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ORIGINAL ARTICLE

Surgical treatment of coronal plane hamate fractures: Clinical and radiological outcomes

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ABSTRACT

Objectives: In this study, we present our extensive case series on hamatometacarpal fracture-dislocations treated with open reduction and internal fixation and share our treatment strategies and outcomes.

Patients and methods: Between March 2014 and November 2022, a total of 17 male patients (mean age: 28.6±7.9 years; range, 18 to 49 years) with isolated hamate fracture or a fracture involving the base of the fourth and/or fifth metacarpals who underwent surgery and were followed for a minimum duration of 12 months were retrospectively analyzed. Mechanism of injury, type of hamate fracture, presence of associated metacarpal fracture-dislocations, demographic data, time to surgery, postoperative duration of immobilization and complications were noted. Functional assessment was performed using Disabilities of the Arm, Shoulder, and Hand (DASH) scoring and grip strength was evaluated using a hand dynamometer.

Results: The mean follow-up was 5.8±2.2 (range, 2 to 8) years. All patients were male, with fractures on the dominant side, and the primary mechanism of injury was punching a hard surface. Surgical fixation primarily involved a single screw, with Kirschner wires used for metacarpal stabilization. The mean time to return to work was 61±22 (range, 35 to 90) days. The mean grip strength of the injured and uninjured side was 40.5±3.6 kg and 42.1±3.5 kg, respectively (p=0.415). The mean DASH score at the final follow-up was 5.6±4.8. All patients achieved clinical union, with no malunions, and full range of motion was restored. Two cases of ulnar nerve neuropraxia fully resolved.

Conclusion: The surgical treatment of coronal plane hamate fractures associated with the fourth and fifth metacarpal base fracture-dislocations can provide good functional recovery in these complex fractures.

Keywords: Clinical outcomes, coronal plane fracture, hamate fracture, metacarpal dislocation, surgical treatment.

Hamate fractures are rare fractures of the carpal region, but may result in significant functional limitations and disabilities.[1] These injuries typically occur as a result of high-energy trauma, such as punching a fixed object. The position of the wrist during a punch can directly affect the type of fracture and the severity of the injury.[2]

Hamate fractures are typically classified as either hook or body fractures, with body fractures being considerably rarer than hook fractures. The Hirano and Inoue classification further subdivides hamate body fractures based on the fracture pattern and location within the coronal plane.[3] According to their system, type 1 fractures involve the coronal plane of the hamate body, while type 2 fractures are sagittal fractures. This classification aids in the understanding of fracture mechanics and guides treatment decisions. Since hamate fractures are often associated with injuries to the fourth and fifth

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carpometacarpal (CMC) joints, they are referred to as hamatometacarpal fracture-dislocations, and these injuries are considered complex.[4] In the emergency setting, attention is typically focused on the fourth and fifth CMC joints, with treatment planning based on the stability of this complex region, which may lead to overlooking hamate fractures. Additionally, factors such as which of the fourth and fifth metacarpals are involved, which CMC joint is dislocated, and the location of the hamate body fracture are critical in influencing treatment decisions.[5]

Review of the literature reveals a significant gap in studies addressing the classification and treatment of CMC fracture-dislocations, particularly those associated with coronal plane fractures of the hamate.[6] There is currently no established consensus regarding the exact indications for surgical intervention in these complex injuries. The decision-making process for surgical treatment remains largely subjective, with varying recommendations depending on the fracture-dislocation pattern, severity of instability, and surgeon preference.[7] Moreover, precise surgical techniques, including the ideal approach for fixation, the type of implants, and postoperative protocols, have not been standardized. These factors contribute to inconsistent outcomes in clinical practice.[7] In the present study, we present our extensive case series on hamatometacarpal fracture-dislocations, complex injuries as we define them, and share our treatment strategies and outcomes.

