European Journal of Trauma and Emergency Surgery (2025) 51:43
https://doi.org/10.1007/s00068-024-02717-2

ORIGINAL ARTICLE

Ulnoradial - metacarpal reconstruction for emergency one-stage procedure in complicated wrist amputation

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Received: 20 November 2022 / Accepted: 4 October 2024

Abstract

Background Complicated wrist amputation caused by severe trauma poses a real challenge for orthopedic and hand surgeons. This study aimed to evaluate a procedure of ulnoradial-metacarpal reconstruction as a rescue option in this challenging situation.

Methods In total, 12 patients with complicated wrist amputation induced by serious injury were selected from 2015 to 2020 and followed up for 1∼6 years at a level 1 trauma center. All patients underwent initial treatment in the Emergency Department followed by transfer to the main operating theater for emergency ulnoradial-metacarpal reconstruction. Patient demographics, surgical techniques, clinical outcomes, and complications were also retrieved from medical records. Functional outcomes were assessed with Disabilities of Arm, Shoulder and Hand score (DASH) and Mayo Wrist Score (MWS). Descriptive statistics were used to calculate, including frequencies for categorial variables and mean values and ranges for continuous variables.

Results The mean age of patients was 49.3 years (ranging from 41 to 61 years), with ten males and two females. The mean time to union was 4.8 months; 11 patients had a complete union. There was one case of nonunion due to bone resorption resulting from inadequate blood supply and smoking. Compared with the contralateral limb, the total active motion of the hand was 25% (ranging from 17 to 38%), and grip strength was 7% (ranging from 0 to 18%). Neither tip nor key pinch was present. Mean 2-point discrimination was 10.6 mm (ranging from 8 to 12 mm). All mean outcome scores indicated moderate disability, including disabilities of Arm, Shoulder, and Hand (12; ranging from 4 to 27). Based on Mayo Wrist Score, all patients were loss of wrist function forever. The majority of patients were satisfied with the hand function after recovery.

Conclusion Despite all patients experiencing significant impairments in their overall hand function, ulnoradial-metacarpal fusion presents a viable option for hand replantation in instances where the carpus has been irreparably damaged.

Type of study/level of evidence Therapeutic IV.

Keywords Wrist amputation · Ulnoradial-metacarpal reconstruction

Introduction

Wrist amputations are uncommon but devastating [1]. The prevalence of wrist extremity amputation is estimated to be approximately 11.6 per 100,000 adults [1]. Wrist amputation presents challenges in management, especially at the carpus level [2]. Due to the severance of the wrist amputation, the anatomical structure becomes disorganized, thereby complicating the process of reconstruction. In rare cases, the carpus of the affected hand is mangled and therefore destroyed beyond reconstruction or unsalvageable. In this setting, ulnoradial-metacarpal reconstruction may be considered to restore a sensate, functional hand.

The rarity of wrist amputations underscores the complexity of devising optimal surgical strategies, especially when faced with irreparable damage to the wrist. Current philosophies prioritize the preservation of the hand whenever feasible, as advancements in prosthetic technology still leave a substantial functional gap between artificial limbs and natural hands. The diverse degrees of freedom of the human arm

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Published online: 24 January 2025

and the agility and sensory feedback of the hand can only be slightly replicated using modern prosthetic technology [3]. In addition, a limb prosthesis not only is expensive, but also not available everywhere and especially not suitable for every type of patient. Therefore, a natural hand with severe post-traumatic functional limitations may be more functional than prosthetics [4, 5]. To our knowledge, there are no documented standard techniques for reconstruction at the carpus level following wrist amputation.

The goal of this study was to present our case series of ulnoradial-metacarpal reconstruction. Additionally, we seek to evaluate the functional outcomes of this approach through a comprehensive analysis of our patient case series. Specifically, we elucidate the clinical progression of our patients and delineate their advancement using validated functional outcome measures in this study.

