Outcomes of Free Adipofascial Flaps Combined With Tenolysis in Scarred Beds

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Purpose To review our outcomes of transferring vascularized free adipofascial flaps used to change the local tissue conditions at the time of tenolysis in adhesion-prone beds.

Methods Eleven free adipofascial flaps were transplanted in 10 patients after tenolysis on the forearm (3 cases), the dorsum of the hand (5 cases), or the dorsum of the proximal phalanx (3 cases). All recipient areas had badly scarred beds, 7 of which had previously failed tenolyses. In addition to tenolysis (10) or the insertion of bridging tendon grafts (1), arthrolysis of several involved joints and bone fixation for nonunion (3 cases) were carried out simultaneously. The adipofascial flap was then wrapped around the tendons or interposed between the scarred tissue and the freed tendons. In 8 cases, the flap was the lateral arm adipofascial flap, whereas adipose flaps from the toes were used for the fingers.

Results All flaps survived without vascular crisis. In all cases, total active motion was similar to the passive motion obtained at surgery. Average Disabilities of the Arm, Shoulder, and Hand score improved from 69 to 10, and average Patient-Rated Wrist Hand Evaluation score improved from 65 to 9. Secondary surgery was needed to reduce the bulk of the flap in 3 patients. One patient required an additional procedure to obtain an optimum result.

Conclusions Free adipofascial flaps provided satisfying results in this group of patients. The flaps should be considered when the bed is scarred or after a failed tenolysis. *(J Hand Surg Am. 2014;39(2):269–279. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Microsurgery, tenolysis, tendon surgery, crushed hand, frozen hand.

Tenolysis is unlikely to produce a successful result when tendons are encased in a solid mass of scar tissue. By the same token, tendon grafts placed in a scarred bed are unlikely to function well, because tendon gliding requires the presence of a nonadherent, unscarred vascular bed. Conventionally, this problem is managed by using a 2-stage tendon graft, employing a silicone rod to create a new sheath.

The concept of interposing vascularized tissue (fascial flaps) between the tendons and the bed to improve gliding has been used sparingly in injuries with poor prognosis, mainly in the acute and subacute period.[1–3] Scheker et al[4] presented outstanding results in single-stage reconstructions of compound defects on the dorsum of the hand by passing the tendons grafts through the fat of the flap, which was used concomitantly to provide cover. Unfortunately, this option is not applicable when the tendons are in continuity. In a case of an extremely scarred volar forearm in which flexor tendons were grafted, Smith and Ross[5] used a tubed radial forearm fascial flap to wrap the tendons and isolate them from the scar, with

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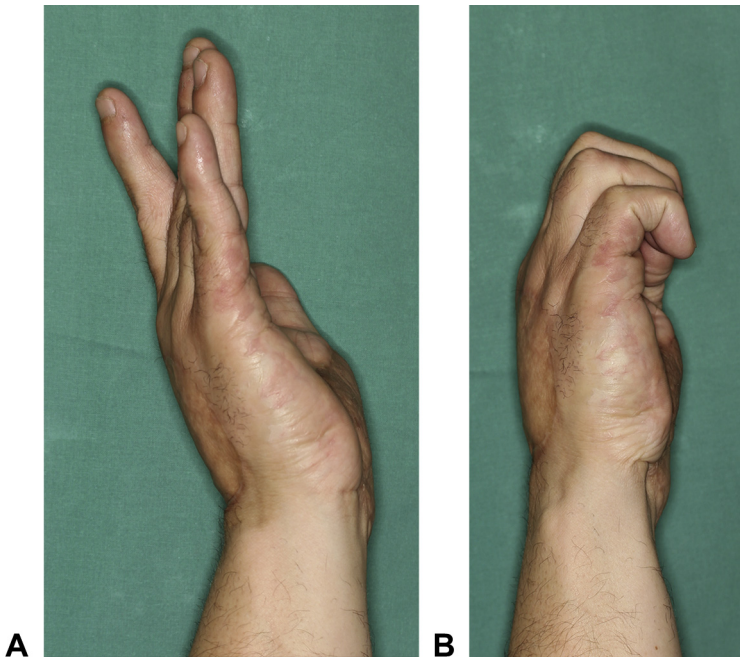

FIGURE 1: Status after 2 extensor tenolyses in a patient who experienced a complex injury (case 5). **A** Active extension. **B** Active flexion.

good results. Free temporalis fascial flaps for gliding have also been reported sparingly in the upper and lower limb in the chronic setting, mainly in the form of case reports.[2,3,6,7]

In the past 4 years, we have been treating failed tenolysis cases or adhered tendons lying in scarred beds (Fig. 1) by redoing the tenolysis and changing the local environment by interposing a vascularized fat-containing free flap. In this report, we present the outcomes of a consecutive series of 10 patients (11 free adipofascial flaps). With this approach, maintenance of intraoperative passive motion and high satisfaction is to be expected in failed tenolysis patients.

