Salvage of Extensively Scarred Hands: Wide Awake Tenolysis and Interpositional Free Tissue Transfer

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**INTRODUCTION**

Tenolysis combined with simultaneous nerve grafting is a formidable encounter in secondary reconstructive procedures in management of hand injuries. Extensive tendon adhesions and failure of primary nerve reconstruction are usually pertinent to poor vascularity of the soft tissue coverage and wound complications.

Few authors advocate tenolysis with or without tendon grafts, combined with nerve grafting at the same procedure. A staged reconstructive approach carries the risk of inadvertent nerve injury and inevitable scarring.

In such instances, tendon reconstruction or adhesiolysis and nerve grafting rarely result in satisfactory outcomes. These poor results could be attributed to severely scarred bed, interruption of the nerve take due to early tendon rehabilitation, or failed tenolysis due to reluctant active exercise.

Interposition of vascularized fascial flaps has been described as a salvage procedure to address radiation injuries, peripheral vascular diseases, and extensive tissue fibrosis. According to previous studies, the well vascularized fascial flaps improved tendon gliding and excursion after a dedicated tenolysis.

In this study, we extended the use of the wide awake local anesthesia no tourniquet (WALANT) technique for awake tenolysis of extensive forearm adhesions, and performed a free adipofascial interposition flap to wrap the tendons after tenolysis, separating them from the reconstructed nerves in a single reconstructive procedure.

**Background:** This study introduced a dedicated technical approach to extensive hand adhesions, combined with failed primary nerve reconstruction. Wide awake tenolysis and interpositional free tissue transfer forge the main facets of the proposed reconstructive strategy.

**Methods:** A prospective study was conducted, including 22 patients diagnosed with extensive tendon adhesions in addition to failed primary nerve repair. After wide awake tenolysis, 20 adipofascial radial forearm flaps and two ALT flaps were used to wrap the tendons, whereas the nerves were grafted after complete separation from the tendons. Nerve recovery; final total range of motion of the fingers; and the disabilities of the arm, shoulder, and hand score were recorded in detail.

**Results:** All flaps healed uneventfully. Final assessment of the median nerve revealed M3 or more motor power and S3 sensory recovery in all patients except one patient who attained no muscle power at all and S1 as regards the sensory assessment. The ulnar nerve evaluation revealed that two of five patients did not recover motor power at all (M0), and the remaining three patients recovered M3 motor power with variable sensory outcomes. Final assessment of total range of motion of the fingers and the DASH score showed a statistically significant improvement except for one patient.

**Conclusion:** WALANT tenolysis and interposition of well vascularized fascial flaps along with simultaneous nerve grafts in extensively scarred hands provided good functional outcomes. (Plast Reconstr Surg Glob Open 2021;9:e3949; doi: 10.1097/GOX.0000000000003949; Published online 14 December 2021.)
PATIENTS AND METHODS

In the period between 2017 and 2020, 22 patients were managed with a single-stage procedure of tenolysis with or without tendon grafts, free adipofascial wrap flaps, and simultaneous nerve grafts. Ethical approval was obtained and all procedures performed in this study were in accordance with the ethical standards of Tanta University research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The Human Investigation Committee (IRB) of Tanta University approved this study.

Inclusion and Exclusion Criteria

We included patients with previous multiple flexor tendons combined with nerve injuries at the level of the palm, wrist, or distal forearm in zone III–V, who presented 3–9 months following primary repair with limited or useless range of motion (ROM) of the fingers and with no signs of nerve recovery following primary nerve repair.

Patients with skeletal instability, secondary joint changes, or initial signs of nerve recovery were excluded based on preoperative assessment, which included clinical and radiological evaluation in addition to electrophysiological studies.

Surgical Technique

The site of injury was explored in all patients using the WALANT technique. The original technique of WALANT (described by Lalonde) was adopted. Nerves and tendons were initially identified, followed by tenolysis until all finger joints are freely mobile and release of joint contractures is achieved while the patient is awake to ensure adequate release. (See Video 1 [online], which displays the range of motion at the end of tenolysis and contracture release under WALANT.)

