comminution, the screw was inserted without the compression sleeve. Hand strengthening was initiated at clinical union (ie, resolution of fracture site tenderness). In all cases, the patient started strengthening exercises at 4 weeks postoperatively.

Clinical examination and postoperative measurements were performed by the primary surgeons in a nonblinded fashion at routine postoperative intervals (ie 2 weeks, 6 weeks, and 3 months). Active digital range of motion was measured with a handheld goniometer. Grip strength was measured using a Jamar dynamometer (Asimov Engineering, Los Angeles, California) on the third setting. Serial postoperative radiographs were evaluated for fracture union, MCP joint narrowing, arthrosis, and chondrolysis. Complications and secondary procedures were cataloged based on follow-up visits.

## Results

Chart review from 2010 to 2017 identified 91 consecutive skeletally mature patients diagnosed and treated surgically for closed, displaced fractures of the metacarpal neck (N = 56) and axially stable shaft fractures (N = 35) with limited-open retrograde intramedullary headless screw fixation. All metacarpal fractures were closed. There were no associated neurovascular insults. The cohort included 12 women and 79 men, with a mean age of 28 (range = 15-69) years. Eighty-two patients were right-handed, and the dominant hand was injured in 78 (86%) of 91 cases. Eighty-eight percent of fractures occurred in the small finger metacarpal (50 neck fractures and 30 shaft fractures) (Table 1). Two patients had extension of their neck fracture through metacarpal head. Seven patients sustained concomitant high-energy upper extremity injuries.

Mean metacarpal neck and metacarpal shaft sagittal plane deformity are reported in Table 1. Fifty of the 56 neck fractures presented with 40° or greater angulation. Six patients with metacarpal neck fracture underwent fixation for angulation of less than 15°.

Fifty-six patients had greater than 3 months of postoperative follow-up, 35 patients were available at 6 months

**Table 2.** Comparing the Advantages, Disadvantages, and Available Literature of Currently Available Techniques for Metacarpal Fixation.

| Fixation Approach | Advantages | Disadvantages | Contributing manuscripts |
|---|---|---|---|
| Kirschner wire | Limited dissection | Delayed postoperative mobilization<br>Pin infection rates: 5.1%-6% | Ali et al[14] (follow-up rate not reported: range not reported)<br>Stahl and Schwartz[23] (follow-up rate not reported: range = 6-52 wk, mean/median not reported)<br>Hsu et al[24] (follow-up rate not reported: mean = 11 wk, range = 3-69 wk) |
| ORIF | Early mobilization | Significant dissection<br>Complication rate: 35%-57% | Fusetti et al[5] (follow-up rate = 63%: mean = 54.4 wk, range = 24-108 wk)<br>Page and Stern[6] (follow-up rate = 95%: mean = 26 wk, range = 2-180 wk) |
| IMHS | Early mobilization<br>Limited dissection | Intra-articular approach<br>Long-term data still compiled | Boulton et al[15] (NA case report)<br>Ruchelsman et al[13] (follow-up rate = 51%: mean = 52 wk, range = 12-132 wk)<br>del Piñal et al[22] (follow-up rate = 100%: mean = 76 wk, range = 20-216 wk)<br>Doarn et al[25] (follow-up rate = 100% in 9 patients: mean = 36 wk, range = 6-57 wk) |

*Note.* ORIF = open reduction with internal fixation; IMHS = intramedullary headless screw.

follow-up, and 23 patients were available 1 year after surgery. All 91 patients achieved full composite flexion (pad-to-distal palmar crease distance = 0 mm), and all achieved full functional arc of MCP motion at latest follow-up. Postoperative mean MCP joint flexion-extension arc was 88° (range = 55°-110°). Only 3 patients demonstrated less than 65° of isolated MCP flexion (range = 55°-60°). Grip strength was available for 52 patients and measured 104.1% of the contralateral hand (range = 58%-230%). Radiographic union data were available for 86 patients. Seventy-six percent (65/86) achieved radiographic union by the end of week 6 (range = 2-10 weeks). Five patients were lost to follow-up prior to radiographic union. Clinical union (ie, lack of tenderness at the fracture site) always preceded radiographic union. All patients were using their hand without restriction at 6 weeks.

