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Clinical Outcomes of Using Retrograde Intramedullary Headless Screw for Fixation of Metacarpal Fractures

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ABSTRACT

Background: Metacarpal fractures are among the most common hand injuries. Surgical fixation options vary, but complications such as stiffness and hardware-related problems remain a challenge. Retrograde intramedullary headless screw (IMHS) fixation has emerged as a minimally invasive option that enables early mobilization.
Aim: This study aims to evaluate the outcomes of metacarpal fractures treated with retrograde IMHS fixation.
Subjects and Methods: We conducted prospective research on 20 cases (31 metacarpal fractures) treated with retrograde IMHS fixation. Data included demographics, fracture characteristics, operative details, complications, total active motion (TAM), grip strength, union time, Disabilities of the Arm, Shoulder, and Hand (DASH) score, visual analogue scale (VAS) for pain, and return-to-work time.
Results: All fractures united within a mean of 6.6 weeks. Patients achieved an average TAM of 94% and grip strength of 93% compared to the contralateral side. Mean DASH and VAS scores were low and return to work averaged 4.3 weeks. Complications were minor and transient. Subgroup analysis showed no significant differences except delayed return to work in multiple fractures and higher DASH scores in spiral fractures.
Conclusion: Retrograde IMHS fixation provides excellent stability, early mobilization, rapid union, and high patient satisfaction with low complication rates. It represents a reliable alternative to traditional fixation methods for managing metacarpal fractures.
Keywords: Hand surgery, Minimally invasive, Intramedullary screw.

INTRODUCTION

Metacarpal fractures account for nearly one-third of all hand fractures[(1)] and are especially common among young, active individuals. These injuries often result from direct trauma, falls, road traffic accidents, or work-related incidents. Although many metacarpal fractures can be managed conservatively, unstable, displaced, or multiple fractures often require surgical fixation to restore alignment, maintain stability, and allow early mobilization[(2)].

Traditional fixation techniques include Kirschner wires (K-wires), plate-and-screw constructs, and intramedullary devices. While K-wires are widely used due to their simplicity and low cost, they often require prolonged immobilization and have higher rates of complications such as pin tract infections, loosening, and secondary removal procedures[(3)]. Plate fixation offers rigid stabilization but at the expense of soft tissue stripping, tendon adhesions, and higher complication rates, including stiffness and hardware irritation[(4)]. These limitations highlight the need for techniques that balance stability with minimally invasive principles.

Retrograde intramedullary headless screw fixation has recently gained attention as an alternative surgical option. This technique provides stable internal fixation through a small dorsal incision, preserves surrounding soft tissues, and permits immediate range-of-motion exercises[(5)]. By eliminating hardware prominence and reducing postoperative stiffness, IMHS fixation may accelerate recovery and improve patient satisfaction.

The goal of this research was to prospectively evaluate the clinical and functional results of cases with metacarpal fractures treated using retrograde IMHS fixation, with emphasis on union time, range of motion, grip strength, patient-reported outcomes, and complication profile. Additionally, we sought to explore whether fracture pattern or multiplicity influenced final outcomes.

SUBJECTS AND METHODS

Study Design and Setting: This prospective, single-arm multicenter study was conducted at Suez Canal University Hospital.

Participants: A total of 20 consecutive adult patients (≥18 years) with acute or subacute (≤3 weeks) displaced, unstable metacarpal shaft fractures were enrolled following giving an informed consent. Inclusion criteria included age and ability to provide informed consent. Exclusion criteria were pathological, open, comminuted, or thumb fractures; fractures involving the base or head; associated tendon or nerve injuries; and active infection. This study lasted for one year.

Sample Size: Sample size was determined based on a standard deviation of 4.3° for active range of motion[(6)], with a 95% confidence level and 2° margin of error, yielding 18 patients. On account for dropouts, 20 patients were included.

