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Neo-Forearm Functional Reconstruction after Temporary Ectopic Hand Implantation for Salvage of Hand after Extensive Crush Injury to Forearm

Raja Tiwari, MS, MCh[1] Suvashis Dash, MS, MCh[1] Shashank Chauhan, MS, MCh[1] Shivangi Saha, MS, MCh[1] Misha Ahir, BPT, MPT[1] Maneesh Singhal, MS, MCh[1]

[1] Department of Plastic, Reconstructive and Burns Surgery, All India Institute of Medical Sciences, New Delhi, India

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Address for correspondence Raja Tiwari, MS, MCh, Department of Plastic Surgery, All India Institute of Medical Sciences, R.no 219, Burn & Plastic Surgery Block, Ansari Nagar, New Delhi, Delhi 110029, India (e-mail: tiwariraja1981@gmail.com).

Abstract

Background Extensive crush injuries to forearm pose a unique problem where replantation of uninjured hands to the forearm is not immediately possible due to difficulties in delineating tissue necrosis. Ectopic hand implantation preserves the hand and allows replanting the hand back to the forearm stump, but the tissues preserved in the stump could be inadequate to provide good hand function. In these subsets of cases, forearm reconstruction with composite flaps may offer a better chance of getting good hand function.

Methods We present a case of a 29-year-old male, a left-handed factory worker, with severe crushing of the left forearm by a hydraulic pressing machine with a relatively undamaged hand. A three-staged reconstruction was done with the recovery of the left hand after below elbow amputation and replanted to the left lower third of leg. Then a neo-forearm was reconstructed using a functioning free fibula, vastus lateralis muscle, and anterolateral thigh skin flap. Finally, the ectopically banked hand was returned to the reconstructed neo forearm.

Results After 2 years follow-up, protective sensation and grip strength of 2 pounds had developed in the hand. The disabilities of arm, shoulder, and hand score was 21, and he was able to perform multiple tasks using the left hand independently and as an assistive hand.

Conclusion The consensus on indications of ectopic banking is still open for debate. The addition of our ectopic replantation technique followed by neo-forearm reconstruction and replantation of the hand into the reconstructed neo-forearm, which is a novel concept, will broaden the horizon of reconstructive paradigm.

Keywords
- hand
- replantation
- free tissue transfer

Microvascular reconstruction in the form of replantation has been life-changing. With refinements and the addition of newer techniques, the indications of replantation have been broadened. One such technique is ectopic tissue banking of amputated parts.[1] The indications are segmental injuries with extensively damaged or badly contaminated proximal parts, while the distal part is comparatively undamaged. Crush injury with loss of extensive soft tissues precludes replantation of the

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organ in a single stage in various clinical scenarios in which case an ectopic replantation becomes a useful option. Other indications are gunshot wounds, and high-voltage electricity burns, where the extent and edge of tissue necrosis are difficult to determine and progress gradually.[2] Ectopic replantation of fingers, hands, forearms, feet, penis, and scalps has been reported in the literature.[3–8] However, ectopic replantation of the hand, followed by reconstruction of neo-forearm and replantation of the hand onto the reconstructed neo-forearm, is a novel concept, which brings in pristine tissue to take over the function of damaged tissues, thereby offering better functional recovery. This concept of neo-forearm creation will broaden the horizon of the reconstructive paradigm.

Case Report

A 29-year-old male, a left-hand dominant factory worker, presented to emergency with a crush injury of the left forearm by a hydraulic pressing machine. The patient had severe crushing of the left forearm, approximately 5 cm distal to the elbow joint, all the way to the wrist crease involving the skin, soft tissue, neurovascular structures, and bones, but his hand was relatively undamaged (►**Fig. 1**).

After clinical examination, different options for the patients were discussed and explained to the relatives. The first option to preserve his hand was to perform a two-staged ectopic hand replantation to the leg followed by a hand-to-elbow replant later once the stump became healthy. Alternatively, if preserving the hand was not a priority, then an immediate below-elbow amputation could be completed, and later a unilateral hand transplant or rehabilitation with a myoelectric prosthesis could be offered in the future. After much deliberation and discussion about the risks involved, it was decided to perform a novel approach of a three-staged procedure with an initial ectopic hand replantation, followed by reconstruction of a neo-forearm and then the transfer of hand to neo-forearm.

In this plan, the first stage included ectopic replantation of the left hand on the left ankle, and the second stage was the reconstruction of the neo-forearm unit using free anterolateral thigh (ALT) with vastus lateralis muscle and free fibula with soleus and flexor hallucis longus (FHL) functioning muscle flaps, and lastly, in the third stage, transfer of the ectopically replanted hand onto the neo-forearm was to be performed. The timeline for different stages is demonstrated in ►**Fig. 2.**

Stage 1 (Day 0)

Preoperative Planning—For First Stage: Ectopic Hand Replantation

A computed tomography angiogram of bilateral lower limbs was done to rule out any vascular anomalies. The angiogram

Fig. 1 Demonstration of extensive injury to all structures of the forearm including crushed forearm bones (**A**) with muscles and skin (**B** and **C**). The hand was relatively undamaged (**D** and **E**). The proximal forearm stump was severely shortened with only a 5cm length beyond the elbow crease (**F**). Immediate ectopic reimplantation of the hand was performed to the right leg (**G**) using an external fixator (**H**).

