SCIENTIFIC ARTICLE

Complications Following Intramedullary Screw Fixation for Metacarpal Fractures: A Systematic Review

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Purpose There has been a recent increase in the use of intramedullary screws (IMS) for the surgical treatment of metacarpal fractures. While IMS fixation has been shown to produce excellent functional outcomes, postoperative complications have yet to be fully explored in a comprehensive way. This systematic review quantified the incidence, treatment, and results of complications following IMS fixation for metacarpal fractures.

Methods A systematic review was performed using PubMed, Cochrane Central, EBSCO, and EMBASE databases. All clinical studies that documented IMS complications following metacarpal fracture fixation were included. Descriptive statistics were analyzed for all available data.

Results Twenty-six studies were included: 2 randomized trials, 4 cohort studies, 19 case series, and 1 case report. Among the 1,014 fractures studied, 47 complications were reported across all studies (4.6%). Stiffness was the most common, followed by extension lag, loss of reduction, shortening, and complex regional pain syndrome. Other complications included screw fracture, bending, and migration; early-onset arthrosis; infection; tendon adhesion; hypertrophic scar; hematoma; and nickel allergy. Eighteen of the 47 (38%) patients with complications underwent revision surgery.

Conclusions Complications following IMS fixation of metacarpal fractures are relatively uncommon. *(J Hand Surg Am. 2023;■(■):1.e1-e16. Copyright © 2023 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Complications, fracture, hand surgery, intramedullary screw, metacarpal.

Online Exclusive

METACARPAL FRACTURES ARE ONE of the most frequently encountered fractures of the upper extremity, with an incidence as high as 13.6 per 100,000 person-years in the United States.[1] While most metacarpal fractures can be managed nonsurgically, displaced, unstable, and multiple metacarpal fractures are often considered indications for surgical intervention.[2] Historically, techniques for metacarpal fracture fixation have included intramedullary and transverse Kirschner wires (k-wires), interfragmentary screws, and plate constructs.[3] Previous studies have demonstrated similar outcomes across these techniques and have described distinct benefits and complication profiles related to each modality.[4,5] However, there remains a paucity of data on alternative repair techniques,

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such as intramedullary screws (IMS), for treating unstable metacarpal fractures.[5]

Since it was first described in 2010,[6] IMS fixation for metacarpal fractures has grown in popularity among hand surgeons. Prior studies have demonstrated IMS to have a low complication rate of 2.5% to 5.3%, with the benefit of early mobilization and decreased soft-tissue morbidity.[7–10] To our knowledge, no studies have comprehensively reviewed postoperative complications following IMS fixation for metacarpal fractures. Considering the growing utilization of IMS, a broader assessment and understanding of all IMS-related complications is warranted.

The purpose of this study was to perform a systematic review of the current literature to determine the incidence, treatment, and results of all postoperative complications for metacarpal fractures treated with IMS fixation.

MATERIALS AND METHODS

Literature search and study eligibility

A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[11] using PubMed (MEDLINE), Cochrane Library (Wiley), EBSCO, and EMBASE (Elsevier) databases. The search was conducted from January 1, 2000, to April 1, 2022, and all references, regardless of the publication date, were considered. A broad query of the search terms "intramedullary" AND "metacarpal" was used across the four databases to capture all relevant literature.

Two independent reviewers (C.C.A and T.L.T) screened all identified titles and abstracts for the presence or absence of a mention of complications following IMS fixation of metacarpal fractures. Discrepancies were resolved by a third reviewer (C.M.J). Complications were defined based on each author's description and methodology to provide a comprehensive summary of available data. General categories included infection, loss of fixation, hardware failure, malrotation, malunion, nonunion, postoperative stiffness, tendon adhesions, and repeat surgical interventions. Full-text articles were extracted and reviewed for the following inclusion criteria: (1) clinical studies (randomized control trial, cohort studies, case series, and case reports) investigating outcomes of metacarpal fracture surgically treated with IMS, (2) studies reporting the presence or absence of complications related to IMS fixation, and (3) studies printed in or translated into English. All references within the included studies were cross-referenced for potential inclusion. Biomechanical studies, cadaveric studies, animal studies, technique articles without outcomes, systematic reviews, meta-analyses, textbook chapters, expert opinions, commentary letters, and editorials were excluded.

Data evaluation

Following final exclusion, standard data extraction was performed for the following items: institution, study period, study design, patient demographics such as age, sex, follow-up time, injured metacarpal, fracture type, instrumentation (including brand and model), surgical technique, operative time, number of screws, screw diameter, rehabilitation protocol, postoperative complications, complication incidence, time to complication, and treatments/revisions necessary. Included studies were further assessed for methodological quality and risk of bias by 2 independent reviewers (C.C.A and T.L.T). Randomized studies were assessed using the Cochrane Risk-of-Bias (RoB2.0) tool,[12] and nonrandomized studies were evaluated using the Risk of Bias in Non-randomized Studies-of Interventions (ROBINS-I) tool.[13]

Descriptive statistics were reported for all available data. Due to substantial heterogeneity among the included studies and the scarcity of available complication-specific patient demographics, multivariable analyses and meta-analyses could not be performed.