MATERIALS AND METHODS

Between 2009 and 2012, 11 consecutive adipofascial free flaps were performed in 10 patients for encased tendons: 3 in the forearm, 5 on the dorsum of the hand, and 3 on the dorsum of a proximal phalanx. The extensors were involved in 8 cases, the digital flexors in the forearm in 2, and a combination of wrist extensors and long thumb tendons in 1. All flaps were performed after the initial wounds had closed and after physical therapy (which included braces and assisted active and passive exercises) had reached a plateau. Eight were lateral arm adipofascial free flaps and 3 were fat-only flaps harvested from the lateral side of the hallux (2 flaps) or the second toe (1 flap).

In 4 patients, the gliding flap was indicated at the time of primary tenolysis because the bed was so poor that a good result was not foreseen otherwise. The rest had had previous unsuccessful tenolysis (1 or more) before the flap, including 5 carried out by the first author in 4 cases (Table 1).

At the latest follow-up visit (mean, 23 mo; range, 13 mo to 4 y), active range of motion was recorded in the involved joints and compared with preoperative active and intraoperative passive measurements. When the extensor tendons were involved, the range of motion was recorded precisely and reported for the joint(s) involved. The change when the tendons were involved at the wrist was also recorded. Patient-Rated Wrist-Hand Evaluation and Disabilities of the Arm, Shoulder, and Hand questionnaires were administered preoperatively and postoperatively. Patients were also asked about any problems regarding the donor site.

Our institution does not require institutional review board approval; however, all patients were aware of the treatment aims, understood the risks and possible benefits, and were aware of reconstructive alternatives.

Surgical technique

Except for the fingers, management of the adhered tendons, whether flexor or extensor, was similar. A sterile tourniquet was placed as high as possible on the arm. The tendons were released from all adhesions,

TABLE 1. Demographics of Patients

Case	Age	Sex/ Dominance	Original Injury, mo	Mechanism of Injury	Treatment (Including Before Referral)	Osseous Defect/Plates	Coverage Quality	Previous Tenolysis	Total Previous Operations
1	51	M/D	9	Crush/infection	Infection + failed posterior interosseous flap + secondary healing	No	Scarred	1	3
2	53	M/ND	10	Chainsaw injury	Tendon repair	Radius metaphyseal defect	Scarred	1	3
3	30	M/ND	24	Laceration	Tendon rupture + re-repair × 2 tendon graft dehiscence + partial flap necrosis + HBSI	No	Scarred	2	10
4	47	M/D	4	Press injury	Ext fixator/HBSI	Nonunion ulna	Scarred	0	0
5	38	M/D	22	Conveyor belt	Free gracilis + tendon grafts EDC 2−5	No	Good (gracilis)	2*	2
6	15	F/D	8	Avulsion/motor vehicle accident	Distally based hand flap/unspecified tendon work/HBSI	Fx 3−5 MCP/ Kirschner wires	Scarred	0	1
7	37	M/D	6	Crush	Debridement	Fx 1−5 MCP/Plating 1−4. Screws 5.	Good	0	2
8	61	M/ND	6	Circular saw	Tendon repair	Dorsal cortical injury	Good	1*	0
9	34	M/ND	16	Crush	Revascular Index. Zone IV extensor repair in 2−5.	Fx P1 Kirschner wires	Good	1*	2
10	34	M/ND	16	Crush	Revascular Index. Zone IV extensor repair in 2−5.	Undisplaced P1 Fx.	Good	1*	2
11	40	M/D	18	Crush/avulsion	Hand revascularized. Repair median/ulnar nerve—all FDP/ FCR/FCU Undetected intrinsic compartment. HBSI.	Radius plating + ulna excision	Atrophic scarring	0	3

D/ND, Dominant/nondominant; EDC, extensor digitorum communis; FDP/FCR/FCU, flexor digitorum profundus/flexor carpi radialis/flexor carpi ulnaris; HBSI, healing by secondary intention; Fx, fracture; MCP, metacarpophalangeal; P1, proximal phalanx.

*The tenolysis operations were carried out by the first author before the index operation.