PATIENTS AND METHODS

This two-center, retrospective study was conducted at Ümraniye Training and Research Hospital and Metin Sabancı Baltalimanı Bone Diseases Training and Research Hospital, Department of Orthopedics and Traumatology and Hand Surgery between March 2014 and November 2022. Medical records of patients who underwent surgery for carpal bone fractures were reviewed. Inclusion criteria were as follows: patients older than 16 years with an isolated hamate fracture or a fracture involving the base of the fourth and/or fifth metacarpals who underwent surgery for the hamate fracture and a minimum follow-up time of 12 months. Exclusion criteria were as follows: having open fractures, previous hand injuries, pathological fractures, congenital deformities of the extremity, or associated injuries other than fractures at the base of the fourth and fifth metacarpals. Initially, there were 31 patients operated for hamate fractures associated with fourth and fifth metacarpal base instability or fractures. Of these, nine were excluded due to insufficient follow-up, and five were excluded as they were operated for avulsion fractures and did not have preoperative computed tomography (CT) imaging. Finally, a total of 17 male patients with isolated hamate fractures (mean age: 28.6±7.9 years; range, 18 to 49 years) were included in the study. A written informed consent was obtained from each patient. The study protocol was approved by the Ümraniye Training and Research Hospital Clinical Research Ethics Committee (date: 07.12.2023, no: B.10.1.TKH.4.34.H.GP.0.01/480). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Age, sex, occupation, dominant hand, fracture site, and trauma mechanism were documented for all patients. At the final follow-up visit, the range of motion (ROM) for the wrist, fourth and fifth metacarpophalangeal (MCP), proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints, as well as any complications and unexpected events, were recorded. Alignment, classification, and the quality of reduction were assessed using full lateral radiographs and CT images. The quality of reduction was assessed using the Kjaer classification criteria. According to this system, reductions are categorized based on the degree of articular surface gap or step-off. An excellent or anatomic reduction is defined as having a gap or step-off of less than 1 mm. A good reduction is characterized by a gap or step-off between 1 and 2 mm. Finally, a poor reduction is classified as having a gap or step-off greater than 2 mm.[8] These measurements were performed using a picture archiving and communication system (PACS), and radiological assessments were conducted by the first two authors. Any disagreement was solved under the supervision of the senior surgeon.

Patient comfort and functional outcomes were evaluated using the Disabilities of the Arm, Shoulder and Hand (DASH) score, a 30-item self-report questionnaire designed to assess physical function and symptoms in patients with upper limb disorders, with scores ranging from 0 (no disability) to 100 (maximum disability).[9] Grip strength was measured at the final follow-up visit using the Jamar Plus+ hand dynamometer (Patterson Medical Ltd., Nottinghamshire, UK), with readings converted to kilograms for analysis.[10]

The indication for surgical intervention was instability or direct dislocation at the base of the fourth and fifth metacarpals caused by the hamate fracture (Inoue and Hirayama type 2a coronal splitting fractures). Instability was assessed manually, and a CT scan was performed for all patients. If a dorsal angulation causing more than 2 mm of displacement in the sagittal plane was detected in the hamate fracture, it was considered an unstable fracture requiring surgical fixation.[11] An open reduction and internal fixation (ORIF) of hamate bone with headless 2.7 mm headless cannulated screw was performed in all patients.