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Preoperative Assessment: Baseline demographics, hand dominance, mechanism of injury, affected metacarpals, side involved, and fracture patterns were recorded. All patients underwent plain radiographs (**anteroposterior** (AP) and oblique views). Splints and analgesics were applied until surgery.

Surgical Technique: Procedures were performed under regional block anesthesia. Following closed or mini-open reduction, a 1–1.5 cm dorsal incision was made over the metacarpal head, followed by longitudinal splitting of the extensor tendon **(Figure 1A)**.

A guide wire was then inserted into the dorsal one-third of the metacarpal head and advanced retrograde across the fracture into the metacarpal base under fluoroscopy **(Figure 1B)**. Screw length was determined and was confirmed fluoroscopically (**Figure 1C**), and the canal was reamed just past the fracture site. A headless compression screw was inserted manually with fingers flexed to avoid rotational deformity **(Figure 1D)**. In long oblique or spiral fractures, reduction was maintained with a clamp during fixation (**Figure 1E**). The screw was buried beneath the articular cartilage **(Figure 1F)**, the guide wire was removed, and soft tissues were repaired. Reduction and fixation were confirmed fluoroscopically.

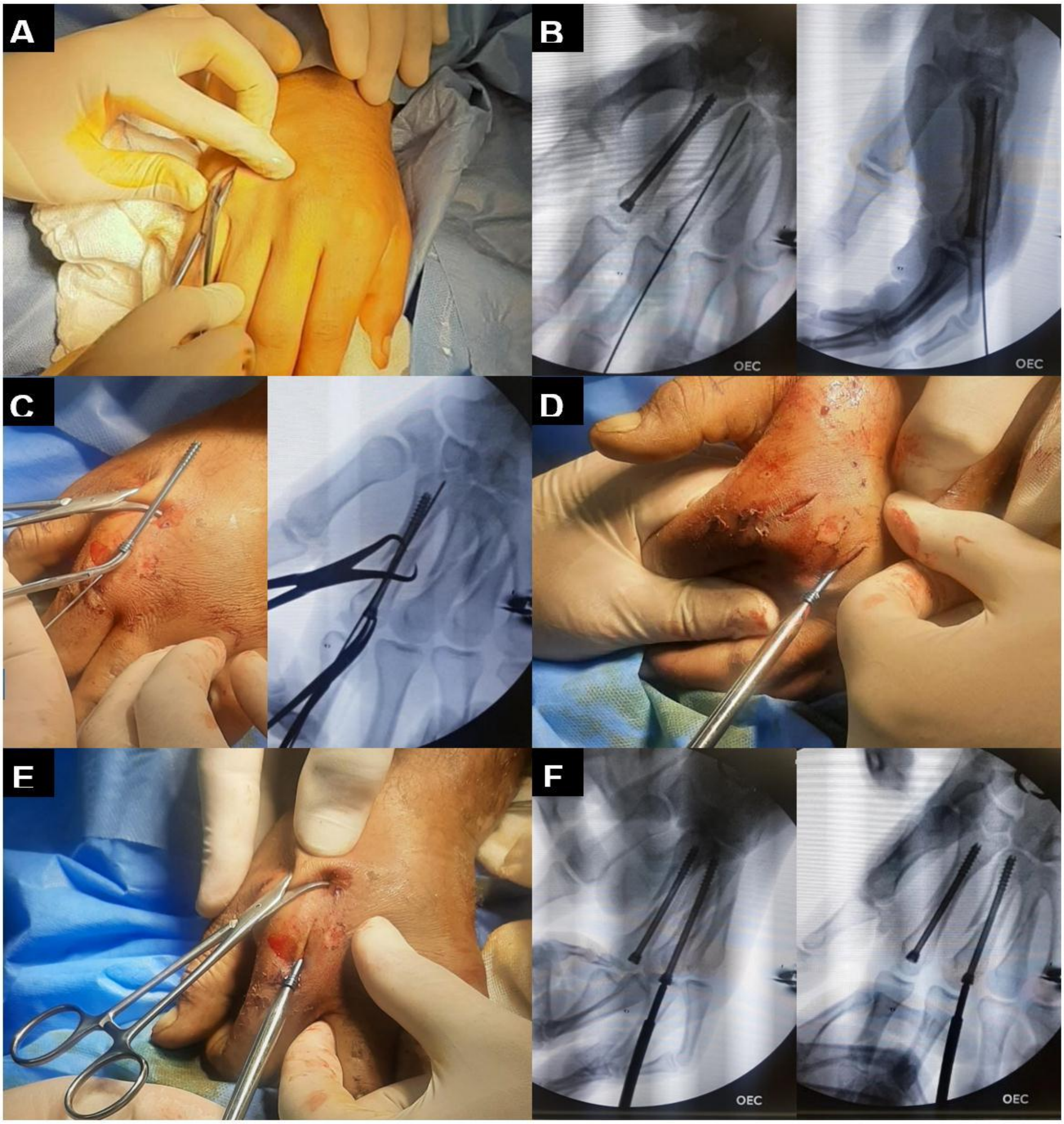

Figure 1: Surgical technique of retrograde intramedullary headless screw fixation for metacarpal fractures. A. Small dorsal incision with longitudinal splitting of the extensor tendon to expose the metacarpal head, B. Advancing the guide wire into the dorsal third of the metacarpal head and then retrograde past the fracture level to the base of the metacarpal, C. Confirming the appropriate screw size, D. Driving the screw with the fingers flexed, E. Using a clamp to maintain proper reduction during fixation, F. Confirming screw placement with fluoroscopy.

Postoperative Protocol: Patients were placed in a bulky dressing for 48 hours. Three patients requested splints for two weeks. Immediate active range-of-motion exercises were encouraged. Follow-up evaluations were scheduled every two weeks for three months.

