Outcome of Early Motion Protocol for Total Hand Replantation: 1- and 2-Year Postoperative Results

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Abstract

Keywords

- hand
- wrist
- replant
- amputation
- hand therapy
- early motion protocol

Introduction We review the benefits of early motion protocols following replantation of a total right hand amputation at 1 and 2 years after replantation, and provide recommendations for postoperative management.

Materials and Methods Replantation of the entire right hand in zone-4 was performed and supported by rigid external fixation spanning the forearm and hand. An early active “place-and-hold” motion protocol was initiated within the first 3 postoperative days. Metacarpophalangeal joint extensors were tethered by the pins, limiting full excursion. This resulted in stiffness and extensor adhesions that required a staged extensor tenolysis; however, all joints remained supple. The early motion protocol prevented the need for significant flexor tenolysis and joint releases.

Results Early motion rehabilitation protocols can produce very successful results in complex replantation. The enhanced stability afforded by external fixation of the wrist allowed us to perform aggressive early rehabilitation.

Conclusion This case highlights the benefits of early active motion (limiting the need for complex joint and flexor tendon releases) and demonstrates the degree of extensor adhesions caused by even minor extensor tendon tethering. This aggressive rehabilitation approach can produce excellent range of motion, and likely limit the need for secondary tenolysis and joint release procedures.

Introduction

Limb amputation is a critical injury, with severe vocational and psychosocial ramifications if not properly reconstructed or salvaged. More than 50 years have passed following the first successful limb replantation and since then, many efforts have been made to better understand the dynamics of replantation surgery following complete amputation. The goal is to yield even more successful outcomes of replant function. The purpose of this study is to highlight a case of a 57-year-old man who sustained a traumatic complete right hand amputation, successfully replanted, who subsequently experienced the benefits of an early active motion rehabilitation protocol, and discuss the results seen at 1 and 2 years' follow-up in comparison to long-term data reported with traditional rehabilitation techniques.

Materials and Methods

A 57-year-old man presented with a complete traumatic amputation of his right hand as a result of a work-related injury. The amputation occurred through the proximal metacarpal bases, noted on physical examination as shown in ►Fig. 1A. During the initial surgery, provisional fixation was established with open reduction and fixation using an antegrade–retrograde placement of intramedullary K-wires (placed directly through the metacarpal bases antegrade, and then passed retrograde for fixation after the hand was reduced onto the wrist) for each of the five metacarpal fractures. A suture anchor was placed in the thumb metacarpal base during ligamentous reconstruction of the first carpometacarpal (CMC) joint. The reduction was further supported and reinforced by the use of a uniplanar external

fixator spanning the forearm, wrist, and replanted hand, placed at the end of the case. Microscope-assisted repairs were performed for the ulnar and radial arteries, three veins, and each of the ulnar, median, and radial sensory nerves. Eight flexor tendons in zone-4 and nine extensor tendons in zone-6 were repaired as shown in ►Fig. 1B. Prophylactic decompression fasciotomies were performed to prevent postreperfusion compartment syndrome and xenograft was applied to the fasciotomy wounds that we could not safely close primarily. At the conclusion, the pin-based fixation was reinforced with a rigid spanning external fixator, securing the hand to the forearm, with plans to develop enough stability at the wrist to tolerate our early active-assisted rehabilitation protocol for his fingers.

Early motion hand therapy was initiated on day 3 after the initial replantation surgery, using an active-assisted “place-and-hold” motion protocol.¹⁻³ The occupational hand therapists evaluated the patient in the intensive care unit, and worked with him closely. Short breaks were taken around the days of subsequent surgery, but he was otherwise immersed in his rehabilitation. Following discharge, he was seen twice weekly by the hand therapists and continued to work diligently performing the home-based components of his therapy.