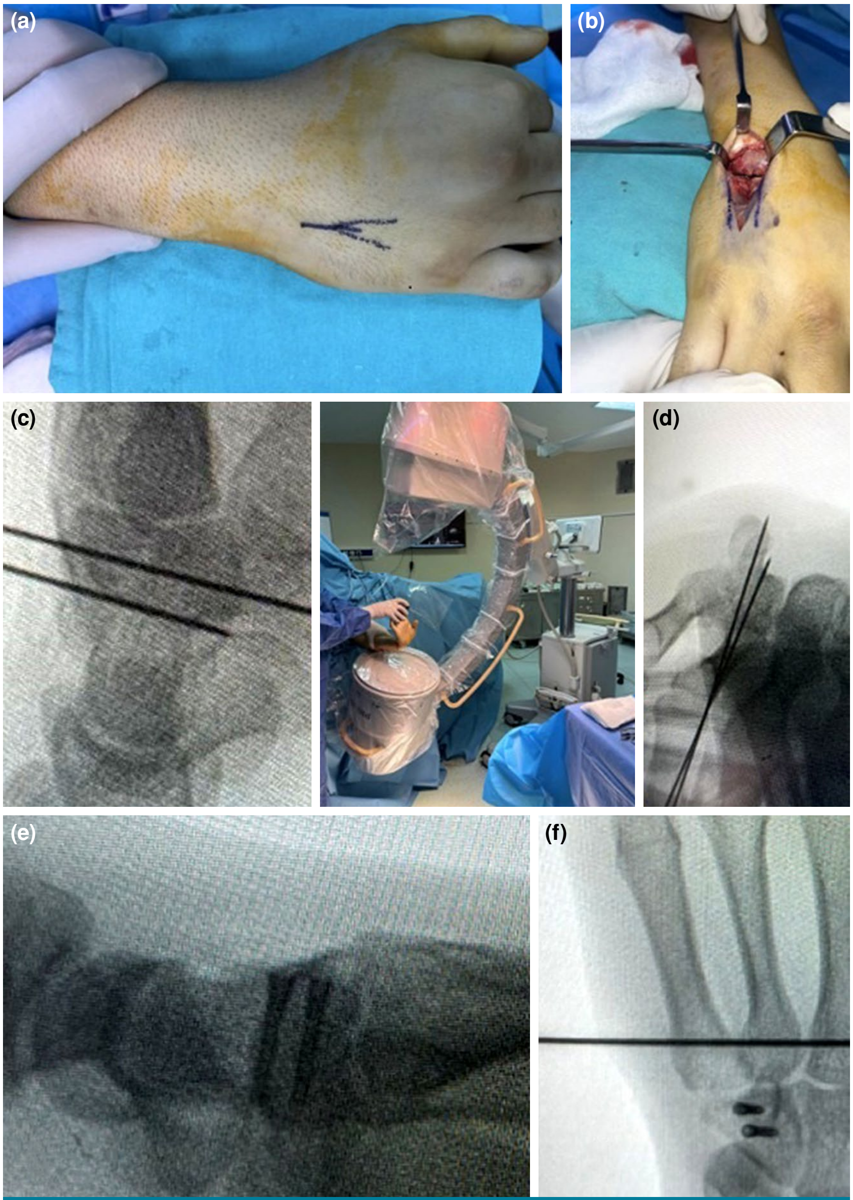

FIGURE 1. A 23-year-old male with a hamate fracture associated with a 5th metacarpal fracture (Case 2). **(a)** The junction of the 4th and 5th metacarpal bases and the planned incision between them are marked. **(b)** Hamate bone and metacarpal base exposed. **(c, d)** The optimal direction of screws is marked with guide wires under fluoroscopic guidance. **(e, f)** AP and lateral images showing perfect reduction of the hamate fracture with two screws and the 5th metacarpal base with a single K-wire.

AP: Anteroposterior.

Surgical technique

All patients were operated in the supine position under infraclavicular block anesthesia. Following the application of a tourniquet to the upper arm, the forearm was placed in pronation, and a 2-cm dorsal longitudinal incision was made at the level of the hamatometacarpal joint. The dorsal sensory branch of the ulnar nerve was identified and protected (Figure 1a). By retracting the extensor carpi ulnaris to the ulnar side and the extensor digiti minimi and extensor digitorum tendons to the radial side, the joint was exposed. Traction was applied to the fourth and fifth fingers, allowing visualization of the hamate joint surface (Figure 1b). The joint and fracture site were cleared, and anatomic reduction was achieved. Temporary fixation was performed using two Kirschner wires (K-wires), and the reduction was confirmed under