Outcome Measures: Operation time and intraoperative complications, radiological union time in weeks, total active motion (TAM), as a percentage of the contralateral side and grip strength ratio, between injured and non-injured hand, pain using visual analogue scale (VAS), disability, using the Arabic version of the Quick DASH scale, return-to-work interval in weeks and postoperative complications.

Statistical Analysis

Data were analyzed utilizing SPSS v25. Continuous variables were reported as mean ± SD and range, while categorical data were presented as frequencies. Comparisons were made between fracture patterns and single versus multiple fractures using unpaired t, Mann-Whitney, and Kruskal-Wallis tests, with Bonferroni correction as appropriate. Significance was set at $p < 0.05$.

Ethical Approval:

The research was permitted through the Ethics Committee Orthopedic Surgery and Trauma, Faculty of Medicine, Suez Canal University. Institutional Ethics Committee approval was (No. ORT/5133). All participants gave written informed consent before enrolment. The research adhered to the Helsinki Declaration throughout its execution.

RESULTS

Table 1 shows that twenty patients (15 males, 5 females) with a mean age of 34.9 years were included. Most patients (85%) had right-hand injuries, and 85% had injuries in the dominant hand. Nine patients (45%) sustained injuries from accidental falls. Nine patients (45%) had multiple metacarpals involved.

Table 1. Demographics and Clinical Characteristics

Variable		Data
Total number of patients		**20 (100%)**
Age *mean ± SD (range)*		**34.9 ± 11.4 (20 – 59)**
Sex *n (%)*	**Male**	**15 (75%)**
	Female	**5 (25%)**
Comorbidities *n (%)*	**No comorbidities**	**17 (85%)**
	Diabetes mellitus	**2 (10%)**
	Hypertension	**1 (5%)**
Mode of Injury *n (%)*	**Accidental fall**	**9 (45%)**
	Road Traffic Accident	**6 (30%)**
	Direct hit	**3 (15%)**
	Work-related	**2 (10%)**
Side *n (%)*	**Right**	**17 (85%)**
	Left	**3 (15%)**
Dominance *n (%)*	**Yes**	**17 (85%)**
	No	**3 (15%)**
Single vs. multi[illegible] fractures *n (%)*	**Single fracture**	**11 (55%)**
	Multiple fractures	**9 (45%)**

Data are presented as mean ± SD or n (%).