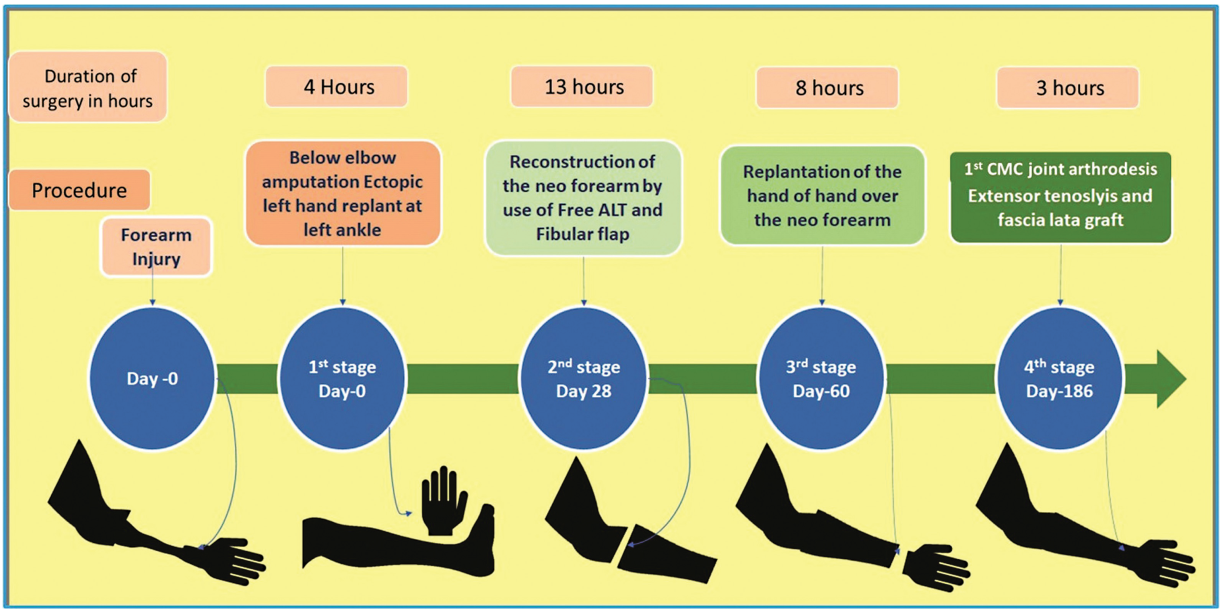

Fig. 2 Timeline of different stages of reconstruction of neo-forearm.

showed triple vessel patency without any evidence of vascular anomalies. The left leg was chosen to do an ectopic replant of the hand because this positions the skin paddle from the proximal leg toward the radial side of the hand (►**Fig. 1**). This in turn is optimum for later anastomosis and nerve coaptation over the reconstructed forearm and avoids any pressure over the repairs. Fibula from either leg could be taken and used after rotation, but since the hand was implanted on the left leg, the right side was available for fibular harvest in the subsequent stage.

Operative Steps of Stage 1

After below elbow amputation was performed, the stump was closed with the available skin flaps. The left hand was recovered from the crushed forearm and ectopic replantation was performed on the left lower third of the leg. An external fixator was used to stabilize the hand onto the shin of the tibia. The radial artery was anastomosed to the posterior tibial artery (PTA) in an end-to-side fashion. The two venue comitans of the radial artery were anastomosed with the two venae comitans of PTA, and one dorsal vein was attached to the great saphenous vein. The saphenous nerve was coapted to the median nerve of the hand. The total duration of the surgery was around 4 hours.

Stage 2 (Day 28): Neo-Forearm Creation

Preoperative Planning—for Second Stage

This stage was complex in terms of planning and execution. The contralateral forearm girth was measured and found to be 26 cm in the proximal forearm and 22 cm in the mid-forearm region. We planned to take the maximum possible skin flaps along with the free osteomyo-cutaneous fibula flap (FFF) without causing gross deformity of the donor site, and the rest of the skin requirement was planned to be recruited from the ALT flap.

Regarding the transfer of a functioning motor unit for hand function, based on Doi's protocol, to enable a prehensile function to hand, one muscle unit was planned to be used for finger flexion and another one for finger extension function.[9] In addition, we used a third muscle unit to provide independent thumb flexion. The soleus and the FHL were planned to be harvested with FFF for finger and thumb flexion restoration. Vastus lateralis was planned to be taken with the ALT flap and was to be used for the extension function restoration. The availability of donor nerves and blood vessels was checked and is shown in ►**Fig. 3**.