Materials and methods

Our hospital is a Level 1 trauma center. Hand and plastic surgery are available 24/24 h. After approval by our institutional review board, we conducted a retrospective review on all patients. Patients with traumatic amputation at or close to the carpus level were considered for inclusion. Those with injuries distal to the carpals or proximal to the distal radius and ulna were excluded.

Twelve patients who had undergone complicated wrist amputation due to severe injury were selected from the years 2015 to 2020 at a level 1 trauma center and subsequently followed up for a duration ranging from 1 to 6 years. Each patient received immediate ulnoradial-metacarpal reconstruction following management in the main operating theater. Data pertaining to patient demographics, surgical techniques employed, clinical outcomes, and any encountered complications were meticulously extracted from medical records. Descriptive statistical analyses were conducted, encompassing frequency distributions for categorical variables and the calculation of mean values and ranges for continuous variables.

Follow-up assessment

Patients who met inclusion criteria were completed during the outpatient visits for follow-up and evaluated by a single examiner in our clinic. We took anterior-posterior radiographs of the wrist and hand to assess for fracture union if necessary for CT examination. During these encounters, functional outcome was evaluated with the following means.

1. We evaluated flexor and extensor recovery of all fingers with total active motion (TAM) of each digit. The full dynamic activity of each digit and the hand was calculated as a percentage compared with the uninjured, contralateral hand.
2. We assessed grip strength using a calibrated dynamometer with the forearm in neutral rotation and the wrist in neutral flexion extension. Key pinch and tip pinch were evaluated with a calibrated pinch gauge. These values were compared with the contralateral hand and reported as a percentage.
3. Neurologic recovery of sensitivity was assessed using static 2-point discrimination (2PD) on the ulnar and radial aspect of each digit. These values were averaged for all digits.
4. To standardize outcomes, two validated questionnaires were completed at the visits: Mayo Wrist Score (MWS) and Disability of the Arm, Shoulder, and Hand (DASH).

Surgical technique

A single senior surgeon performed all surgical procedures. The patient was placed in the horizontal supine position. Nerve block anesthesia was used (brachial plexus block) routinely. The affected extremity was repeatedly cleaned with hydrogen peroxide and Iodophor and isolated with sterile drapes in the operation area. After applying sterile drapes in the operation area, a sterile tourniquet was placed on the upper arm, followed by debridement. The fracture ends were fixed with Kirschner wire. The tendons, blood vessels, and nerves were repaired accordingly. Incision decompression was also performed on the opisthenar to prevent ischemia-reperfusion injury for patients whose replantation was needed if necessary. Skin grafting or flap transplantation was further performed according to the situation of the wound. Active rehabilitation training was completed, and functional reconstruction was conducted if necessary Table 1.

Graph review and result recording

Patient demographics and surgical techniques were collected from medical records. After the study protocol was approved, we conducted a prospective face-to-face follow-up investigation. The following data were collected: disabilities of the arm, shoulder, and hand (DASH) score, Mayo Wrist Score (MWS), grip strength, tip pinch, key pinch, 2-point discrimination, time to union, and complications (Fig. 1).

Table 1 Functional outcome questionnaire results

Case	Real disabilities of the arm, shoulder, and hand score (DASH)	Mayo wrist score (MWS)
1	4	0
2	8	0
3	18	0
4	14	0
5	12	0
6	15	0
7	11	0
8	12	0
9	9	0
10	27	0
11	9	0
12	5	0

*Higher score signifies greater disability

Results

During the 1 to 6-year duration of the study, 12 patients fulfilled the inclusion criteria, with an average follow-up period of 2.8 years. The mean age of the patients was 49.3 years, ranging from 41 to 61 years, encompassing 10 males and 2 females. Among these cases, seven exhibited lesions on the right and dominant sides, while five presented lesions on the left and nondominant sides. 9 patients had work-related machine injuries (the most common type of injury) and 3 patients had road traffic accidents. The patient demographics are shown in Table 2. Patients were assessed in the emergency room about a mean of 5.8 h after injury. 3 patients required compartment release of the hand. All patients suffered from extensive carpal damage. Bone shortening was performed for the purpose of the reconstruction of normal finger appearance and function. K-wire was used to attain bony fixation of the amputated hand. After reperfusion, the median, radial, and ulnar nerves were primarily repaired in all cases. Nerve autografts were used with the peroneal nerve in 3 patients as a result of a long segmental nerve defect. All flexor and extensor tendons were repaired Table 3 and 4.