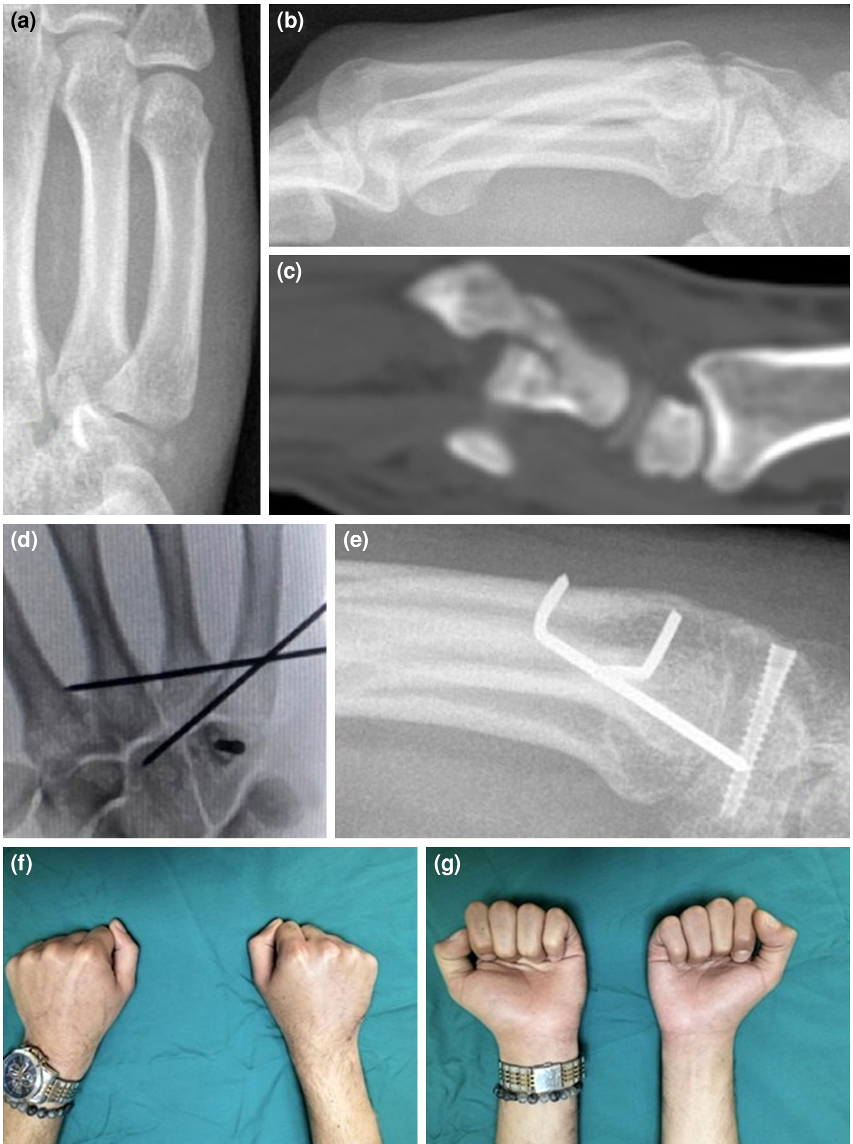

FIGURE 2. A 27-year-old male with a hamate fracture associated with 4th and 5th metacarpal base dislocation without a base fracture (Case 5). **(a, b)** Note that the dislocation of the metacarpal bases is not visible on X-rays, **(c)** but the coronal plane fracture is clearly seen on the sagittal CT image. **(d, e)** Postoperative AP and lateral X-rays showing perfect reduction at postoperative Week 4. **(f, g)** Clinical images demonstrating full range of motion at the two-year postoperative follow-up.
CT: Computed tomography; AP: Anteroposterior.

fluoroscopy (Figure 1c). To prevent the screws from exiting the hook of the hamate and damaging volar structures, the wrist was placed in maximum dorsiflexion, and the fluoroscope was angled at 30 degrees to visualize the relationship between the hook of the hamate and the K-wires (Figure 1d). After confirming the proper placement of the temporary wires, the hamate was fixed with a single headless cannulated 2.7-mm screw (Figure 1e). To maintain stability and aid in the healing of the dorsal capsule and ligaments, a 1.5 mm K-wire was placed from the ulnar side of the fifth metacarpal to the third metacarpal, along with another K-wire from the fifth metacarpal to the carpal region (Figures 1, 2 and 3). The ends of the K-wires were bent, trimmed, and left outside the skin. After confirming the reduction of the CMC joints, reduction of the hamate, and proper alignment under fluoroscopy, the surgery was completed by placing the wrist in a short arm splint, leaving the MCP joints free for movement. Depending on the patient's general condition, fracture type, wound site, and edema, active finger and MCP joint movements were usually initiated on postoperative Day 2.