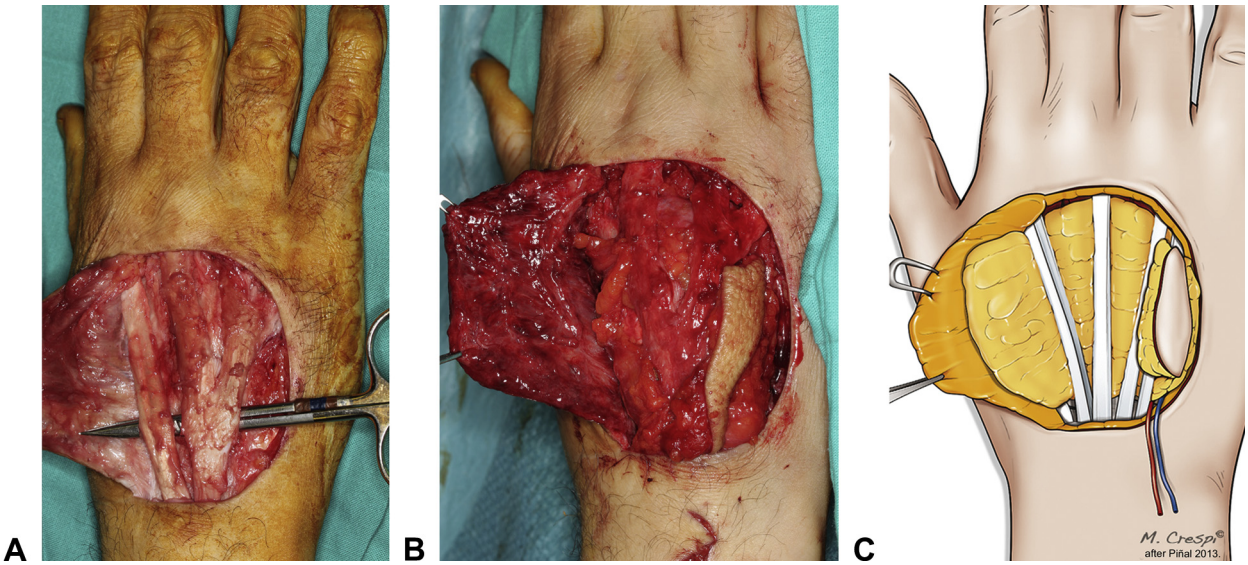

FIGURE 2: **A** Case 5 after the third tenolysis. **B** The adipofascial flap has been inset, as shown in **C** before anastomosis of its terminal branches of the posterior interosseous vessels.

and standard joint releases were performed as required. Except for bone grafting, all bony work, hardware applications, modifications, or removal was done at this stage. Traction on the tendons proximally was used to rule out any other cause of adherence. For patients with adhesions in the forearm, this was recorded and used to monitor any improvement.

An ipsilateral lateral arm adipofascial flap was planned in the distal third of the arm but always proximal to the lateral epicondyle, because over the epicondyle the fat layer is too thin. The flap was elevated as described by Yousif et al,[8] but a thicker layer of fat was incorporated superficial to the fascia. A small skin island was included in all cases to cover any defect and to monitor flap viability. The rest of the flap consisted of adipofascial wings, extending as far as necessary to fully encircle the tendons. The donor artery was the posterior radial collateral artery in 7 cases and the profunda brachii artery in 1. Cancellous bone graft, if needed, was harvested by creating a small window in the lateral epicondyle. The tourniquet was released to verify the blood supply to the flap.

Again under tourniquet control, the flap was inset to isolate the tendon(s) from the scarred bed. Sometimes, this involved wrapping the flap around an individual tendons or groups of tendons or interposing the flap between or around a group of tendons. The skin island was then placed at a convenient edge of the surgical wound or specifically in an area of skin loss (Fig. 2). Alternatively, the flap was split between perforators[9] to allow the tendons to pass through it (Figs. 3, 4). In each case, isolation of the tendons from the scarred bed, hardware, or any devascularized bone or thinned skin was the goal. Anastomoses were carried out end-to-side to the major vessels or preferably end-to-end to a local side branch.

The procedure was slightly different for the fingers. There, the lateral bands were excised and only the central band was preserved. All scarred tissue and bony overgrowth underneath the central band was excised with a rongeur until a uniform layer of apparent healthy bone was obtained. Then, the capsule of the proximal interphalangeal joint was released in the standard fashion until a full range of motion was obtained. Traction on the flexor tendon at the wrist helped identify any further areas of adherence. A fat flap was harvested from the side of the hallux or second toe and wrapped around the central band (Fig. 5). Revascularization was carried out to a digital artery and a subcutaneous vein. In 2 cases, digital artery flow was reestablished by anastomosing the flap's artery distally in a flow-through fashion.

