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In Focus

Intramedullary Nail Fixation for Metacarpal Fracture: A Case Report and Review of the Clinical and Biomechanical Evidence

John J. Heifner, MD, [*] Peter A. Falgiano, MD, [*] Austin T. Vegas, DO, [†] Lori R. Chambers, MD, [†] Deana M. Mercer, MD [‡]

[*] Miami Orthopaedic Research Foundation, Miami, FL
[†] Department of Orthopaedic Surgery, Larkin Hospital Miami, FL
[‡] Department of Orthopaedics, University of New Mexico, Albuquerque, NM

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We present two cases of complex metacarpal fractures treated with an intramedullary locking nail. This is an emerging fixation method that minimizes tissue insult, provides sufficient stability, and allows early mobilization. Locking nails accommodate the capture of fractured fragments in complex unstable patterns and provide longitudinal and rotational stability. The described intrafocal technique is intended to improve coaxial placement of the wire into the medullary canal.

Metacarpal fractures occur most frequently in young men because of forceful axial load from various mechanisms.[1] Recent investigation demonstrated an increased rate of metacarpal fractures across the late 2010s.[2] A majority of these fractures are simple stable patterns that perform favorably with conservative treatment. Unstable fractures require internal fixation to reduce the risk of shortening, rotational deformity, and consequential dysfunction. Stiffness is one of the most common complications following surgical treatment, which highlights the importance of postoperative mobilization.[3]

Metacarpal fracture fixation has evolved as surgeons attempted to optimize the continuum between construct stability and early mobilization. Kirschner wires (K-wires) are used to fix stable fractures because these options do not provide longitudinal or rotational stability. The unique “Bouquet osteosynthesis” uses multiple wires to improve construct stability; however, an immobilization phase and the exposed wires reduce the utility of this option. Although plate and screw constructs are biomechanically advantageous compared with K-wires and have demonstrated satisfactory clinical outcomes, the extent of soft tissue disruption required for implantation may increase the risk of extensor tendon dysfunction and dysesthetic scar.[4–6]

Intramedullary nails (IMNs) provide stable fixation, and the minimally invasive nature of this technique is clinically and biologically advantageous. Furthermore, the biomechanical profile of threaded metacarpal nails has demonstrated superiority over plate and screw and K-wire constructs.[7–9] Because of the morphology of the metacarpal canal, novel design threaded nails may provide a more suitable intramedullary fit compared with headless compression screws.[8,10] Metacarpal locking nails have been recently described although evidence remains limited.[11–13] The frequency of recent reports on IMNs for metacarpal fracture indicates increased utilization of this technique.

We report on two cases of metacarpal fracture treated with an intramedullary locking nail. Furthermore, we review the literature to aggregate the clinical and biomechanical evidence for novel design metacarpal nails. Informed consent by each patient was given prior to the collection of case data.

Case Report

Case 1

A 25-year-old man sustained a gunshot to the left hand. Radiography demonstrated a comminuted unstable shaft fracture of the

Corresponding author: John Heifner, MD, Miami Orthopaedic Research Foundation, 11801 SW 90th Street Suite 203, Miami, FL 33186.
E-mail address: johnjheifner@gmail.com (J.J. Heifner).

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Figure 1. **A** Coronal maximum intensity projection of venous phase contrast-enhanced computed tomography (CT) of a 52-year-old man showed a replaced right hepatic artery (red arrowhead) parallel to the portal vein (blue arrowhead) arising from the superior mesenteric artery (red arrow), and Sarin type I gastroesophageal varices (asterisk). **B** Digital subtraction angiography (DSA) image following portal puncture and advancement of a microcatheter showed opacification of the superior mesenteric artery and replaced right hepatic artery. **C** DSA of the replaced right hepatic artery from right femoral arterial access showed opacification of both hepatic arterial (red arrowhead) and portal venous (blue arrowhead) branches, confirming arterioportal fistula formation. **D** After repositioning of the transjugular wire and catheter into the portal system, a covered stent was deployed across the tract. **E** Portal DSA following deployment of the covered stent and coil embolization of the varices showed flow through the shunt with decreased flow into the varices. **F** Completion arteriogram confirmed complete resolution of the arterioportal shunt, and no arterial extravasation or pseudoaneurysm.