FIGURE 3. Patient No. *8.* An 18-year-old male with a right hamate fracture. **(a)** Preoperative X-rays: Standard AP and lateral views do not adequately reveal the full extent of the fracture, while the oblique view highlights the displaced fracture with instability at the 4th and 5th metacarpal base. **(b)** Initial postoperative X-ray series showing anatomical reduction following open reduction and internal fixation (ORIF). **(c)** X-rays taken at 6 years postoperatively show no signs of osteoarthritis; the patient remains pain-free with a full range of motion in all hand and finger joints.
AP: Anteroposterior.

TABLE I
Demographic, clinical and functional data of patients

Case	Age/Sex	Occupation	Injured site	Dominant hand	Trauma mechanism	4th metacarp fracture	5th metacarp fracture	Time to surgery (Days)	Return to work (Days)	Grip strength of healthy side (kg)	Grip strength of injured site (kg)	DASH score	Implant	Complication
1	49/M	Worker	Right	Right	Punching a wall	None	None	6	35	42	38,5	2,3	1 screw, 1 K-wire	
2	23/M	Worker	Right	Right	Punching a wall	None	Present	5	40	46	42,3	13,6	2 screws, 1 K-wire	Ulnar nerve neuropraxia preoperatively
3	34/M	Worker	Right	Right	Punching a wall	Present	None	10	45	38,3	36,6	2.3	1 screw, 1 K-wire	
4	29/M	Machine operator	Left	Left	Punching a wall	Present	None	3	45	46	44.5	2.3	1 screw	
5	27/M	Worker	Right	Right	Punching a wall	Dislocated	Dislocated	1	90	38	36,3	4.5	1 screw, 2 K-wires	
6	32/M	Worker	Right	Right	Punching a wall	Present	Present	35	45	38	36	2,3	1 screw, 2 K-wires	
7	30/M	Worker	Right	Right	Punching a wall	Present	Present	7	90	44	40	2,3	1 screw, 2 K-wires	
8	18/M	Office boy	Right	Right	Punching a head	Present	Present	21	90	37,3	38,6	2,3	1 screw, 2 K-wires	
9	31/M	Worker	Right	Right	Punching a wall	Present	None	9	45	38,5	38	2,3	1 screw, 2 K-wires	
10	32/M	Worker	Right	Right	Punching a wall	Present	None	11	50	42,5	44	4,5	1 screw, 2 K-wires	
11	22/M	Worker	Right	Left	Punching a wall	Present	None	26	60	46,5	44	2,3	1 screw, 2 K-wires	
12	20/M	Worker	Right	Right	Punching a wall	None	Present	17	45	40,3	35,3	13,6	1 screw, 2 K-wires	
13	26/M	Worker	Left	Left	Punching a wall	None	Present	13	45	42	44	4,5	1 screw, 2 K-wires	
14	42/M	Office boy	Right	Right	Punching a wall	None	Present	8	50	46	44	13,6	1 screw, 2 K-wires	
15	21/M	Office boy	Right	Right	Punching a table	Present	None	14	90	46	46,7	4,5	1 screw, 2 K-wires	
16	23/M	Worker	Right	Right	Punching a wall	Present	None	7	90	38,5	38	4,5	1 screw, 2 K-wires	
17	28/M	Taxi driver	Right	Right	Punching a wall	Present	None	15	90	46	43,3	15.9	1 screw, 2 K-wires	Ulnar nerve neuropraxia postoperatively

The patients were called for visit on Days 10 and 20, and at Weeks 4 and 6, and at three months after surgery. The splints were removed, if there was clinic union. Union was defined as a pain-free fracture with palpation at the first month visit.[12] After splint removal, K-wires for metacarpal fractures were removed at six-week visit and ROM exercises for the wrist, MCP, PIP, and DIP joints were recommended and use of the hand for daily activities was allowed after removal of splint.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Continuous data were expressed in mean ± standard deviation (SD) or median (min-max), while categorical data were expressed in number and frequency. Statistical evaluation was performed to define descriptives. A p value of <0.05 was considered statistically significant.

RESULTS

Baseline demographic, clinical and functional data of the patients are summarized in Table I.

The mean follow-up was 5.8±2.2 (range, 2 to 8) years. In all cases, the fractures occurred on the dominant side. The mechanism of injury was punching a hard surface (e.g., wall, table, and in one case, a skull) in all cases. Of the cases, 12 (70%) were construction workers, and three (17%) were office workers. In three cases (17.6%), an associated fourth and fifth metacarpal base fracture was evident. A sole fourth metacarpal base fracture was observed in nine (52%), a fifth metacarpal base fracture in seven (23%), and a pure dislocation without fracture of the fourth and fifth metacarpal base in one patient (5%).

