Intramedullary Fixation of Metacarpal Fractures Using Headless Compression Screws

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Abstract

Introduction The purpose of this study is to examine the clinical results of retrograde intramedullary headless screw (IMHS) fixation for metacarpal fractures.

Methods A retrospective review was performed on 16 patients with 18 metacarpal fractures who underwent IMHS fixation at a single institution. The average age was 32 years. The indications for surgery included rotational malalignment (five patients), multiple metacarpal fractures (five patients), angular deformity (four patients), and shortening greater than 5 mm (two patients). The average length of follow-up was 19.4 weeks (median 10.2 weeks).

Results Functional outcome was considered excellent in all patients with total active motion in excess of 240 degrees. Active motion was initiated within 1 week of surgery. No secondary surgeries were performed related to a complication of IMHS fixation.

Conclusion IMHS fixation of metacarpal fractures is an efficacious treatment modality for patients with comminution, multiple fractures, malrotation, and those who require rapid mobilization. It obviates the need for immobilization or more extensive plate and screw fixation techniques with excellent clinical results.

Keywords
- metacarpal fracture
- intramedullary fixation
- headless compression screw
- minimally invasive

Background

There is a lack of consensus on optimal treatment methods for operative fixation of metacarpal fractures.[1] Classic treatment options include plate and screw fixation or percutaneous fixation with Kirschner wires (K-wires).[1,2] For subcapital fractures or those fractures involving the metacarpal neck, the lack of distal purchase can preclude plate and screw fixation. Short oblique, transverse, comminuted, or multiple metacarpal shaft fractures typically require more rigid fixation with lag screws or plate and screw constructions. Plate and screw fixation can be associated with considerable metacarpophalangeal stiffness, necessitating secondary implant removal and joint release. While K-wire fixation for metacarpal fractures often results in bony union, it necessitates a period of immobilization and has a complication rate up to 16%.[3,4] Bouquet pinning with intramedullary wires placed in an antegrade manner can often be satisfactory but requires immobilization, future implant removal, and may not always offer secure fixation or rotational control.[5] Periarticular fractures of the upper extremity can be reliably treated with buried intra-articular fixation.[6–14] This series presents the clinical results of a relatively new technique of fixation for metacarpal fractures using retrograde intramedullary headless screws (IMHS) that allows early mobilization with minimal complications.

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Table 1 Demographic and clinical data for patients undergoing IMHS for metacarpal neck fractures

	Number	Mean (range)
Patients	16	
Male	13	
Female	3	
Age (y)		32 (17–74)
Fractures treated by IMHS	18	
Index	1	
Middle	1	
Ring	3	
Small	13	
Multiple MC fractures	5	
Follow-up (wk)		19 (2–79)
FCF, FCE at latest visit	18	

Abbreviations: FCE, full composite extension; FCF, full composite flexion; IMHS, intramedullary headless screw; MC, metacarpal.

Methods

Data Source

Institutional Review Board approval was obtained for the work represented here. We conducted a retrospective review of patients at a single institution who underwent IMHS for metacarpal fractures between 2007 and 2015. All patients were operated on and followed by the senior author.[6] We included skeletally mature patients who had single or multiple metacarpal fractures treated with IMHS fixation. Skeletally immature patients and those with intra-articular involvement at the metacarpophalangeal (MCP) joints were excluded.

The electronic medical record was reviewed for demographic data including age and sex, as well as clinical information such as fracture location, length of follow-up, digit(s) involved, postoperative range of motion, and complications. The demographic and clinical data are summarized in ►**Table 1**. There were 18 fractures in 16 patients who met the inclusion criteria and treated using the operative technique listed earlier. The mean age was 32 years (range, 17–74 years). The mechanisms of injury included forcefully striking an object (eight patients), fall (five patients), and sports related (two patients). One patient suffered a dog bite and had an open wound over the radial side of the hand, distant from the fifth metacarpal fracture, which itself was closed. All the other fractures were closed, with no open wounds on the hand. Four patients had multiple metacarpal fractures.