As is customary in our microsurgical practice, before clamp release, a bolus of 1,500 U of heparin was injected intravenously. Furthermore, patients were given a continuous perfusion with heparin 250 to 500 U/h for 48 hours, which was reduced to half for another 48 hours, and then subcutaneous heparin for 2 more weeks. Patients were discharged after 4 to 5 days. Except for patient 2, who was immobilized for 3 weeks, active range of motion was started immediately—even during admission—while maintaining a splint for comfort. Assisted exercises

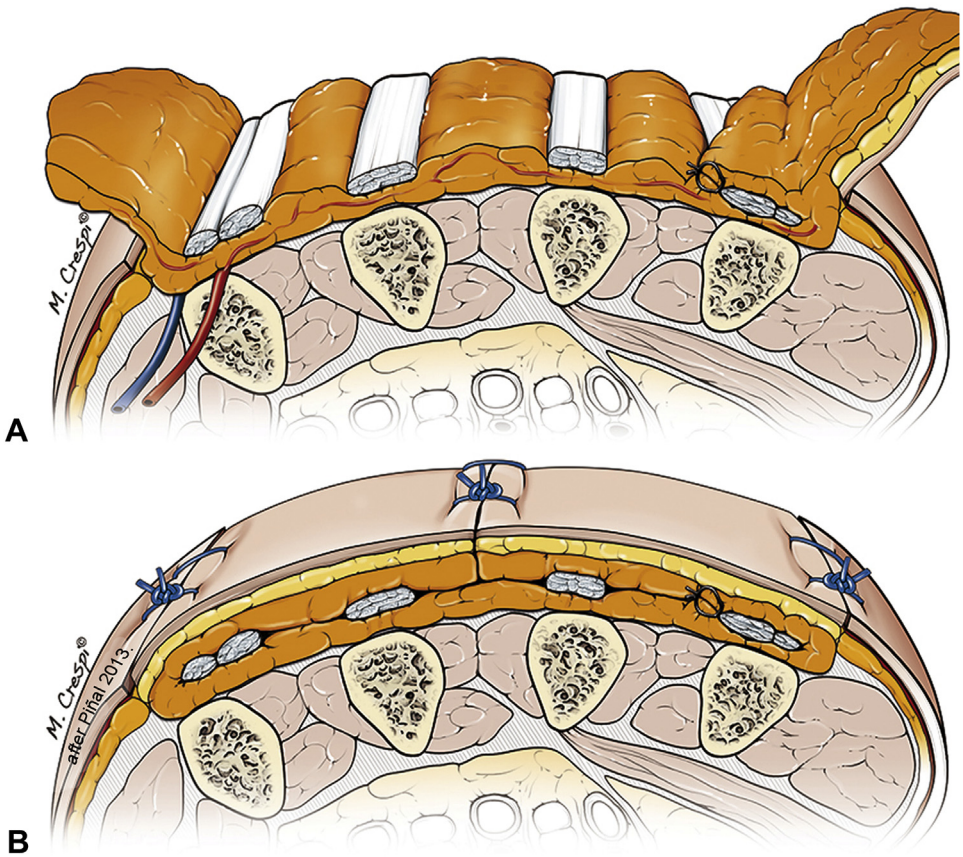

FIGURE 3: A When needed, the flap can be divided between perforators, allowing the tendons to lie on the fat of the flap **B**.

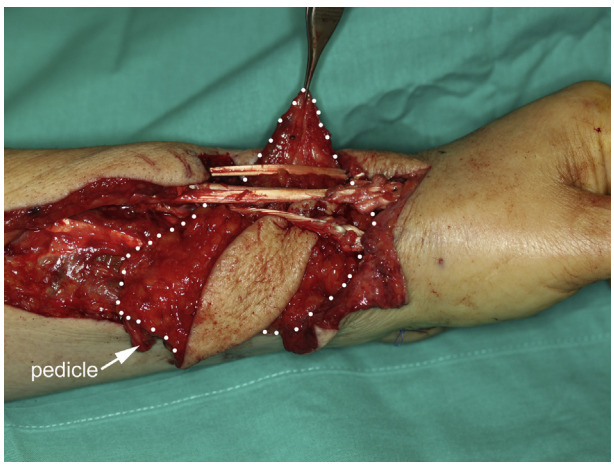

FIGURE 4: Case 2. Before division of the flap, as shown in Figure 3. An adipofascial wing is passed under the grafted radial wrist extensor and abductor pollicis longus tendons, thereby isolating them from the bone graft underneath. The extensor pollicis longus and flexor pollicis longus will be wrapped in similar fashions using the adipofascial wings (outlined with dots).

and passive stretching were added immediately. Night extension splinting with aluminum splints was prescribed for several months for any proximal interphalangeal joint contracture. Any deficit of passive flexion of the metacarpophalangeal joint after arthrolysis was immediately treated with custom-made progressive flexion orthoses, which the patient wore always at night and in between exercises, as needed.

RESULTS

All flaps survived without complications. Adjunct procedures were often performed to improve the range of motion in the form of capsulotomies and arthrolysis (Table 2). Patients 2, 6, 7, and 11 had cancellous bone graft and/or plating inserted beneath the lysed tendons. In patient 2, the tendons were so badly damaged that interpositional tendon grafts were required.