RESULTS

A total of 919 articles from the four databases were identified from the initial search query. Following title and abstract screening, 42 articles remained and underwent full-text review, of which 26 studies met the final inclusion criteria (Fig. 1).[14–39]

Table 1 summarizes the characteristics of the included studies. Most (77%) studies were performed at a single institution, with study periods ranging from 2007 to 2019. Of the included articles, two were randomized control trials,[14,16] four were retrospective cohort studies,[15,17–19] 19 were case series,[20–37,39] and one was a case report.[38] Assessment of the randomized control trials showed that both studies had some concerns for bias based on the RoB2.0 tool (Supplementary Figure 1; available online on the Journal's website at www.jhandsurg.org). For the nonrandomized studies, 12 had a moderate risk of bias, and 11 had a serious risk of bias based on the ROBINS-I tool (Supplementary Figure 2; available online on the Journal's website at www.jhandsurg.org).

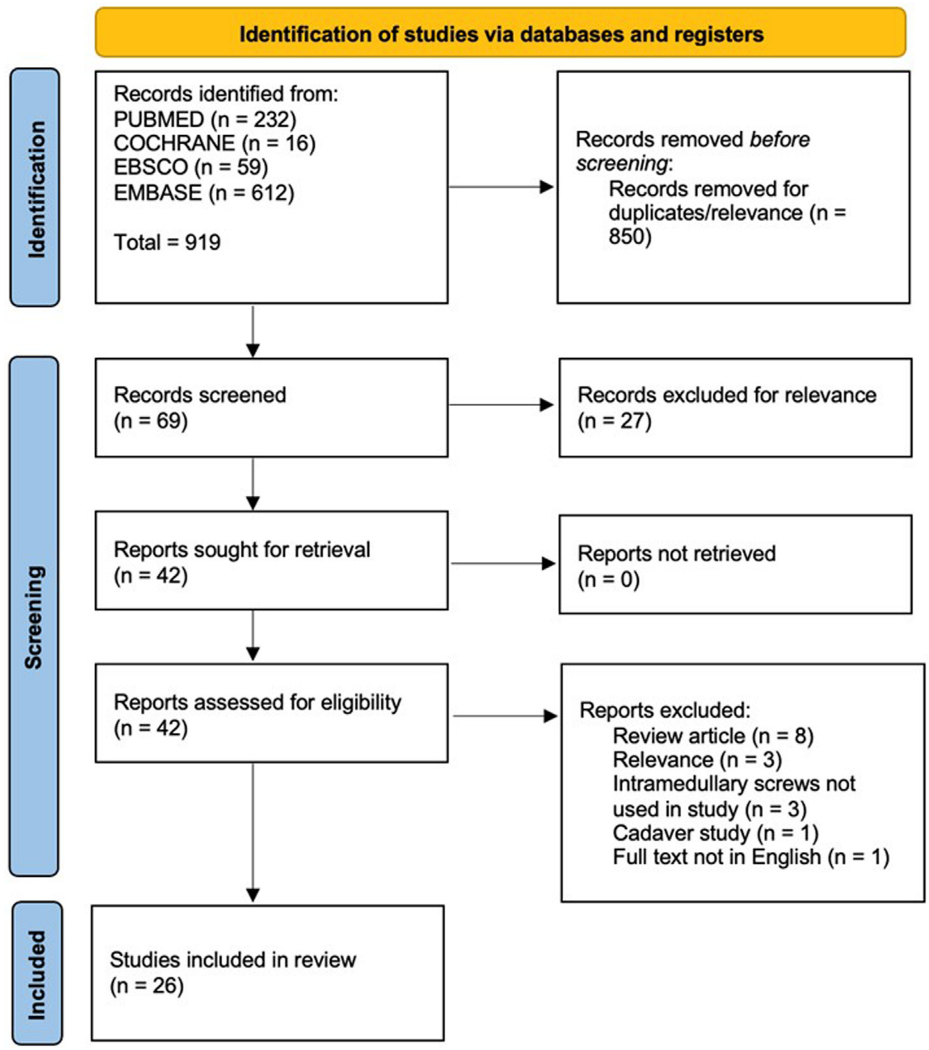

FIGURE 1: Flow chart for the systematic review performed under Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

Patient demographics and surgical details from the included studies are described in Table 2. A total of 1,014 fractures were studied. Most articles studied base, shaft, or neck fractures in metacarpals 2–5 (Table 2). Two studies evaluated only the fifth metacarpal neck and/or shaft fractures,[16,26] and one study evaluated only first metacarpal base fractures.[32] The mean age was 33 years (range 23–63), and 17% of patients were women. The mean follow up was 9.3 months (range 3–19). All fractures studied were treated with headless cannulated screws, but the screws were from a variety of manufacturers. Ninety-six percent of the fractures were repaired with a single screw. Ninety-two percent of the fractures were repaired in a retrograde fashion (Table 2). Screws utilized ranged from 2.2 mm to 4.1 mm in diameter. Specifications for screw length were seldom reported.

