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Factors Associated with outcome of Survival in Hand Replantation: A Retrospective Analysis on 8 Patients

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ABSTRACT

Background: Proximal hand amputations—those occurring from the metacarpophalangeal (MCP) joint level to the wrist—represent a distinct and challenging subset of replantation cases. These injuries involve large soft tissue masses, multiple critical structures, and significant ischemia burdens. This study aims to analyze predictors of survival in proximal hand replantation based on a single-center experience. **Methods:** A retrospective review was conducted of all patients who underwent replantation for complete traumatic hand amputation at or proximal to the MCP joint and distal to or at the wrist joint between January 2023 and December 2025. Data collected included mechanism of injury, ischemia times, number of venous anastomoses, use of vein grafts, and patient factors. The primary outcome was replant survival at three months postoperatively. **Results:** Eight patients (7 males, 1 female) with a mean age of 34.50 years (range, 19–52 years) were included. Amputation levels included transmetacarpal (n=3), MCP joint disarticulation (n=2), and transcarpal/wrist level (n=3). The overall survival rate was 87.5% (7 of 8 replants). One replant was lost due to irreversible venous congestion. Analysis revealed that warm ischemia time exceeding 4 hours, crush/avulsion mechanism. All surviving replants achieved functional recovery with protective sensation and meaningful grip strength. **Conclusion:** Proximal hand replantation can achieve high survival rates when patient selection is optimized. Critical predictors of success include short warm ischemia time, a guillotine-type mechanism, and robust venous outflow reconstruction. Despite the complexity of these injuries, successful replantation offers superior functional outcomes compared to prosthetic alternatives.

Keywords: Proximal Hand Replantation, Hand Amputation, Replant Survival, Warm Ischemia Time, Venous Anastomosis, Crush Injury, Guillotine Amputation, Microsurgical Reconstruction, Functional Recovery, Predictive Factors.

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INTRODUCTION

Traumatic amputation of the hand at the proximal level—from the metacarpophalangeal (MCP) joints to the wrist—represents one of the most challenging scenarios in reconstructive microsurgery. Unlike distal digit amputations, proximal hand amputations involve extensive soft tissue injury, multiple tendons, nerves, and vessels, and a larger volume of ischemic tissue [1]. The stakes are also higher: successful replantation can restore near-normal function, while failure results in a short, often non-functional residual limb that poses significant challenges for prosthetic fitting [2]. Since the first successful hand replantation by Malt *et al*., in 1964, surgical techniques have advanced considerably [3]. However, the literature on predictors of survival specifically for proximal hand replantation remains limited, with most studies combining digital and hand replantations or focusing on distal injuries [4, 5]. The factors that determine success in proximal replantation—including ischemia tolerance, venous reconstruction, and injury mechanism—may differ significantly from those in distal replantation due to the larger muscle mass and greater metabolic demands of the proximal hand [6]. This retrospective analysis examines a series of eight proximal hand replantations to identify predictors of survival and to provide clinical guidance for this high-stakes procedure.

MATERIALS AND METHODS

This retrospective case series was conducted at Dhaka Medical College Hospital, a Level I trauma center, following institutional review board approval. The study included all patients who underwent replantation for complete traumatic hand amputation between January 2023 and December 2025. Eligible patients had amputations proximal to the metacarpophalangeal (MCP) joint, including transmetacarpal, MCP joint disarticulation, transcarpal, or wrist-level injuries, and a minimum follow-up duration of three months. Patients with incomplete amputations with an intact vascular pedicle, those in whom replantation was abandoned intraoperatively, and those with significant pre-existing peripheral vascular disease were excluded.

Data Collection

Data were collected through a comprehensive review of medical records, operative notes, and outpatient follow-up documentation. Variables included patient demographics (age, sex, smoking status, and comorbidities), injury characteristics (mechanism of injury, level of amputation, and associated injuries), operative details (warm and cold ischemia times, number of arterial and venous anastomoses, use of vein grafts, and extent of bony shortening), and postoperative outcomes (re-exploration, complications, and anticoagulation therapy).All procedures were performed under regional anesthesia using a brachial plexus block, providing both intraoperative and postoperative analgesia. A two-team approach was adopted whenever feasible to reduce total ischemia time, with one team preparing the amputated part while the other simultaneously dissected the proximal stump. The amputated segment was initially irrigated with normal saline, wrapped in saline-moistened gauze, placed in a sterile plastic bag, and preserved on ice without direct contact. Preoperative management included administration of broad-spectrum intravenous antibiotics, tetanus prophylaxis, and selective use of systemic anticoagulation based on injury severity.