After release of all adhesions and completion of tenolysis, the patients were put under general anesthesia. A radial forearm adipofascial flap was selected unless a larger skin paddle needed to be recruited to allow tension-free closure after the added volume of the flap was taken into consideration. Thus, radial forearm adipofascial flap with a small skin paddle was harvested from the contralateral limb in case of small defects at the wrist or digits (Fig. 1).

Large ALT fasciocutaneous flap was performed when large areas of scarring in the forearm were present.

Tendon grafts and preparation of the recipient vessels were performed. Flexor digitorum superficialis tendons were the main donor grafts used. In the meantime, the selected flap was being harvested. Tendons were ensheathed with the adipofascial part of the flap separating tendons from nerves (Fig. 2). Free gliding of tendons and maximal ROM of fingers were confirmed after this step. Grafting of the injured nerves was executed using autogenous sural nerve graft passing through the well vascularized fat component of the flap. Internal topography of the nerves was appreciated, and a selective group fascicular pattern of repair was performed (Fig. 3). The skin was closed, incorporating the flap’s skin paddle for a tension-free closure after meticulous hemostasis (Fig. 4). A dorsal slab with a bulky soft dressing was applied while maintaining the wrist in modest flexion, the metacarpophalangeal joints at 60 degrees, and the interphalangeal joints in extension.

Postoperative Care

In tenolysis cases with no tendon grafts, early passive and active exercises were initiated on the third to fifth postoperative day, whereas in cases of tendon grafts, only passive exercises were initiated on the fifth day postoperative, and active flexion exercise was postponed to the third week postoperatively. Edema control was emphasized along with pain control. The sutures were removed on the second to third week followed by a patient tailored rehabilitation program. The slab was removed after 3 weeks and replaced by a wrist brace. The patient-specific rehabilitation program was conducted for the subsequent 6 months.

Study Measures

Important demographic and clinical data were collected, including age, handedness, occupation, smoking index, and interval between the last surgery and index procedure. We planned a follow-up over 12 months, with regular monthly visits. During every visit, nerve assessment,

Takeaways

**Question:** What could be the best reconstructive option for management of extensive tendon adhesions combined with nerve injuries?

**Findings:** In this prospective case series, patients with extensive hand adhesions and failed primary nerve repair were enrolled in the study. Tenolysis under WALANT was performed in addition to free transfer of adipofascial flap to wrap the tendons and to separate them from the overlying reconstructed nerves.

**Meaning:** Single-stage reconstruction of tendons and nerves in addition to application of interpositional adipofascial flaps would provide good functional outcomes in extensively scarred hands.

Fig. 1. Adipofascial radial forearm free flap with a small skin paddle.
ROM, and patient-reported outcome were measured. Postoperative patient assessment and data collection were performed by an independent surgeon.

Nerves were assessed as follows. For the motor functions, the median nerve recovery was defined by recovery of thumb opposition, whereas the recovery of the ulnar intrinsic functions following surgery was defined by an improvement of at least two of the five following signs from the baseline: an ability to flex the metacarpophalangeal joints without proximal inter-phalangeal joint flexion (achieving an intrinsic-plus position), a negative Froment’s sign, resolution of the clawing deformity, a negative Wartenberg’s sign, and a return of the ability to cross fingers. Medical research council scale was used for objectively grading the final motor and sensory recovery. Baseline preoperative and postoperative total active ROM of the fingers was recorded in addition to the patient-reported outcomes using the Disabilities of the Arm, Shoulder, and Hand (DASH) score.

RESULTS

Twenty-two eligible patients were enrolled in the study and managed with 20 radial forearm flaps in addition to two anterolateral thigh flaps, combined with immediate nerve grafting. All the flaps healed uneventfully. Minor dehiscence at the donor sites of the two ALT flaps was encountered and was managed conservatively. Table 1 provides the relevant patient demographics and details of the injury and operative interventions. Tenolysis was performed in all patients, whereas tendon grafting was conducted in 11 cases (50%).

Total active ROM of all involved fingers improved in 20 patients, with a mean improvement of 160 degrees ± 49 degrees SD and 48 degrees ± 16.5 degrees SD in the fingers and the thumb, respectively. However, one patient (no. 5) attained a useless postoperative ROM, and the other (no. 20) experienced worsening of ROM (Fig. 5).