Complications are summarized in Table 3. Of the 1,014 metacarpals studied, 47 (4.6%) complications were identified. Both functional and screw-related complications were described. The most common postoperative complication was stiffness (three studies [incidence, 0.9%]). Less common complications were extension lag (four studies [incidence, 0.5%]), the loss of reduction (three studies [incidence, 0.5%]), complex regional pain syndrome (CRPS) (two studies [incidence, 0.5%]), and shortening (one study [incidence, 0.5%]). Rarely reported complications included early-onset arthrosis, hematoma, hypertrophic scar, infection, nickel allergy, periarticular click, shortening, tendon adhesion, and trigger finger (Table 3). Screw-related complications included bent screws (two studies [incidence, 0.4%]), fractured screws (two studies [incidence, 0.4%]), and screw migration (two studies [incidence, 0.2%]).

TABLE 1. Characteristics of the Included Studies

Author (y)	Study Period (y)	Data Source	Study Design	Risk of Bias	Total Fractures	Age, y (mean ± SD [range])	Male/ Female	Follow up, mos (mean ± SD [range])	Fracture Digit (Location)
Aita et al (2021)[16]	2016–2017	Dual Institution	Randomized Control Trial	Some Concerns	21	30 (18–52)	NR	14 (6–15)	5 (neck)
Kibar et al (2022)[14]	2017–2019	Single Institution	Randomized Control Trial	Some Concerns	37	33 (18–61)	28/6	12	2–5 (shaft)
García-Medrano et al (2022)[17]	2019	Dual Institution	Retrospective Cohort	Serious	20	38 (18–53)	16/4	4 (2–7)	2–5
Coucerio et al (2018)[15]	2009–2017	Single Institution	Retrospective Cohort	Moderate	19	32 (18–59)	16/3	NR	2–5
Esteban-Feliu et al (2021)[18]	2011–2017	Single Institution	Retrospective Cohort	Moderate	65	NR	NR	NR	3–5
Brewer et al (2021)[19]	2016–2019	Single Institution	Retrospective Cohort	Moderate	13	NR	NR	NR	NR
Ruchelsman et al (2014)[23]	2010–2014	Single Institution	Prospective Case Series	Moderate	39	28 (16–66)	34/5	13 (3–33)	2,4,5 (shaft, neck)
Barrera-Ochoa et al (2020)[32]	2015–2018	Single Institution	Prospective Case Series	Moderate	13	29 (18–51)	12/1	19 (6–33)	1 (base)
Tobert et al (2016)[20]	2007–2015	Single Institution	Retrospective Case Series	Serious	18	32 (17–74)	13/3	5 (0.5–20)	2–5 (shaft, neck)
Warrender et al (2020)[21]	2007–2016	Multi Institution	Retrospective Case Series	Serious	160	29 (15–69)	123/27	5 (0.5–21)	2–5
del Piñal et al (2015)[22]	2008–2013	Single Institution	Retrospective Case Series	Serious	48	NR	NR	19 (5–54)	NR
Sellers et al (2020)[24]	2010–2016	Single Institution	Retrospective Case Series	Serious	42	NR	NR	NR	2–5 (shaft, neck)
Eisenberg et al (2020)[25]	2010–2017	Single Institution	Retrospective Case Series	Moderate	91	28 (15–69)	79/12	10 (1–71)	2–5 (shaft, neck)
Doarn et al (2015)[26]	2011–2013	Dual Institution	Retrospective Case Series	Moderate	9	32 (19–54)	9/0	9 (2–14)	5 (shaft, neck)
del Piñal et al (2022)[27]	2012–2020	Single Institution	Retrospective Case Series	Serious	16	34 (17–66)	12/4	NR	2–5 (base, shaft, neck)
Casal et al (2018)[28]	2013–2017	Single Institution	Retrospective Case Series	Serious	62	36	47/6	12 (6–48)	2–5

(Continued)

TABLE 1. Characteristics of the Included Studies (Continued)