Stump Preparation

After the below elbow amputation, we waited approximately 1 month for the healing of the stump to allow the inflammation to subside. Negative pressure wound dressing was also used to hasten the process. On the day of the second stage, the stump was dissected meticulously to explore neurovascular structures. Two arteries (ulnar and radial), four veins, and three nerves (anterior interosseous branch of median N, posterior interosseous branch of radial nerve, and ulnar nerve) were identified.

Double Flap Harvest

Free fibula flap harvest was done by the standard anterior approach, a skin paddle of 12×10 cm was marked and peroneal perforators were identified. After the fibular osteotomy was completed, the peroneal artery pedicle was found posterior to the tibialis posterior muscle. The motor nerve to the FHL usually enters the middle part of the muscle as per literature[9] however, in our case the nerve was found much lower down, and this provided extra length for nerve coaptation. The motor nerve was traced proximally and cut from its origin to tibial nerve. The FHL muscle was dissected distally and included in the flap. Next, the soleus muscle was dissected, and 2 cm distal to the origin of the peroneal

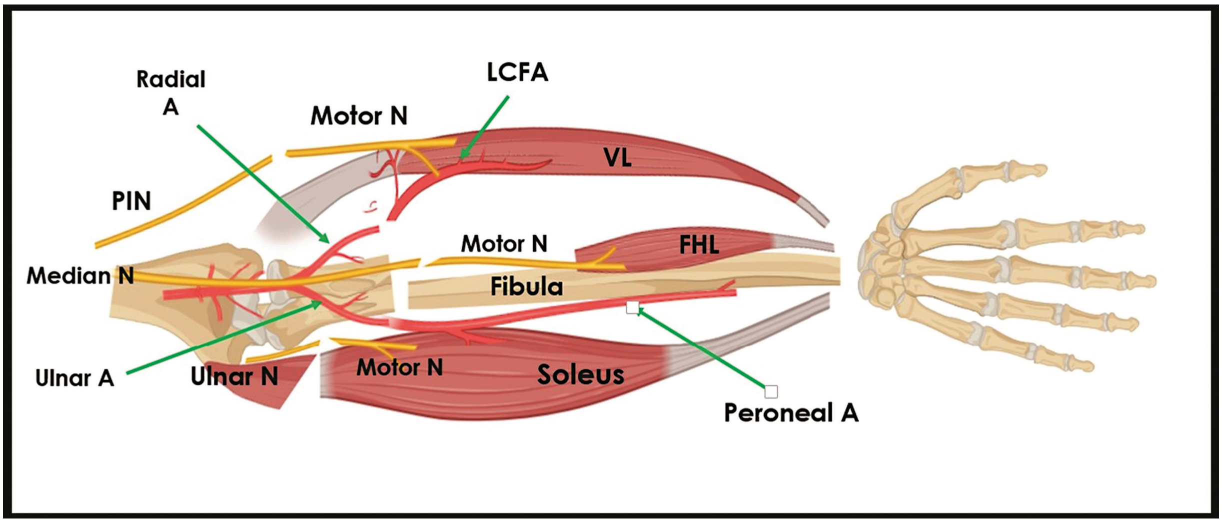

Fig. 3 Demonstration of the operative plan for total functional forearm reconstruction. FHL, flexor hallucis longus; LCFA, lateral circumflex femoral artery.

artery there was a sizable perforator entering the right hemi soleus, and the muscle was raised based on this perforator. The posterior incision was committed, and one-third of the Achilles tendon and right hemi-soleus were included in the flap. The motor branch to the soleus was also isolated from the tibial nerve and included in the flap (►**Fig. 4A**).

ALT flap harvest was started while the first team was fixing the fibula flap to the elbow. A skin paddle of 30 × 18 cm, vastus lateralis muscle of 20 × 5 cm, and a 7 cm long motor nerve to vastus lateralis were included with the flap (►**Fig. 4B**).

Bone Fixation, Anastomosis, and Flap Inset

The fibula was fixed to the ulna by use of an eight-hole limited-contact dynamic compression (LCDC) plate and screw (►**Fig. 5A**). After the fixation, vascular anastomosis was performed, with the peroneal artery to the ulnar artery and one vena comitans to the median cubital vein, and the second one to a vena comitans of the ulnar artery. The motor nerve of the soleus was coapted to the ulnar nerve. FHL motor nerve coapted to the anterior interosseous nerve. Descending branch of lateral circumflex femoral artery was anastomosed to the radial artery, its vena comitans to the vena comitans of the radial artery. Posterior interosseous nerve coapted to the motor branch of vastus lateralis. The soleus muscle was proximally weaved to residual flexor muscle and vastus lateralis muscle was sutured to residual extensor muscles. The hemi-soleus, FHL, and vastus lateralis tendons were sutured to each other across the fibula bone to maintain muscle fiber length. The skin of the two flaps was closed over the suction drain to complete the creation of the neo-forearm (►**Fig. 5B–D**).