The IMHS was used in 2 select cases for a metacarpal shaft delayed union (n = 1) and a nascent metacarpal neck malunion (n = 1) following index plate fixation of both fractures. Both progressed to complete union following IMHS fixation.

At latest follow-up, early arthrosis was noted in 1 patient (head split component). There were 3 cases of shaft refracture after recurrent blunt trauma, following prior evidence of full osseous union with the screw in place. In these cases, revision was uncomplicated. Formal ORIF was performed with plate/screw fixation, and the broken intramedullary screw was removed through the fracture site, obviating the need to perform MCP arthrotomy.

## Discussion

There is no consensus on ideal fixation technique for metacarpal neck/shaft or proximal phalanx fractures.[2,3,7,8,18] When surgery is required, these fractures are commonly fixed with either percutaneous K-wire techniques or ORIF.[13-17] Technique selection is predicated upon fracture- and patient-specific factors in conjunction with surgeon preference. Recently, there has been an increasing trend to use of headless compression screws for metacarpal fracture fixation with promising results at select centers (Table 2).

A 2007 review by Ali et al[14] demonstrated that K-wire fixation was the most commonly used surgical technique for fixation of metacarpal and phalangeal fractures.

Although percutaneous K-wire fixation offers the advantage of limiting surgical dissection, it requires supplemental postoperative immobilization.[19-21] Prolonged immobilization (>4 weeks) may yield suboptimal functional outcomes and increase flexor/extension adhesions and articular contractures. In addition, 2 large studies by Stahl and Schwartz[23] and Hsu et al[24] found postoperative pin tract infection rates of 6% and 5.1%, respectively. Although burying the pin may reduce the infection risk,[26,27] it may require return to the operating room for hardware removal.

ORIF is frequently used for both metacarpal and phalanx fractures.[5,6,9,10] However, authors who have specifically examined the complication rates of these procedures have reported less than satisfactory results.[5,6,9] Fusetti and colleagues[5] studied 129 consecutive patients with metacarpal fractures fixed with ORIF and found that 35% of patients had significant complications. Page and Stern examined 105 consecutive metacarpal fractures and found that 57% of cases had complications. Given the intimate relationship of the dorsal capsule and the extensor hood at the distal metacarpal level, periarticular plating of distal metacarpal neck and subarticular fractures may create extensor adhesions and extension contractures necessitating secondary removal of hardware, extensor tenolysis and extension contracture release.

In an attempt to find a hybrid solution between K-wire fixation and open techniques for distal metacarpal fractures with limited bone stock, Boulton and colleagues[15] in 2010 reported the utilization of an intramedullary headless screw for subarticular metacarpal fracture fixation. This technique was further evaluated in a 3-dimensional computed tomographic (3D-CT) study, which examined the articular

ramifications of retrograde headless bone screws for intramedullary metacarpal fixation.[17] It was found that the intra-articular screw occupied minimal metacarpal head surface area and subchondral head volume, thus representing a viable option for fracture fixation.[17] A 2014 series by Ruchelsman et al[13] reported 3-month follow-up data for 20 patients treated with IMHS and found that all patients acheived full active MCP extension or hyperextension at 3 months. Longer term data published by del Piñal and colleagues[22] retrospectively reviewed 69 heterogeneous metacarpal and phalangeal fractures treated with cannulated headless compression screws and reported satisfactory outcomes at an average follow-up of 19 months. Doarn et al presented 10 patients after IMHS fixation. Mean return to full active life was 6 weeks, mean radiographic union of 7 weeks, and symmetric grip strength was obtained with no complication. All patients achieved full composite flexion and extension.[25] In this series, it is possible that mean time to radiographic union may appear delayed in some cases, as patients without complication did not routinely undergo radiographs between weeks 2 and 12.