Author (y)	Study Period (y)	Data Source	Study Design	Risk of Bias	Total Fractures	Age, y (mean ± SD [range])	Male/ Female	Follow up, mos (mean ± SD [range])	Fracture Digit (Location)
Poggetti et al (2018)[30]	2014−2015	Single Institution	Retrospective Case Series	Serious	25	33 (19−59)	24/1	4 (2−6)	2−5 (base, neck)
Nucci et al (2018)[39]	2014−2015	Single Institution	Retrospective Case Series	Moderate	25	NR	NR	NR	NR
Jann et al (2018)[31]	2014−2016	Single Institution	Retrospective Case Series	Moderate	20	38 (20−77)	15/0	4 (1−17)	2,4,5 (base, shaft, neck)
Poggetti et al (2021)[29]	2014−2019	Multi Institution	Retrospective Case Series	Moderate	135	NR	NR	NR	NR
Folberg et al (2021)[33]	2015−2018	Single Institution	Retrospective Case Series	Serious	21	34 ± 14 (18−75)	19/2	NR	2,3,5 (neck)
Thakker et al (2021)[34]	2016−2018	Single Institution	Retrospective Case Series	Serious	30	29 (20−59)	24/3	NR	4,5 (neck, head)
Camacho et al (2021)[35]	2016−2019	Multi Institution	Retrospective Case Series	Moderate	45	23	NR	6 (2−36)	NR
Siddiqui et al (2019)[36]	2018−2019	Single Institution	Retrospective Case Series	Moderate	32	31 ± 13 (17−68)	26/6	NR	2−5 (base, neck)
Feldman et al (2020)[37]	NR	Single Institution	Retrospective Case Series	Serious	24 (21−58)	1/2	NR	2,4,5	1
Hoang and Huang (2019)[38]	NR	Single Institution	Case Report	NA	5	63 (50−75)	1/1	3 (0.5−6)	2−5 (shaft)

Note. NR, not reported; NA, not applicable.

TABLE 2. Patient Demographics and Surgical Details of Included Studies

Author (y)	No. of Screws	Antegrade/ Retrograde	Instrumentation (Model-Brand)	Screw Diameter (mm)	Operative Time (min)	Rehabilitation Protocol
Aita et al. (2021)[16]	2	Retrograde	Headless Cannulated Screw (HCS-DePuy Synthes)	2.4, 3.0	NR	NR
Barrera-Ochoa et al. (2020)[32]	1	Retrograde	Headless Cannulated Screw (FootMotion-Newclip Technics)	4.0	18 (15—26)	During the first week, patients were placed in soft bandage and asked to perform active range of motion, passively assisted exercises and use the hand for daily activities. Unrestricted activities were permitted after 3—4 wk.
Brewer et al. (2021)[19]	NR	NR	Cannulated Screw	NR	66.1 ± 7.1	NR
Camacho et al. (2021)[35]	1	Retrograde	Headless Cannulated Screw (HCS-DePuy Synthes)	3.0	NR	NR
Casal et al. (2018)[28]	1	Retrograde	Headless Cannulated Screw (Acutrak-Acumed; AutoFIX-Tarma)	2.5, 3.5, 4.0	NR	Patients were immobilized for an average of 7 d, followed by active mobilization (excluding cases with soft-tissue injuries).
Coucerio et al. (2018)[15]	1	Retrograde	Headless Cannulated Screw	2.4, 3.0	NR	NR
del Piñal et al. (2015)[22]	1	Retrograde	Headless Cannulated Screw (AutoFIX-Small Bone Innovations)	3.0, 4.0	NR	Immediate range of motion exercises were started. Formal therapy was not required for simple fractures.
del Piñal et al. (2022)[27]	1	Retrograde	Headless Cannulated Screw (AutoFIX-Stryker)	3.0	NR	Immediate range of motion exercises were encouraged. Formal therapy and orthoses were utilized in cases where additional osteotomy was performed.
Doarn et al. (2015)[26]	1	Retrograde	Headless Cannulated Screw (HCS-DePuy Synthes)	3.0	NR	Patients were initially immobilized in an ulnar gutter plaster splint. Hand therapy was initiated within 5—7 d and patients were switched to a custom ulnar gutter resting orthosis. Once full range of motion and radiographic healing was obtained, resting orthosis was discontinued.
Eisenberg et al. (2020)[25]	1	Retrograde	Headless Cannulated Screw (HCS-DePuy Synthes)	2.4, 3.0	NR	Active and active-assisted range of motion was permitted within the first week. A removable ulnar gutter orthosis with interphalangeal joints free was worn until suture removal, then gradually weaned. Strengthening was begun at 4 wk postoperatively.

(Continued)

TABLE 2. Patient Demographics and Surgical Details of Included Studies (Continued)

