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Original Article

Threaded intramedullary headless nail fixation for fractures requiring carpometacarpal stabilization

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ABSTRACT

Carpometacarpal (CMC) fracture-dislocations are uncommon hand injuries, with few studies available regarding their treatment. The current operative treatment options include fixation with K-wires, mini-screws, or plates, though there is no standardized approach because of varying injury patterns and complications associated with each device. The INnate™ threaded intramedullary nail is a relatively novel treatment option that has shown promise in metacarpal fracture fixation by facilitating faster mobilization and recovery with enhanced rotational stability and no compression to prevent fracture displacement and shortening. This study assesses the efficacy of the INnate™ nail for fixation of CMC fracture-dislocations of the second through fifth joints.

Nine patients with fourteen CMC fracture-dislocations treated with the INnate™ nail at the University Medical Center between 2019 and 2021 were enrolled in the study. We evaluated postoperative outcomes in terms of pain, total active range of motion (TAM), and return to normal activities.

Of the nine patients, seven returned for follow-up. The average time to radiographic union was 11.5 weeks. At final follow-up, no patient reported pain ($n = 6$). Four patients had 100% TAM, 1 had

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95% TAM, and 1 had 25% TAM. The average percentage of normal activity resumed was 84.0% ($n = 5$). No significant complications were reported. One patient had a dorsal spanning plate; hence, we were unable to record outcomes measures regarding the CMC injury. An additional patient had diminished ROM of the injured hand, but his last follow-up was only 1 month postop.

Our pilot data overall suggest that the INnate™ threaded intramedullary nail has the potential to improve treatment algorithms for CMC fracture-dislocations.

Introduction

Hand and upper extremity injuries account for approximately 26% of all US emergency department encounters, with fractures accounting for 19.9% of these injuries.[1] While hand fractures are common, traumatic fracture-dislocations involving the carpometacarpal (CMC) joint are rare, constituting less than 1% of all hand injuries.[2] In general, fracture-dislocations are defined by the direction of dislocation and type of carpal and/or metacarpal fracture present. They are further differentiated by the degree of injury, amount of articular surface affected, and the specific CMC joints involved.[2–6] The fourth and fifth CMC joints are the most subject to injury as they are more mobile than the second and third joints.[4]

Nonoperative and operative treatment options vary based on the severity of the injury.[3] Conservative management through closed reduction with or without percutaneous fixation and splint immobilization is sufficient for CMC fracture-dislocations that are relatively stable, with well-aligned joints.[2,3,7] Operative intervention is necessary for more complex injuries that are unstable in nature because of the minimal articular surface area remaining between the carpal and metacarpal bones.[5,6] These injuries often include open fracture-dislocations, fractures with substantial intra-articular damage, or those with concomitant carpal or metacarpal fractures.[2] Operative treatment is believed to achieve higher rates of union while also minimizing the risk for redislocation and development of secondary osteoarthritis that can further compromise ROM and functional strength.[2,3,7] Thus, there is a growing trend toward operative intervention.

K-wires are the most common fixation modality used in the hand and wrist, including CMC fracture-dislocations, because of their low cost and versatility.[2,8,9] However, pin tract infection (reported incidence of 2–34%),[8,10–16] pin loosening and migration, nonunion, and malunion can lead to complications in this technique.[8,11,12,17,18] Plate fixation is an alternative to K-wires, though it has been associated with inferior functional outcomes and may result in diminished ROM.[17] Dorsal buttress plating allows for early postoperative mobilization but symptomatic hardware and plate failure lead to complications.[19,20]

A relatively novel operative treatment for hand fracture fixation is the INnate™ threaded intramedullary nail (ExsoMed, AlisoViejo, CA, US). The INnate™ nail may allow for earlier postoperative motion and faster recovery times because of the lack of need for splinting and/or subsequent hardware removal than the previously described techniques. It was designed to treat metacarpal fractures, with augmented thread pitch and a noncompressive design to control rotation and avoid shortening and displacement during insertion. The INnate™ nail has demonstrated enhanced rotational stability in metacarpal fracture fixation because of its threads being anchored in the bone endosteum and cortex, as well as a higher load to failure, than the K-wires.[21] Given these benefits and the lack of a gold standard treatment modality for CMC fracture-dislocations, the INnate™ nail may be uniquely suited

to treat fractures with more complex intra-articular damage by advancing the nails across the CMC joint into the adjacent carpal bone. Our study evaluates the outcomes of this novel approach in the treatment of CMC fracture-dislocations of the second through fifth joints using the INnate™ threaded intramedullary nail.

