SCIENTIFIC ARTICLE

Intramedullary Compression Screw Fixation for Middle Phalangeal Fractures

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Purpose This study aimed to evaluate short- and medium-term clinical and patient-reported outcomes of intramedullary compression screw fixation for extra-articular middle phalangeal fractures.

Methods A retrospective study was performed on a series of 20 patients (with a total of 23 fractured digits) who underwent fixation of middle phalangeal fractures between January 2020 and March 2023. The results from this cohort were compared against those for plate and K-wire fixation in the literature.

Results Total active motion was 246°; Quick Disabilities of the Arm, Shoulder, and Hand (*Quick*DASH) score was 4.9; verbal numerical pain score was 1.1 of 10; mean time for return to work was 62.5 days; and a single complication was noted in the entire cohort.

Conclusion Intramedullary screw fixation is a viable option in the treatment of extra-articular middle phalangeal fractures. It offers a favorable postoperative range of motion, good duration for return to function, excellent rates of complication, and low pain scores. *(J Hand Surg Am. 2024;■(■):1.e1-e8. Copyright © 2023 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Fracture, intramedullary, middle, phalangeal, screw.

Online Exclusive

METACARPAL AND PHALANGEAL fractures are among the most common musculoskeletal injuries and account for approximately 10% of all fracture presentations, with phalangeal fractures occurring at almost double the rate of metacarpal fractures.[1–3]

Treatment goals in the management of middle phalangeal fractures are to ensure sufficient fracture stability with satisfactory reduction and alignment to permit early motion and rehabilitation.[4] When operative intervention is required, the choice of surgical modality used is influenced by patient characteristics, mechanism of injury, fracture pattern, and preference of the operating surgeon.[3,5] Surgical options include stabilization via Kirschner wires (K-wires), plates, external fixators, lag screws or intramedullary screws

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(IMS).[1,6] Despite the broad range of options available, consensus on the ideal treatment has been reached, due to relatively limited and varied outcomes data and differing opinions on the respective advantages and disadvantages of each therapeutic modality.[4,7–10]

Kirschner wires provide a rapid and inexpensive fixation method, obviate tissue dissection, and are removable.[11] However, K-wire fixation does not facilitate absolute stability and so can lead to loss of position, potentially necessitating a period of immobilization, which, in conjunction with soft tissue tethering, can lead to joint stiffness.[11] The percutaneous nature of fixation also increases the risk of infection.[3,10,12] Plate fixation affords rigid stability, which is advantageous in deformity reduction, but invariably requires longer operating times and more extensive tissue dissection, which results in loss of gliding planes, increased incidence of tendon adhesion, and decreased range of motion.[3,11,13] Lag screws can be used in the setting of long oblique or spiral fractures and offer clinical outcomes comparable with other modalities. However, lag screw use is limited to these specific fracture patterns, may increase the rate of nonunion, and has the disadvantage that minor drilling inaccuracies can result in loosening and loss of fixation.[11,13,14]

Intramedullary compression screw fixation for phalangeal fractures has gained popularity over the last decade. This technique attempts to mitigate the traditional compromise between invasiveness and secure fixation by reducing the risk of undesirable tendon disturbance while simultaneously offering favorable construct stability.[15] Novel methods of instrumentation and implementation have broadened the range of fractures in which they can be used.[16] Although there has been increasing evidence in the literature to support the use of IMS in proximal and distal phalanges, there is little published on their utility in middle phalangeal fractures, with no studies dealing exclusively with this pathology.[4,6,15] Thus, the aim of this study was to assess clinical and patient-reported outcomes following the use of IMS fixation for middle phalangeal fractures.

MATERIALS AND METHODS

This study was performed as a retrospective cohort, assessing outcomes in a series of patients treated by two fellowship-trained hand surgeons across five sites in Sydney and the Gold Coast, Australia. Following approval by the institutional ethics committee, records of all patients who had received intramedullary screw fixation of middle phalangeal fractures under the care of the two surgeons in the 38-month period between January 2020 and March 2023 were procured from a database. Patient details were identified by cross-referencing from the computerized medical records systems of both public and private hospitals. Patients were eligible for inclusion if they had single or multiple middle phalangeal fractures treated with IMS fixation, were skeletally mature at the time of operation, had at least six months follow-up, and consented to receiving telehealth surveys and providing clinical photographs for measurements. Skeletally immature patients, those with pathological fractures, and those treated before 2020 were excluded.