Author (y)	No. of Screws	Antegrade/ Retrograde	Instrumentation (Model-Brand)	Screw Diameter (mm)	Operative Time (min)	Rehabilitation Protocol
Esteban-Feliu et al. (2021)[18]	1	Retrograde	Headless Cannulated Screw (Hand Plating System - OsteoMed)	3.0	25.1 ± 5.2	Patients were immobilized in bulky soft dressing and hand movement was started immediately. Unprotected motion was permitted upon clinical healing. A protective nocturnal splint was prescribed to prevent proximal interphalangeal joint extensor lag.
Feldman et al. (2020)[37]	1	Retrograde	Headless Compression Screw	NR	NR	NR
Folberg et al. (2021)[33]	1	Retrograde	Headless Cannulated Screw (Herbert-type)	3.0	<45 (10−42)	Patients were instructed to mobilize fingers within the first week as tolerated and encouraged further with decreased pain and edema at days 5−7. Formal therapy was reserved for patients with slowly progressing range of motion at 3 wk.
García-Medrano et al. (2022)[17]	1	Retrograde	Headless Cannulated Screw (Herbert-type-Acumed)	NR	NR	Patients were protected with an elastic bandage and encouraged to mobilize their fingers immediately. Bandage and sutures were removed after 10 d, allowing for full active range of motion exercises.
Hoang and Huang (2019)[38]	1	Antegrade and Retrograde	Headless Cannulated Screw (Acutrak-Acumed; HCS-DePuy Synthes)	3.0, 4.1	NR	Patients were placed in a short-arm plaster orthosis and began hand therapy at 4−5 d postoperatively for active range of motion exercises. A removable thermoplast orthosis was given for nighttime use. Strengthening and weightbearing was initiated following radiographic and clinical healing (typically 6−12 wk postoperatively).
Jann et al. (2018)[31]	1	Retrograde	Cannulated Compression Screw (CCS SpeedTip-Medartis)	2.2, 3.0	21 (5−45)	Immediate active range of motion was started under the guidance of a hand therapist. Passive mobilization and strengthening was begun at 4 wk postoperatively.
Kibar et al. (2022)[14]	1	Retrograde	Headless Cannulated Screw (TST Union Medical Devices)	3.0, 4.0	23 ± 10 (5−45)	Immediate active wrist and finger exercises were started on postoperative day 1 and gradually progressed. Formal therapy was reserved for patients who did not achieve full range of motion by 4 wk postoperatively.

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TABLE 2. Patient Demographics and Surgical Details of Included Studies (Continued)

Author (y)	No. of Screws	Antegrade/ Retrograde	Instrumentation (Model-Brand)	Screw Diameter (mm)	Operative Time (min)	Rehabilitation Protocol
Nucci et al. (2018)[39]	1	Retrograde	Headless Cannulated Screw (CCS SpeedTip-Medartis; HCS-DePuy Synthes)	3.0	NR	Patients were encouraged to begin active range of motion exercises immediately after surgery.
Poggetti et al. (2018)[30]	1	Retrograde	Headless Cannulated Screw (CCS SpeedTip-Medartis; HCS-DePuy Synthes)	3.0	NR	Patients with single fractures received buddy dressing to the adjacent fingers and a splint was used in cases of multiple fractures. Patients were encouraged to actively move their fingers immediately after their surgery.
Poggetti et al. (2021)[29]	1	Antegrade and Retrograde	Headless Cannulated Screw (CCS SpeedTip-Medartis; HCS-DePuy Synthes; BSS Mikai)	3.0	NR	Patients were encouraged to actively move their fingers immediately after their surgery.
Ruchelsman et al. (2014)[23]	1	Retrograde	Headless Cannulated Screw (HCS-DePuy Synthes)	2.4, 3.0	NR	Patients were placed in a removable hand-based ulnar gutter orthosis until suture removal, then gradually weaned. Patients were encouraged to perform active range of motion exercises within the first postoperative week. Strengthening exercised started at 4 wk postoperatively.
Sellers et al. (2020)[24]	1	Retrograde	Headless Cannulated Screw (HCS-DePuy Synthes)	2.4, 3.0, 3.5	NR	Hand therapy was started within 3−5 d postoperatively, which included active and passive range of motion, and application of a resting orthosis.
Siddiqui et al. (2019)[36]	1	Retrograde	Headless Screw	2.4, 3.0	NR	Patients were immobilized with splints for 1 wk postoperatively.
Thakker et al. (2021)[34]	1	Retrograde	Headless Compression Screw (Acutrak-Acumed)	3.5, 4.0	NR	NR
Tobert et al. (2016)[20]	1	Retrograde	Headless Cannulated Screw (HCS-DePuy Synthes)	3.0	NR	Patients were immobilized in forearm-based volar and dorsal splints. Rehabilitation was started at 5−7 d postoperatively.
Warrender et al. (2020)[21]	1	Retrograde	Headless Cannulated Screw (HCS-DePuy Synthes)	2.4, 3.0	NR	NR

Note. NR, not reported; NA, not applicable. Operative time reported as mean ± SD (range).