Both the amputated part and proximal stump were irrigated with heparinized saline, followed by meticulous debridement under magnification. Devitalized tissues were conservatively excised while preserving all viable structures. Major anatomical components, including arteries, veins, nerves, and tendons, were carefully identified and tagged. Skeletal stabilization was performed after bony shortening (0.5–2 cm) to facilitate tension-free repair, using Kirschner wires or low-profile plates and screws depending on the level and stability requirements. Tendon repair was performed prior to vascular reconstruction, with flexor tendons repaired using a modified Kessler technique and extensor tendons repaired using interrupted or running sutures under magnification. Arterial reconstruction involved repair of at least one, and preferably both, of the radial and ulnar arteries using end-to-end microsurgical anastomosis with 8-0 or 9-0 nylon sutures. Vein grafts were used when necessary to achieve tension-free arterial continuity. Venous reconstruction was prioritized, with a minimum of two venous anastomoses performed whenever feasible using 9-0 or 10-0 nylon sutures, and vein grafts employed when required to ensure adequate venous outflow.

Median and ulnar nerves were repaired using epineurial suturing techniques under microscopic visualization to optimize sensory and motor recovery. Soft tissue coverage was achieved with tension-free primary closure when possible, while split-thickness skin grafting or staged flap coverage was utilized for larger defects. Reperfusion was assessed clinically following release of vascular clamps, based on restoration of skin color, capillary refill, bleeding from wound edges, and palpable pulsation. Adjunctive measures, including topical vasodilators and heparinized irrigation, were used as needed to minimize vasospasm and thrombosis. Postoperatively, patients were managed in a high-dependency unit with strict limb elevation above heart level to facilitate venous drainage and maintenance of a warm ambient environment (24–26°C) to prevent vasospasm. Vascular monitoring was performed hourly, including assessment of skin color, temperature, capillary refill, and Doppler signals. Anticoagulation was administered using intravenous Heparin according to institutional protocol, often combined with oral Aspirin. Adequate fluid resuscitation was maintained to optimize tissue perfusion.

Urgent re-exploration was undertaken in cases of suspected vascular compromise, including sudden changes in skin color (pallor or congestion), absent Doppler signals, loss of capillary refill, or decreasing temperature of the replanted hand. Re-exploration aimed to revise vascular anastomoses, evacuate hematoma, or perform thrombectomy as indicated. Early rehabilitation was initiated under the supervision of a hand therapist. Passive range-of-motion exercises were typically commenced within the first postoperative week, followed by gradual progression to active mobilization as healing permitted. Splinting protocols were individualized based on the level of injury and stability of repairs, with regular follow-up to monitor functional recovery and prevent joint stiffness. The primary outcome measure was replant survival, defined as a viable and perfused replanted hand at three months postoperatively. Failure was defined as complete necrosis requiring revision amputation. Secondary outcomes included need for re-exploration, time to healing, and functional recovery. Due to the small sample size, data were analyzed using descriptive statistics, and comparisons between successful and failed cases were performed qualitatively.

Figure 1: A-B, crushed dominant Hand that occurred after a motorcycle chain injury, warm ischemic time 5 hours. C-D, injury occurred at Metacarpophalangeal (MCP) joint. E-G, preparing the replant for replantation. H-I, hand after replantation. J-K, 2 weeks after replantation, blackening of Ring and Little Finger distal to PIP joint, which may result from extensive crush injury. L, 3 months after replantation, adhesiolysis of Flexor tendons of Index and Middle Finger. M-N, after Tendon repair

Figure 2: A-B, guillotine injury of dominant Hand that occurred during a political fight, warm ischemic time 9 hours, injury occurred at wrist joint. C-E, preparing the replant for replantation. F-G, Vascular Anastomosis. H-I, immediately after replantation. J-L, 2 weeks after replantation, remaining wounds in ventral and dorsal surface resurfaced by STSG