One week later, Integra (Integra Lifesciences Corp., United States) was applied to the open wounds to allow tendon gliding during rehabilitation and develop a better wound bed in preparation for skin graft closures as shown in ►Fig. 2. At the same time, the fixation to the thumb and little finger metacarpal base fractures was augmented with an additional pin to each site after stress-view examination under dynamic fluoroscopy to allow us to continue with our aggressive rehabilitation protocol.

Two weeks later, split-thickness skin grafts were applied to the volar and dorsal fasciotomy wounds. The skin grafts were sutured down with a quilting technique and reinforced with Tisseel (Baxter International Inc., United States) to withstand our ongoing early motion rehabilitation protocol. This facilitated complete healing of the skin grafts without compromising the tendon-gliding protocol.

Eight weeks following the initial surgery, the patient underwent removal of the external fixator. The K-wires had been removed previously as the fractures healed. Under fluoroscopic monitoring, a very careful closed manipulation

was performed under anesthesia to augment his therapy and reduce some of the stiffness related to the fixation. We performed a careful limited manipulation of the wrist and metacarpophalangeal (MCP) joints, and full manipulation of the interphalangeal (IP) joints. Each joint was separately manipulated, followed by the entire hand in a composite fashion. He returned to therapy the next day.

Six months following the initial procedure, the patient presented with full passive range of motion, but with some MCP joint extensor lags, related to the early tethering of the extensor mechanisms by the K-wires. Extensor tenolysis was performed on extensor tendons of digits two through five at the MCP joints, resulting in ~50% correction of the extensor lags.

Six months after this (i.e., 1 year postoperatively), after completing a full rehabilitation course for this tenolysis procedure, he requested the extensor tenolysis to be repeated. The second tenolysis was performed in a wide-awake fashion under local anesthesia and was found to be much more successful. Following tenolysis, he was placed into full active and passive-assisted posttenolysis hand therapy motion protocols on postoperative day 1. Results of 2 years after replantation are shown in ►Fig. 3.

Results

The final result yielded nearly full active and passive range of motions. Individual independent finger motion results are

Fig. 2 Postoperative replantation.

Fig. 1 (A) Preoperative amputated hand and (B) intraoperative replantation.

Fig. 3 Two years postoperative results: (A) digital abduction; (B) digital extension; (C) digital flexion; and (D) wrist flexion.

shown in ► **Table 1**. Total active motion (TAM) was calculated as: flexion (CMC/MCP + MCP/proximal interphalangeal [PIP] + interphalangeal [IP]/distal interphalangeal [DIP]) extension (CMC/MCP + MCP/PIP + IP/DIP).

Discussion

Amputation of an extremity is a devastating injury that results in profound financial and psychosocial detriments. Given the amplitude and ramifications of such an injury, the attempt and success of replantation of the severed limb are paramount. Since the first known upper extremity replantation in 1962, technology and understanding of pre-, intra-, and postoperative management have grown exponentially.⁴ Such great operative investment is deemed worthwhile as replanted upper limbs are described as far superior to current day prostheses.⁵ Current literature displays many successful replantation operations with survival of the limb reported as high as 94%.^{4,6} The success of limb replantation is determined by the vessel anastomosis, where the overall quality of the bone, tendon, nerve, and skin repair determines the success of the functional outcome.⁷

In reference to measurement of outcome assessment of this patient population; however (aside from grip strength, two-point discrimination, and degree of range of motion), overall outcome success remains subjective in the eyes of the patient. Many factors play supporting roles in outcome satisfaction, varying from patient to patient. This includes the psychological state of mind postinjury, commitment and dedication to the rehabilitative process, and outlook on life postreplantation. All of these aforementioned factors can directly and indirectly affect the success of the operation.

Rehabilitative motion is a cornerstone during the postoperative period, with motion initiated as early as postoperative day 1.⁸ Barring early complications, standard management by the senior author of this case report (S.M.W.) is the establishment of strict early motion protocol for all replantation

patients within the first 3 postoperative days. With this rehabilitation goal in mind, our surgical constructs are developed with the capacity to facilitate and initiate this early motion protocol as the goal. In this patient, given the extra-articular metaphyseal metacarpal base level of the amputation, we utilized a simple anterograde–retrograde intramedullary pinning technique⁹ for provisional fixation, initially placing the pins anterograde directly through the metacarpal bases in the amputated part as shown in ► **Fig. 4**.