TABLE 3. Complications, Treatments, and Outcomes From the Included Studies

Author (y)	Fractures	Complication	Total incidence (%)	Per study incidence (%)	Time to complication (wk)	Treatment	Results
Eisenberg et al. (2020)[25]	91	Arthrosis	0.1	1/91 (1.1)	Final follow up (unspecified)	NR	NR
Camacho et al. (2021)[35]	45	Bent screw	0.4	2/45 (4.4)	4 (n = 1) 8 (n = 1)	ORIF. The bent screw was extracted through the metacarpal head and a new compression screw (3.0 mm diameter and 40 mm length) was placed.	Both patients achieved clinical healing at 4 wk and returned to usual activities thereafter. Full range of motion of the metacarpophalangeal joint (0° to 90°) was achieved in both patients.
Warrender et al. (2020)[21]	160	Bent screw		2/160 (1.3)	72 (n = 1) 24 (n = 1)	None (n = 1) ORIF with plate and screws, and removal of broken screw (n = 1)	One patient presented 18 mos postoperatively for medical clearance and an incidental bent screw was found. The patient was asymptomatic and fractured healed well, so no further treatment was required. The second patient sustained blunt trauma to the hand 6 mos post index procedure, requiring a revision ORIF. No further information was reported about this patient's outcome.
Casal et al. (2018)[28]	62	Complex regional pain syndrome	0.5	2/62 (3.2)	NR	Medical and rehabilitation treatment (unspecified)	The patient had no persistent symptoms or functional repercussions.
Brewer et al. (2021)[19]	13	Complex regional pain syndrome		3/13 (23)	NR	NR	NR
Coucerio et al. (2018)[15]	19	Extension lag	0.5	1/19 (5.3)	NR	None	Extension lag did not interfere with the patient's activities of daily living. Quick DASH score was 6.8 at final follow up.
Folberg et al. (2021)[33]	21	Extension lag		1/21 (4.8)	NR	NR	The patient had a 10° extension lag and 10° less flexion of the metacarpophalangeal joint compared to their contralateral hand. This did not have functional repercussions and returned to previous activities with no complaints.

(Continued)

TABLE 3. Complications, Treatments, and Outcomes From the Included Studies (Continued)

Author (y)	Fractures	Complication	Total incidence (%)	Per study incidence (%)	Time to complication (wk)	Treatment	Results
García-Medrano et al. (2022)[17]	20	Extension lag		2/20 (10)	NR	None (n = 1) Removal of hardware (n = 1)	One patient had a 30° extension lag at the proximal interphalangeal joint and did not request revision surgery. Final quick DASH score was 2.27. The second patient had pain and a 20° extension lag at the metacarpophalangeal joint, requiring revision surgery (removal of hardware). Final quick DASH score was 2.27.
Jann et al. (2018)[31]	20	Extension lag		1/20 (5)	NR	None	The patient had a 25° extension lag but declined recommendation for a tenolysis procedure.
García-Medrano et al. (2022)[17]	20	Hematoma	0.1	1/20 (5)	NR	NR	Revision surgery was not required. Final quickDASH score was 15.91.
Casal et al. (2018)[28]	62	Hypertrophic scar	0.1	1/62 (1.6)	NR	None	The patient had no persistent symptoms or functional repercussions.
Brewer et al. (2021)[19]	13	Infection	0.1	1/13 (7.7)	NR	NR	NR
Aita et al. (2021)[16]	21	Loss of reduction	0.5	1/21 (4.8)	NR	None	Although indicated, the patient did not undergo a revision surgery.
Camacho et al. (2021)[35]	45	Loss of reduction		1/45 (2.2)	Initial postop visit (unspecified)	ORIF. The screw was removed at the proximal fracture line and a new compression screw was placed.	The patient recovered well with rehabilitation, achieving full range of motion of the metacarpophalangeal joint (0° to 90°). Clinical and radiographic healing of the fracture site were observed at 4- and 6-wk post revision surgery. The patient returned to work 4 wk post reintervention.
Esteban-Feliu et al. (2021)[18]	65	Loss of reduction		3/65 (4.6)	NR	Removal of hardware	NR

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TABLE 3. Complications, Treatments, and Outcomes From the Included Studies (Continued)

Author (y)	Fractures	Complication	Total incidence (%)	Per study incidence (%)	Time to complication (wk)	Treatment	Results
Warrender et al. (2020)[21]	160	Nickel Allergy	0.1	1/160 (0.6)	2	Failed topical steroid treatment. Subsequent, removal of hardware	The patient noted a rash and swelling similar to that of a prior nickel exposure. Due to the direct temporal correlation and immunological confirmation, the screw was removed once the fracture healed. The screw was subsequently removed at 3 mos with no sequelae.
Ruchelsman et al. (2014)[23]	39	Periarticular click	0.1	1/20 (5)	NR	None	Intermittent periarticular click with active metacarpophalangeal range of motion. Did not require further treatment.
Eisenberg et al. (2020)[25]	91	Screw fracture	0.4	3/91 (3.3)	NR	ORIF with plate and screws, and removal of broken screw through fracture site.	NR
Warrender et al. (2020)[21]	160	Screw fracture		1/160 (0.6)	40	ORIF with plate and screws, and removal of broken screw	NR
del Piñal et al. (2015)[22]	48	Screw migration	0.2	1/48 (2.1)	52	Removal of hardware	Range of motion improved in the adjacent finger by 40° following screw removal. Excellent results (up to 250° of total active motion) were obtained at final visit.
Jann et al. (2018)[31]	20	Screw migration		1/20 (5)	NR	Removal of hardware	This patient was asymptomatic but underwent removal of hardware to prevent future damage to their joint cartilage.
Casal et al. (2018)[28]	62	Shortening (maximum 4 mm)	0.5	5/62 (8)	NR	None	The patient had no persistent symptoms or functional repercussions.
Feldman et al. (2020)[37]	3	Stiffness	0.9	1/3 (33)	12	None	This did not interfere with the patient's activities of daily living and no further intervention was necessary.