The mean time to surgery was 12±8.7 (range, 1 to 35) days. In only one patient, two screws were used for fixation of the hamate fracture, while the remaining cases were treated using a single screw. For one case, a Kirschner (K)-wire was not necessary for stabilizing the associated fourth metacarpal base fracture. A single or two K-wires were used for all remaining metacarpal injuries for fixation. An anatomic reduction of the fracture and dislocation of the fourth and fifth metacarpal base was obtained in all of the patients (Table I).

The mean time to return to work was 61±22 (range, 35 to 90) days. The mean grip strength of the injured side was 40.5±3.6 (range, 35 to 46) kg, while the mean grip strength of the uninjured side was 42.1±3.5 (range, 37 to 46) kg. There was no statistically significant difference between the grip strengths of the injured and uninjured sides (p=0.415). The

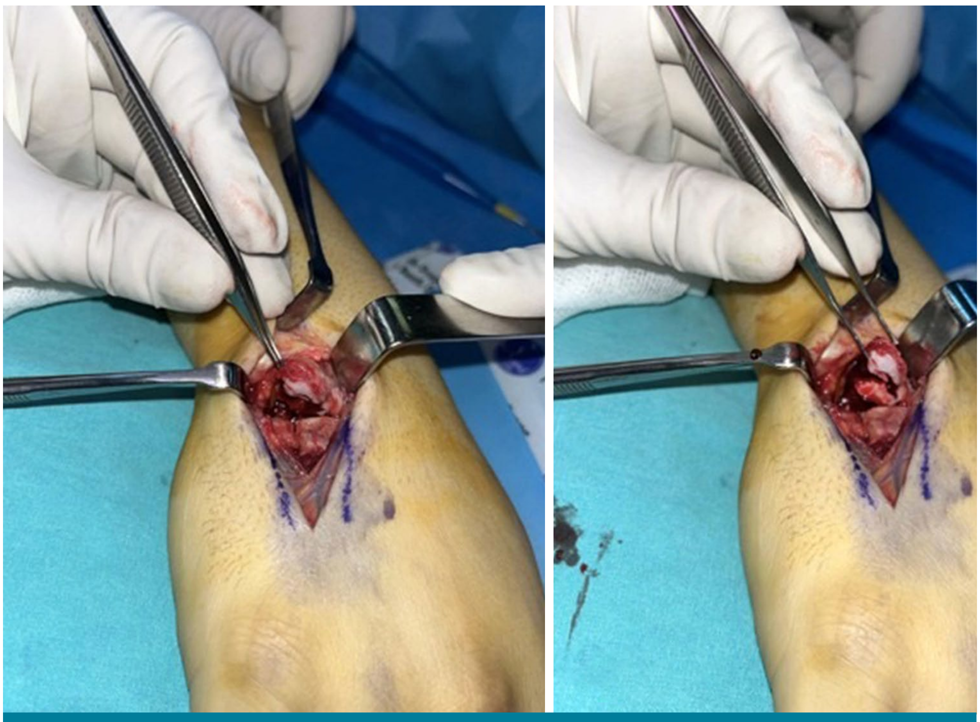

FIGURE 4. The images showing that the hamate dissection was extended to the ulnar side, elevating the cortex to correct the joint step-off.

mean DASH score at the final follow-up was 5.6±4.8 (range, 2.3 to 15.9) (Table I).

At the final visit, the ROM for the wrist, MCP, PIP, and DIP joints was full and within normal ranges for all patients (Figure 2). Clinical union was achieved at the first-month visit for all patients, and K-wires were removed at six weeks. No malunion was detected in any of the patients.

Ulnar nerve neuropraxia was detected in two patients. In one patient, it was present prior to surgery, while in the other, it was identified postoperatively. However, both patients fully recovered after two and three months of follow-up, respectively.

In our series, two cases involved displaced fragments that created a step-off at the joint, preventing proper reduction. To address this, the incision was extended dorsally toward the ulnar side of the hamate to remove the displaced fragment and achieve intra-articular reduction (Figure 4).