Following replantation, we reinforced the fixation with rigid external fixation spanning from the radius to the hand, to create a construct strong enough to tolerate early active tendon forces. During the next planned surgery, we also evaluated the fracture fixation stability under fluoroscopy to determine the response to the rehabilitation protocol, and found the little finger and thumb metacarpal fixations have some minor instability. We therefore added a second oblique pin to each fracture to further reinforce the fixation stability and empower our hand therapists to optimally employ their rehabilitation techniques.

In this case, we did not initially recognize the tethering of the extensor mechanisms by the K-wires as they emerged from the distal hand through the metacarpal heads. The consequence of this was dual-level dense robust adhesions from (1) the pin exit sites and soft tissues to the extensor mechanisms at the MCP joint levels, and also (2) scarring of the extensor tendon repairs to the fracture sites in zone-6, due to inadequate postoperative tendon excursion secondary to the tethering. The patient responded to subsequent treatment, but required two extensor tenolyses, which also included a side-to-side index-to-middle finger extensor tendon transfer. Since this case, when employing the anterograde–retrograde intramedullary fixation technique, we now use a miniopen incision distally around the MCP joints to visualize the pin sites as they relate to the extensor mechanisms and revise pin placement as necessary to avoid impingement or tethering of the extensor tendons.

Table 1 Functional outcomes at 1- and 2-year follow-up

Postoperative follow-up data				
	1 year	2 years		
Grip (kg)	19.9	36.3		
Lateral pinch (kg)	3.6	5.9		
Wrist flexion (deg)	58	60		
Wrist extension (deg)	47	58		
Ulnar deviation (deg)	28	35		
Radial deviation (deg)	12	20		
Supination (deg)	61	60		
Pronation (deg)	75	70		
Total active motion				
Thumb	CMC joint (deg)	MCP joint (deg)	IP joint (deg)	Total (deg)
1-year postoperative	40	57	73	170
2-year postoperative	45	39	67	151
	MCP joint (deg)	PIP joint (deg)	DIP joint (deg)	Total (deg)
Index finger				
1-year postoperative	48	95	25	168
2-year postoperative	70	85	41	196
Middle finger				
1-year postoperative	50	92	62	204
2-year postoperative	73	85	55	213
Ring finger				
1-year postoperative	59	84	45	188
2-year postoperative	67	80	60	207
Little finger				
1-year postoperative	71	80	45	196
2-year postoperative	78	73	65	216

Abbreviations: CMC, carpometacarpal; DIP, distal interphalangeal; IP, interphalangeal; MCP, metacarpophalangeal; PIP, proximal interphalangeal.

Fig. 4 (A) Five preplaced intramedullary pins; (B) fixation in place; and (C) X-ray of the replant construct.

Table 2 Total active motion comparison

	Total active motion (deg)			
	Our patient		Patel et al, 3.9 years	Cavadas et al, 7.7 years
	1 year	2 years		
Thumb	170	151	61	23
Index finger	168	196	105	174
Middle finger	204	213	100	168
Ring finger	188	207	106	164
Little finger	196	216	88	134
Total digit motion	926	983	460	663

Similar studies on replantation of flexor zone-4 level amputations without the use of early motion protocol have been reported previously. Patel et al examined a cohort of five patients with an average follow-up of 3.9 years implemented passive motion postoperatively within confines of postoperative bracing and at 2 weeks began active motion therapy.¹⁰ Another study by Cavadas et al reported on six patients with an average follow-up of 7.7 years, and they started passive motion therapy at 5 days postoperative and began active motion therapy at 3 weeks.¹¹ The side-by-side comparison of the TAM of the previous literature and our results is presented in ►Table 2. In this comparison, we found our postoperative results at just 1 and 2 years following this early motion rehabilitation protocol to be substantially more mobile and flexible than the long-term results seen with traditional postoperative rehabilitation protocols. This further demonstrates the large beneficial effect of implementing early motion protocol after hand replantation.