These data presented here further demonstrate that IMHS is a safe, effective, and durable solution for metacarpal neck and axially stable shaft fractures. Isthmal purchase with headless cannulated screw fixation confers relative stability to these fracture patterns and facilitates early postoperative mobilization and functional rehabilitation.[28] Although this technique requires an intra-articular starting point, a 3D-CT analysis study found that metacarpal head surface area and subchondral head volume were minimal.[17] A 2017 study by Avery and colleagues[29] found that, when compared with K-wires, headless compression screws for metacarpal neck fractures were biomechanically superior in load to failure, 3-point bending, and axial loading. In this large series, early functional rehabilitation yielded excellent clinical and functional outcomes without loss of fixation or nonunion. All patients were using their hand in an unrestricted fashion by 6 weeks, which is consistent with clinical outcomes report in other series on the averages reported in the literature (del Piñal et al[22] = 10.8 weeks; Doarn et al[25] = 6 weeks).

This large follow-up series confirms our early-term clinical, functional, and radiographic outcomes following IMHS for metacarpal neck and axially stable shaft fractures. There are distinct advantages to this technique, including the opportunity for early functional mobilization, avoidance of K-wire site morbidity, and the ability to avoid soft tissue and periosteal morbidity associated with plate fixations. In select patient cohorts such as elite athletes, we have found this technique to offer significant advantages over percutaneous and formal ORIF techniques as isthmal purchase confers relative stability, which facilitates early functional rehabilitation of the hand, obviates the need for postoperative immobilization, and allows the athlete to return to sport-specific cardiovascular conditioning regimens without risk of pin-site infections. Although this procedure requires an articular starting point, this current clinical series confirm prior 3-dimensional modeling data[17] and long-term radiographic data do not demonstrate significant articular sequelae. Although indications for this technique continue to expand (ie, more proximal axially stable shaft fractures, nonunions, and malunions), long-term, randomized, prospective studies are needed to directly compare the utility and outcomes of this procedure with other commonly used surgical options for displaced and angulated metacarpal neck and shaft fractures.

## Ethical Approval

This study was approved by our institutional review board.

## Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

## Statement of Informed Consent

This study was performed under an approved retrospective institutional review board (IRB). No consent was required as the IRB determined the study to be of minimal risk to patients and that attempts to obtain retrospective consent may have a significant negative impact on 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.

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## References

1. Chung KC, Spilson SV. The frequency and epidemiology of hand and forearm fractures in the United States. *J Hand Surg Am*. 2001;26(5):908-915. doi:10.1053/jhsu.2001.26322.
2. Carpenter S, Rohde RS. Treatment of phalangeal fractures. *Hand Clin*. 2013;29(4):519-534.
3. Green DP, Hotchkiss RN, Pederson WC, et al. *Green's Operative Hand Surgery*. Philadelphia, PA: Elsevier; 2005.
4. Omokawa S, Fujitani R, Dohi Y, et al. Prospective outcomes of comminuted periarticular metacarpal and phalangeal fractures treated using a titanium plate system. *J Hand Surg Am*. 2008;33(6):857-863. doi:10.1016/j.jhsa.2008.01.040.