Table 2 shows that in total, 31 metacarpal fractures were treated: 39% in the little finger and 35% in the ring finger. Fracture patterns were mostly transverse (42%) and short oblique (26%).

Table 2. Fracture Characteristics

Variable		Data
Total number of fractures		**31 (100%)**
Affected Metacarpals *n (%)*	**Index**	**3 (10%)**
	Middle	**5 (16%)**
	Ring	**11 (35%)**
	Little	**12 (39%)**
Fracture Patterns *n (%)*	**Transverse**	**13 (42%)**
	Short oblique	**8 (26%)**
	Long oblique	**5 (16%)**
	Spiral	**5 (16%)**

Data are presented as n (%).

Table 3 shows that the average surgical time was 18.7 minutes (range 14–26). No intraoperative complications were recorded. All fractures united radiographically within an average of 6.6 weeks. Three minor complications were observed: one hematoma (5%) and two cases of transient stiffness (10%), all resolving within three months. No major complications occurred. At final follow-up, the mean TAM was 94% of the contralateral hand, while grip strength ratio averaged 93%. Mean DASH score was 1.9 and mean VAS pain score was 1.3. Return to work occurred at a mean of 4.3 weeks.

Table 3. Outcome Measures

Measure	Data
Operation time (minutes)	**18.7 ± 4.0**
Intraoperative complications	**0 (0%)**
Minor Complications	**3/20 (15%)**
Hematoma	**1/20 (5%)**
Stiffness	**2/20 (10%)**
Major Complications	**0 (0%)**
Union rate	**20/20 (100%)**
Radiological union (weeks)	**6.6 ± 2.0**
Return to work (weeks)	**4.3 ± 1.5**
TAM (%)	**94.3 ± 4.7%**
Grip strength ratio (%)	**92.6 ± 7.5%**
DASH score	**1.9 ± 3.9**
VAS	**1.4 ± 0.6**

Data are presented as mean ± SD or n (%)

Table 4 shows that patients with multiple fractures (45%) demonstrated significantly higher DASH scores and required a longer time to return to work compared to those with single fractures, as tested by the Mann–Whitney test. Among fracture patterns, spiral fractures were associated with significantly higher DASH scores compared to transverse fractures ($p = 0.019$, Kruskal–Wallis test), while other outcomes did not differ significantly between groups.

Table 4. Subgroup Analysis of Outcomes

Fracture	TAM (%)	Grip strength (%)	DASH	VAS	Time to Union (weeks)	Return to Work (weeks)
Number						
Single (N=11)	95.6 ± 3.6	93.7 ± 9.0	0.6 ± 1.5	1.2 ± 0.4	6.2 ± 1.4	3.5 ± 0.5
Multiple (N=9)	92.6 ± 5.5	91.2 ± 5.4	3.5 ± 5.2	1.6 ± 0.7	7.0 ± 2.6	5.2 ± 1.8
P-value	0.238	0.642	0.03[a] (MW)	0.196 (MW)	0.048[a] (MW)	0.029[a] (MW)
Pattern						
Transverse N=13	95.0 ± 3.3	92.2 ± 8.3	1.2 ± 2.6[c]	1.6 ± 0.8	7.5 ± 2.9	4.6 ± 1.7
Short oblique N=8	93.3 ± 4.2	91.4 ± 7.5	1.7 ± 2.4	1.5 ± 0.5	6.4 ± 1.2	4.1 ± 1.3
Long oblique N=5	95.6 ± 2.6	93.8 ± 4.0	1.4 ± 1.2	1.0 ± 0.0	6.4 ± 0.9	5.6 ± 1.9
Spiral (N=5)	86.9 ± 8.4	91.9 ± 1.3	10.4 ± 7.5[c]	1.0 ± 0.0	5.2 ± 1.1	4.8 ± 1.6
P-value	0.347 (KW	0.359 (KW)	0.019[b] (KW)	0.081 (KW)	0.298 (KW)	0.512 (KW)

Data are presented as mean ± SD

[a]. Statistically significant p-value at 0.05 level, tested by the Mann-Whitney test.