Whenever possible, we recommend implementing this early active motion “place-and-hold” protocol within the first few days after surgery. While the mechanism of injury and patient characteristics often factor heavily into postoperative rehabilitation pathways, the surgeon’s choice of operative techniques is often the key factor regarding whether a patient and the given repairs can tolerate these types of early active motion rehabilitation programs. As such, we encourage replant surgeons to consider specifically selecting reconstructive techniques strong enough to permit subsequent aggressive rehabilitation. The potential benefits of this strategy include minimizing additional significant operations, specifically complex tenolysis, and joint releases which carries many risks including possible tendon ruptures. In this case, we were able to avoid complex flexor tenolysis and joint releases, but did require extensor tenolysis due to technical issues (i.e., the pin-based extensor tendon impingement)—a complication we now specifically avoid.

Conclusion

In conclusion, major limb replantation (specifically zone-4 hand replantation) can greatly benefit from the use of an aggressive early active-assisted rehabilitation including tendon-gliding techniques such as “place-and-hold.” This can provide improved final range of motion, and decreased need

for complex and extensive revision surgeries such as tenolysis and joint release. A key component of this algorithm is the operative commitment to strong tendon repair and fracture fixation techniques capable of tolerating such early active-assisted rehabilitation protocols, and to confirm that the hardware does not encroach upon the tendons. Equally, the patient must embrace understanding, resilience, and dedication to the hand therapy protocol. We have detailed and described our replantation case in which we implemented an early motion protocol and reported functional outcomes measured at the 1- and 2-year follow-up periods, resulting in excellent functional outcome.

Conflict of Interest

None declared.

References

- Chesney A, Chauhan A, Kattan A, Farrokhyar F, Thoma A. Systematic review of flexor tendon rehabilitation protocols in zone II of the hand. *Plast Reconstr Surg* 2011;127(4):1583–1592
- Farzad M, Layeghi F, Asgari A, Ring DC, Karimlou M, Hosseini SA. A prospective randomized controlled trial of controlled passive mobilization vs. place and active hold exercises after zone 2 flexor tendon repair. *Hand Surg* 2014;19(1):53–59
- Kannas S, Jeardeau TA, Bishop AT. Rehabilitation following zone II flexor tendon repairs. *Tech Hand Up Extrem Surg* 2015;19(1):2–10
- Ng WK, Kaur MN, Thoma A. Long-term outcomes of major upper extremity replantations. *Plast Surg (Oakv)* 2014;22(1):9–13
- Salminger S, Sturma A, Roche AD, et al. Functional and psychosocial outcomes of hand transplantation compared with prosthetic fitting in below-elbow amputees: a multicenter cohort study. *PLoS One* 2016;11(9):e0162507
- Gulgonen A, Ozer K. Long-term results of major upper extremity replantations. *J Hand Surg Eur Vol* 2012;37(3):225–232
- Maricevich M, Carlsen B, Mardini S, Moran S. Upper extremity and digital replantation. *Hand (N Y)* 2011;6(4):356–363
- Bueno E, Benjamin MJ, Sisk G, et al. Rehabilitation following hand transplantation. *Hand (N Y)* 2014;9(1):9–15
- Kim JK, Kim DJ. Antegrade intramedullary pinning versus retrograde intramedullary pinning for displaced fifth metacarpal neck fractures. *Clin Orthop Relat Res* 2015;473(5):1747–1754
- Patel AA, Blount AL, Owens PW, Askari M. Functional outcomes of replantation following radiocarpal amputation. *J Hand Surg Am* 2015;40(2):266–270
- Cavadas PC, Thione A, Rubí C. Hand amputations at the radiocarpal level with proximal neuromuscular avulsion. *J Hand Surg Am* 2016;41(1):70–75