5. Fusetti C, Meyer H, Borisch N, et al. Complications of plate fixation in metacarpal fractures. *J Trauma*. 2002;52(3):535-539.
6. 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. doi:10.1016/S0363-5023(98)80157-3.
7. 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. doi:10.1007/s00402-006-0254-y.
8. Berman KS, Rothkopf DM, Shufflebarger JV, et al. Internal fixation of phalangeal fractures using titanium miniplates. *Ann Plast Surg*. 1999;42(4):408-410.
9. Kurzen P, Fusetti C, Bonaccio M, et al. Complications after plate fixation of phalangeal fractures. *J Trauma*. 2006;60(4):841-843. doi:10.1097/01.ta.0000214887.31745.c4.
10. Pun W, Chow S, So Y, et al. Unstable phalangeal fractures: treatment by A.O. screw and plate fixation. *J Hand Surg Am*. 1991;16(1):113-117.
11. Foucher G. "Bouquet" osteosynthesis in metacarpal neck fractures: a series of 66 patients. *J Hand Surg Am*. 1995;20(3, pt 2):S86-S90.
12. Kozin SH, Thoder JJ, Lieberman G. Operative treatment of metacarpal and phalangeal shaft fractures. *J Am Acad Orthop Surg*. 2000;8(2):111-121.
13. Ruchelsman DE, Puri SK, Feinberg-Zadek N, et al. Clinical outcomes of limited-open retrograde intramedullary headless screw fixation of metacarpal fractures. *J Hand Surg Am*. 2014;39(12):2390-2395. doi:10.1016/j.jhsa.2014.08.016.
14. Ali H, Rafique A, Bhatti M, et al. Management of fractures of metacarpals and phalanges and associated risk factors for delayed healing. *J Pak Med Assoc*. 2007;57(2):64-67.
15. Boulton CL, Salzler M, Mudgal CS. Intramedullary cannulated headless screw fixation of a comminuted subcapital metacarpal fracture: case report. *J Hand Surg Am*. 2010;35(8):1260-1263. doi:10.1016/j.jhsa.2010.04.032.
16. Itadera E, Oikawa Y, Shibayama M, et al. Intramedullary fixation of proximal phalangeal fractures through a volar extratendon sheath approach. *Hand Surg*. 2011;16(2):141-147. doi:10.1142/S0218810411005230.
17. ten Berg PW, Mudgal CS, Leibman MI, et al. Quantitative 3-dimensional CT analyses of intramedullary headless screw fixation for metacarpal neck fractures. *J Hand Surg Am*. 2013;38(2):322-330e2. doi:10.1016/j.jhsa.2012.09.029.
18. Agarwal AK, Pickford MA. Experience with a new ultralow-profile osteosynthesis system for fractures of the metacarpals and phalanges. *Ann Plast Surg*. 2006;57(2):206-212. doi:10.1097/01.sap.0000215925.58902.bc.
19. Galanakis I, Aligizakis A, Katonis P, et al. Treatment of closed unstable metacarpal fractures using percutaneous transverse fixation with Kirschner wires. *J Trauma*. 2003;55(3):509-513. doi:10.1097/01.TA.0000029368.40479.A2.
20. Liew KH, Chan BK, Low CO. Metacarpal and proximal phalangeal fractures—Fixation with multiple intramedullary Kirschner wires. *Hand Surg*. 2000;5(2):125-130.
21. Rhee SH, Lee SK, Lee SL, et al. Prospective multicenter trial of modified retrograde percutaneous intramedullary Kirschner wire fixation for displaced metacarpal neck and shaft fractures. *Plast Reconstr Surg*. 2012;129(3):694-703.
22. del Piñal F, Moraleda E, Ruas JS, et al. Minimally invasive fixation of fractures of the phalanges and metacarpals with intramedullary cannulated headless compression screws. *J Hand Surg Am*. 2015;40(4):692-700. doi:10.1016/j.jhsa.2014.11.023.
23. Stahl S, Schwartz O. Complications of K-wire fixation of fractures and dislocations in the hand and wrist. *Arch Orthop Trauma Surg*. 2001;121(9):527-530.
24. Hsu LP, Schwartz EG, Kalainov DM, et al. Complications of K-wire fixation in procedures involving the hand and wrist. *J Hand Surg Am*. 2011;36(4):610-616. doi:10.1016/j.jhsa.2011.01.023.
25. Doarn MC, Nydick JA, Williams BD, et al. Retrograde headless intramedullary screw fixation for displaced fifth metacarpal neck and shaft fractures: short term results. *Hand (N Y)*. 2015;10(2):314-318. doi:10.1007/s11552-014-9620-3.
26. Hargreaves D, Drew S, Eckersley R. Kirschner wire pin tract infection rates: a randomized controlled trial between percutaneous and buried wires. *J Hand Surg Br*. 2004;29(4):374-376. doi:10.1016/j.jhsb.2004.03.003.
27. van Aaken J, Beaulieu JY, DellaSanta D, et al. High rate of complications associated with extrafocal kirschner wire pinning for distal radius fractures. *Chir Main*. 2008;27(4):160-166. doi:10.1016/j.main.2008.05.005.
28. Melamed E, Hinds RM, Gottschalk MB, et al. Comparison of dorsal plate fixation versus intramedullary headless screw fixation of unstable metacarpal shaft fractures: a biomechanical study. *Hand (N Y)*. 2016;11(4):421-426. doi:10.1177/1558944716628485.
29. Avery DM III, Klinge S, Dyrna F, et al. Headless compression screw versus Kirschner wire fixation for metacarpal neck fractures: a biomechanical study. *J Hand Surg Am*. 2017;42(5):392e1-392e6. doi:10.1016/j.jhsa.2017.02.013.