11 patients had a complete union, and the other one required autologous bone graft with the fixation of locking steel plate to achieve bone healing. The mean time to union was 4.8 months. A series of upper limb functional rehabilitation training could improve strength and function in all patients. Functional outcomes were measured by DASH scores. The mean DASH score was 12 points, ranging from 4.0 to 27 points. The active forearm pronation was primarily dependent on the compensation of the shoulder joint due to the loss of distal radioulnar joints. The mean grip strength was 3.7 kg (1.6–5.6 kg) on the affected side and 31.5 kg (27–45 kg) on the healthy extremity. 11 patients were very satisfied with the appearance of the forearm after reconstruction on the basis of description, "The length of the limb is the function." though one patient was somewhat satisfied. All patients were able to resume daily activities.

Follow-up

The average TAM of the entire hand was 25% of the contralateral side. The patient treated with a ulnoradial-metacarpal reconstruction had TAM of the wrist that was 0 of the contralateral extremity. All patients treated with ulnoradial-metacarpal reconstruction achieved fusion at follow-up and had no wrist motion. Patients covered on average 10.6 mm (range, 8–12 mm) of 2 PD, and all patients noted cold intolerance.

Functional outcomes were recorded for all patients at follow-up. A professional rehabilitation program was initiated during the hospitalization. A therapist gave directions to perform the passive motion at the shoulder, elbow, and digits under the aid of the postoperative orthosis. At two weeks, passive range of motion was initiated with skilled therapy in the outpatient setting. In addition to motion exercises, our plan also emphasized early desensitization techniques (with a variety of textures and vibrations). Special activities to assist with activities of daily living were performed, including reaching and grasping coordination with cone stacking, grip strength and forearm strengthening with wrist rollers. Place-and-hold exercises and electrical stimulator exercises were performed for intrinsic and extrinsic muscles.

Discussion

The majority of upper limb amputations, although unusual, are functionally and psychosocially destructive. Ischemia time, extent of soft tissue damage and bony destruction have a major impact on the surgeon's decision to attempt a replantation. In 2007, Sabapathy et al. [6] investigated the functional outcomes of 22 patients with replantation. They concluded that replantation is a beneficial procedure. In 2017, Mattiassich et al. [7] reported long-term results of upper limb replantation and concluded that long-term effects are possible. Mattiassich et al. did not only examine hand amputation.

However, the destruction of the wrist is a special challenge in upper limb amputation, as the surgeon has to deal with a difficult anatomic situation than the other amputation group, especially at the carpus level. Ulnoradial-metacarpal reconstruction has been used as a rescue option for complex wrist amputations according to the explanation, "The length of the limb is the function." Therefore, ulnoradial-metacarpal