(Continued)

TABLE 3. Complications, Treatments, and Outcomes From the Included Studies (Continued)

Author (y)	Fractures	Complication	Total incidence (%)	Per study incidence (%)	Time to complication (wk)	Treatment	Results
Jann et al. (2018)[31]	20	Stiffness		1/20 (5)	NR	Tenoarthrolysis of the metacarpophalangeal joints	The patient had a severe flexion deficit following their primary polytrauma of two metacarpal and one phalanx fractures. Following revision surgery, he would go on to achieve good function and 80° of flexion in both metacarpophalangeal joints.
Coucerio et al. (2018)[15]	19	Stiffness		2/19 (11)	NR	None	Both patients declined further surgeries, removal of hardware or tenolysis. Final quick DASH scores were 22.7 and 4.5, respectively.
Siddiqui et al. (2019)[36]	32	Stiffness		3/32 (9.4)	NR	NR	NR
Thakker et al. (2021)[34]	30	Stiffness		2/21 (10)	4–8	Capsulotomy and tenolysis	The first patient presented at 4–8 wk follow up with 185° of total active motion following primary repair. They received revision surgery at 5, 8, and 18 mos to achieve full range of motion (270°). The second patient presented at 4–8 wk follow up with a total active motion of 200°. Following revision surgery at 5 and 8 mos, they returned to full activity and 270° of motion.
Brewer et al. (2021)[19]	13	Tendon adhesion	0.1	1/13 (7.7)	NR	NR	NR
Casal et al. (2018)[28]	62	Trigger finger	0.1	1/62 (1.6)	8	Steroid injection	The patient had no persistent symptoms or functional repercussions.

Note. NR, not reported; NA, not applicable.

Overall, 2% of cases required additional surgery (1.8%) or medical management (0.2%) following IMS fixation. Among the 47 complications reported, 18 underwent revision surgery with either ORIF, the removal of hardware, or tenolysis (38% [total incidence, 1.8%]); two cases complicated by CRPS received unspecified medical treatment and therapy (4.2% [total incidence, 0.19%])); and a single case complicated by trigger finger was treated with a steroid injection (2.1% [total incidence, 0.1%])) (Table 3).

DISCUSSION

The utilization of IMS for managing unstable metacarpal fractures has grown over the past decade, likely due to its minimally invasive nature and excellent clinical outcomes.[10] Purported advantages of IMS include early postoperative mobilization and minimal soft-tissue morbidity.[21,25,40] Moreover, rigid fixation may allow for a faster return to work/sport at a reduced risk for adverse events.[40] Nevertheless, IMS carries distinct drawbacks, such as articular cartilage and extensor tendon disruption secondary to retrograde screw insertion.[22,41,42] After analyzing 26 articles, the overall rate of IMS complications was 4.6% (range, 0%−39%). The most common postoperative complications were stiffness, extensor lag, loss of reduction, CRPS, and shortening. Although the type, complexity, and severity of postoperative complications varied, most were successfully treated and resolved at the final follow up.

Stiffness was the most common complication, occurring in 0.9% of cases. Of the nine stiffness cases reported, three (33%) underwent revision surgery. The etiology underlying postoperative stiffness is likely multifactorial, possibly associated with polytrauma and limited postoperative rehabilitation. Jann et al described a single case of severe flexion deficit secondary to a severe polytrauma of two metacarpals and one phalanx that was immobilized for over 1 month.[31] The patient eventually required arthrolysis of the MCP joints and achieved good function with 80° of MCP flexion at the final follow up. The authors suspect that the prolonged immobilization period hindered functional outcomes in this patient.

In a study of nine cadavers, Strauch et al described a direct relationship between metacarpal shortening and MCP extension lag, which demonstrated that for every 2 mm of shortening, there is an average of 7° of extension lag.[43] In our study, extension lag at the MCP joint and metacarpal shortening occurred in 0.5% of cases. Of the five cases of extension lag reported, only one underwent revision surgery.[17] A study from our review reported five cases of metacarpal shortening up to 4 mm following IMS fixation.[28] While one might expect this degree of shortening (estimated 28° of extension lag) to require further management, none of the patients reported symptoms or functional deficits.

Loss of reduction occurred in 0.5% of total cases. Of the five cases reported, four underwent revision surgery. The loss of reduction directly affects fracture healing and often requires urgent surgical intervention to prevent malunion. Esteban-Feliu et al postulated that their complications were likely the result of an overly dorsal screw entry point in two cases and inadequate screw length in a third case.[18] Although IMS does not provide absolute rotational control of the fracture as a plate and screws would, relative rotational control can be achieved with a screw sized appropriately for a tight fit in the metacarpal isthmus. These findings emphasize the importance of appropriate screw size to achieve the sufficient bone purchase of the distal fragment. Since there were no reported complications of rotational malunion, rotational control may not be critical in the fixation of the axially stable fractures (eg, transverse and short oblique) for which this technique is best suited.