Active range of motion similar to or better than the intraoperative range of motion, but never a full arc of motion, was achieved postoperatively in all 3 patients with forearm injuries (Fig. 6). In cases involving the fingers, improvements were remarkable, but the cases were too dissimilar to have enough numbers for meaningful statistical analysis. The rough numbers are given in Table 3 (Fig. 7). The average Patient-Rated Wrist-Hand Evaluation score improved from 65 to 9 ($P < .001$) and the average Disabilities of the

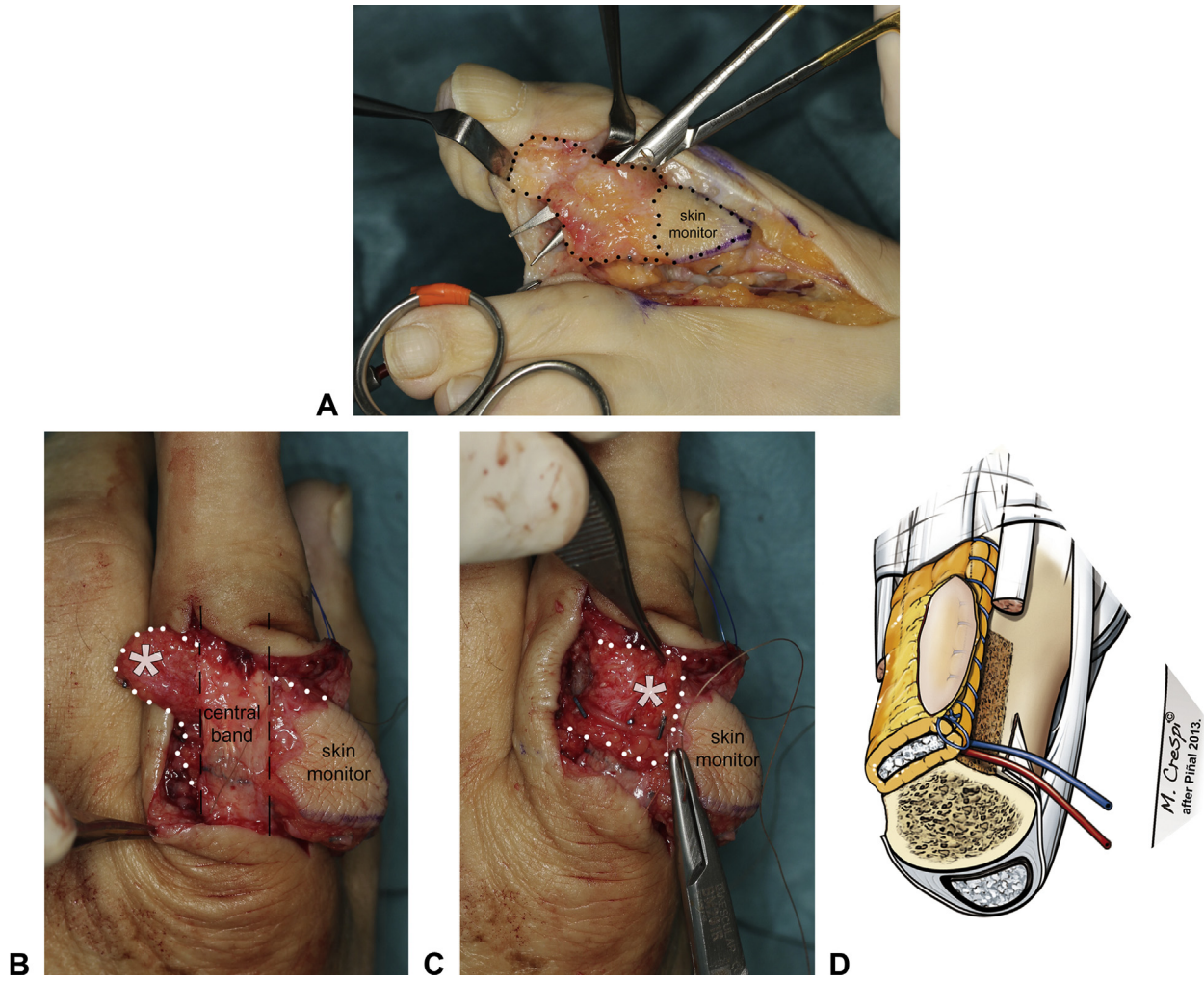

FIGURE 5: Case 8. **A** Adipofascial flap from the lateral side of the hallux. The skin flaps have been elevated just at the subdermal level, leaving intact a small skin island to serve as a monitor. The peroneal nerve has been left in place. **B** After the lateral bands have been excised, the flap (asterisk) is passed underneath and wrapped around the central band. **C** The digital artery is now located superficially. **D** Schematic representation of the operation.

Arm, Shoulder, and Hand score improved from 69 to 10 ($P < .001$) (Table 3).