Except for two patients (nos. 1 & 20), DASH scoring revealed a considerable postoperative improvement with the average preoperative and postoperative DASH score
| Patients | Age (y) | Gender | Mechanism of Injury | Location of Injury (Volar Side) | Injured Tendons | Injured Nerves | Main Arterial Injury | Time of Initial Injury (mo) | Flap Type | Tendon Grafts |
|----------|---------|--------|---------------------|---------------------------------|-----------------|---------------|---------------------|-----------------------------|-----------|--------------|
| 1        | 24      | Man    | Laceration          | Distal forearm and volar wrist  | All zone V flexor tendons | M & U         | —                   | 6                           | RFF       | —            |
| 2        | 33      | Man    | Crush injury        | Distal forearm and volar wrist  | Zone IV flexor tendons (index, middle, ring & little), FCU | M & U         | +U                  | 5                           | RFF       | Index and middle fingers |
| 3        | 35      | Man    | Electrical saw injury | Distal forearm                  | Zone V flexor tendons, ulnar artery | M & U         | +U                  | 7                           | ALT       | —            |
| 4        | 28      | Man    | Crush injury        | Distal forearm                  | Zone V flexor tendons, FCU       | U             | +U                  | 5                           | RFF       | Ring finger |
| 5        | 37      | Man    | Crushing/avulsion injury | Distal forearm and wrist       | Zone V flexor tendons, FCU       | M & U         | —                   | 5                           | RFF       | Index finger |
| 6        | 21      | Man    | Laceration          | Hand                            | Zone III flexor tendons (index, middle, ring) | M branches    | —                   | 6                           | RFF       | —            |
| 7        | 41      | Man    | Laceration          | Distal forearm and wrist        | Zone V FDSs                  | M             | —                   | 5                           | RFF       | —            |
| 8        | 27      | Woman  | Crush injury        | Distal forearm and wrist        | Zone IV & V: all FDSs & FDPs (middle, ring, little) | M & U         | +U                  | 4                           | RFF       | —            |
| 9        | 20      | Man    | Laceration          | Distal forearm and wrist        | Zone IV & V: FDSs, FDP index & FPL | M             | +R                  | 7                           | ALT       | FDP index & FPL |
| 10       | 37      | Woman  | Crush injury        | Distal forearm and wrist        | Zone IV FDSs, FDPs             | M             | —                   | 4                           | RFF       | —            |
| 11       | 22      | Man    | Laceration          | Wrist                           | Zone IV FDSs, FDSs, FDPs       | M             | —                   | 6                           | RFF       | FDPs, FPL |
| 12       | 26      | Man    | Laceration          | Wrist                           | Zone IV FDSs, FDSs, FPL        | M & U         | +R                  | 8                           | ALT       | —            |
| 13       | 26      | Man    | Crush injury        | Distal forearm and wrist        | Zone IV FDSs, FDP index & middle, FCR | M & U         | —                   | 9                           | RFF       | FDP index, middle, ring |
| 14       | 31      | Man    | Crush injury        | Hand and wrist                  | Zone III & IV, FDSs index, middle, ring, FDP index | M branches  | —                   | 5                           | RFF       | —            |
| 15       | 35      | Man    | Laceration          | Wrist                           | Zone IV FDSs, FDPs             | M & U         | +U                  | 5                           | RFF       | —            |
| 16       | 28      | Man    | Crush injury        | Palm, wrist and distal forearm  | Zone III, IV, FDSs, FDPs, FPL  | M             | +U                  | 5                           | ALT       | —            |
| 17       | 30      | Man    | Laceration          | Distal forearm and wrist        | Zone IV, V FDSs, FDPs, FPL     | M             | +R                  | 7                           | RFF       | FDPs, FPL |
| 18       | 36      | Man    | Laceration          | Hand and wrist                  | Zone III, V, FDSs, FDPs, FPL   | M & U         | +U                  | 6                           | RFF       | FDP index |
| 19       | 28      | Man    | Laceration          | Hand and wrist                  | Zone III & IV FDSs, FDPs       | M             | —                   | 4                           | RFF       | —            |
| 20       | 42      | Man    | Laceration          | Hand and wrist                  | Zone IV FDSs, FDPs             | M             | —                   | 5                           | RFF       | —            |
| 21       | 29      | Man    | Crush injury        | Hand                            | Zone III FDSs, FDPs             | M branches & U | —                   | 6                           | RFF       | FDP index |
| 22       | 35      | Man    | Laceration          | Hand and wrist                  | Zone IV FDSs, FDPs, FPL        | M             | —                   | 6                           | RFF       | FPL, FDS index |

ALT, anterolateral thigh flap; FCU, flexor carpi ulnaris; FDP, flexor digitorum profundus; FDS, flexor digitorum superficialis; FPL, flexor pollicis longus; M, median; R, radial; RFF, radial forearm free flap; U, ulnar.
of 86.09 and 33.27, respectively. The mean improvement was 58.7 points ± 8.9 SD (Table 2).