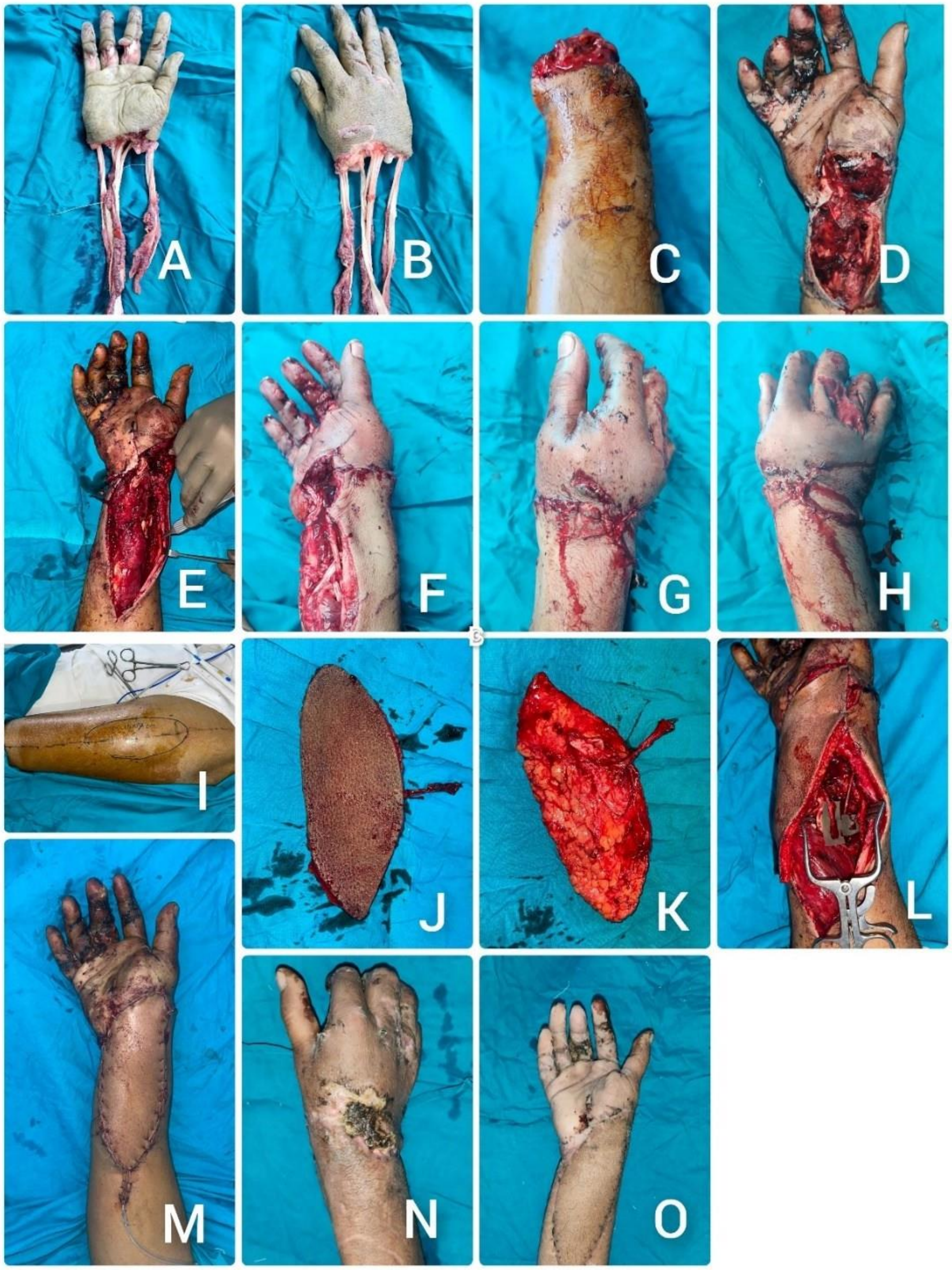

Figure 3: A-B, avulsed dominant Hand that occurred after machinary injury, warm ischemic time 8 hours. C, injury occurred just proximal to Wrist joint. D-H, 1 week after replantation, a soft tissue defect in flexor aspect of forearm. I-K, harvesting of anterolateral thigh (ALT) Flap. L, preparing the recipient vessels. M, immediately after flap inset. N-O, 1 month after replantation

RESULTS

Patient Demographics and Injury Characteristics

A total of eight patients met the inclusion criteria. The cohort consisted of seven males and one female, with a mean age of 34.50 years (range, 19–52 years). All injuries were work-related or due to high-energy trauma. Mechanism of injury was guillotine-type (sharp amputation) in five patients (62.5%) and crush/avulsion in three patients (37.5%).