Patient 7 required further surgery to improve the range of motion in the little finger. At the first operation, the flap was not large enough to wrap the extensor digiti minimi, and this tendon was relatively free of scar. In the second operation, the extensor digiti minimi was stuck to the metacarpal. This time, the contribution of the extensor digiti minimi to the metacarpophalangeal joint of the little finger was excised, and the capsulotomy of the fifth metacarpophalangeal joint was redone, with good results. Despite our utmost care to avoid oversized flaps, this patient, as well as 2 more (out of 5 who had flaps on the dorsum of the hand), required secondary debulking surgery. This attests to the unforgiving intolerance of the skin on the dorsum of the hand to minimal increases in bulk, which is unavoidable because the flap has to wrap around itself in some cases.

Patient 6 was a student who experienced a motorcycle accident; the others had sustained work-related injuries. All went back to their original work except patient 4, who resumed lighter work, and patient 2, who retired as a lumberjack but worked on his farm without limitations.

Seromas were frequent in the lateral arm donor site and controlled by aspiration weekly (maximum of 3 times) in the office and compressive bandage. No patient asked for scar revision or was unhappy about the scar.

DISCUSSION

Transfer of vascularized tissue into an exhausted bed is a common practice in recalcitrant nonunions,[10,11]

TABLE 2. Surgical Findings

Case	Location	Tendons Involved	Capsulotomies	Miscellaneous Concomitant Procedures	Flap	Subsequent Procedures
1	Dorsum of hand	EDC 2−5 tenolysis	MCP 3−5		LAAFF	Flap debulking
2	Radial and volar forearm	Tendon graft ECRL/ECRB/APL, tenolysis EPL-FPL	None	Bone graft radius	LAAFF	None
3	Dorsum of thumb, hand, and distal forearm	Tenolysis EPL and ECRB-ECRL	MCP 1+ IP	Partial resection previous flap	LAAFF	Flap debulking and z-plasties × 2
4	Volar forearm	FDP and FDS	None	Wrist arthroscopy + ulna ORIF	LAAFF	Several unrelated
5	Dorsum of hand	EDC 2−5	MCP 2−5		LAAFF	None
6	Dorsum of hand	EDC 3−5	MCP 3−5	Plate third and fourth metacarpals	LAAFF	None
7	Dorsum of hand	EDC 2−5	MCP 2, 3, 5	Bone graft index metacarpal	LAAFF	Redo capsulectomy small, half flap debulking pending HWR and debulking
8	P1 index finger	Extensor apparatus*	PIP arthrolysis		Peroneal side hallux	None
9	P1 middle finger	Extensor apparatus*	PIP arthrolysis	Fourth finger tenolysis	Peroneal side hallux	None
10	P1 little finger	Extensor apparatus*	PIP arthrolysis	Fourth finger tenolysis	Peroneal side second toe	None
11	Volar forearm	Mass flexors-FPL, excision FDS	Volar MCP 2-5	Radius plate removal, bone graft radius	LAAFF	None

ECRL/ECRB/APL, extensor carpi radialis longus/extensor carpi radialis brevis/abductor pollicis longus; EDC, extensor digitorum communis; EPL-FPL, extensor pollicus longus-flexor pollicus longus; FDP, flexor digitorum profundus; FDS, flexor digitorum superficialis; IP, interphalangeal; MCP, metacarpophalangeal joint; PIP, proximal interphalangeal joint; HWR, hardware removal; LAAFF, lateral arm adipofascial flap; ORIF, open reduction internal fixation.

*See text for details of the surgical technique.