index metacarpal (Fig. 1A–C). The decision was made for surgical fixation with a locking nail inserted in retrograde fashion. The metacarpal locking nail (Skeletal Dynamics) is titanium with proximal and distal locking options for 1.9-mm screws. The screw holes are positioned near the ends of the nail to facilitate capture of short segment fractures. The nail can be rotated to align the trajectory of the locking screws for fragment fixation. Intrafocal technique was used to facilitate coaxial placement of the guide wire into the proximal or distal canal. A reduction wire was passed through the skin and fracture site into the distal fragment. The wire was driven out the metacarpal head distally with the metacarpophalangeal joint in flexion. This allowed control of the distal fragment to facilitate reduction. The fracture was reduced and confirmed fluoroscopically. Then, the wire was advanced into the proximal fragment up to the base of the metacarpal. Sequential manual reaming was performed to maximize nail diameter with the canal. The nail was attached to a guide and then inserted retrograde, with impaction as needed. Provisional K-wire fixation was inserted proximally and distally, and then, the near cortex was drilled for the unicortical locking screws. At 9 months after surgery, the patient had complete range of motion with intact sensation and minimal pain during activities of daily living. Anatomic alignment was noted clinically and radiographically (Fig. 1D–F).

Case 2

A 58-year-old woman sustained a hand injury from a closing car door. Radiographic investigation demonstrated long oblique fractures of the index and middle metacarpal (Fig. 2A, B). Surgical fixation with a locking nail was indicated due to concern for instability which is common in this fracture pattern and in multiple metacarpal fractures. Percutaneous clamping was used to maintain position of the proximal and distal fragments during anterograde wire insertion. The nail was provisionally pinned proximally and distally during drilling and insertion of the locking screws (Fig. 2C, D). The middle metacarpal was treated in a similar fashion following the index metacarpal. At 7 months after surgery, the patient demonstrated clinical stability, no evidence of deformity with a complete composite fist, and nearly full restoration of function (Fig. 2E, F).

Literature review

The review was narrowed to novel rigid nails intended for intramedullary fixation of metacarpal fractures. Headless compression screws and flexible nails were not included. Across 3 retrospective series (N = 135) (Table 1), threaded nails demonstrated a mean time to radiographic union of 8.7 weeks.[14–16] The most common complications were bent screws and stiffness (9% and 6.8%, respectively, in one study).[16] In aggregate, the functional outcomes were satisfactory with low rates of complication. Three biomechanical reports compared threaded nails with K-wires and plate and screw constructs (Table 2).[7–9] Each report applied three-point bending loads intended to simulate the native forces that act on the metacarpals in the sagittal plane. Beaumont et al[9] (N = 88) tested a 3.6-mm and a 4.5-mm nail across simulated shaft fractures in the index, middle, ring, and little metacarpals. Metacarpals fixed with a nail had normalized force and stiffness values that were significantly closer to the native bone than those fixed with a plate and screw construct. Wallace et al[7] (N = 14) did not provide the size

Figure 2. **A** and **B** Radiography demonstrating long oblique fractures of the index and middle metacarpal. **C** and **D** The nails were provisionally pinned, and the screws inserted under fluoroscopic guidance. **E** and **F** Radiography of locking nail fixation for metacarpal fracture at 7 months after surgery.