Stage 3 (Day 60): Hand to Neo-Forearm Transfer

Initial Dissection

Two-team approach was done, and one team started the dissection of the neo-forearm. Space was created between the two flaps anteriorly, and delineation of the previously plicated tendons, brachial artery, vena comitans, and median nerve was done. A distal 3 cm of the fibula was exposed, and its end was freshened to aid in bony fixation. The second team harvested the replanted hand, along with the PTA its vena comitans, vascularized saphenous nerve, great saphenous vein, and a thin strip of skin paddle (10 × 4 cm) based on a perforator from the PTA (►**Fig. 6A,B**).

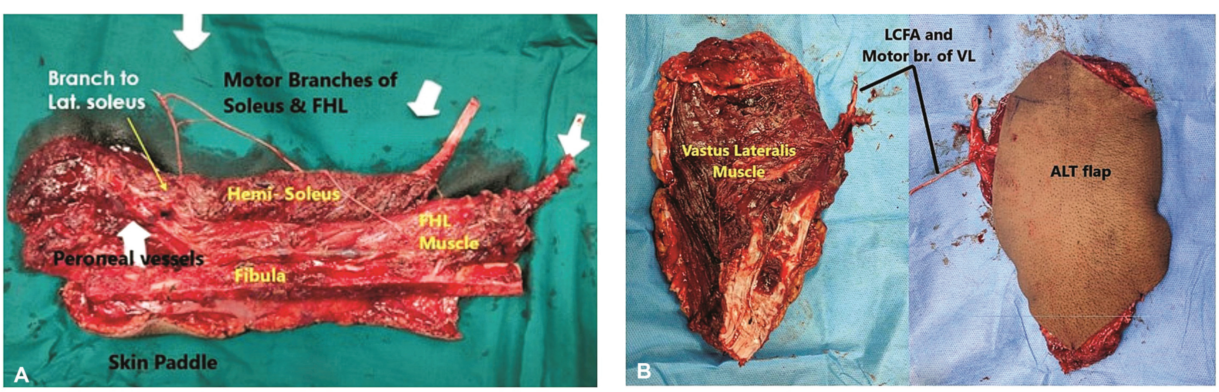

Fig. 4 (A) Demonstration of the harvested fibular flap with its vascular pedicle, soleus and flexor hallucis longus (FHL) muscle units, and their motor nerves. (B) Harvest of anterolateral thigh (ALT) flap with vastus lateralis muscle and its motor branch and skin flap dimensions.

Fig. 5 Formation of neo-forearm. (**A**) Bony plating of the fibular free flap to ulna using LCDCP and screw. (**B**) Repair of flexor hallucis longus and soleus muscles to the medial epicondyle. (**C**) The skin islands of both flaps were approximated after anastomosis to assess tension. (**D**) Completion of skin inset and formation of neo-forearm.

Bone Fixation, Anastomosis, Tendon Tensioning, and Flap Inset

The lunate of the hand was freshened and fixed to the fibula. An eight-hole LCDC plate was crewed between the fibula and the third metacarpal. The PTA from the hand was anastomosed to the brachial artery in end to the side manner, vena comitans to venae comitans of the brachial artery, and the great saphenous vein (GSV) to the cephalic vein. For extensor tendon tensioning, the wrist was kept in a neutral position, and all fingers in a flexed position, the vastus lateralis muscles was pulvertafted to extensor digitorum communis, under maximal tension. For flexor tendons, the wrist was in neutral position, metacarpophalangeal (MP) joints in 70-degree flexion, interphalangeal joint in full extension, the hemisoleus muscle was pulvertafted to flexor digitorum profundus under maximal tension. Lastly with the thumb maximally abducted, the interphalangeal joint is in full extension and FHL in maximal tension. Nerve coaptation was done between the proximal end of the vascularized saphenous nerve (attached distally to the median nerve) and the anterior fascicles of the median nerve in the cubital fossa. The posterior tibial perforator-based skin flap was placed between the ALT and FFF flap and closed (►**Fig. 6C**).

Stage 4 (Day 128)

The postoperative passive range of motion was limited due to the formation of adhesions between extensor digitorum communis (EDC) repaired with the vastus lateralis muscle over the LCDC plate that is used for wrist fusion. Hence, extensor tendon tenolysis was done and a fascia lata graft was placed between the extensor tendon and vastus lateralis muscle to ease excursion (►**Fig. 7A–C**). Our rehabilitation protocol is described in ►**Table 1** and it aimed to allow an early passive range of motion exercises of all joints until the development of muscle innervation and to switch to active and passive range of motion exercises thereafter.

Postoperative Complication

During the reconstruction, a few complications were encountered. After the below elbow amputation, there were stump infections due to crushed components, which were managed conservatively to preserve the length of the residual forearm, with serial debridement and negative pressure wound dressing. We also encountered extensor adhesions that were managed with tendon grafting. The bone healing was good and the donor sites healed without any complications (►**Fig. 8**). No other complications occurred during all phases of reconstruction.