Materials and methods

All patients treated with the INnate™ threaded intramedullary nail at the University Medical Center between October 2019 and September 2021 were retrospectively enrolled in the study (Table 1). Only cases involving the second through fifth digits were included, totaling nine patients with 14 CMC fracture-dislocations. Preoperative radiographs, including posteroanterior, lateral, and oblique views, were collected for each patient. Two patients with open metacarpal fractures (2 and 6) also had preoperative CT scans of their injured hands. Though there is no absolute indication for preoperative CT scans, additional imaging may be needed for inconclusive radiographs, concerns of occult fracture, or multiple CMC dislocations. Fixation involved the use of either a 3.6 mm or 4.5 mm INnate™ nail, with lengths of 50 mm, 55 mm, or 65 mm (Figure. 1). Longitudinal incision of the skin, extensor tendon, and capsule was performed prior to surgical repair. In accordance with the manufacturer's surgical technique guide, a K-wire was used to provide preliminary fixation while measuring the length needed to advance each nail through the metacarpal into the corresponding carpus. Suitable nail lengths were then selected and positioned under fluoroscopic guidance (Figure. 2). A cannulated drill was passed over the guide wire to the desired depth, followed by the selected implant. Reduction was held as the implant was advanced into the bone past the fracture site. Fluoroscopic evaluation and intraoperative physical exam, including gross inspection and wrist tenodesis, were performed to assess correct metacarpal rotation.

Data were collected from routine postoperative visits. VAS pain scores, time to radiographic union, total active range of motion (TAM), and return to normal activities were collected at each visit. Descriptive statistics were performed to evaluate endpoints (Table 2).

Table 1
Patient details.

Subject	Age	CMC injuries treated	Injury mechanism	Concomitant injuries
1*	26	2nd MC intra-articular base fracture with dislocation	Motorcycle collision	5th P1 fracture, 3rd & 4th CMC dislocation
2	18	2nd & 3rd CMC fracture-dislocations	GSW	Open 2nd & 3rd MC shaft fractures
3	35	4th & 5th CMC dislocations, 4th MC intra-articular base fracture	ATV rollover	5th P1 fracture
4	19	4th MC intra-articular base fracture with dislocation, 5th CMC dislocation	Firework explosion	1st CMC dislocation, partial amputation of 1st and 3rd digits
5	38	4th MC intra-articular base fracture with dislocation, 5th MC base dislocation	Punch injury	n/a
6	32	2nd CMC dislocation	GSW	Open 2nd, 3rd, 4th MC fractures, 5th CMC dislocation, complete laceration of ECRB & EDM, complete laceration of FDS & FDP to index finger
7*	27	2nd & 3rd MC intra-articular base fractures	GSW	n/a
8	19	5th CMC fracture- dislocation	ATV rollover	4th MC proximal shaft fracture
9	22	4th MC intra-articular base fracture	Punch injury	5th CMC dislocation

* Patients 1 and 7 lost to follow-up.

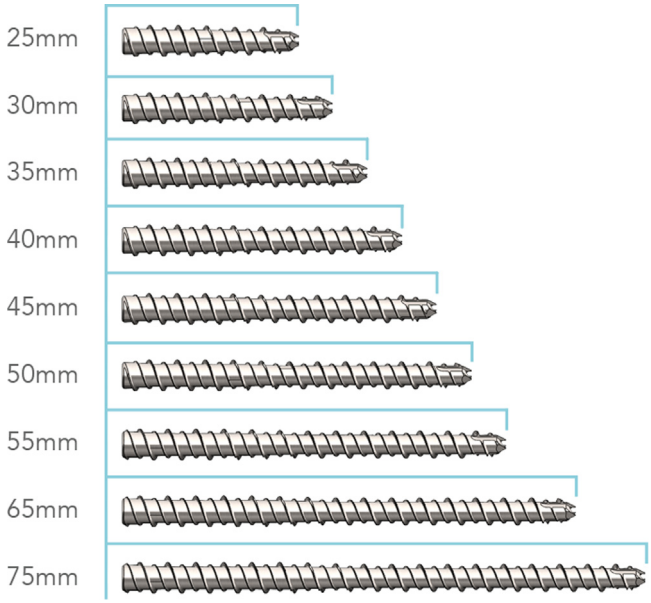

Figure 1. INnate™ intramedullary threaded nails (50–65 mm used).