[b]. Statistically significant p-value at 0.05 level, using the Kruskal Wallis Test.

[c]. Statistically significant difference between spiral and transverse fractures (P-value=0.019, adjusted by the Bonferroni correction for multiple tests).

CASE PRESENTATION

CASE 1

A 22-year-old female with transverse fractures of the right 4th and 5th metacarpals underwent surgery 5 days post-injury, with both fractures fixed using 3.0 mm screw after closed reduction. The 25-minute procedure was uncomplicated. Postoperatively, a bulky dressing was applied to allow early active ROM exercises and later replaced with a small wound dressing until sutures were removed after one week. Pain was minimal (VAS score 1), and the patient resumed work and achieved fracture union by week 6. She achieved 94% total active motion of the normal hand, 100% grip strength, and a DASH score of 0, with no complications over 7 months of follow-up.

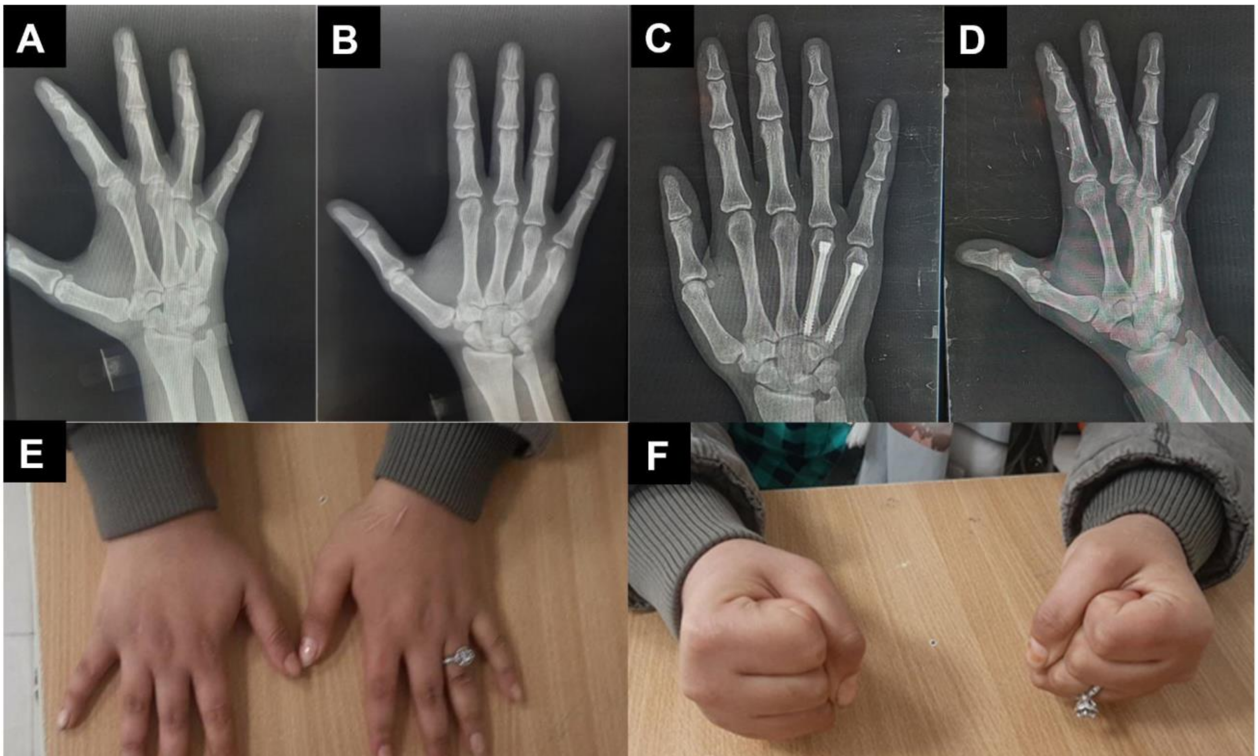

Figure 2: 22-year-old female patient. Oblique (A) and AP (B) preoperative X-rays showed transverse fractures of the 4th and 5th metacarpals. AP (**C**) and oblique (**D**) postoperative X-rays showed osseous union after fixation with 3.0 mm IMHS. She regained full composite range of motion (**E** and **F**).

CASE 2

A 27-year-old male with a long oblique diaphyseal fracture of the left 3rd metacarpal from a fall underwent surgery 2 days post-injury. Following closed reduction, the fracture was fixed using 3.0 mm IMHS. Postoperatively, a bulky dressing was applied to allow early active ROM exercises and replaced by a smaller wound dressing after three days. Sutures were removed after one week. Pain was minimal (VAS score 1), and the patient resumed activities by week 4, with fracture union confirmed at week 6. The patient achieved 100% total active motion, 100% grip strength, and a DASH score of 0, with no complications during the 3-month follow-up.