Outcome

After 2 years of follow-up, there was a development of protective sensation in the hand but there was no two-point discrimination. Thumb flexion started at 16 weeks. Finger flexion at 20 weeks. Finger extension started around 18 weeks and improved following adhesiolysis. The total active range of motion of the fingers was 100 degrees and for the thumb, it was 50 degrees. The grip strength was 2 pounds and the disabilities of arm, shoulder, and hand (DASH) score was 21; the patient could perform multiple tasks using the left hand independently and as an assistive hand. He has key pinch, grasp, hook grip present, and good elbow strength. He can hold large objects with his left hand. The overall aesthetics of the extremity was preserved (►**Fig. 9**). He could play badminton, water plants, and even stabilize a pen between his fingers and thumb and can write using the proximal muscles (►**Supplementary Videos 1–3** [online only]).

Supplementary Video 1

Writing. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0043-1778080.

Supplementary Video 2

Water drinking. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0043-1778080.

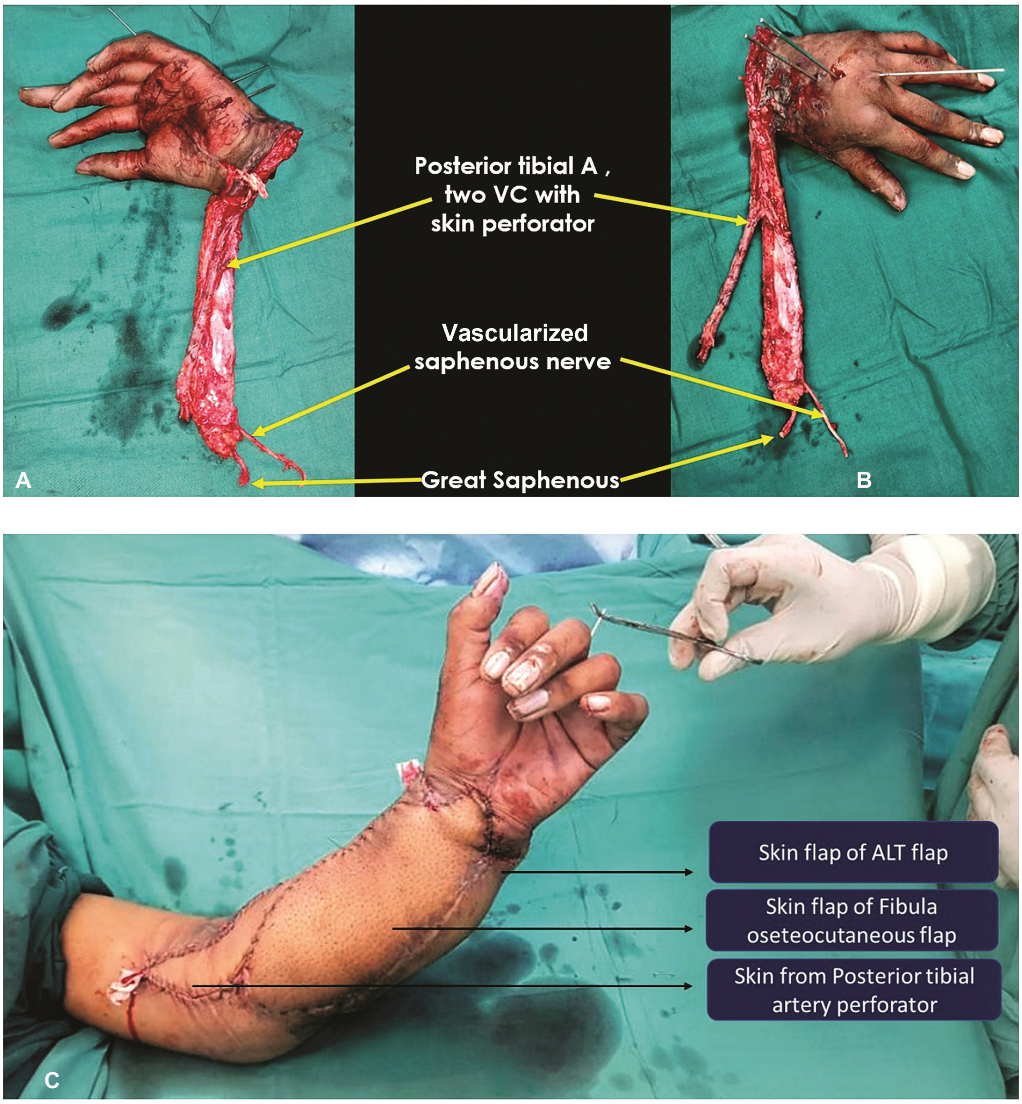

Fig. 6 (**A**,**B**) Appearance of hand after harvest from left ankle along with harvested skin flap from the leg, vascularized saphenous nerve, and posterior tibial artery, and great saphenous vein. After completion of hand transfer and attachment to the neo-forearm, the hand appeared well vascularized (**C**). ALT, anterolateral thigh.

Supplementary Video 3

Hand elevation 20m Trim. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0043-1778080.