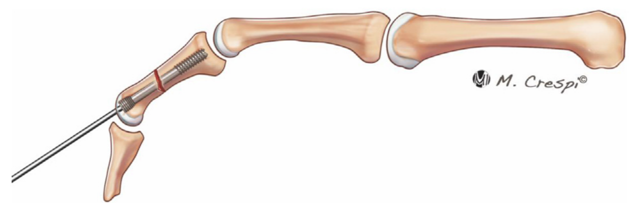

FIGURE 1: Illustration depicting retrograde intra-articular insertion of an intramedullary compression screw for the fixation of a middle phalanx fracture.

All fractures were fixed using a retrograde intra-articular insertion technique.[6] This involved closed fracture reduction using ligamentotaxis, with the distal interphalangeal joint generally held in a position of maximal flexion to counteract the deforming forces of the interossei and extrinsic flexor and extensor tendons.[6,15] A guidewire was then percutaneously inserted retrograde through the distal interphalangeal joint, aiming center on both the coronal and sagittal radiographs. Once satisfactory guidewire placement was achieved, a small cutaneous incision was performed, and potential screw length was measured. A 1.7-mm or 2.2-mm cannulated compression screw (Medartis [Medartis AG]), depending on the required length, was then inserted, with care being taken to hold the fist in relaxed flexion with a normal digital cascade until the completion of screw insertion, to ensure that the applied torque did not cause any malrotation (Figs. 1–4). All patients commenced active range of motion within one week, with a hand-based thermoplastic splint at rest and buddy strapping to the adjacent digit to maintain rotational control.

After patient identification, two medical students (A.G. and H.A.) collated basic demographic information, fracture characteristics (including location and pattern), fixation approach, and the presence of

FIGURE 2: Preoperative radiographs of displaced ring and index middle phalangeal fractures requiring fixation.

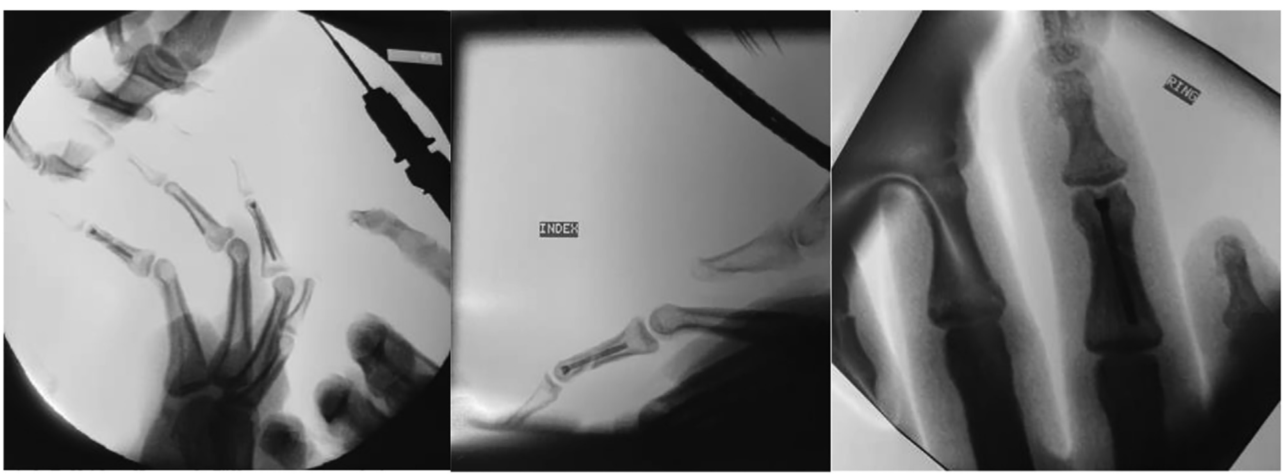

FIGURE 3: Intraoperative fluoroscopy of intramedullary screw fixation of middle phalangeal fractures.

complications from the medical records. This information was cross-referenced against data previously collected during clinical review and compiled in a spreadsheet by the treating surgeons to ensure accuracy. All fractures included had been displaced more than 2 mm or were considered unstable, warranting fixation. A clinical review of patients was performed at standard intervals of one, six, 12 and 26 weeks, with further reviews when deemed necessary by the treating surgeon. The presence of complications was noted by the treating surgeon during clinical review. Cross-sectional telehealth surveys were then completed at variable postoperative durations, between six and 44.4 months, assessing return to work and return to full function, as well as outcome measures in the form of a Quick Disabilities of the Arm, Shoulder, and Hand (*Quick*DASH) and a pain score on the verbal numerical rating scale (VNRS). Complications were defined as any infection, malunion, severe stiffness, requirement for revision surgery, or hardware failure (both during or after surgery). Full function was defined as a return to full use of the surgically fixated digit(s) without restriction or pain for activities performed before surgery. This was based on a combination of objective clinical assessment by the treating surgeon and subjective patient reporting regarding ability to participate in activities of daily living.