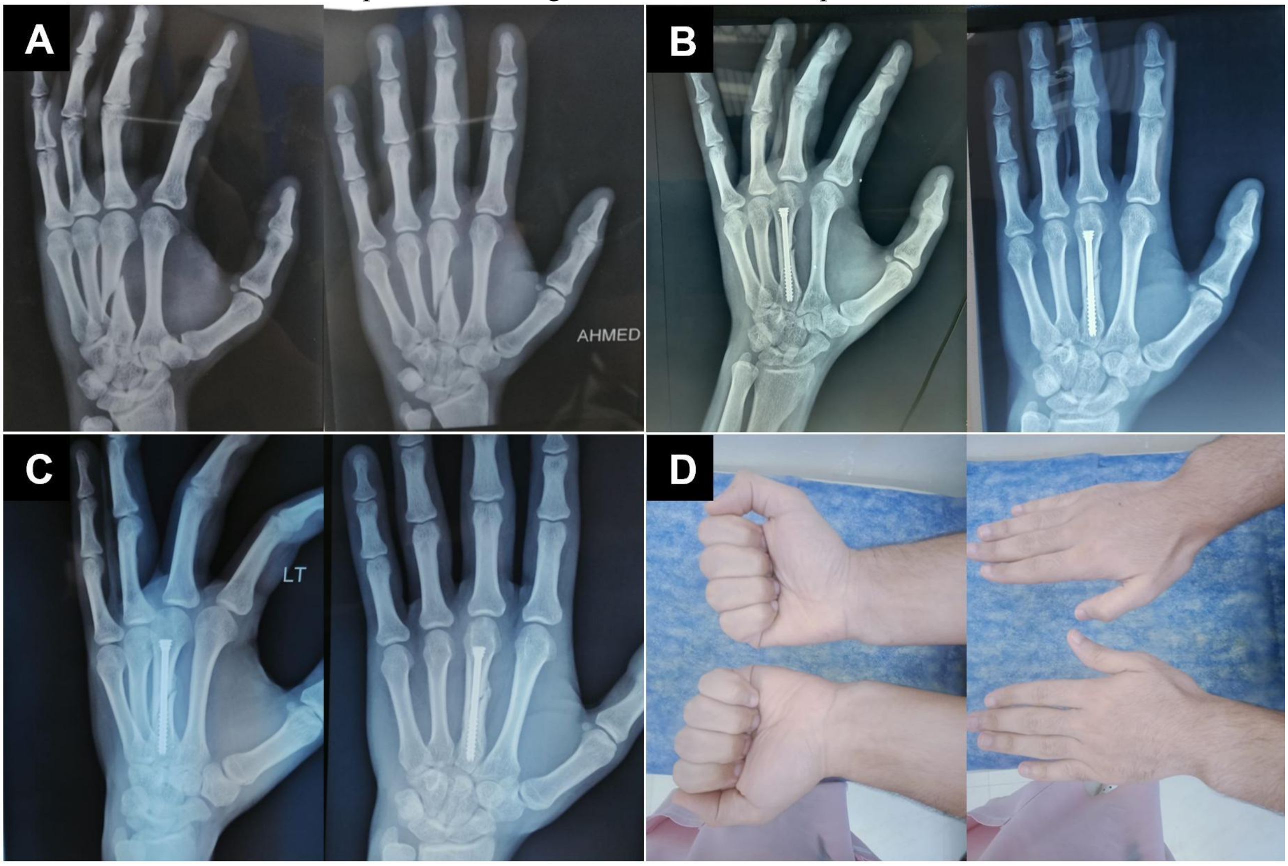

Figure 3: 27-year-old male patient. (A) Preoperative x-rays showing long oblique fracture of the left 3rd metacarpal. (B) 4-weeks postoperative x-rays showing good reduction after fixation with 3.0 mm IMHS. (C) 6-weeks postoperative x-rays showing fracture union. (D) The patient regained full composite range of motion.

DISCUSSION

Metacarpal fractures are common and usually treated conservatively, however sometimes surgical fixation is indicated. Traditional methods are K-wires and plates. K-wires usually need prolonged immobilization while plates necessitate extensive dissection that often causes stiffness. Studies on metacarpal fractures treated with K-wires reported complication rates of 16-35%. Plate fixation showed complication rates of 16-36%. These complications often led to significant functional impairment and required reoperations [3]. Many biomechanical studies showed that IMHS provide reliable stability[7], providing union while allowing for early mobilization and minimal splinting. This, along with its minimal invasiveness, improves recovery and minimizes complications.

This study shows that IMHS fixation offers excellent stability, short operations, minimal complications, and early return to work. With early mobilization and minimal splinting, all patients achieved full union, restored excellent TAM and grip strength, and reported low DASH and VAS scores. Several studies report similar operation times ranging from 21 to 26 minutes [8]. IMHS and K-wire fixation show similar operation times, both significantly shorter than plate and screw fixation [9].