Discussion

There are several sites of ectopic replantation, that have been described in the literature. The choice of recipient site for ectopic replantation is based on factors like superficial location, ease, and rapid dissection, constant and reliable anatomy, ability to provide immobilization, and potential to provide skin, nerve, and blood vessel length. As per reports, the recipient artery used in the lower abdomen area was the deep inferior epigastric artery; in the ankle was the PTA; in the thigh area was the femoral artery or its branches; in the dorsal foot was the dorsal pedis artery; in groin area it was the superficial circumflex iliac artery or superficial inferior epigastric artery; in the thoracic wall, it was the thoracodorsal artery. Godina preferred Thoracodorsal vessels for ectopic banking of the amputated part and cautioned against using the groin region due to its mobility[2–8] and potential for injury due to hip flexion. Majority of literature now suggests the use of the contralateral distal upper limb as a suitable site for ectopic replantation.[3,10] However, this also exposes an uninjured limb to surgical risks including infection, stiffness, and scarring.[11] In our case, one upper extremity was severely damaged and risking the other for salvage was not advisable. We chose the ankle as the site for replantation because the PTA is superficial at that location, stable temporary fixation of the ectopic hand with the tibia using an external fixator is possible and a skin flap, donor nerves, and tendons can be easily harvested for future reconstruction. Patient can be easily taught to ambulate, while maintaining gap between

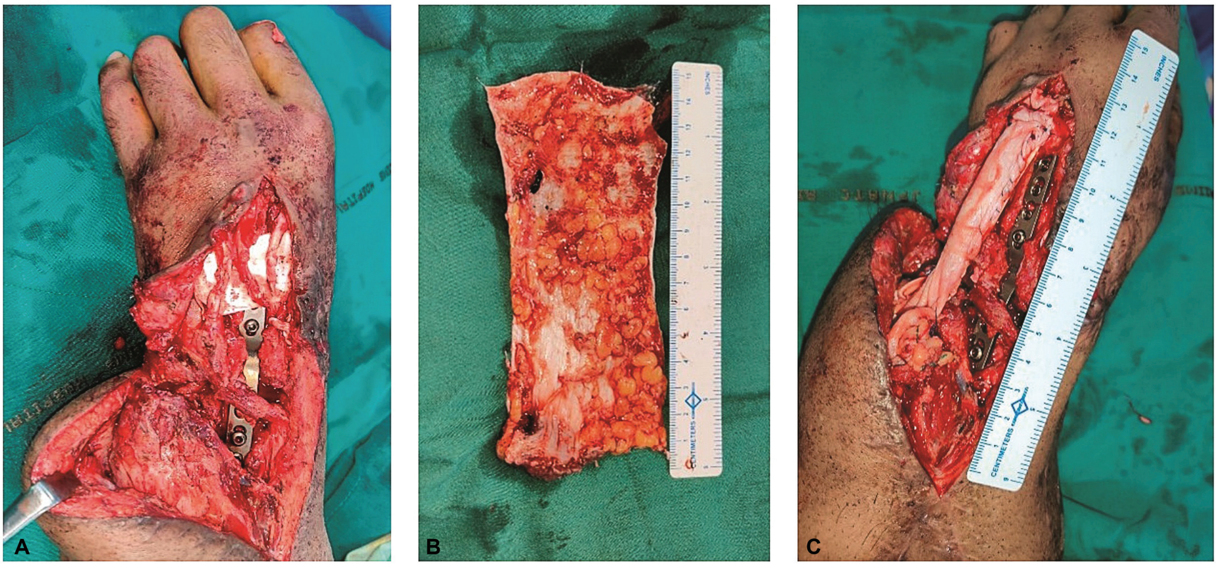

Fig. 7 Extensor tendons were found to have adhered to the metallic plate on the dorsal surface (**A**). A fascia lata graft was harvested from the right thigh (**B**) and grafting was done between the vastus lateralis muscle proximally and extensor digitorum communis and extensor pollicis longus tendons distally (**C**).

the two lower limbs. This prevents any chance of injury to the ectopically banked hand. An additional advantage is that in this position the MP joints automatically fall in a position of flexion due to gravity, preventing collateral ligament shortening and therefore functional splint may not be required.

The time interval between the initial ectopic replantation and transfer to the anatomical site has many variations based on different clinical situations. The shortest interval described is 8 days for a forearm replantation to 6 months for a hand replantation[4,12,13] As per literature, ectopic hand replantations were usually implanted between 1 and 6 months intervals. Cavadas in his article suggested that there is an increased chance of scaring around the vessel when temporary replantation is done for longer periods, and it leads to difficult dissection.[5] In our case, we did not contemplate any dissection in the previously implanted vessels; therefore, it was safe to wait for 2 months for transfer. Most of the ectopic replantation was performed in two stages; in our case one additional stage was required as the neo-forearm reconstruction was done.[13–15]

Fixation of the replantation by external fixators, cross Kirschner wires (K-wires), and compression plates has been described. For major replantation, compression plates are a better choice for their durability as well as load-bearing capacity,[13–15] while K-wires are easy to apply and procedures can be done very quickly, these have less stability compared with plates. Similarly, external fixation is useful for sturdy fixation, and for infective cases where regular debridement is required; however, this procedure is time-consuming and not suitable for small parts. We chose to use an external fixator for ectopic implantation to provide stable fixation of the hand to the shin of the tibia. This prevented