Injury characteristics are detailed in ►**Table 2**. The indications for surgery included rotational malalignment (five patients), multiple metacarpal fractures (five patients), angular deformity (three patients), shortening greater than 5 mm (two patients), and one patient with equivocal angular deformity (50 degrees, apex dorsal) who was a baseball pitcher seeking an

Table 2 Injury characteristics of each patient

Patient	MC fractured	Location of fracture treated by IMHS	Treatment	Angulation (deg) of MC treated by IMHS	Comments
1	4th, 5th	Neck	ORIF 4th, IMHS 5th	25	Comminution of 5th MC
2	5th	Neck	IMHS 5th	55	Rotational deformity
3	5th	Neck with shaft extension	IMHS 5th	37	Segmental fracture with rotational deformity
4	2nd, 4th	Neck	IMHS 2nd, ORIF 4th	13	Multifocal upper limb trauma
5	3rd, 4th	Neck	IMHS 3rd, IMHS 4th	49 (3rd), 66 (4th)	Comminution of 3rd/4th
6	5th	Shaft	IMHS 5th	< 10	Displaced with 6 mm shortening
7	5th	Neck	IMHS 5th	46	Comminution with 7 mm of shortening
8	5th	Shaft	IMHS 5th	45	Transverse fracture
9	5th	Shaft	IMHS 5th	50	Transverse with rotational deformity
10	5th	Neck with shaft extension	IMHS 5th	57	Comminution
11	3rd, 4th, 5th	Shaft	ORIF 3rd and 4th, IMHS 5th	50	Transverse fracture
12	4th	Shaft	IMHS 4th	42	Transverse fracture
13	5th	Neck	IMHS 5th	48	Rotational deformity
14	5th	Neck	IMHS 5th	48	Rotational deformity
15	5th	Neck	IMHS 5th	50	Throwing athlete
16	4th, 5th	Neck	IMHS 4th, IMHS 5th	49 (4th), 51 (5th)	Comminution with malrotation

Abbreviations: IMHS, intramedullary headless screw; MC, metacarpal; ORIF, open reduction internal fixation.

Fig. 1 Preoperative anteroposterior, oblique, and lateral radiographs of a 32-year-old man with comminuted fourth and fifth metacarpal neck fractures and clinical malrotation.

expedited recovery. One patient sustained multifocal upper extremity trauma (radiocarpal dislocation, index, and ring metacarpal shaft fractures, minimally displaced small finger proximal phalanx fracture) and fixation was performed despite minimal angulation, given that he had ipsilateral monomelic polytrauma. All fractures were treated with 3.0 mm partially threaded headless compression screws (►**Figs. 1** and **2**) based on preoperative templating of the medullary canal diameter. The length of the screws varied from 32 to 45 mm. The average length of follow-up was 19.4 weeks (median, 10.2 weeks).

Operative Technique

The senior author performed the operations on each patient using the same technique at a single academic medical

Fig. 2 Postoperative radiographs after intramedullary headless screw fixation.

institution. The details of this technique have been previously published.[6] Preoperative templating was performed to determine the diameter of the medullary canal at its narrowest portion (isthmus), which would guide choice of screw size. A small incision was used over the dorsal aspect of the MCP joint. The extensor mechanism was incised in a longitudinal fashion through its central portion over the metacarpal head. In fractures of the fifth metacarpal, the extensor mechanism was split at the confluence of the extensor digitorum communis and extensor digit quinti. A capsulotomy was performed to expose the dorsal quarter of the metacarpal head articular surface.