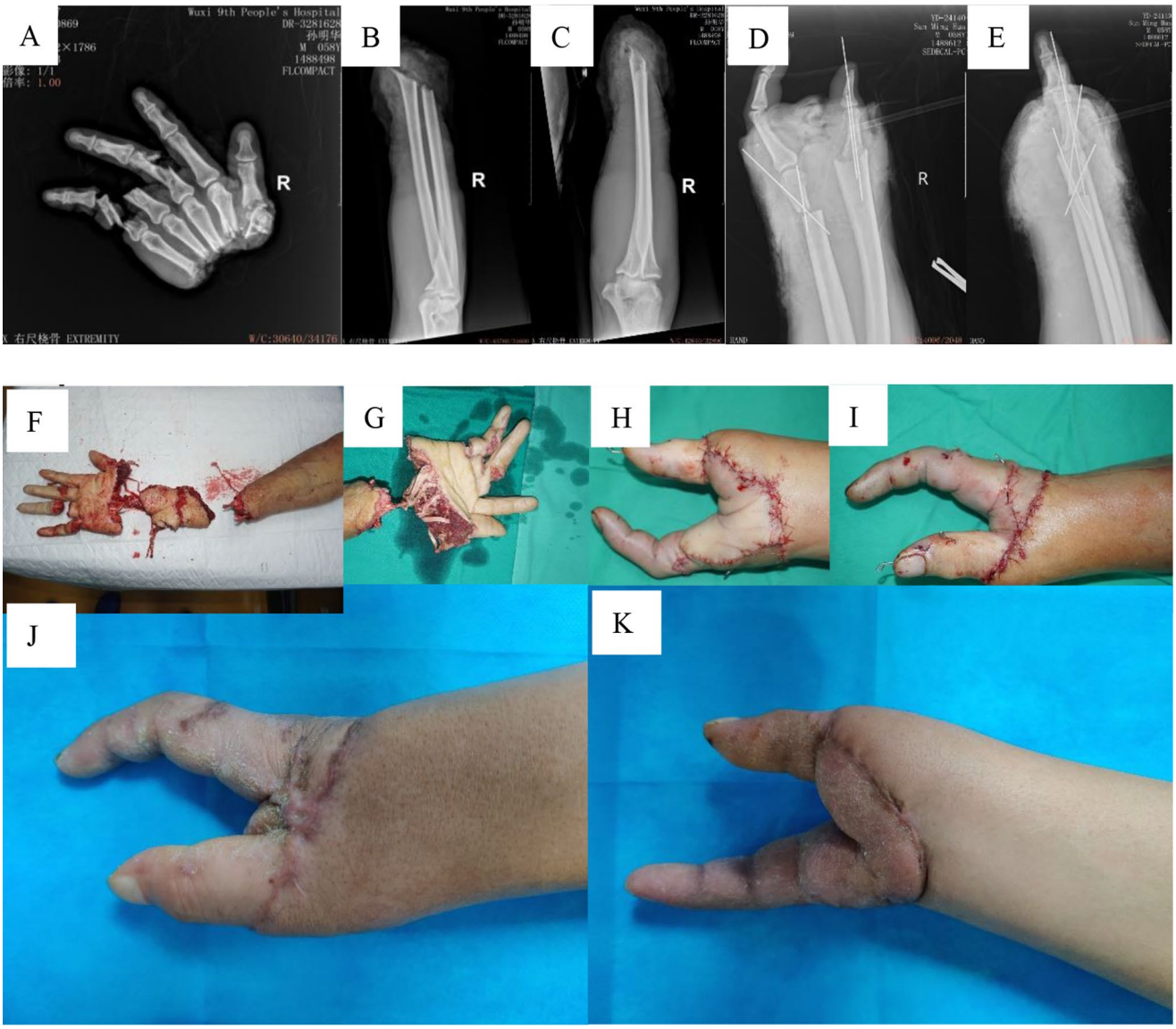

Fig. 1 A 58-year-old man with complex wrist amputation combined with severed fingers due to a mechanical crush injury received emergency ulnoradial-metacarpal reconstruction. **A**-**C**. Pre-operative X-ray; **F**-**G**. Appearance of injured limb; **D**-**E**. Postoperative X-ray showing ulnoradial-metacarpal reconstruction; **H**-**K**. Postoperative appearance

reconstruction can be an alternative to preserve severe acute wrist amputation and provide therapeutic means. Long-term rehabilitative challenges are multiple and highly dependent on the type and level of injury. Among amputations proximal to the hand, those at the radiocarpal level allow more options for function owing to intact shoulder, elbow, and distal radioulnar joints. The process of distal replants is associated with grip strength, sensory recovery, and intrinsic recovery.

