SCIENTIFIC ARTICLE

Clinical Outcomes of Limited-Open Retrograde Intramedullary Headless Screw Fixation of Metacarpal Fractures

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Purpose To evaluate clinical and radiographic outcomes in patients treated with limited-open retrograde intramedullary headless compression screw (IMHS) fixation for metacarpal neck and shaft fractures.

Methods Retrospective review of prospectively collected data on a consecutive series of 39 patients (34 men; 5 women), mean age 28 years (range, 16−66 y) treated with IMHS fixation for acute displaced metacarpal neck/subcapital (N = 26) and shaft (N = 13) fractures at a single academic practice between 2010 and 2014. Preoperative magnitude of metacarpal neck angulation averaged 54° (range, 15° to 70°), and shaft angulation averaged 38° (range, 0° to 55°). Patients used a hand-based orthosis until suture removal and began active motion within the first week. Clinical outcomes were assessed with digital goniometry, pad-to-distal palmar crease distance, and grip strength. Time to union and radiographic arthrosis was assessed. Twenty patients reached minimum 3-month follow-up, with a mean of 13 months (range, 3−33 mo).

Results All 20 patients with minimum 3 months of follow-up achieved full composite flexion, and extensor lag resolved by 3-week follow-up. All patients demonstrated full active metacarpophalangeal joint extension or hyperextension. Grip strength measured 105% (range, 58% to 230%) of the contralateral hand. No secondary surgeries were performed. There were 2 cases of shaft re-fracture from blunt trauma following prior evidence of full osseous union with the screw in place. All patients achieved radiographic union by 6 weeks. There was no radiographic arthrosis at latest follow-up. One patient reported occasional clicking with metacarpophalangeal joint motion not requiring further treatment.

Conclusions Limited open retrograde IMHS fixation proved to be safe and reliable for metacarpal neck/subcapital and axially stable shaft fractures, allowed for early postoperative motion without affecting union rates, and obviated immobilization. This technique offers distinct advantages in select patients. *(J Hand Surg Am. 2014;39(12):2390−2395. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Metacarpal fracture, hand trauma, headless screw, intramedullary fixation, minimally invasive surgery, clinical outcomes.

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Fixation buried beneath the articular surface is well accepted for various upper extremity fractures.[1–9] Multiple fixation techniques for displaced and markedly angulated metacarpal neck and subcapital fractures and axially stable shaft fractures include percutaneous and limited open antegrade (ie, bouquet pinning),[10] retrograde (ie, longitudinal intramedullary fixation),[11] transmetacarpal Kirschner wire constructs,[12] and plate fixation.[13] Each technique has advantages and disadvantages. There is no consensus on an optimal treatment modality.[13]

The use of quantitative 3-dimensional computed tomography techniques to better define articular fracture characteristics is well established.[1,15–19] Recent 3-dimensional computed tomography data from our group support the use of an articular starting point for these extra-articular fractures.[1] We now report clinical and radiographic outcomes of limited-open retrograde intramedullary cannulated headless screw fixation. A case report from our institution previously described this technique for a subcapital metacarpal neck fracture with limited distal bone stock precluding plate fixation.[14]

Retrograde intramedullary fixation using a cannulated headless screw can be achieved using a limited-open extensor-splitting approach and represents only one additional step beyond longitudinal intramedullary retrograde Kirschner wire fixation of these fractures through the metacarpal head articular surface. The headless design allows for fixation buried beneath the articular surface and allows for early postoperative motion.[20] Direct visualization of the starting point additionally potentially eliminates multiple attempts at achieving the correct starting point during percutaneous Kirschner wire insertion for retrograde intramedullary fixation.

With increasing clinical experience using this technique for metacarpal neck fractures, we have expanded our indications in select cases to include fractures presenting after callus formation precluded closed reduction and axial-stable transverse mid-diaphyseal fractures that are reducible with closed manipulation. The purpose of the present study was to determine the clinical and radiographic outcomes in patients treated with limited-open retrograde intramedullary headless screw fixation for metacarpal neck and shaft fractures. We hypothesized that this technique would yield satisfactory results, represent a reliable alternative to percutaneous Kirschner wire and open plate fixation constructs, and minimize complications associated with these respective techniques.

METHODS

Following institutional review board approval, retrospective evaluation of prospectively collected clinical and radiographic data from our upper extremity trauma database between 2010 and 2014 identified 39 consecutive patients diagnosed and treated surgically for closed, displaced fractures of the metacarpal neck (N = 26) and shaft (N = 13) with limited open retrograde intramedullary headless screw fixation. Twenty-three neck fractures and 10 shaft fractures treated were in the small finger (Table 1). Two patients with splitting of the metacarpal heads were excluded from this cohort of extra-articular neck and shaft fractures. The cohort included 5 women and 34 men, with a mean age of 28 years (range, 16–66 y). Thirty-six patients were right-handed, and the dominant hand was injured in 36 of 39 (92%). All fractures were closed. There were no associated neurovascular insults.