A guide wire was placed in a retrograde fashion through the distal fragment. Under fluoroscopic guidance, the fracture was reduced and the guide wire was advanced across the fracture site. After confirmation of adequate fracture reduction, an appropriately sized cannulated drill was used to drill over the guide wire. A 3-mm partially threaded headless screw (Synthes, West Chester, Pennsylvania, United States) was placed. The screw head was buried beneath the articular cartilage so as to achieve distal purchase in the subchondral bone. Proximal purchase of the screw was achieved at the isthmic level within the medullary canal. Final confirmation of fracture reduction was performed with fluoroscopy and the extensor mechanism was closed with inverted 3–0 Ethibond (Ethicon, Somerville, New Jersey, United States) suture, such that the knots were buried within the tendon, to avoid causing later suture-related problems. Patients were immobilized in forearm-based volar and dorsal splints molded with the hand in the intrinsic plus position up to the fingertips, and asked to follow-up in 5 to 7 days for initiation of rehabilitative exercises.

Results

At the time of last follow-up, all 16 patients (18 digits) had an excellent functional outcome with total active motion greater than 240 degrees (►**Fig. 3**). There were no complications during the postoperative period. One patient presented for a pre-employment clearance over 19 months after fracture fixation and was noted to have a united fracture and a bent IMHS on plain films related to a secondary punching episode. However, at the time of follow-up, he had no pain and full range of motion of the involved digit (►**Fig. 4**).

Fig. 4 Radiographic appearance of a patient who forcefully struck an object postoperatively. No range of motion deficits were observed clinically.

Discussion

The majority of metacarpal fractures can be treated nonoperatively. Most commonly, the axial deformity is apex

Fig. 3 Clinical outcome at 7 months postoperatively.

dorsal and the rotational deformity is associated with supination of the ring and small finger. The limit of acceptable deformity for closed treatment of metacarpal neck fractures has not been definitively established but it increases from index finger to small finger due to the decreasing rigidity of the carpometacarpal joints. It has been suggested that the acceptable limit of metacarpal neck fracture angulation should not exceed 10 to 15 degrees more than the motion allowed at the carpometacarpal articulation. Therefore, subcapital fractures angulated greater than 45 degrees in the ring and small finger may be considered suitable for reduction and fixation. The theoretical justification for these numbers is based on shortening of the resting lengths of intrinsic musculature when angulation exceeds 30 degrees, which may in turn lead to difficulties in recovering total active motion in the affected digit.[15] Rotational deformity can be an indication for fixation of metacarpal neck and shaft fractures as it can result in significant clinical dysfunction of the hand. For example, a 10-degree rotational deformity at the level of the metacarpal results in a 2-cm overlap at the level of the nail plate during digit flexion.[16] The treatment of multiple displaced metacarpal fractures is typically surgical due to the inherent instability, concern for stiffness from associated soft tissue injuries and loss of physiologic force transductions if malunion occurs.[17]

Transverse subcapital and long-oblique shaft fractures of the metacarpals are often treated with percutaneous K-wire fixation.[2] This method of treatment produces reliable rates of union. However, it necessitates a period of immobilization and adherence to a follow-up schedule for pin removal. In addition, tethering of the extensor mechanism can occur due to the orientation of the K-wires. The complication rate has been reported as high as 16% and includes pin pull out, nonunion, and pin tract infection with potential osteomyelitis.[3,4] In comminuted fractures of the metacarpal neck, intermetacarpal K-wire fixation to the adjacent metacarpal using the biomechanical principles of external fixation, which provides control of angular deformity, can be very effective. However, the potential complications include those previously listed for K-wire techniques.[18]

Fixation with a plate and screws is possible if the fracture occurs at the metacarpal shaft/neck junction or extends proximally into the shaft. This method provides a more rigid fixation allowing early motion but requires more extensive dissection. However, if plates and screws are used in very distal fractures, distal plate extension can result in extensor mechanism adherence to the plate, leading to a loss of motion. Therefore, use of plate fixation in distal metacarpal fractures should be considered very carefully. In one study, the complication rate for plate and screw fixation of metacarpal fractures was 31%.[19]

Given the complications associated with typical methods of fixation, the senior author first described the technique of intramedullary headless screw fixation in a case report of a comminuted subcapital metacarpal fracture.[6] The rationale for this technique includes the ability to hold reduction and prevent rotational instability with distal fixation in the subchondral bone and proximal fixation in the endosteal isthmus of the medullary canal. The buried location of the screw obviates the need for subsequent removal. The rotational stability and lack of requisite hardware removal are improvements over previously described intramedullary nail techniques for metacarpal fractures.[20] Biomechanically, the fixation strength of intramedullary devices and multiple K-wire fixation are comparable.[21] Additional benefits to this technique include early mobilization (typically within 5 days) with subsequent rapid recovery of motion and function.