Table 1
Summarization for Reviewed Studies on Clinical Outcomes Following Nail Fixation of Metacarpal Fracture

Study	N	F/U (wk)	Injury/Fracture Pattern	Nail Type
Bach et al,[19] 2006	10	104	Metacarpal shaft	Locking nail (Smith and Nephew)
Baum et al,[14] 2023	11	12	Metacarpal fracture with CMC dislocation	Threaded nail (INnate)
Giron et al,[15] 2023	80	10	NR	Threaded nail (INnate)
Hoelscher,[16] 2024	44	6	Metacarpal shaft	Threaded nail (INnate)
Niempoog et al,[11] 2018	3	106	Metacarpal shaft	Locking nail

CMC, carpometacarpal; F/U, postoperative follow-up; N, sample size for metacarpal outcomes; NR, not reported.

of the tested nail(s) across simulated neck fractures of the index, middle, ring, and little fifth metacarpal. The nail demonstrated significantly higher load to failure (P =.039) compared with the plate and screw construct. Patel et al[8] simulated neck fractures in 16 matched pairs of ring and little metacarpals, then reamed with a 2.7-mm drill; however, no nail size was reported. Metacarpals fixed with a nail demonstrated significantly higher load to failure (P =.005) and stiffness compared with those fixed with K-wires (P <.001). Two of the three biomechanical studies did not report a nail diameter, which is a curious omission for an investigation into the

Table 2
Summarization for Reviewed Studies on Biomechanical Outcomes for Nail Fixation of Metacarpal Fracture

Study	N*	Loading Protocol*	Fracture Location	Nail Type
Beaumont et al,[9] 2024	34 with nails, 30 with plates	3-point bending	Metacarpal shaft	Threaded nail (INnate)
Patel et al,[8] 2023	16 with nails, 16 with wires	3-point bending	Metacarpal neck	Threaded nail (INnate)
Wallace et al,[7] 2023	8 with nails, 6 with plates	3-point bending	Metacarpal neck	Threaded nail (INnate)
Boonyasirikool et al,[12] 2018*	10 with nails, 10 with plates, 10 with wires	3-point bending	Metacarpal shaft	Locking nail

* N, sample size for metacarpal fixation, Boonyasirikool et al tested chicken bone.

stability properties of a fixation device. The anatomical work by Boonyasirikool and Niempoog[10] noted that metacarpal nails should maximize fit within the medullary canal. The mean canal width at the isthmus of the ring finger was 3 mm, which was the smallest size across the index, middle, ring, and small metacarpals. The biomechanical study by Beaumont et al[9] reported that nine 3.6-mm nails and one 4.5-mm nail were used in the ring finger. The authors reported that metacarpals fixed with the 4.5-mm nail had significantly higher normalized stiffness than those fixed with a 3.6-mm nail. Although undersizing is prudent when there is concern for endosteal compromise, the surgeon should aim to maximize fit within the canal space.

The concept of locking intramedullary fixation for metacarpal fractures was initially described in the mid-1990s by Gonzalez et al[17] and then reported in 2006 by Orbay and Touhami[18] and Bach et al.[19] The techniques described by Gonzalez et al[17] and Bach et al[19] provided sufficient stability; however, the extensive approach necessitated a period of immobilization. This technique was often limited to injuries with extensive soft tissue disruption that provided access for implantation. Orbay and Touhami[18] reported satisfactory results for flexible nailing with a proximal locking mechanism. To minimize tissue abrasion, a plastic cap covering the exposed end of the wire or block splinting was used. Novel design locking nails for metacarpal fracture are rigid with locking options intended to facilitate fragmentary capture of a wider spectrum of fractures.[13] Complex patterns including spiral fractures, combination head split and shaft fractures, and cases with central segmental bone loss may be best addressed with locking nails. Furthermore, locking nails may be more advantageous than threaded nails in multiple metacarpal fractures because of the commonality of instability in these cases. Niempoog et al[11] and Boonyasirikool et al[12] reported clinical and biomechanical results, respectively, for a stainless-steel locking nail with multiple options for 1.5-mm screws. Unlimited motion was encouraged on day one after surgery, with progressive loading parameters. The authors describe retrograde insertion for the middle metacarpals, with anterograde for the border metacarpals that avoid the extensor tendons. Niempoog et al[11] reported that full motion was achieved in all cases at 4 weeks and radiographic union at 4–6 weeks after surgery. Boonyasirikool et al[12] reported a significantly higher load ($P < .05$) to failure in bending for the same locking nail compared with a dorsal plate and crossed K-wires. Importantly, the peak static load in the nail group was greater than those that may be encountered during normal activities.[20,21]