Mean metacarpal neck apex dorsal/volar angulation and mean metacarpal shaft sagittal plane deformity are reported in Table 1. Twenty-five of the 26 neck fractures presented with 40° or greater angulation. A single index finger neck fracture underwent fixation for angulation of 15°. Three axial-stable shaft fractures underwent fixation due to malrotation. One of the rotated shaft fractures had an adjacent digit injury requiring surgical intervention as well and required early motion.

Operative technique

Operative treatment was performed in all cases by the 3 senior authors (D.E.R., M.I.L., M.R.B.) in a single academic hand surgical practice using the identical technique. Limited-open retrograde headless compression screw (HCS) fixation was performed through a small extensor-split over the metacarpophalangeal joint followed by a limited dorsal arthrotomy. Closed reduction without disruption of the fracture site was confirmed under fluoroscopic guidance, and a 1.1 mm Kirschner 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 metacarpophalangeal (MCP) joint flexion. The Kirschner wire was then over-drilled and replaced with a 2.4 mm or 3.0 mm cannulated HCS (Synthes, Paoli, PA) based upon preoperative templating of the dimensions of the isthmus of the intramedullary canal (Fig. 1).

In 5 cases, the patient presented in a delayed fashion with radiographic callus present precluding

TABLE 1. Fracture Characteristics

	Index (N = 3)	Middle (N = 0)	Ring (N = 3)	Small (N = 33)	All Digits (N = 39)
Neck					
Number	2	0	1	23	26
Mean Angulation, degrees; mean (range)	33 (15–50)	N/A	50 (50)	56 (40–70)	54 (15–70)
Shaft					
Number	1	0	2	10	13
Mean Angulation, degrees; mean (range)	40 (40)	N/A	38 (35–40)	38 (0–55)	38 (0–55)

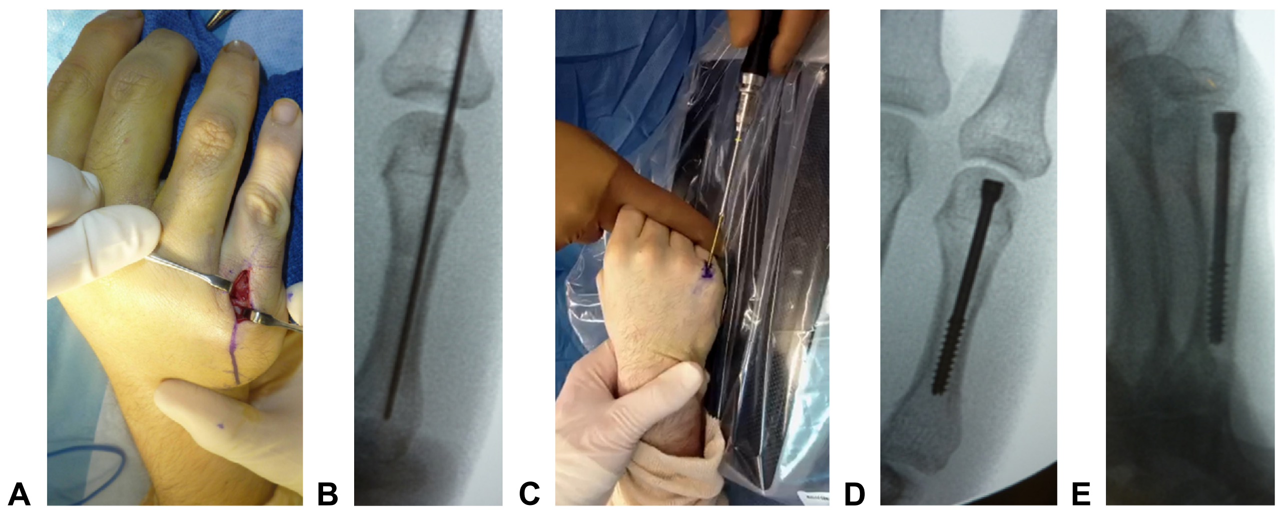

FIGURE 1: Limited-open retrograde headless screw fixation: **A** Limited-open dorsal-central tendon splitting exposure. **B** Following anatomic closed reduction, a 1.1-mm guide-wire is advanced through the dorsal corridor of the metacarpal head in line with the medullary canal. **C** The screw is then inserted over the guide-wire and buried deep to the articular surface. **D, E** Guide-wire is removed, leaving fracture stabilized by the screw.

closed reduction. In these cases, a separate dorsal incision was made at the fracture site to perform open osteoclasis, facilitating anatomic reduction prior to retrograde fixation.