Figure 2. Preoperative imaging showing initial injuries of patients 9 and 5.

Results

Nine male patients were included in our cohort, with a median age of 26.2 (range 18–38). The ExsoMed INnate™ threaded intramedullary nail was used to treat 14 CMC fracture-dislocations of the second through fifth digits. Most injuries involved the second, fourth, and fifth joints. The most common mechanism of injury was blast injury, followed by motor vehicle collision. Five patients had two concurrent CMC fracture-dislocations (Table 1).

Follow-up data were collected on seven patients. Two patients never returned for postoperative follow-up. The average time to radiographic union was 11.5 weeks ($n = 7$, range 8.1–17.6 weeks).

The mean follow-up interval was 11.9 weeks (range 4.1–17.4 weeks). All patients had VAS pain score of 0 at this point ($n = 6$). The average percentage of normal activity resumed was 84.0% ($n = 5$,

Table 2
Outcomes of INnate™ intramedullary threaded nail fixation for CMC fracture-dislocations at a mean follow-up of 11.9 weeks.

Variable (number of fractures)	Mean ± St. Dev. (range)
Radiographic union (weeks) ($n = 7$)	11.5 ± 4.2 (8–18)
VAS pain (points) ($n = 6$)	0 ± 0 (0)
% total active motion (TAM) ($n = 6$)	86.7 ± 30.3% (25–100)
% normal activity resumed ($n = 5$)	84.0 ± 19.8% (50–100)

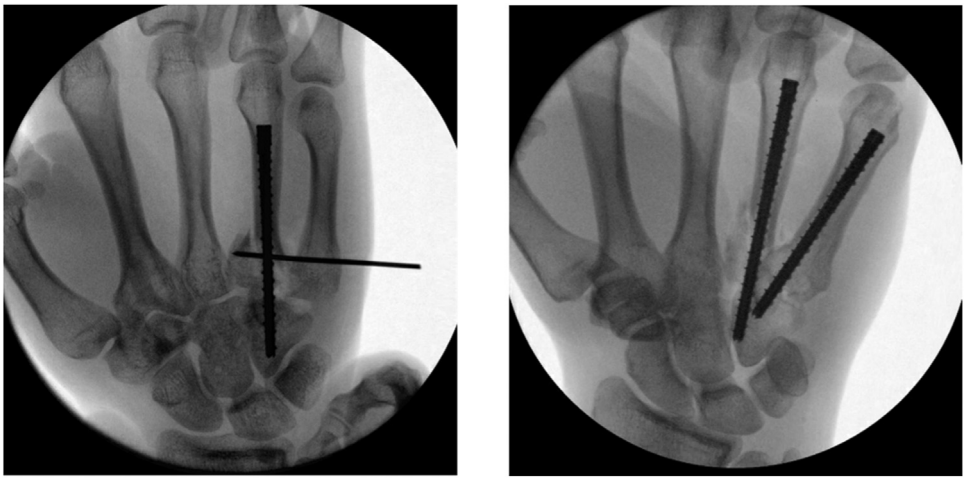

Figure 3. Intraoperative fluoroscopic-guided placement of the INnate™ intramedullary threaded nail in the fourth and fifth CMC joints (left: patient 9; right: patient 5).

range 50–100%). The average TAM was 86.7% (4 patients had 100% TAM, 1 had 95% TAM, and 1 had 25% TAM), and five of six patients were able to make a full composite fist (Table 2). Postoperative X-rays showing radiographic healing are provided in Figure. 3.