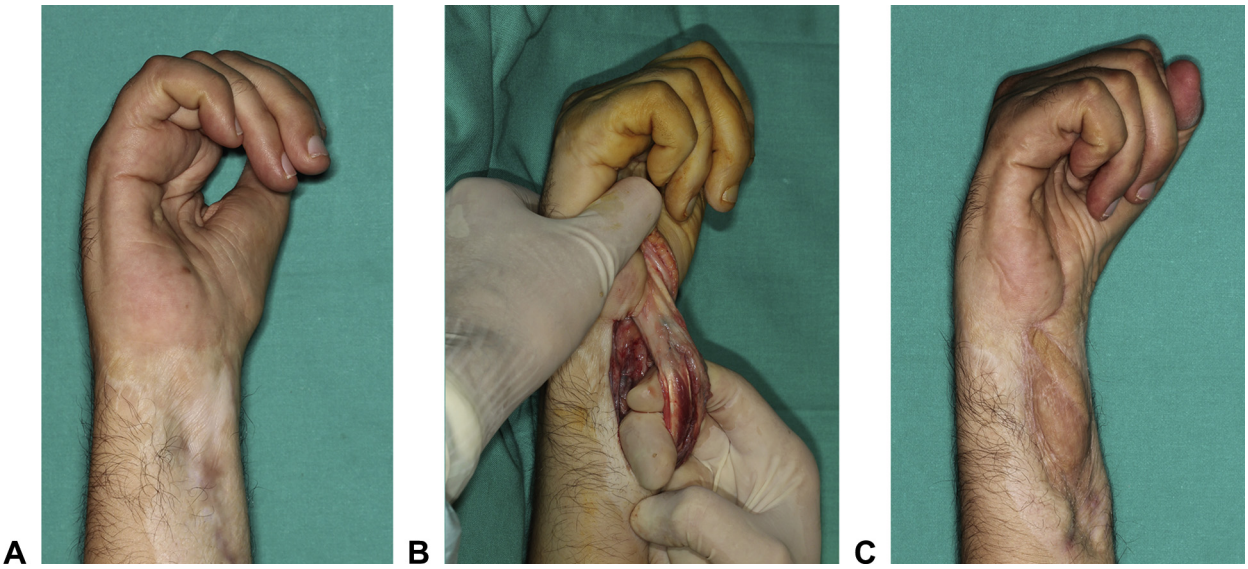

FIGURE 6: Case 11. **A** Preoperative active flexion. **B** Flexion achieved by traction after capsulectomy and tenolysis. **C** Active flexion at the last follow-up visit. Same patient as in Figure 8.

radiotherapy wounds,[12] peripheral vascular disease,[13] or scarred nerves.[14] Hence, it seems logical that beds that have no gliding surfaces[15] would benefit by applying the same rationale (ie, provide gliding surfaces). The concept of a flap to promote gliding would be better accepted if one considers that tendons are simple ropes with no extensibility capabilities and that except in the synovial sheath, tendons need fat and areolar tissue to glide. In other fields of hand surgery, such as tendon transfers, it is well accepted that the path of the tendon should pass through a scar-free, well-vascularized bed or intrasynovial sheath.

After having had promising results using adipofascial flaps in the subacute setting in cases with a poor prognosis, we extended the indication to failed tenolysis or to any situation in which the bed was expected to be inadequate. This included multisurgical cases, wounds that had healed by secondary intention, previously infected beds, and beds with massive hardware under the tendons. Our results seem to support the use of flaps that promote gliding in those settings.

Similar results might have been achieved with a well-executed tenolysis or with the use of chemical deterrents to adhesions. However, when the bed is scarred, it is unlikely that tenolysis will give any substantial improvement in the range of motion, and 7 of our cases had already failed tenolyses. Membranes or anti-adherence barriers have been used in acute flexor injuries and after tenolysis with promising results in experimental situations, but with mixed results clinically.[16–18]

During the operation, one should take care to isolate the tendons with the gliding flap from any tissue devoid of good blood supply (ie, scarred tissue, plates, or fractures). Otherwise, the tendons will be encased by scar again. The only case in which the procedure partially failed and required further tenolysis was case 7, in which the flap was too small to cover an area of exposed bone and the adjacent extensor digiti minimi tendon. Although the lateral arm flap is a convenient flap because it is located in the same limb and yields a benign scar, it has size limitations,[8,9] but a standard lateral arm flap should provide enough tissue to cover most tenolyses in hand surgery.

Flaps such as the temporalis fascia flap have a similar size limitation and have the risk of local alopecia. Furthermore, they are much more difficult to monitor, because they do not have a skin island, so necrosis could go undetected.[19] If the need arises, much larger flaps for gliding can be harvested from the anterolateral thigh or from the scapular region. Harvesting the omentum has inherent morbidity and should be reserved for special cases, if any.[20]

Local adipofascial flaps can also be used, even without sacrifice of a major artery.[5] However, considering that the tissue required must retain its optimum blood supply to minimize any scarring tendency, it is logical to choose a free flap that bears the first angiosome, rather than a pedicled or reversed flap, which does not.[21] Although an advantage of the lateral arm flap is its thinness, this flap is still too thick for the dorsum of the hand. Of the 5 cases in which the flap was used for the dorsum of the hand,

TABLE 3. Final Outcomes

Case	Follow-Up, mo	Total Active Motion			Patient-Rated Wrist Hand Evaluation		Disabilities of the Arm, Shoulder, and Hand	
		Finger/Joint	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
1	50	Ring MCP	10	90	71	6	81	4
2	36	Thumb*	5	90	90	18	94	12
3	26	Thumb MCP	10	50	80	0	75	0
4	23	Little†	15	155	95	12	100	24
5	20	Middle MCP	5	90	68	10	60	5
6	19	Little MCP	0	85	32	4	48	6
7	18	Little MCP	10	75	69	20	80	22
8	18	Index PIP	5	80	58	12	47	13
9	15	Middle PIP	5	85	44	0	53	2
10	15	Little PIP	0	85	44	0	53	2
11	13	Ring†	80	165	60	18	74	19
Average	23				64.63	9.09	69.54	9.90
P Value‡					< .001		< .001	

MCP, metacarpophalangeal; PIP, proximal interphalangeal.
Only the joint or digit most affected is reported.
*Total active motion of the contralateral thumb (trapezial-metacarpal + metacarpophalangeal + interphalangeal = 145°) was used as reference in this patient.
†Total active motion of the most affected finger (normal = 260°) is reported for forearm patients.
‡Compared statistically using a 2-tailed, paired *t* test.