Many studies noted no intraoperative complications [10], however, there were instances of intraoperative conversions from IMHS to plate fixation due to major comminution, wide IM canal, or screw breakage. Postoperatively, some immobilized the fractures in a splint for 1 to 2 weeks, switched to a removable custom resting orthosis for range of motion (ROM) exercises, and discontinued the splint once the fracture healed . Others used local dressing, buddy-strapping, and immediate active range of motion (AROM) [8].

Previous studies consistently reported favorable outcomes after IMHS fixation [10]. Radiographic union typically occurs within 5–7 weeks, with high union rates [6]. Functional recovery is excellent, with grip strength reaching 88–105% of the contralateral side and TAM values ranging from 243° to 252° [6].

Return-to-work times vary with fracture complexity, from 3.6 weeks to 10.9 weeks, with systematic reviews reporting 4.7–7.5 weeks on average. Patient-reported outcomes also reflect high satisfaction and minimal disability, with low VAS and DASH scores reported across multiple studies. Comparative studies highlight the advantages of IMHS fixation over traditional methods. IMHS provides shorter casting durations, less need for rehabilitation, earlier return to work or daily activity, improved MCP motion and function, and significantly lower DASH scores and higher grip strength [(11)].

Complications with IMHS are uncommon. While some series reported no complications, others noted low rates of stiffness or minor hardware-related issues. Systematic reviews consistently found complication rates between 2.5% and 5.3%, with stiffness being the most frequent and reoperation rarely required [(6)].