Discussion

CMC fracture-dislocations vary in complexity and severity; thus, a variety of nonsurgical and surgical methods have been accepted for managing these injuries. In a 2020 systematic review including 13 studies of ulnar-sided CMC fractures and fracture-dislocations, the authors found that the majority of acute-stable injuries were treated nonoperatively or with percutaneous surgical methods, whereas unstable or subacute fractures with more extensive comminution were treated more commonly with open surgical management.[3] The majority of CMC fracture-dislocations involve the fourth and fifth metacarpals that have increased mobility because of their saddle configuration with the hamate bone.[2,4] Because of common instability of ulnar-sided fracture-dislocations, open surgical management is preferred to achieve stable reduction and avoid degenerative arthritis and long-term functional impairments. Furthermore, in cases of open fracture-dislocations or extensive intra-articular damage, open surgical management is also indicated.[2] However, there is a lack of consensus regarding appropriate surgical treatment, likely attributable to the low reported incidence of CMC fracture-dislocation and minimal high-quality literature.[22] Figure. 4.

K-wire fixation is the most common method of treatment, overall yielding satisfactory results in terms of pain, ROM, grip strength, and return to preoperative work.[2,4–6,8,17] One study showed that open reduction and internal fixation (ORIF) and closed reduction percutaneous pinning (CRPP) with K-wires provided adequate joint alignment with little subluxation.[23] However, a significant number of patients developed postoperative infections (10.9% of CRPP patients and 37.5% of ORIF).[23] Pin tract in-

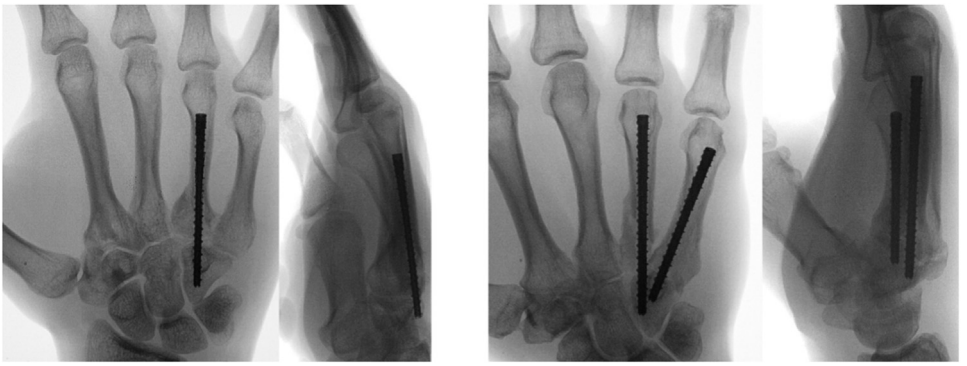

Figure 4. 8.1 week (patient 9) and 12.4 week (patient 5) postop imaging.

fections are a common complication associated with K-wires, and multiple studies have reported further problems, including pin loosening, loss of reduction, symptomatic nonunion, nerve and tendon injury, and osteomyeltis.[8,10–12] A retrospective study involving 408 K-wires reported that 14% were associated with complications that included pin migration and minor infection. Furthermore, 3% resulted in major complications (deep infection, nonunion, malunion, or fractures through the pin site) that required secondary surgical intervention.[8] K-wire fixation also requires splinting and subsequent removal 4–6 weeks postoperatively, delaying mobilization until the pins are removed.[2]

ORIF with mini-screws or temporary mini-plates has been endorsed because of the increased stability and rigid fixation compared with K-wires.[6,18,24] Screws can be used to fix avulsion fractures of the hamate while temporary plates with screws can be placed across the fourth and fifth joints for comminuted fractures. Two studies investigated the use of both mini-screws or temporary mini-plates for unstable ulnar CMC fracture-dislocations. One study reported that for both techniques the mean grip strength was 90% of the contralateral side, VAS hand pain score was 1.7, and DASH score was 9.4, though two patients had grade I arthritic changes at 1-year follow-up.[6] The second study noted that all patients (6 rigid screw and 5 plate fixation) returned to work with full recovery of hand function; however, two of five patients (40%) treated with bridge plating reported symptomatic implants and limited ROM.[24] A 2020 systematic review of ulnar CMC fracture-dislocations reported a complication rate of 33% for patients who underwent plate and screw construction, and all major complications because of painful or failed implants required hardware removal.[25] Furthermore, a retrospective study comparing K-wire vs. plate fixation for hamatometacarpal injuries found that clinical outcomes using K-wires were superior to that of plate fixation given the statistically significant difference in the average DASH and Michigan Hand Outcomes Questionnaire scores.[17] The major complaint of the plate group was impairments in performing fine motor activities, likely attributable to CMC joint stiffness.[17] Thus, despite the stability that plate fixation can provide, joint mobility is often concurrently compromised.[17,24]