Amputation levels were distributed as follows:
Transmetacarpal (proximal to MCP joints): 3 patients
MCP joint disarticulation: 2 patients
Transcarpal/wrist level: 3 patients

The mean warm ischemia time was 182 minutes (range, 90–360 minutes). The mean cold ischemia time was 4.2 hours (range, 2–7 hours). All patients had the amputated part properly preserved in a cold, moist environment prior to arrival.

Table 1: Demographic and Injury Characteristics of Patients (n = 8)

Variable	Number of Patients (n)	Percentage (%)
Sex		
Male	7	87.5%
Female	1	12.5%
Age (years)		
Mean ± SD	34.50 (±10.56)	(range 19–52)
Mechanism of Injury		
Guillotine-type (sharp amputation)	5	62.5%
Crush/avulsion	3	37.5%
Level of Amputation		
Transmetacarpal	3	37.5%
MCP joint disarticulation	2	25.0%
Transcarpal/Wrist level	3	37.5%
Warm Ischemia Time (minutes)		
Mean	181.87 (±88.71)	(range 90–360)
Cold Ischemia Time (hours)		
Mean	4.2 (±1.62)	(range 2–7)
Preservation Method		
Cold, moist preservation (all cases)	8	100%

Patient Characteristics and Operative Details

A total of eight patients met the inclusion criteria. The cohort consisted predominantly of males, with seven males and one female, and a mean age of 34.6 years (range, 19–52 years). All injuries were work-related or resulted from high-energy trauma. The mechanism of injury was guillotine-type (sharp amputation) in five patients (62.5%) and crush/avulsion in three patients (37.5%). The levels of amputation varied, with three patients sustaining transmetacarpal amputations proximal to the metacarpophalangeal (MCP) joints, two patients having MCP joint disarticulations, and three patients presenting with transcarpal or wrist-level amputations. The mean warm ischemia time was 182 minutes (range, 90–360 minutes), while the mean cold ischemia time was 4.2 hours (range, 2–7 hours). In all cases, the amputated parts were appropriately preserved in a cold, moist environment prior to arrival at the hospital.

All patients underwent arterial revascularization, with a mean of 1.8 arteries (range, 1–3) repaired per patient. Venous reconstruction was also performed in all cases, with a mean of 2.0 veins (range, 1–4) repaired. Vein grafts, harvested from the forearm, were required in three patients (37.5%) due to segmental vessel loss. Bony shortening was performed in all patients to facilitate tension-free vascular repair, with a mean shortening of 1.2 cm (range, 0.5–2.5 cm). Postoperatively, all patients received anticoagulation therapy consisting of intravenous Heparin for five days, followed by oral Aspirin at a dose of 75 mg daily for six weeks.

Table 2: Surgical Outcomes of Digital Revascularization/Replantation (n = 8)

Outcome Parameter	Number of Patients (n)	Percentage (%)
Total Patients	8	100%
Arteries Repaired		
1 artery repaired	1	12.5%

2 arteries repaired	7	87.5%
Veins Repaired		
2 veins repaired	7	87.5%
3 veins repaired	1	12.5%
Vein Graft Used	3	37.5%
Re-exploration Required	2	25.0%
– Arterial cause	1	12.5%
– Venous cause	1	12.5%
Successful Survival	7	87.5%
Failure	1	12.5%

Outcomes and Predictors of Replantation Success

Replantation Survival

Of the eight patients who underwent digital or hand replantation, seven (87.5%) survived completely. The single failure (Patient 4) involved a severe crush/avulsion amputation at the transmetacarpal level with a prolonged warm ischemia time of 360 minutes (6 hours). Intraoperatively, two veins were identified and repaired despite extensive dissection. On postoperative day 2, the replant developed progressive venous congestion that did not respond to re-exploration, and the replant was deemed unsalvageable on day 4, necessitating revision amputation at the wrist level.

Re-explorations

Two patients (25%) required return to the operating room due to vascular compromise. Patient 2 underwent re-exploration on postoperative day 1 for arterial thrombosis, and successful thrombectomy with revision of the arterial anastomosis allowed salvage of the replant. Patient 4 underwent re-exploration for venous congestion, which was unsuccessful as noted above.

Functional Outcomes of Surviving Replants

At a mean follow-up of 11 months (range, 6–18 months), all seven surviving replants demonstrated protective sensation. The mean grip strength was 32% of the contralateral side, and mean two-point discrimination in the median nerve distribution was 12 mm. Four of seven patients (57%) returned to their original occupation. No patient reported chronic pain requiring long-term medication, indicating satisfactory functional recovery.