Clinical photographs of the sagittal profile of the affected digit, in full active flexion and extension,

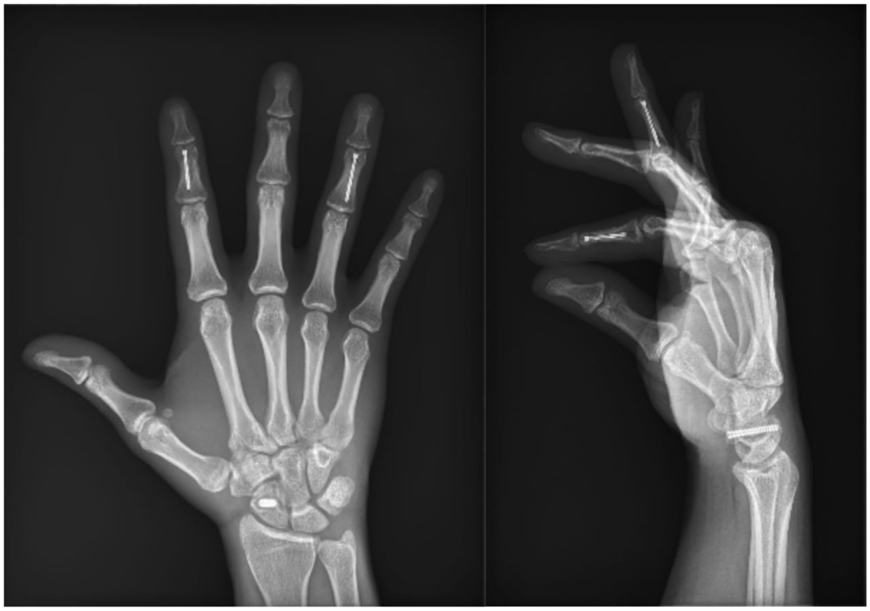

FIGURE 4: Postoperative imaging of fixated middle phalanges.

were also obtained. These photographs were provided by patients following a strict protocol, provided via email, derived from an amalgamation of two studies detailing the standardization of clinical photography.[17,18] This included the use of default mobile device camera settings with no zoom applied; use of the rear-facing camera only; photographs taken without flash in direct daylight at distances of 30 cm and 50 cm; near-identical patient and digit positioning, against a plain white background; and no post-acquisition changes through the use of computer software. In cases with suboptimal imaging or quality, the patients were recontacted and guided through the process via video link. The clinical photographs were collected and initially appraised by the two medical students with subsequent review by the treating surgeon.

Total active motion (TAM) was then calculated via the digital angle measurement application Angles in Photo, Version 1.01 (Kubilay Erdogan). This application allows for digital goniometry assessment via measurement tools overlaying imported images or videos.[19] TAM is used as defined by the American Society for Surgery of the Hand as the sum of active motion of the metacarpophalangeal and interphalangeal joints of a digit and can be compared to a norm of 260°. Final physical assessment and radiographs to confirm union were performed during routine clinical follow-up, whereas evaluation of TAM via photographs and completion of questionnaires were performed remotely at a later date.

Quantitative variables were evaluated through the calculation of means, ranges, and 95% confidence intervals (CI). Power analysis (set at 90% with a 5% level of significance) deemed a sample size of 19 digits required to perform comparative analyses for TAM and *Quick*DASH, 21 digits for return to work and return to full function, and 22 digits for VNRS. Determination of distribution was achieved via the Shapiro−Wilk test. Comparison of nominal and interval variables was performed using the Mann−Whitney U test when nominal variables were limited to two values. Comparison of nominal and interval variables when nominal variables exceeded two groups was performed through the implementation of the Kruskal−Wallis test. Comparison of two interval variables was performed using Spearman's rank correlation coefficient. In all applicable statistical tests, P values $< .05$ were considered significant.[20]

A narrative comparison of comparable outcomes between IMS, K-wire, and plate fixation was undertaken through an examination of relevant literature published within the past 10 years. A period search of Ovid MEDLINE, Embase Classic+Embase 1947, PubMed, and Cochrane Reviews using Wolters Kluwer Ovid (Alphen aan den Rijn) was carried out from August 2013 to August 2023. The results from database searches were imported into Endnote (Clarivate).