With increasing clinical experience with this technique for metacarpal neck fracture, we have expanded our indications in select cases to include axial-stable transverse mid-diaphyseal fractures that are reducible with closed manipulation.

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.

Evaluation

Twenty patients were available for clinical and radiographic evaluation at a minimum of 3 months postoperatively, 16 patients were available at a minimum of 6 months follow-up, and 10 patients were available 1 year after surgery. Clinical examination was performed by the treating surgeons. Active digital range of motion was measured with a handheld goniometer. Range of motion of the injured digit at latest follow-up is reported. Grip strength was measured using a Jamar dynamometer (Asimov Engineering, Los Angeles, CA). Serial postoperative radiographs were evaluated for fracture union, MCP joint narrowing, arthrosis, and chondrolysis. Complications and secondary procedures were catalogued.

TABLE 2. Clinical Results

Clinical Outcome	Results
% Union at 6 weeks	100 (20 of 20)
% With full composite flexion	100 (20 of 20)
% With full or hyperextension MCP joint	100 (20 of 20)
Mean MCP joint flexion in degrees (range)	88 (70−100)
Mean MCP arc of motion in degrees (range)	90 (70−105)
% Grip strength of contralateral hand (range)	105 (58−230)
% Significant complications	0 (0 of 20)
% Minor complications	5 (1 of 20)

Data included for patients with minimum 3 months of follow-up.

RESULTS

Results are reported for the 20 patients who presented for minimum 3 month follow-up (Table 2). All patients demonstrated full active MCP joint extension or hyperextension at latest follow-up. All patients achieved full composite flexion. Mean MCP joint flexion measured 88° (range, 70° to 100°). The mean extension−flexion arc measured 90° (range, 70° to 105°). Grip strength measured 105% (range, 58% to 230%) of the contralateral hand. No secondary surgeries were performed. All patients achieved radiographic union by 6 weeks. Two patients sustained re-fracture of the metacarpal shaft due to repeat high energy trauma after reaching full osseous union and full motion, and these patients were treated with screw removal and revision open reduction internal plate/screw fixation. There was no arthrosis or chondrolysis on plain films at latest follow-up. One patient reported an occasional intermittent periarticular click with active MCP joint motion that did not require further treatment.

DISCUSSION

The vast majority of metacarpal neck fractures can be treated nonsurgically, as apex dorsal angulation can be functionally compensated for in the ring and small fingers with the 20° to 30° of motion at the carpometacarpal joints. There is no consensus regarding the degree and magnitude of acceptable angulation in the ring and small finger metacarpal necks. Volar angulation between 30° and 70° has been reported as acceptable in small clinical series.[21−23] Cadaveric studies suggest that with more than 30° of apex dorsal deformity at the metacarpal neck there is decreased functional length of the intrinsics and reduced efficiency in the flexor system during MCP joint motion.[24,25] Given the rigid nature of the index and long finger carpometacarpal joints, reduction and stabilization of neck fractures in these metacarpals is considered for sagittal plane deformity greater than 10° to 15°. Pseudo-clawing and rotational deformity are also indications for reduction and stabilization.

Various fixation techniques[10−13] have been described for the reduction and stabilization of displaced and markedly angulated metacarpal neck, subcapital, and shaft fractures. Optimal management of these fractures is not well established. Selection of technique remains based upon fracture characteristics and surgeon preference.

Optimal surgical fixation will limit surgical exposure of the fracture site, allow for early postoperative mobilization to regain full MCP joint motion and extensor excursion, expedite return to activities of daily living and work or sport, and minimize the need for removal of hardware. This technique creates a small extensor split and dorsal arthrotomy to access and directly visualize the starting point of screw insertion but leaves the fracture site closed.

Limited-open retrograde intramedullary headless screw fixation achieves these goals and may offer clinical advantages over Kirschner wire fixation and other open techniques. With increasing clinical experience with this technique for displaced and angulated metacarpal neck fractures, we favor this technique over percutaneous K-wire techniques in skeletally mature patients. Additionally, we have expanded our indications in select cases to include acute axial-stable transverse mid-diaphyseal fractures that are reducible with closed manipulation with reliable results achieved. Our series also included fractures irreducible by simple closed manipulation (N = 5). These were addressed with a separate limited dorsal incision for osteoclasis to facilitate reduction. This experience suggests utility of this technique in treating nascent malunions and other acute fractures irreducible by closed means.