Dorsal buttress plating has noted advantages as it acts as a buttress to resist dorsal subluxation of the metacarpal but does not fix the joint.[19,20] This allows for preserved anatomic mobility of the fourth and fifth CMC joints and earlier return of ROM as implant removal is not routinely necessary. In a retrospective review of 11 patients with ulnar-sided CMC fracture-dislocations, dorsal buttress plating was performed with straight plates, T plates, Y plates, or ladder plates. All patients achieved full finger ROM and fracture union without displacement or subluxation at a median of 48 days. However, five patients had to undergo hardware removal because of plate breakage or residual pain.[20] Tan et al. reported similar results in which all four patients treated with dorsal buttress plating achieved 'excellent' ROM, though one patient required removal of hardware because of residual pain.[19] Although small, these studies reported encouraging outcomes data for dorsal buttress plating but did highlight frequent complications of symptomatic hardware and plate failure.

Missed diagnosis and/or inadequate treatment of CMC fracture-dislocations may progress to malunion or residual subluxation of the joint that can cause post-traumatic arthritis. Arthrodesis has been used to relieve pain and restore hand and digit function for patients with symptomatic post-traumatic CMC arthritis.[2,26,27] Given these reported results, some have considered acute arthrodesis as a potential alternative to address unstable fracture-dislocations or those with significant intra-articular damage when traditional fixation is unsuccessful. Two studies reported that early arthrodesis following failed closed reduction or ORIF of unstable second and third CMC fractures-dislocations led to high patient satisfaction and return to work.[26,27]

The INnate™ threaded intramedullary nail was developed to address the shortcomings of historical fixation methods described above. While there are no existing studies evaluating its utility in CMC fracture-dislocations, there are promising data showing improved rotational stability and higher load to failure than the K-wires for metacarpal fracture fixation.[21] These nails likely share benefits analogous to intramedullary headless compression screws such as earlier ROM and faster fracture unification and recovery time, compared with K-wire fixation, because of the lack of need for splinting.[21,28,29] Yet, the major differences between the INnate™ nail and intramedullary headless compression screw are that the INnate™ nail has a noncompressive design (compared with a screw), threads designed for circumferential intermedullary purchase, and a dual diameter to allow easier passage through the isthmus. Thus, the novel design of the INnate™ nail provides further advantages by circumventing the risk for compression and secondary intra-articular shortening. This feature may be exceedingly important when treating more unstable or complex fracture patterns. In addition, the variable lengths available allow it to span across the CMC joint to possibly increase stability and prevent future subluxation. Use of the INnate™ nail may be contraindicated if the head of the metacarpal is split because of the need of an articular head, poor soft tissue coverage, or an active ongoing infection. However, in the event of any complications, the nails can be easily removed.

Our results indicate that the INnate™ threaded intramedullary nail may be effective in the treatment of fracture-dislocations of the second through fifth CMC joints. In five patients, the INnate™ nail was advanced through the fourth and/or fifth metacarpal into the hamate. The remaining 4 patients with second CMC fracture-dislocations were treated by fixating the nail through the metacarpal into the trapezoid. Two of these four patients had concomitant third CMC fracture-dislocation in which the nails were advanced through the third metacarpal into the capitate. Despite the significant injuries in our cohort, stable fixation was achieved without the need for immobilization or subsequent hardware removal. Most patients returned to their normal activities and regained full ROM without pain at their last follow-up visit. One patient (subject 6) had severe bone loss of multiple metacarpal and carpal bones and was also treated with a dorsal spanning plate, which he refused to have removed. As a result, we were unable to record outcomes measures regarding his CMC injury at final follow-up. An additional patient (subject 3) had diminished ROM of the injured hand, but his last follow-up was only 1-month postop and the patient had not begun therapy.

Our pilot data suggest that the INnate™ threaded intramedullary nail has the potential to improve treatment algorithms for unstable CMC injuries or those with significant intra-articular damage. Thus, we recommend further use and research into the efficacy of CMC joint fixation with the INnate™ nail.

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Ethical approval

Approval for this study was obtained from our Institutional Review Board (LUBBOCK IRB #00000096, IRB #: L20–034, submission reference #: 088904), and appropriate informed consent as well as any necessary HIPAA consent was obtained.

Declaration of Competing Interest

None.

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