IMHS consistently showed lower complication and reoperation rates when compared to plates or K-wires. For example, **Kibar *et al.*** [(9)] observed no IMHS complications versus a 35% plate-related rate. **Esteban-Feliu *et al.*** [(12)] found IMHS associated with lower hardware complication rates and fewer reoperations compared to both plates and K-wires.

Similarly, **DelPrete *et al.*** [(11)] reported significantly fewer reoperations with IMHS (4%) compared to plates (11%) and K-wires (11–72%).

In this study, patients with multiple fractures (45%) demonstrated significantly higher DASH scores and required a longer time to return to work compared to those with single fractures, as tested by the Mann–Whitney test. Among fracture patterns, spiral fractures were associated with significantly higher DASH scores compared to transverse fractures (p = 0.019, Kruskal–Wallis test), while other outcomes did not differ significantly between groups. Surgical treatment is generally advised. While ORIF is effective with multiple fractures, it carries higher complication rates [(13)]. K-wires require immobilization and implant removal, with reported complication rates up to 16%. IMHS, providing early mobilization with minimal soft-tissue disruption, shows favorable results as supported by **del Piñal *et al.*** [(14)], who reported good outcomes and a mean TAM of/ 245° (range 210–270°).

Fracture pattern remains a debated factor in IMHS application. Long oblique and comminuted fractures are often excluded due to risks of malreduction and shortening from the compressive effect of screws.

Guidi *et al.* [(15)] highlighted uncertainty about the critical obliquity angle but still recommended against IMHS for long oblique patterns.

Casal *et al.* [(16)] also observed shortening with such fractures, though without functional impact. In our series, IMHS was cautiously used in axially unstable patterns (long oblique, spiral), with outcomes comparable to transverse or short oblique fractures, except for higher DASH scores in spiral fractures (10.4 ± 7.5, p = 0.021). Although IMHS may not be optimal for these fractures, fully threaded non-variable pitch screws now available can avoid compression and shortening, potentially extending indications. **Thomas *et al.*** [(17)] confirmed consistent outcomes across patterns with this newer design.

The retrograde approach for IMHS raises concerns about iatrogenic MCP articular defect. **ten Berg *et al.*** [(18)] found that a 3.0 millimeters screw creates minimal defects, with only 12% contact of the proximal phalanx even in hyperextension. Load transmission mainly occurs in flexion, reducing arthritis risk. Early and midterm results show no signs of arthritis, though long-term data is pending. Comparable defects in scaphoid fixation haven't shown medium-term issues, suggesting minimal long-term effects for the retrograde approach. The antegrade approach has been proposed as a potential solution to minimize the risk of MCP joint and extensor tendon injuries. It is especially suitable for proximal and midshaft fractures with minimal CMC joint disruption, especially for the thumb, middle, and little fingers due to the larger dorsal or ulnar overhang. It is also applicable in pediatric cases since it does not breach the physis.

Hoang *et al.* [(19)] showed its efficacy and reproducibility, however more research is needed to establish its efficacy and safety.

Strengths of this study include its prospective design, examination of various fracture patterns, and high follow-up rate. Limitations include the small sample size, lack of a control group, and relatively short follow-up, precluding assessment of long-term arthritic changes.

Future research should include large, randomized trials comparing IMHS with other fixation methods, with longer follow-up to assess long-term outcomes and MCP joint risks. Further studies on different fracture patterns and patient groups are also needed to confirm its clinical value.

CONCLUSION

Overall, our study reinforces that IMHS fixation is a reliable, minimally invasive technique that improves recovery, reduces morbidity, and enhances patient satisfaction. IMHS should be considered a valuable alternative to traditional fixation methods, particularly for patients requiring fast return to work and functional recovery.

DECLARATIONS

Consent for publication: I certify that each author has granted permission for the work to be submitted.

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Conflicts of interest: None.

Competing interests: None.

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