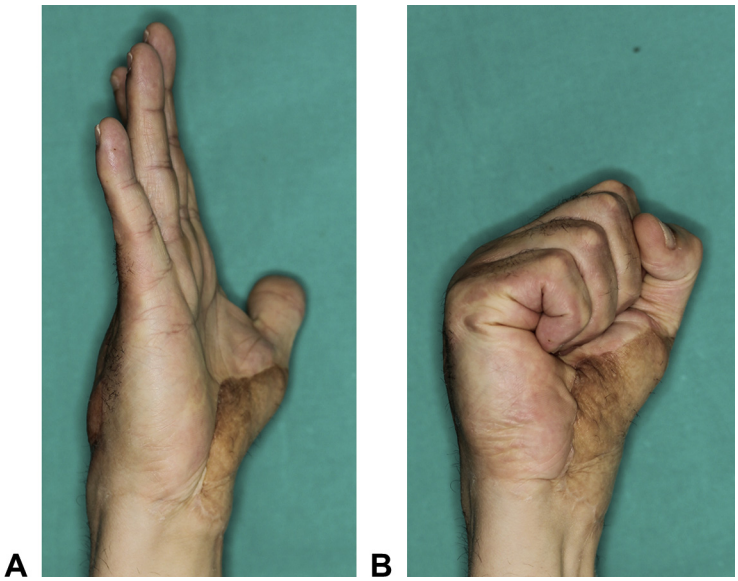

FIGURE 7: **A** Active extension and **B** active flexion in case 5, also shown in Figures 1 and 2, after 2 previous failed tenolysis procedures.

debulking was needed once for 2 cases and twice for 1. We could have used primary flap-thinning procedures[22] but feared this would interfere with the blood supply to the fat.

At the time of the operation, apart from the need to isolate the tendons, full release of any contracted structured (capsules, ligaments, etc) should be carried out. Tendons that are missing or beyond repair are replaced by tendon grafts or are excised, if not critical. Traction should be applied to the proximal tendons to ensure no other sites of adherence exist.

Measurement of improved range of motion yielded the degree of improvement when the extensor tendons were involved. However, when the tendons involved were in the forearm, the measurement was imprecise. All of these patients (2, 4, and 11) had sustained concomitant injuries that had nothing to do with the tenolysis but that interfered with the end result. Nevertheless, the salutary effect of the procedure was revealed by the outcomes questionnaire scores obtained (Table 3). Despite the severity of their injuries, the 3 patients were able to resume gainful employment (patient 2 as a farmer, patient 4 in lighter work as a packer, and patient 11 as a punch press operator).

Apart from the inaccurate measurement method, a major flaw of this type of clinical study is that every case is different and there is no precise control group. However, 7 cases had had prior unsuccessful tenolysis and therefore served as their own controls. The only difference from the previous surgery was the insertion of a flap for gliding. Furthermore, it is unlikely that patients who have been operated on several times in the same area or who need further bone grafting or fixation have tissue left for gliding (Fig. 8). Nevertheless, we recognize that a controlled trial between interpositional vascularized fat flaps and conventional tenolysis would be ideal. Cases of such severity are rare, however, which makes such an ideal difficult to attain.

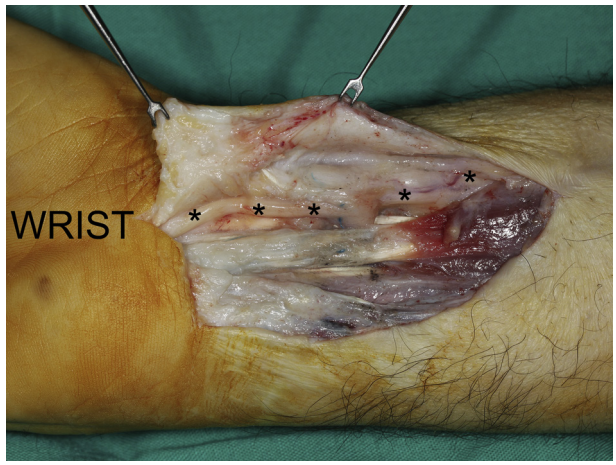

FIGURE 8: Severly scarred bed in a patient with a frozen hand. Typically, structures are barely identifiable. Notice the thickness of the skin flaps, mirroring the quality of the fat and areolar tissue all around. The degree of local devascularization is also evident in the median nerve (asterisks), showing the lack of any vessel on the area of the crush (case 11, the same patient as in Fig. 6).

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