Flexible nails were not included in this review as these devices have differing biomechanical and outcome profiles. Although the literature demonstrates satisfactory clinical outcomes for flexible nails, the locking mechanism may increase the risk of complication and the biomechanical properties of flexible nails may be inferior to that of K-wire constructs.[4,22]

The financial ramifications of intramedullary fixation of metacarpal fractures are an important consideration. Brewer et al[23] reported increased follow-up costs associated with K-wire fixation compared with intramedullary screw of all finger fractures, including those of the metacarpal. The increased costs with K-wire fixation were because of the removal procedure with requisite imaging and additional clinic visits that may not be as frequent with intramedullary fixation.

The aggregate literature demonstrates clinical and biomechanical efficacy for IMN fixation of metacarpal fractures. The noted advantages include minimal soft tissue disruption, ability for early mobilization, and low rates of construct failure. The evolution of devices and techniques has expanded the use of IMN with encouraging short-term results. Early flexible nails achieved satisfactory results within a limited spectrum of fracture patterns. Threaded and locking nails are more stable in bending than flexible nails, and locking nails provide improved longitudinal and rotational stability compared with flexible nails. These characteristics have expanded the fracture patterns that can be effectively stabilized with intramedullary fixation. Furthermore, the strength and durability of threaded and locking nails are advantageous during early mobilization in the young active population that commonly requires metacarpal fracture stabilization. The majority of reports on metacarpal threaded and locking nails were published between 2018 and 2023, which illustrate the increased interest and utilization of this treatment.

Discussion

Intramedullary nailing for metacarpal fractures is an emerging fixation method that minimizes tissue insult, provides sufficient stability, and allows early mobilization. Novel design threaded nails have optimized canal fit and biomechanical profile. However, condylar splits, long oblique and spiral fractures, and those with central segmental bone loss may not be sufficiently stabilized by threaded nails. Locking nails accommodate the capture of fractured fragments in complex unstable patterns and provide longitudinal and rotational stability.

The described intrafocal technique is intended to improve coaxial placement of the wire into the medullary canal. This technique avoids multiple wire passes through the articular surface as trajectory is optimized prior to passing the wire through the articular surface. As with any approach, the surgeon must be conscious of the surrounding structures because the wire entry point may vary based on the metacarpal and the fracture pattern.

Conflicts of Interest

Dr Mercer has association/financial involvement with Skeletal Dynamics (speaker's bureau) and Axogen (speaker's bureau). No benefits in any form have been received or will be received by the other authors related directly to this article.

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References

1. Nakashian MN, Pointer L, Owens BD, Wolf JM. Incidence of metacarpal fractures in the US population. *Hand (N Y)*. 2012;7(4):426–430.