The final active ROMs of the fingers in patients 1 and 6 are shown in Figures 6 and 7, whereas Video 2 and Video 3 display the preoperative and postoperative total ROM in patient 1, respectively. (See Video 2 [online], which displays the preoperative ROM of patient 1.) (See Video 3 [online], which displays the postoperative ROM of patient 1.)

In terms of nerve recovery (Table 3), final assessment of median nerve revealed M3 and M4 motor power in 12 of 19 (63.1%) patients and S3 and S4 sensory recovery in 17 of 21 (80.9%) patients. On the other hand, the final ulnar nerve evaluation revealed that seven of 11 (63.6%) patients recovered M3 motor power. As regards the sensory recovery, eight of 12 (66.6%) patients achieved S3 and S4.

Patient 5 underwent a subsequent surgery in the form of tenolysis to address the poor ROM. The ALT flap in patient 3 was bulky, and thinning of the flap was discussed with the patient; however, the patient was satisfied and refused further interventions. Patient 20 declined any revisional surgery.

Signs of ischemia in the form of mottling and coldness of the hand were detected postoperatively in patient 3. Nevertheless, these signs gradually faded, and hand perfusion improved with no interventions after 8 hours of follow-up.

Table 2. Preoperative and Postoperative DASH Score

| Patient | Preoperative DASH score | Postoperative DASH score |
|---------|-------------------------|--------------------------|
| 1       | 96                      | 32                       |
| 2       | 94                      | 50                       |
| 3       | 80                      | 38                       |
| 4       | 88                      | 21                       |
| 5       | 90                      | 80                       |
| 6       | 92                      | 30                       |
| 7       | 98                      | 42                       |
| 8       | 100                     | 33                       |
| 9       | 80                      | 20                       |
| 10      | 70                      | 18                       |
| 11      | 92                      | 45                       |
| 12      | 90                      | 42                       |
| 13      | 70                      | 20                       |
| 14      | 75                      | 15                       |
| 15      | 90                      | 22                       |
| 16      | 80                      | 10                       |
| 17      | 94                      | 24                       |
| 18      | 90                      | 35                       |
| 19      | 70                      | 10                       |
| 20      | 80                      | 92                       |
| 21      | 90                      | 21                       |
| 22      | 85                      | 22                       |

Fig. 5. Column graph illustrates the mean change in the ROM for the thumb and other fingers.

Fig. 6. Case 1. A, preoperative presentation of patient 1 showing extensive scarring at the wrist region, useless finger flexion, and contracted basal joint of the right thumb. B, Postoperative full active ROM of all fingers.
DISCUSSION

Tenolysis could be a grueling procedure when extensive scarring exists after severe hand injuries. Similarly, in secondary reconstruction, nerve grafting combined with tenolysis is unlikely to be successful. Obviously, tenolysis mandates early postoperative exercise; however, nerve grafts require an absolute immobilization for good take of the grafts. Thus, failure of tenolysis to regain a functional ROM or futile nerve reconstruction is not uncommon. On the other hand, a staged reconstruction carries a potential risk of adhesions or inadvertent nerve injury. This explains the controversy in the literature regarding timing and stages of tenolysis and nerve reconstruction.

Our proposed surgical technique is a single-stage reconstructive procedure, which entails tenolysis under WALANT technique, use of wrapping adipofascial free flap, and nerve grafting. WALANT technique permitted full cooperation of the patient to assess the ROM of the fingers after tenolysis. Using this concept allowed intraoperative detection of factors causing failure, such as secondary tendon rupture, triggering, poor ROM, and bow stringing, and allowed management to be instigated promptly. The results confirmed safety and efficacy of WALANT technique in such large areas of dissection and tenolysis. Thus we believe that the tenolysis under WALANT technique is a crucial step in such cases and this could explain the good total ROM of the fingers at the time of final assessment.