RESULTS

In total, 21 patients with a combined 24 middle phalangeal fractures were identified. One patient was lost to follow-up. As such, 20 patients were included in the study, yielding a cohort of 23 fractures - three

TABLE 1. Characteristics of Fractures Treated

Fracture Location and Pattern	Number (n = 23)
Transverse mid-shaft	14
Transverse distal shaft	3
Comminuted mid-shaft	2
Oblique mid-shaft	1
Oblique proximal shaft	1
Proximal metaphysis	1
Condylar	1

TABLE 2. Duration of Return to Work and Return to Full Function of the Surgically Repaired Digit/s for Patients*

Variable	Patients (n = 20)
Mean duration of return to work (d)	62.5 (95% CI, 55.7−72.2)
Range (d)	(14−100)
Variable	**Patients (n = 20)**
Mean duration of return to full function (d)	105.9 (95% CI, 80.9−121.6)
Range (d)	(40−200)

*Full function was defined as return to full use of the surgically fixated digit(s) without restriction or pain in activities performed before surgery. This was based on a combination of objective clinical assessment and subjective patient reporting.

patients sustained two middle phalangeal injuries. The patients were mostly between 16 and 65 years of age (one patient was older than 66 years of age), yielding a mean age of 39.6 years. Sixteen of the 20 patients were men. Characteristics of fractures treated are detailed in Table 1. Seventeen patients had associated injuries, including other fractures (13 patients), tendon injuries (two patients), or ligament injuries (two patients). One patient had mild Dupuytren contracture on the affected digit; another underwent concurrent stabilization of a previous nonunion of the proximal phalanx on a separate digit. Fourteen injuries occurred on the nondominant left-hand side, with the ring (eight fractures) and little fingers (seven fractures) most commonly involved. Over two-thirds of fractures were caused by direct blows (16 fractures), with the remainder occurring after crush injuries, falls, or penetrating trauma. Four participants received an operation and rehabilitation under a workers' compensation claim.

The mean follow-up was 23.6 months (range 6−44.3). One intraoperative complication was reported, where the head of the intramedullary screw broke during insertion. No postoperative complications were noted. The mean time for return to work was 62.5 days, with return to full function at 105.9 days (Table 2). One patient refused to consent to send a digital photograph for measurement—the remaining 22 fractured digits revealed a mean TAM of 246° (range 142−271). All scores recorded for TAM ranged between the "excellent" to "fair" categories, with over half of the scores graded as excellent (Table 3). Mean *Quick*DASH was 4.9 (range 0−20.4), with a mean VNRS of 1.1 (range 0−5) across all patients (Table 4). Seven patients (35.0%) reported a subjective restriction in motion of the affected digit(s).

The small sample size did not yield sufficient power to permit regression analysis between TAM, *Quick*DASH, return to work, and return to full function with variables such as sex, mechanism of injury, multiple injuries, and workers' compensation status.

DISCUSSION

Fractures of the middle phalanges may require fixation to yield adequate stability with satisfactory alignment and reduction, allowing early motion and rehabilitation and avoiding the formation of adhesions and subsequent stiffness.[13] IMS fixation has been increasingly used to provide adequate stability while minimizing tissue dissection and periosteal stripping, allowing increased postoperative range of motion.[4,21] Secondary benefits over alternative modalities may include more rapid recovery and resumption of daily activities, lower operating times and costs, lower rate of extensor tendon complications, and alleviation of the need for hardware removal.[22] Despite the adoption of this treatment modality, there is limited evidence on outcomes following its use in middle phalangeal fractures. A recent systematic review found results on only 43 fractured middle phalanges treated in this manner in the literature, with limited outcomes reporting on the mean duration of surgery, time to union, TAM, DASH, and grip strength.[21]

Our study found a mean TAM of 246°, *Quick*-DASH of 4.9, VNRS of 1.1, time for return to work of 62.5 days, and complication rate of 4.3%. Only one previous study assessing outcomes after IMS stabilization of middle phalangeal fractures was available for direct comparison, and this study reported a mean TAM of 238° and a *Quick*DASH score of 5.1

TABLE 3. Total Active Motion at the Time of Cross-Sectional Follow-Up*

Outcome at the Last Follow-Up	Fractures ($n = 22$) Mean (95% CI)
TAM score	246° (231−261)

Outcome at the Last Follow-Up	Variable	Fractures ($n = 22$)	%
TAM group	Excellent (>260°)	12	54.5
TAM group	Good (195−259°)	8	36.4
TAM group	Fair (130−194°)	2	9.1
TAM group	Poor (<130°)	0	0

TAM, total active motion.
*Categorical ranges for TAM were applied according to the American Society for Surgery of the Hand classification.