Amar et al. [1] reported that all replanted hands survived in their cases. Despite the survival of 100% of digits in the surviving patients, outcomes evaluation demonstrated various degrees of functional impairment in their series. Similar results were reported previously. Hoang et al. [8] investigated a cohort comprising 5 young men who underwent replantation procedures for radiocarpal-level amputations. During follow-up sessions spanning from 26 to 46 months, they exhibited total active motion (TAM) ranging from 75 to 85% compared to the contralateral side, a static two-point discrimination (2-PD) measurement reduced to 8 to 12 mm, and experienced a loss of intrinsic muscle function. Mahajan and Mittal [9] presented findings from a cohort of 17 patients, aged 2 to 55 years, who underwent radiocarpal replantation procedures. The majority of patients exhibited total active motion (TAM) ranging from 50 to 70% compared to the contralateral extremity, along with decreased intrinsic muscle function and a static two-point discrimination (2-PD) exceeding 10 mm. Among the 14 patients with

Table 2 Injury characteristics

Case	Age(yr), sex	Mechanism of injury	Side	Bones forming
1	41, M	Crush	R	Ulnoradial-metacarpal
2	53, M	Accident	R	Ulnoradial-metacarpal
3	48, F	Crush	L	Ulnoradial-metacarpal
4	45, M	Accident	L	Ulnoradial-metacarpal
5	47, M	Cut	R	Ulnoradial-metacarpal
6	58, M	Crush	R	Ulnoradial-metacarpal
7	42, M	Accident	R	Ulnoradial-metacarpal
8	44, M	Crush	L	Ulnoradial-metacarpal
9	49, F	Crush	L	Ulnoradial-metacarpal
10	55, M	Cut	R	Ulnoradial-metacarpal
11	52, M	Crush	R	Ulnoradial-metacarpal
12	61, M	Crush	L	Ulnoradial-metacarpal

R: right side; L: left side

Table 3 Follow-up functional outcomes

Case	Grip strength Kg	Tip pinch Kg	Key pinch Kg	2-point discrimination mm
1	1.6	0	0	8.5
2	5.2	0	0	12.0
3	4.8	0	0	11.0
4	5.0	0	0	12.0
5	3.3	0	0	10.0
6	4.6	0	0	12.0
7	2.1	0	0	8.0
8	3.3	0	0	11.0
9	4.7	0	0	12.0
10	2.4	0	0	9.0
11	5.6	0	0	12.0
12	1.8	0	0	10.5

Table 4 Follow-up time and time of union

Case	Follow-up time (year)	Time to union (month)
1	2.7	4.2
2	3.2	5.1
3	1	4.8
4	5.1	4.3
5	6	5.5
6	3.3	4.5
7	4.8	5.2
8	2.3	4.1
9	1.5	3.5
10	1.4	5.5
11	1	5
12	1.3	5.9

available follow-up data, 10 reported reasonable satisfaction despite these observed outcomes. The reported total TAM values in these studies exceeded our results, likely due to the fact that our subjects experienced loss of wrist joint anatomy in nearly all cases, resulting in decreased motion of the wrist and digits in terms of tip pinch and key pinch due to the loss of intrinsic muscles. Nevertheless, akin to our investigation, patients in these studies also exhibited some restoration of active finger motion. We draw conclusions that ulnoradial-metacarpal reconstruction could restore partial appearance and function of the hand, though the carpal bone had been missing in view of our study. Our outcome scores demonstrated that many patients could not continue to work because of poor intrinsic function, but they were able to take on everyday lives.

The limitations of our study encompass its retrospective design, the limited sample size encompassing patients with varying degrees of injury, and the absence of intermediate outcome measures. Additionally, some patients had brief follow-up periods, potentially skewing outcomes, which might present more favorably with extended follow-up or subsequent surgical interventions. The incorporation of cost analysis would be instrumental in elucidating the financial implications associated with replantation procedures. Prospective multicenter investigations hold promise in offering insights into comparable patient populations, thereby affording a more substantial cohort for analysis.

Declarations

Competing interests The authors declare no competing interests.

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