Nevertheless, one patient showed signs of ischemia represented by mottling of the hand after extensive dissection of the forearm. This patient has improved with no intervention at all after 8 hours of follow up and good warming of the hand. The use of vascularized flaps to address extensively scarred tissues is a well-described technique in the literature. The previously reported indications entailed wrapping nerves after neuroma reconstruction, management of radiotherapy wounds, and offering a good gliding surface for the tendons after tenolysis. This study extended the indications of vascularized fascial flaps to address conditions of extensive tendon adhesions and failure of primary nerve reconstruction. After tenolysis alone, Del Pinel et al. reported good outcomes of free adipofascial flaps combined with tenolysis in scarred beds in an elegant study, including 10 patients. However, they concluded that controlled trial is necessary to compare interpositional vascularized fat flaps and conventional tenolysis. In other words, tenolysis alone may be sufficient and gives comparable results in such cases.

However, we believe that this may be true in patients with isolated tendon injuries, but associated nerve injuries would change the whole situation and mandate the transfer of well vascularized flaps. In addition to setting smooth gliding surfaces for the tendons, the interpositional flaps would augment the blood supply to the nerve grafts and mitigate its interruption by early tendon motion after tenolysis. This compartmentalization of tendons and

Table 3. Final Grading of the Motor and Sensory Recovery of the Involved Nerves on the MRC Scale

| Median Nerve | Ulnar Nerve |
|--------------|-------------|
| S3+ M4 | S3 M0 |
| S3 M3 | S3 M2 |
| — — | — — |
| S3 M3 | S2 M3 |
| S3+ M3+ | — — |
| S3 M3 | S1+ M0 |
| S3+ M3 | S2 M3 |
| S4 M3 | — — |
| S4 M4 | — — |
| S3+ M1 | S3 M2 |
| S3 M0 | — — |
| S4 — | — — |
| S2 M0 | S4 — |
| S3+ M3 | S3 M3+ |
| S4 M3 | — — |
| S0 M0 | S3 M3 |
| S4 M4 | — — |
| S2 M0 | — — |
| S4 — | S4 M3 |
| S4 M2 | — — |

Fig. 7. Case 6. A, preoperative presentation of patient 6 showing extensive scarring at the right palm, useless finger flexion, and flexion deformity of the index finger. B, Postoperative index extension. C, Postoperative active ROM of the same patient.
nerves makes these patients candidates for a single stage reconstruction.

A radial forearm flap with a small skin paddle was selected to address the resultant small defects. The adipofascial part of the flap is usually thin with a large surface area allowing good wrapping of the tendons with minimal bulk. The small skin paddle was necessary for a tension free closure of the wound. The main drawback of this flap is donor site morbidity at the contralateral forearm, including the sacrifice of radial artery and unsightly split thickness graft.

The ALT flap was preserved for large defects. Bulkeness of the flap was obvious in the two patients where the ALT flap was used, although both patients did not ask for further thinning of the flaps. Other adipofascial flaps were described in the literature such as temporoparietal fascial flaps, lateral arm flaps, and groin fascial flaps. We believe that these flaps are not big enough to address such cases effectively.

All the patients enrolled in the study exhibited a significant improvement of the total ROM of involved fingers except for two patients. These results are superior in comparison with the results of tenolysis only reported in the literature. Such good results might be attributed to tenolysis under WALANT technique along with the use of interpositional flaps.

The final assessment of reconstructed nerves revealed good functional results which are comparable with previously reported results of secondary nerve reconstruction.

However, there were various variables apart from the surgical technique that could have affected nerve recovery, including site of injury, time of nerve reconstruction, and length of the nerve graft, which represent limitations to this study. An ideal study mandates a standardization of such parameters for an objective assessment of the nerve reconstruction with minimal confounders. The main limitation of this study is the lack of control group.

Based on the reported results, WALANT tenolysis, with or without tendon grafts, in addition to interpositional fascial flaps combined with simultaneous nerve grafting could be an effective single stage salvage procedure for management of extensively scarred denervated hands with good outcomes.

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