Although percutaneous Kirschner wire techniques limit soft tissue dissection, 3 to 4 weeks of postoperative immobilization is required to minimize the risk of superficial and deep pin track infections that may necessitate early Kirschner wire removal and additional procedures. Kirschner wires left in place may be cut and buried beneath the skin or left protruding through the skin where the tip is bent.[26] Two large series reported similar overall complication rate (16%) following percutaneous Kirschner wire fixation of various hand and wrist fractures.[27,28] Major complications included osteomyelitis, tendon rupture, nerve injury, and pin track infection. Pin track infection rates were 5% to 6% in both series.[27,28] Buried K-wires may reduce the incidence of infection[29−31] but potentially increase the risk of a tendon rupture[32] or necessitate return to the operating room for removal.[30] Use of multiple retrograde K-wires has yielded good outcomes.[33] However, this technique requires serial percutaneous violation of the articular surface with multiple passes of Kirschner wires. Further, the pins remain percutaneous for 5 weeks postoperatively, which precludes early functional rehabilitation and return to some activities of daily living. Antegrade bouquet pinning avoids an articular start point and provides intramedullary fixation but has notable rates of extensor (9%) and flexion lag (9%) at conclusion of treatment and high rates of malreduction at the time of surgery (12%).[10] This technique also required planned secondary surgery for removal of hardware.

In contrast, formal open reduction internal fixation may achieve rigid fixation and facilitate early postoperative rehabilitation, but complications are well described.[34,35] In a series of 129 patients with 157 metacarpal fractures treated by open reduction and internal plate fixation, Fusetti et al reported complications in more than one-third of patients, including delayed union, extensor adhesions and stiffness, fixation failure, complex regional pain syndrome and deep infection.[34] Page et al found a similar major complication rate of 36% in 105 metacarpal and/or phalangeal fractures stabilized with plates.[35] The newer pre-contoured angular-stable locking plates available in customized configurations (ie, T-, Y-, and L-shapes) may avoid the need to abut the dorsal articular margin for distal shaft shaft/neck fractures. When there is limited distal bone stock and metaphyseal bone in subcapital fractures, however, often the plate needs to be placed to the level of the dorsal articular margin where the extensor mechanism is confluent with the dorsal capsule.

Buried intramedullary fixation with isthmal purchase allows active and active-assisted motion within the first postoperative week. A removable hand-based ulnar-gutter orthosis with the metacarpophalangeal joints in intrinsic plus position and the interphalangeal joints free is worn until suture removal and then is gradual discarded. Hand strengthening is initiated when clinical union is achieved.

This technique minimizes complications associated with K-wires and formal open plating techniques. Direct visualization of the starting point additionally potentially eliminates multiple attempts at achieving the correct starting point during percutaneous Kirschner wire insertion for retrograde intramedullary fixation. Multiple attempts to achieve an articular starting point with pure percutaneous Kirschner wire techniques may increase the risk of chondrolysis or compromised wire purchase. With neck comminution, the screw is inserted without the compression sleeve. Fixation relies on metacarpal isthmal fixation, similar to the biomechanical basis of intramedullary screw or nail fixation used elsewhere.[36–39] Therefore, the diameter of the isthmus must be templated preoperatively to ensure 3-point intramedullary fixation. For diaphyseal fractures, screw length must be sufficient to ensure the leading threads of the screws are advanced and extend proximal to the fracture line. In this HCS system, 2 options with regard to the length of the leading threads (ie, short or long leading threads) allowed expansion of this technique to axially stable diaphyseal fractures. This technique is contraindicated in fractures with intraarticular extension and in skeletally immature patients.

Quantitative 3-dimensional computed tomographic analyses support the use of an articular starting point for fixation of these fractures.[1] In 3-dimensional models simulating this technique, metacarpal head surface area and subchondral head volume occupied was minimal. Additionally, articular surface area violation was least during clinically relevant sagittal plane arc of motion because the dorsal articular starting point is in line with the medullary canal and avoids engagement of the center of the articular base through a majority of the sagittal plane arc. These clinical results and outcomes data help to validate this technique.

This study has the inherent limitations of a retrospective series. Although this was a consecutive series, prospective, randomized trials comparing multiple treatment modalities would further elucidate optimal treatment of displaced and angulated metacarpal neck and shaft fractures. As the majority of injuries were small finger metacarpal fractures in male patients, it is difficult to make assumptions about outcomes in other digits. The fractures in the other digits in this series all achieved union and full motion. The long-term impact of articular insertion starting points for subchondral headless screw fixation for these and other articular/periarticular fractures requires further study.

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