Table 1 Rehabilitation protocol after each stage and duration after injury

Day	Operative stage	Rehabilitation protocol
Day 1	Stage 1 Ectopic replantation of hand	Passive ROM exercises for MP, IP of hand Active and PROM for elbow and shoulder joints
Day 28	Stage 2 After reconstruction of neo-forearm	PROM of ectopic hand continued AROM shoulder started from day 6 PROM elbow (tolerable range) AROM for elbow started from day 13
Day 60	Stage 3 Transfer of hand to neo-forearm	PROM all fingers started from day 2 PROM for shoulder and elbow from day 7 AAROM for shoulder and elbow—day 14 Electrical stimulation: Intermittent galvanic current stimulation for 2 weeks. Could not be continued due to COVID-19 lockdown
Day 186	Stage 4 After extensor tendon adhesiolysis and grafting	Guarded PROM exercises for fingers continued for 6 weeks followed by AROM exercises and vocational training

Abbreviations: AAROM, active assistive ROM; IP, interphalangeal; MP, metacarpophalangeal; PROM, passive range of motion; ROM, range of motion.

Fig. 8 Good healing of skin and all muscles was observed (**A**) along with good bony union (**B**). The donor sites healed without any complications (**C** and **D**).

any damage to the neurovascular structures due to motion. We used LCDC plate fixation for the reconstruction of the forearm and implantation of the hand. It may also be noted here that both plates should be fixed in different planes on the fibula; otherwise the portion of the bone between the two plates becomes vulnerable to stress fractures.

All ectopic replantations are done in two stages; in our case the replantation was done in three stages as the forearm was created in the intermediate stage. With the increase in the number of stages, the transfer of replanted part to its original location gets delayed, which may lead to fibrosis surrounding the vessel and difficult to dissect. Higgins describes two cases where three-stage reconstruction was done; in the intermediate stage free tissue was used to cover the amputation stump.[10]

In the case of ectopic replantation, we have used a two-team approach, to decrease the surgical time, fatigability, and better outcome. In the second stage, one team harvested the free ALT and free fibula, while the other team prepared the arm vessels for forearm reconstruction. Replanting the hand onto the neo-forearm in the second stage could have increased the operative time, blood loss, and chances of complications; therefore, we decided to transfer the hand in the third stage. In the final stage too, the ectopic hand was dissected by one team, while the neo-forearm dissection and vessel preparation were done by another team to cut down the total operative time.

The required bone length for this reconstruction was calculated based on the measurement of the contralateral limb length minus the residual radius bone of the amputation stump. After the second stage, the distal stump fibula was exposed and we had to remove 2 cm of the bone stump to achieve wound closure.

Our case was not a straightforward replantation, but rather a complex reconstruction problem where a neo-forearm was created to mimic the function of forearm muscles. We have used Doi's principle of muscle unit transfer to mitigate this problem.[9] Three muscle units were transferred to provide motor units for flexion and extension functions. The volar reconstructed muscle was motorized with different nerves (ulnar nerve to Soleus & AIN to FHL) to provide an independent function to fingers and thumb. The extensor reconstruction was done using the radial nerve to provide en masse extension.

The functional result of the hand was good with sensory and motor recovery. The DASH score is 21. The patient was able to perform many day-to-day tasks including writing, gardening, opening the door, drinking water from a bottle, and even holding a racquet to play badminton. Few studies mention detailed functional results obtained after ectopic implantation. Liaghat and Shabbooie in the article reported a case where the replanted hand has guarded functional outcome limited motor recovery and protective sensations.[4] Cavadas and Wang reported cases of ectopic banking with replantation with the recovery of sensibility in the fingers with good grip strength and MP joint active extension.[5,13] Zhang et al reported results 18 months after surgery and his patients had two-point discrimination on the pulps of the first through fifth digits of 4, 6, 7, 5, and 8 mm, respectively.[14] The patient reported no pain in the hand or forearm and the disability score for the arm, shoulder, and hand was 78. In our case, the sensory recovery was reasonable and the motor recovery was significantly better. We believe the good motor recovery in our case was obtained because, instead of using the fibrotic and shortened muscles left in the forearm, we relied on bringing functioning muscle units from uninjured regions of the lower extremity.

However, hand-to-elbow replantation can be done in a single stage with shortening of the upper limb and using the elbow flexors and extensors to provide flexion and extension of the hand, albeit the elbow function would be lost.[15] Also, the limb appears short and the aesthetic appearance is poor. So, to

Fig. 9 Postoperative functional recovery showing satisfactory grip strength (**A**) and active range of motion (**B**). The patient is able to perform daily tasks such as opening a door (**C**) and holding large objects (**D**). The overall aesthesis of the reconstructed forearm was acceptable (**E**).

preserve the functions of the elbow, and maintain limb length, a neo-forearm reconstruction should be appropriate. As per a systematic review, the survival rate after ectopically banked parts and following immediate replantation of the amputated parts is 81.6 and 100%, respectively.[11] In our case, there was complete survival of all the parts with good function. The success of replantation is due to proper planning, good surgical technique, and institutional rehabilitation.