While less commonly described, screw-related complications following IMS fixation can occur. Two studies reported four cases of bent screws following new recurrent trauma to the operated hand.[21,35] Similarly, two studies described four screw fractures following repeat blunt trauma to the treated hand.[21,25] While the potential for screw bending and fracture following recurrent metacarpal trauma may lead some to question the biomechanical strength of IMS fixation compared with rigid constructs such as plate and screws, IMS demonstrated a higher peak load to failure and stronger stiffness in transverse and oblique metacarpal fractures than dorsal plating and lag screws.[40] Despite the superior biomechanical stability of IMS, treating surgeons should be aware of the risk for refracture following recurrent blunt trauma. Moreover, patients should be properly counseled about the potential for screw-related complications following recurrent trauma.

Two studies reported a total of two cases of screw migration.[22,31] Although asymptomatic, both patients underwent preventative removal of hardware to avoid future damage to their joint cartilage. While there is a low incidence (0.2%) of screw migration following IMS, it should be noted that screw migration may present up to one year postoperatively. Therefore, patients with evidence of migration may benefit from the preemptive removal of hardware to protect their articular cartilage. Posttraumatic arthrosis is a major concern following IMS fixation due to retrograde and antegrade screw insertion at articular surfaces. However, reports of this complication are likely limited due to the short-term clinical follow up in the existing literature. Future studies with longer-term follow-ups are necessary to determine the incidence of early-onset arthrosis following IMS fixation.

Last, less common complications, such as trigger finger and nickel allergy, were also described. A single case of postoperative trigger finger was seen 8 weeks following IMS fixation and resolved with a steroid injection.[28] Previous studies have investigated the relationship between distal radius fractures and the occurrence of postoperative trigger fingers. Wessel et al identified distal radius fractures as an independent risk factor for developing subsequent trigger fingers over a 6-month postoperative period.[44] Moreover, Yeh et al found diabetes mellitus to be a significant risk factor for developing trigger fingers secondary to distal radius fractures.[45] Nevertheless, to our knowledge, the etiology of trigger finger complications secondary to metacarpal fractures and fixation has yet to be explored. Warrender et al reported a single nickel allergy among their 160 fracture case series.[21] Following failed treatment with a topical corticosteroid cream, the patient ultimately underwent removal of the hardware at 3 months once the fracture healed. Nickel allergy is a rare complication of surgical implants. However, operating surgeons should keep it mind, especially in patients with symptomatic rash and/or swelling and a confirmed history of metal allergy.

This study has several limitations. First, most included studies were retrospective, with concern for moderate or serious risk of bias. To capture a wider breadth of data and all reported IMS complications, case reports, case series, and retrospective cohort studies were included in our analysis. While doing so allowed us to synthesize all available data, the studies constituted low-quality evidence. As a result, IMS complications are likely underreported in the existing literature. Second, we could not perform a meta-analysis or multivariate analysis of patient-related risk factors for IMS complications due to limited demographic and comorbidity data across case series and cohort studies. Third, we chose not to establish a strict inclusion criterion concerning what defines a complication. Instead, complications were defined based on each author's description and methodology. Consequently, this likely led to sampling bias and higher complication rates than those reported in previous literature. However, not all complications reported should be considered equal. For example, although both were considered "range of motion complications," generalized decreased range of motion requiring no further treatment, as described in one study, cannot be compared with a severe flexion deficit requiring arthrolysis reported in another. The lack of consensus in defining a complication following metacarpal fracture repair creates a legitimate challenge when interpreting the existing literature. Fourth, some of the complications reported in the present study (eg, stiffness, extension lag, and CRPS) may be more attributable to the fracture itself and less likely due to the use of IMS fixation. However, we believe there is a valid concern that treatments that violate the extensor mechanism and MCP joint capsule, such as in IMS fixation, may predispose to adhesions or capsular contracture compared with an extraarticular fracture treated in a cast or splint. While it would be ideal to identify the risks of complications specific to this treatment, this can only be achieved by performing a comparative analysis across various fixation modalities. As a result, future comparative prospective studies should explore IMS-specific complications. Fifth, as most included studies reported outcomes at less than one year follow-up time, the complications reported are likely limited to those experienced at short-term follow up. Therefore, complications such as early-onset arthrosis, which may present years after IMS fixation, are likely underreported in the current literature. Last, our study only included postoperative complications and did not report intraoperative complications (eg, conversion to alternate fixation methods, intraoperative screw fractures, and others). It is important that the potential for intraoperative complications be considered when using IMS for metacarpal fractures. Moreover, it is possible that many of the reported IMS complications could have been missed intraoperatively and were mislabeled as postoperative complications once they were detected on follow-up imaging or examinations.

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