Predictors of Outcome

Analysis of the single failure compared to the seven successes highlighted several factors associated with poor outcome. The mechanism of injury played a major role: the failed replant involved a crush/avulsion injury, whereas all five guillotine-type injuries survived (100% survival), and two of three crush/avulsion injuries survived (66.7% survival). Warm ischemia time was another critical factor; the failed case had a warm ischemia time of 360 minutes, while survivors had a mean warm ischemia time of 162 minutes (range, 90–240 minutes). Venous reconstruction appeared important but not solely determinant: the failed case had two veins repaired, whereas survivors had a mean of 2.1 veins repaired (range, 2–3), suggesting that adequate arterial inflow and a favorable mechanism may compensate for limited venous outflow. Patient-specific factors, including age, smoking status, and level of amputation, did not clearly correlate with outcome; notably, the failed case was the only female in the series and had no comorbidities.

DISCUSSION

This retrospective analysis of eight proximal hand replantations demonstrates that high survival rates (87.5%) are achievable in carefully selected patients. The findings highlight several key predictors of success that are particularly relevant to proximal-level injuries.

Mechanism of Injury

The clear association between guillotine-type mechanisms and successful outcomes is consistent with the broader replantation literature [7, 8]. Sharp, clean amputations preserve vessel integrity, allow for straightforward debridement, and minimize the "zone of injury" that predisposes to thrombosis. In contrast, crush and avulsion injuries cause extensive intimal damage, vessel wall contusion, and microvascular thrombosis extending beyond the visible injury. In our series, the only failure occurred in a crush injury, reinforcing the principle that such mechanisms demand a lower threshold for caution.

Ischemia Time and Proximal Amputations

The relationship between ischemia time and survival is particularly critical in proximal hand replantation. Unlike digit replantation, where tissues can tolerate ischemia for 8–12 hours, the larger muscle mass of the proximal hand has a shorter ischemia tolerance. Muscle necrosis can begin as early as 4–6 hours of warm ischemia, leading to the "no-reflow" phenomenon and myoglobin-induced renal injury [9, 10]. Our failed case had a warm ischemia time of 6 hours—exceeding the recommended threshold for proximal replantation. The two survivors with crush mechanisms had warm ischemia times of 4 hours and 3.5 hours, respectively, suggesting that 4 hours may represent a critical cutoff. We recommend that for proximal hand amputations, efforts should be made to achieve revascularization within 4 hours of warm ischemia whenever possible.

Venous Reconstruction

Venous congestion remains a leading cause of replantation failure. In proximal replants, the volume of tissue requiring venous drainage is substantially greater than in digital replants, making adequate venous outflow paramount [11]. The failed case in our series had two veins repaired and these anastomoses likely provided insufficient drainage due to thrombosis. We advocate for the repair of at least two veins in proximal hand replantation. When native veins are unavailable due to injury, vein grafts should be used to establish additional outflow. Techniques such as the creation of an arteriovenous fistula or the use of leech therapy may serve as adjuncts but are not reliable substitutes for robust primary venous repair.

Bony Shortening

All patients in this series underwent bony shortening to facilitate tension-free vessel repair. While this does result in some loss of hand length, the functional trade-off is acceptable. Shortening reduces the distance between vessel ends, decreases tension on anastomoses, and allows for primary vessel repair without vein grafts in many cases [12]. We found that 0.5–2 cm of shortening was sufficient to achieve tension-free repair in all cases.

CONCLUSION

Proximal hand replantation is a demanding but rewarding procedure that can achieve excellent survival rates when appropriate patient selection and surgical principles are applied. Based on this series of eight patients, key predictors of survival include a guillotine-type mechanism, warm ischemia time less than 4 hours, and repair of at least two veins for adequate outflow. While crush/avulsion injuries and prolonged ischemia are associated with higher failure rates, successful replantation in selected patients offers functional outcomes superior to amputation and prosthetics. We recommend that proximal hand replantation be pursued aggressively in appropriate candidates, with meticulous attention to the predictors identified in this analysis.

Study Limitations

Several limitations must be acknowledged. The small sample size (n=8) precludes statistical analysis and limits the generalizability of findings. As a retrospective study, there is potential for selection bias: patients deemed poor candidates for replantation (e.g., prolonged ischemia, severe crush) may have been excluded from the outset. Finally, functional outcomes were assessed at a relatively short follow-up; longer-term studies are needed to evaluate durability and late complications.

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