DISCUSSION

Carpometacarpal fracture-dislocations associated with hamate fractures are considered rare and complex injuries. The most optimal approach to treating these injuries still remains a matter of debate, and treatment should be individualized for each patient, taking into account the limitations of existing classification systems. Hamate fractures, particularly those associated with the fourth and fifth metacarpal base instability or fracture-dislocations, are rare and complex injuries. Due to their infrequent occurrence, there is a limited number of studies regarding the optimal management strategies, surgical indications, and long-term outcomes, as well. In our study, we observed excellent functional recovery and union rates following surgical fixation, primarily using a single screw and K-wire stabilization. However, challenges such as diagnosing associated injuries and determining the most optimal surgical approach remain. The findings from our series contribute valuable insights into the management of these complex fractures and provide a foundation for improving treatment protocols.

Hamate body fractures predominantly occur in the dominant arm of young adult males.[13] A review of 120 cases in the literature showed that 96% of patients were male, with an average age of 29 years, and 93% had injuries involving their dominant hand.[6] The most common mechanisms reported were striking a solid object with a clenched fist (52%) and falls (22%). Consistent with these findings, all of our patients were young males with 94% injuries to their dominant hands. However, in contrast to the literature, 100% of our patients sustained their injuries exclusively from striking a solid object with a clenched fist. This discrepancy may be attributed to differences in patient demographics, lifestyle factors, or regional variations in injury mechanisms, suggesting that our patient population may have unique risk factors contributing to this injury pattern as 75% of our series were workers having stressful life styles. Moreover, these fractures are commonly associated with the fourth and fifth metacarpal base fractures or dislocations (60%).[14] In our study, we included only patients who required surgical intervention; thus, we cannot speculate on the incidence of isolated hamate fractures in a broader population. However, our findings align with previous studies, as all 31 patients who underwent surgery had associated metacarpal base pathologies, further supporting that isolated hamate body fractures are, indeed, rare.

Coronal hamate fractures typically occur due to high-energy trauma, such as a direct impact from punching a hard surface or a fall onto an outstretched hand, causing axial compression and shearing forces across the fourth and fifth CMC joints, which lead to intra-articular fracture and instability.[6] The Cain classification, based on hamate fragmentation and associated with the fourth metacarpal base fractures, offers a straightforward approach to classifying hamate injuries.[4] Its primary advantage lies in its simplicity and focus on specific anatomical relationships, which can guide initial treatment planning. However, its reliance on the presence of a fourth metacarpal base fracture as a prerequisite limit its applicability, particularly in cases involving more complex intra-articular fracture patterns. This narrow scope makes it less useful for a broader range of injuries, and its reliance on plain radiographs can lead to missed or misclassified complex fractures, thereby reducing diagnostic accuracy. In this regard, the preoperative CT-based classification by Kim and Shin[15] offers a more detailed and clinically informative approach. The aforementioned study allows for better differentiation between fracture and dislocation injuries, providing a clearer treatment algorithm. However, the lack of distinction between acute and delayed cases in this treatment algorithm creates a gap in clinical practice. On the other hand, the Hirano and Inoue classification, which divides hamate body fractures into coronal (type 1) and sagittal (type 2) fractures, provides a more detailed understanding of the fracture's direction and pattern. This classification is beneficial for identifying the specific mechanics of the injury and for surgical planning, particularly in cases requiring fixation. However, while more comprehensive in describing the fracture pattern, this system lacks clear guidance on associated injuries, such as metacarpal base fractures or dislocations, limiting its utility in treating complex hamate injuries involving surrounding structures. Thus, we recommend to obtain a preoperative CT to define fracture pattern in a more reliable way. Given to the fact that a delayed diagnosis for hamate fractures is extremely common,[16,17] we recommend and opt to use CT images for diagnosis and classification those fractures, as a sagittal image is useful to determine the extent and class of hamate fractures according to Hirano and Inoue classification.[3]