TABLE 4. *Quick*DASH and VNRS Scores at the Time of Cross-Sectional Follow-Up

Outcome at the Last Follow-Up	Patients ($n = 20$) Mean (95% CI)
*Quick*DASH score	4.89 (4.43−5.27)
VNRS score	1.1 (0.86−1.22)

Outcome at the Last Follow-Up	Variable	Patients ($n = 20$)	%
*Quick*DASH score	(0−5)	11	55
*Quick*DASH score	(5−15)	7	35
*Quick*DASH score	(15−35)	2	10
*Quick*DASH score	(>35)	0	0

VNRS, pain on the verbal numerical rating scale; *Quick*DASH, quick disabilities of the arm and hand score.
*Quick*DASH and VNRS scores were calculated per patient. Categorical ranges for *Quick*DASH scores were applied according to the Institute for Work and Health.

from a cohort of five digits.[23] Our results also compare favorably to previous studies of pooled cohorts involving proximal, middle, and distal phalangeal fractures fixed using IMS, although detailed analysis and comparison is inappropriate, given the heterogeneous nature of the cohorts.[2,13,23,24−29]

Alternative modalities of middle phalangeal fracture fixation confer various disadvantages. Percutaneous fixation using K-wires has been shown to necessitate longer periods of immobilization, require secondary hardware removal, and is associated with risks of nonunion and loosening.[12,23,30,31] Outcome data for K-wire fixation of middle phalangeal fractures are similarly limited, with only one study dealing with this treatment exclusively. Al-Qattan reported 29 fractures in 20 patients aged between 20 and 45 years, finding a TAM of 241° in 16 middle phalanges with no concurrent soft tissue injuries and 187° in 13 digits with concurrent soft tissue pathology, over a mean follow-up of 30 weeks.[32] The mean times for return to work in these subcohorts were 105.7 days and 187.6 days, respectively.

Plate fixation obligates additional soft tissue dissection and periosteal stripping, resulting in potentially high rates of tendon and scar adhesions and stiffness.[29,33] In the middle phalanx, the presence of a volar midline longitudinal groove, particularly at the mid-phalangeal level, may render the detection of excessive screw penetration difficult and potentially lead to flexor tendon irritation or rupture.[34] Additionally, the benefits of earlier and more robust mobilization may not extend to final TAM following plate fixation of phalangeal fractures.[2,12,31,33,35−37] No studies reporting outcome data following plate fixation of middle phalangeal fractures were located in the literature, rendering meaningful comparison difficult.

A recent cost analysis found a considerable saving to both the health system and individual patients when IMS fixation of extra-articular phalangeal fractures was performed, compared with plate fixation.[38] Hardware costs were found to be over three times cheaper ($237 vs $725 USD), follow-up demands less burdensome (5 vs 6.3 months), and hardware removal less necessary (4.6% vs 24.0%).[38] Decreased expenditure across both the public and private sectors was noted, as were reduced wage losses.[38] IMS fixation has also recently been demonstrated to have considerably diminished health care costs and wage loss when compared with K-wire fixation.[39]

This study has several limitations. The retrospective nature limits interpretation of cause and effect. Furthermore, the small sample size permits only basic statistical analysis, rendering meaningful comparison unfeasible. TAM was not calculated in comparison to contralateral or adjacent digits, nor was grip strength measured. The absence of contralateral measurements for TAM does not allow for accurate baseline measurements against which to compare. Although postoperative ranges of motion reported in this study are favorable, contralateral values would allow appreciation of the importance of these results. Image acquisition was performed remotely and, despite attempts at standardization, is likely more inaccurate than images captured in clinics where greater uniformity can be achieved. The inclusion of patients with multiple fractures (reflective of a likely greater energy mechanism) may have a confounding effect. As with any retrospective study, the reporting of complications should be considered a minimum estimate, as the study design cannot guarantee that all complications have been detected, particularly those that are minor in nature. Furthermore, complications may have been identified and cared for at alternate institutions. A prospective design, with standardized follow-up durations, would also have ensured greater homogeneity of the data and avoided the need for telehealth surveys at a later date. Variations in DASH scores obtained in person and via telephone interview have been shown to vary more than 14 points (the minimum clinically important difference for this measure), in 5% of patients, and this must be considered when appraising the *Quick*DASH scores in this study.[40] Comparison of this study's results with other cohorts where middle phalangeal fractures have been fixed is also problematic, due to the lack of available literature.

Despite these limitations, this study adds to the available literature pertaining to IMS fixation of middle phalangeal fractures and indicates an acceptable rate of postsurgical complications, return to work and function, range of movement, and functional outcomes when compared with results from alternative fixation methods. IMS fixation is a viable option in the management of suitable middle phalangeal fractures. Further long-term follow-up, and cadaveric studies examining the bony and soft tissue footprint of screw insertion, would be beneficial.

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