2. Tischler EH, Laurent Tsai SH, Wolfert AJ, Suneja N, Naziri Q, Tischler HM. Orthopedic fracture hospitalizations are revving up from E-Scooter related injuries. *J Clin Orthop Trauma*. 2021;23:101607.
3. Sasson DC, Shah ND, Yuksel SS, Kearney AM, Brandt K, Gosain AK. A fourteen-year review of practice patterns and evidence-based medicine in operative metacarpal fracture repair. *Plast Reconstr Surg Glob Open*. 2022;10(1):e4065.
4. Curtis BD, Fajolu O, Ruff ME, Litsky AS. Fixation of metacarpal shaft fractures: biomechanical comparison of intramedullary nail crossed K-wires and plate-screw constructs. *Orthop Surg*. 2015;7(3):256–260.
5. Lv F, Nie Q, Guo J, Tang M. Comparative analysis of the effects of AO mini-plate and Kirschner wire pinning in the metacarpal fractures: a retrospective study. *Medicine (Baltimore)*. 2021;100(26):e26566.
6. Panthi S, Shrestha R, Pradhan J, et al. Open reduction and internal fixation with mini-plate and screws for management of unstable metacarpal fracture among hand injuries in a tertiary care center: a descriptive cross-sectional study. *JNMA J Nepal Med Assoc*. 2021;59(239):653–656.
7. Wallace DR, Shiver AL, Pulliam SK, Byrd BM, McGee-Lawrence ME, Snoddy MC. Intramedullary threaded nail fixation versus plate and screw construct in metacarpal neck fractures: a biomechanical study. *J Am Acad Orthop Surg*. 2023;31(11):e516–e522.
8. Patel M, Castañeda P, Campbell DH, Putnam JG, McKee MD. Threaded intramedullary nails are biomechanically superior to crossed K-wires for metacarpal neck fractures. *Hand (N Y)*. 2023;18(1):55–60.
9. Beaumont CM, Beason DP, McKeon KE. Fracture fixation strength in metacarpal plating versus intramedullary nailing using a 3-point bending model: a cadaveric, biomechanical study. *J Hand Surg Am*. 2024;49(1):57.e1–57.e6.
10. Boonyasirikool C, Niempoog S. Locked intramedullary nail: metacarpal geometry study in adults. *J Med Assoc Thai*. 2014;97(Suppl 8):S194–S198.
11. Niempoog S, Waitayawinyu T, Boonyasirikool C. Metacarpal locked intramedullary nail: surgical technique and preliminary outcome report. *J Hand Surg Asian Pac Vol*. 2018;23(2):259–266.
12. Boonyasirikool C, Tanakeatsakul S, Niempoog S. The metacarpal locked intramedullary nail: comparative biomechanical evaluation of new implant design for metacarpal fractures. *J Med Assoc Thai*. 2015;98(Suppl 3):S91–S95.
13. Lambi AG, Rowland RJ, Brady NW, Rodriguez DE, Mercer DM. Metacarpal fractures. *J Hand Surg Eur Vol*. 2023;48(2_suppl):42s–50s.
14. Baum GR, Dang M, Yeater TB, et al. Threaded intramedullary headless nail fixation for fractures requiring carpometacarpal stabilization. *JPRAS Open*. 2023;35:29–37.
15. Giron A, Cox CT, Choi E, Baum G, McKee D, MacKay BJ. Outcomes of threaded intramedullary headless nail fixation for metacarpal fractures. *Cureus*. 2023;15(11):e48618.
16. Hoelscher VS, Milhoan M, Quiring M, Fix K, Dalton S, Pientka WF 2nd. Outcomes and complications of intramedullary metacarpal fixation. *Hand (N Y)*. 2024:15589447231222518.
17. Gonzalez MH, Hall RF Jr. Intramedullary fixation of metacarpal and proximal phalangeal fractures of the hand. *Clin Orthop Relat Res*. 1996;327:47–54.
18. Orbay JL, Touhami A. The treatment of unstable metacarpal and phalangeal shaft fractures with flexible nonlocking and locking intramedullary nails. *Hand Clin*. 2006;22(3):279–286.
19. Bach HG, Gonzalez MH, Hall RF Jr. Locked intramedullary nailing of metacarpal fractures secondary to gunshot wounds. *J Hand Surg Am*. 2006;31(7):1083–1087.
20. An KN, Chao EY, Cooney WP, Linscheid RL. Forces in the normal and abnormal hand. *J Orthop Res*. 1985;3(2):202–211.
21. Vanik RK, Weber RC, Matloub HS, Sanger JR, Gingrass RP. The comparative strengths of internal fixation techniques. *J Hand Surg Am*. 1984;9(2):216–221.
22. Mirza A, Mirza JB, Thomas TL Jr. Premeasured intramedullary nails for the treatment of metacarpal fractures: novel instrumentation and technique. *J Hand Surg Glob Online*. 2020;2(4):250–255.
23. Brewer CF, Young-Sing Q, Sierakowski A. Cost comparison of Kirschner wire versus intramedullary screw fixation of metacarpal and phalangeal fractures. *Hand (N Y)*. 2023;18(3):456–462.