Limitations

This is a complex reconstructive process, which is time taking and needs multiple surgeries. The patient must be preoperatively counseled regarding the outcome. Meticulous planning for each step is required. We did not consider ulnar nerve grafting owing to the long time that reinnervation may take. In future operations, we may include this as well. The bulk of the flap will be a problem that requires flap thinning. Not only doing replantation matter but making the replanted organ functional in long term is essential. Any complication after the first or second stage will drastically change the future reconstructive goals.

Conclusion

Ectopic implantation is a useful temporary method for the salvage of amputated organs in cases of severe crush or avulsion injuries where urgent replantation cannot proceed. There are various refinements in the techniques of ectopic tissue banking. However, the consensus on the indications of this is still open for debate. With the addition of our technique of neo-forearm creation, the spectrum of reconstruction after hand amputation will be broadened and we believe this is a reproducible technique for other similar cases.

Note
This paper was presented at APSICON 2021(Won PEET prize) and WSRM 2022 (Won Best Case)

Authors' Contributions

Raja Tiwari conceptualized and visualized the study. Suvashis Dash and Raja Tiwari were involved in data curation and methodology. Suvashis Dash, Raja Tiwari, Shashank Chauhan, and Shivangi Saha helped in formal analysis. Maneesh Singhal and Raja Tiwari were involved in project administration. Raja Tiwari, Misha Ahir, and Suvashis Dash wrote the original draft. Shashank Chauhan, Maneesh Singhal, and Shivangi Saha reviewed and edited the manuscript.

Ethical Approval

The authors declare that the procedures were followed according to the regulations established by the Clinical Research and Ethics Committee and to the Helsinki Declaration of the World Medical Association.

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None.

Conflict of Interest

None declared.

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References

1 Trapero A, Thione A, Alonso Carpio M, Pérez-García A. Heterotopic versus ectopic replantation: what's the difference? Plast Reconstr Surg 2021;147(01):180e–181e

2 Godina M, Bajec J, Baraga A. Salvage of the mutilated upper extremity with temporary ectopic implantation of the undamaged part. Plast Reconstr Surg 1986;78(03):295–299

3 Bakhach J, Katrana F, Panconi B, Baudet J, Guimberteau JC. Temporary ectopic digital implantation: a clinical series of eight digits. J Hand Surg Eur Vol 2008;33(06):717–722

4 Liaghat O, Shabbooie Z. Ectopic banking and implantation of an amputated hand. Indian J Orthop 2020;54(05):731–737

5 Cavadas PC, Landin L, Navarro-Monzones A, Soler-Nomdedeu S. Salvage of impending replant failure by temporary ectopic replantation: a case report. J Hand Surg Am 2006;31(03):463–467

6 Wang JN, Wang SY, Wang ZJ, Liu D, Zhao GQ, Zhang F. Temporary ectopic implantation for salvage of amputated lower extremities: case reports. Microsurgery 2005;25(05):385–389

7 Matloub HS, Yousif NJ, Sanger JR. Temporary ectopic implantation of an amputated penis. Plast Reconstr Surg 1994;93(02):408–412

8 Sanger JR, Logiudice JA, Rowe D, Cortes W, Matloub HS. Ectopic scalp replantation: a case report. J Plast Reconstr Aesthet Surg 2010;63(01):e23–e27

9 Sassu P, Acland RD, Salgado CJ, Mardini S, Ozyurekoglu T. Anatomy and vascularization of the flexor hallucis longus muscle and its implication in free fibula flap transfer: an anatomical study. Ann Plast Surg 2010;64(02):233–237

10 Higgins JP. Ectopic banking of amputated parts: a clinical review. J Hand Surg Am 2011;36(11):1868–1876

11 Cho BH, Higgins JP. Revascularization and replantation in the hand: ectopic banking and replantation. Hand Clin 2019;35(02):199–206

12 Doi K, Muramatsu K, Hattori Y, et al. Restoration of prehension with the double free muscle technique following complete avulsion of the brachial plexus. Indications and long-term results. J Bone Joint Surg Am 2000;82(05):652–666

13 Wang JN, Tong ZH, Zhang TH, et al. Salvage of amputated upper extremities with temporary ectopic implantation followed by replantation at a second stage. J Reconstr Microsurg 2006;22(01):15–20

14 Tu Y, Lineaweaver WC, Culnan DM, Bitz GH, Jones KJ, Zhang F. Temporary ectopic implantation for salvaging amputated parts: a systematic review. J Trauma Acute Care Surg 2018;84(06):985–993

15 Naalla R, Singhal M, Dawar R, Maurya M. Salvage forearm to arm replantation. BMJ Case Rep 2020;13(09):e236637