A criticism of this technique has been the violation of the articular cartilage, which occurs when using retrograde headless compression screws in the metacarpals. However, buried intra-articular headless screw fixation is routinely performed in fixation of hand and upper extremity fractures including the scaphoid, radial head, and capitellum without long-term clinical consequences.[8,10,12–14,22,23] A quantitative three-dimensional computed tomographic analysis by ten Berg et al examined the extent of metacarpal head cartilage violation with retrograde IMHS.[24] The amount of surface area mated between the proximal phalanx and metacarpal head was 129 mm^2 through the coronal plane arc and 265 mm^2 through the sagittal plane arc. A 3-mm countersunk headless compression screw represented 8 and 4% of the mated surface area in these respective planes. Due to the intrinsic shape of the metacarpal head and entry site of the headless compression screw, the phalangeal base did not engage the entry site through 87% of the 120 degrees arc of motion in the more clinically relevant sagittal plane. Based on these various studies, it appears to us that at this time, the violation of the articular surface by the screw in this particular location while theoretically relevant is functionally inconsequential in the medium term and refutes the criticism. Long-term studies will help understand the behavior of the MCP joint after using this technique and whether arthritic changes are a potential functional concern.

Another criticism of this technique has been that the use of headless differential pitch screws potentially causes compression and shortening of the metacarpal at the fracture site. Although this is a valid theoretical concern, it appears that due to the proximal endosteal fit of the leading threads, there is virtually no compression generated at the fracture site. The screw functions merely as an internal splint, albeit one more stable than percutaneous wires, thereby affording initiation of early motion and affording excellent functional recovery. Theoretical questions about rotational stability of this construct have also been raised. However, we speculate that the endosteal leading screw thread contact proximally and subchondral trailing screw thread purchase appear to confer highly satisfactory rotational stability and thus far, we have not faced clinical concerns in this regard.

The results of this technique in metacarpal and phalangeal fractures have been published by del Piñal et al.[7] In the 48 metacarpal fractures they reviewed, the mean total arc of motion was 249 degrees and all patients returned to full work duties or leisure activities. Similarly, Ruchelsman et al published clinical data on 20 patients with metacarpal neck and shaft fractures treated with IMHS.[9] At 3-month follow-up, all patients had osseous union, full composite flexion, and extension. The data presented in our series indicate similar findings. Of the 18 digits treated with this technique, all had full composite flexion and extension.

Since the development of this technique to treat fractures of the distal metacarpal, we have expanded the indications to include midshaft metacarpal fractures. We postulate that the biomechanical principle of obtaining endosteal purchase in the proximal fragment shaft provides angular and rotational stability even for fractures proximal to the metacarpal neck. Anecdotally, this has been successful for athletes or patients who prefer a quicker return to motion than K-wire fixation offers or a less extensive operation that plate fixation requires.

The limitations of this study include its retrospective nature, small sample size, and relatively short follow-up period for a clinical series. The small sample size over a 7-year period is attributable to the stringent application of this technique to patients with comminuted, multiple, or malrotated fractures or in those who require rapid mobilization postoperatively. We believe the short follow-up is a testament to the clinical function obtained by these patients after fracture union occurred. We are unable to definitively comment on the risk of long-term MCP arthrosis related to the articular starting point despite the extensive modeling data previously published.[24] The potential difficulty of screw removal in the setting of infection or broken hardware has not been encountered in this or the two other published series and could potentially present a technically challenging complication. We believe this study furthers the current consensus in the literature that IMHS fixation of metacarpal fractures is a safe, efficacious, and advantageous form of treatment.

Note

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