The choice between ORIF and closed reduction and internal fixation (CRIF) in treating hamate fractures depends significantly on the fracture type and the extent of associated instability, particularly in cases involving the fourth and fifth metacarpal base. The CRIF offers a less invasive approach that is particularly effective for non-intra-articular fractures, such as type 1 (hamate hook fractures), type 2a oblique avulsion fractures, and type 2b sagittal plane fractures. These fractures usually do not involve the joint surface and can be managed with percutaneous fixation techniques, which reduce the risk of soft tissue damage, minimize recovery time, and limit complications such as infection and postoperative stiffness.[6] However, the main disadvantage of CRIF lies in its limited applicability to complex intra-articular fractures, where achieving and maintaining accurate reduction without direct visualization can be challenging. In these cases, improper reduction can result in residual instability or malalignment, ultimately compromising the functional outcome. On the other hand, ORIF is often necessary for Hirano type 2a (longitudinal) fractures, as these coronal fractures involve a significant portion of the hamate and lead to intra-articular instability.[5] In such cases, anatomic reduction is critical because failure to achieve proper reduction can result in persistent instability of the fourth and fifth metacarpal bases, leading to poor joint congruity and an increased risk of post-traumatic osteoarthritis and chronic hand pain.[14] The invasive nature of ORIF, however, carries risks such as postoperative scarring, prolonged recovery, and increased edema, particularly when larger incisions are required to achieve reduction. Eder et al.[14] in their case series of 19 patients with coronal hamate fractures, concluded that conservative treatment was not advisable due to high complication rates, including persistent CMC joint subluxations and lack of pain relief. Kono et al.[18] emphasized that ORIF, as opposed to a closed approach, offered several benefits: precise anatomical reduction of the hamate, restoration of the articular surfaces, and the ability to address associated injuries. Based on our study findings, we believe that an ORIF is the most optimal operative technique to obtain anatomic reduction and prevent early or late complications for type 2a coronal longitudinal fractures in line with the literature.

Wharton et al.[13] reported that non-displaced fractures treated conservatively with casting yielded good outcomes, while fractures managed with K-wires often resulted in incomplete reduction and less favorable results. Although rigid internal fixation provided excellent radiographic alignment, it did not always correlate with improved functional outcomes. We agree with their conclusion that internal fixation using only K-wires may not provide adequate stability. Therefore, we opted for cannulated headless screws for fixation. This approach resulted in better outcomes in terms of maintaining radiological alignment, achieving union, and obtaining excellent clinical results. However, it is of utmost importance to note that surgical intervention did not yield optimal outcomes in every case. In our series, two cases involved displaced fragments that created a step-off at the joint, preventing proper reduction. To address this, the incision was extended dorsally toward the ulnar side of the hamate to remove the displaced fragment and achieve intra-articular reduction. However, in both cases, we observed that postoperative edema was more pronounced and lasted longer compared to other cases, likely due to the extended ulnar incision. Additionally, once the hamate was stably fixed, spontaneous reduction and stabilization of the fourth and fifth metacarpal dislocations occurred. This approach successfully resolved the displacement, but came with the complication of prolonged edema. Thus, an extended approach should be avoided, if possible, since an ulnar nerve neuropraxia seems to be very likely for the interventions performed at this level.[19] Moreover, despite the fact that lower DASH scores seemed to be perfect, the lowest scores were performed by these patients after a mean three years of follow-up for these two patients.

Nonetheless, this study has several limitations. First, the retrospective nature of the study may introduce biases in data collection and interpretation, as it relies on medical records and follow-up data. Second, the sample size was relatively small, with only 17 cases, which may limit the generalizability of the findings to a broader population. Additionally, while we used a standardized functional assessment tool (i.e., DASH), other outcome measures could have provided a more comprehensive evaluation of functional recovery. Finally, the follow-up period, while sufficient for most patients, may not capture long-term complications or functional deficits. Further multi-center, large-scale, prospective studies with longer follow-ups are needed to confirm these findings.

In conclusion, in this series of hamate fractures, surgical fixation using headless screws and K-wires resulted in excellent clinical and radiological outcomes. All patients achieved clinical union, with full restoration of ROM and no instances of malunion. Grip strength and functional outcomes were satisfactory, with no significant differences between the injured and uninjured sides. In the light of these findings, we suggest that surgical intervention with stable fixation provides good functional recovery in these complex fractures, although further studies with larger cohorts are still warranted.

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