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Functional reconstruction in large and complex soft tissue defects of forearm and hand with multifunctional anterolateral thigh flap

Önkol ve eldeki geniş ve kompleks yumuşak doku kayıplarının anterolateral uyluk flebi ile fonksiyonel onarımı

Kaan Gideroğlu, M.D.,[1] Hüsamettin Çakıcı, M.D.,[2] Serkan Yıldırım, M.D.,[3]
Şükrü Yazar, M.D.,[1] Tayfun Aköz, M.D.[3]

Department of [1]Plastic and Reconstructive Surgery, [2]Orthopedics and Traumatology,
Medical Faculty of Abant Izzet Baysal University, Bolu, Turkey;
[3]Department of Plastic and Reconstructive Surgery, Dr. Lütfi Kırdar Kartal Training and Research Hospital, İstanbul, Turkey

Objectives: The aim of this study was to evaluate the results of free anterolateral thigh (ALT) flap reconstruction for large and complex soft tissue defects of forearm and hand.

Patients and methods: Thirteen patients (11 males, 2 females; mean age 32.5 years; range 18 to 55 years) underwent free ALT flap reconstruction for forearm and hand defects. The etiology of defects was crush injury in nine patients, tumor excision in two patients, electric burn in one patient, and unstable scar excision in one patient. In five patients a flow through ALT flap was used to reconstruct vascular defects. In tree patients a vascularised fascial ALT flap was used to reconstruct the tendon defects and in five patients neurosensory ALT flap was used. Patients were followed for 44±14.6 months. Chen classification was used to evaluate functional outcomes at the end of the postoperative first year.

Results: All flaps survived completely in 11 patients. In the other two patients marginal necrosis was observed. These areas with necrosis healed after debridement and daily dressings. The functional results were satisfactory in 11 patients according to Chen classification (6 patients Chen I and 5 patients Chen II) and poor in two patients (Chen III).

Conclusion: The anterolateral thigh flap represents an excellent option for covering various complex defects in the forearm and hand. The flap provides a thin, pliable, vascularized tissue for covering the exposed tendons, nerves, bones, and reconstruct deficiencies.

Key words: Complex forearm and hand defects; functional hand reconstruction, soft tissue coverage; tumor.

Amaç: Bu çalışmada önkol ve eldeki geniş ve kompleks yumuşak doku eksikliklerinin serbest anterolateral uyluk (ALU) flebi ile onarım sonuçları değerlendirildi.

Hastalar ve yöntemler: Ön kolda ve elde kompleks ve geniş doku kaybı olan 13 hastaya (11 erkek, 2 kadın; ort. yaş 32.5 yıl; dağılım 18-55 yıl) serbest ALU flep ile onarım yapıldı. Hastaların dokuzunda doku kaybının nedeni ezilme yaralanması, ikisinde tümör çıkarılması, birinde elektrik yanığı ve birinde unstable skar dokusu çıkarılmasıydı. Beş hastada arter defektini onarmak için flow through ALU flep, üç hastada tendon defektlerini onarmak için vaskülarize fasya ALU flebi beş hastada ise nörosensöriyal ALU flebi kullanıldı. Hastalar 44±14.6 ay boyunca takip edildi. Fonksiyonel sonuçlar ameliyat sonrası birinci yılda Chen sınıflaması kullanılarak değerlendirildi.

Bulgular: On bir hastada flepler tam olarak yaşadı. Kalan iki hastada ise flep kenarlarında yer yer minimal nekroz oluştu. Nekroze olan bu alanlar debride edildikten sonra pansumanla iyileşti. On bir hastada fonksiyonel sonuçlar tatminkarken (6 hasta Chen I ve 5 hasta Chen II), iki hastada kötüydü (Chen III).

Sonuç: Anterolateral uyluk flebi, çeşitli kompleks ön kol ve el defektlerinin kapatılmasında mükemmel bir seçenektir. Tendon, sinir ve damarsal yapıların üzerinin kaliteli bir dokuyla kapatılmasının yanında bu dokuların eksikliklerinin onarımını da sağlar.

Anahtar sözcükler: Kompleks ön kol ve el defekti; fonksiyonel el onarımı, yumuşak doku örtüsü; tümör.

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• Correspondence: Kaan Gideroğlu, M.D. Abant İzzet Baysal Üniversitesi Tıp Fakültesi Plastik ve Rekonstrüktif Cerrahi Anabilim Dalı, 14280 Gölköy, Bolu, Turkey. Tel: +90 374 - 253 46 56 / 3373 Fax: +90 374 - 253 46 15 e-mail: kaangideroglu@hotmail.com

Functional hand reconstruction in complex tissue defects is a challenging problem to be solved. Immediate soft tissue coverage is needed, especially if tendons, nerves, bones and vascular structures are involved, to prevent infection and further tissue loss.[1] The regional flaps, including the reverse radial forearm and posterior interosseus flaps, cannot occasionally be used in extensive soft tissue injuries due to their inadequate size and injury to their pedicles.[1] Groin flap or abdominal flaps are alternative to regional flaps.[2,3] However, they require a two-staged operation, longer immobilization period and fixation to the groin or chest and abdomen. In complex upper extremity defects, free tissue transfer is the preferred technique.[4,5] The usage of several free flaps including the radial forearm, anterolateral thigh (ALT) flap, scapular fasciocutaneous flap and rectus abdomis and latissimus dorsii muscle flap have been reported in the literature.[6] The anterolateral thigh flap has gained popularity in the last decade for the reconstruction of soft tissue defects located in the head and neck and extremities and it is considered by some to be the ideal flap for soft tissue reconstructions.[7] The aim of this study was to evaluate the thirteen patients, in whom simultaneous large skin and tendon or nerve or artery defects were reconstructed with a multifunctional ALT flap in the forearm and hand and the functional results obtained from these patients.

PATIENTS AND METHODS

In this cross-sectional descriptive study between 2002 and 2007, we used the ALT flap in 13 cases (11 males, 2 females; mean age 32.5 years; range 18 to 55 years) to cover the hand and wrist defects. The etiology of defects was crush injury in nine cases, electric burn in one case, tumor excision in two cases and unstable scar excision in one case. The dorsal and the palmar aspects of the hand and forearm were involved in six and seven patients respectively. Other affected structures and tissues are presented in Table I.

The treatment of the crush and burn injuries consisted of the debridement of devitalized tissues. After the surgical debridement, the bone stabilization and tendon repair were performed. In patients operated for skin tumor or unstable scar tissue, the tendon repair followed the tumor or scar excision. Tendon repairs were performed primarily in five cases, by tendon grafts in seven cases and by tendon transfers in one patient. A vascularized fascia segment of the ALT flap was used as a tendon graft for the reconstruction of the tendon defects in two patients and as a double layered gliding surface surrounding the tendons in one patient. Nerve injuries were repaired primarily with the epineural suture technique in four cases, and by sural nerve grafts in four other cases. The average size of the ALT flaps was 11x16 cm. In five patients, an ALT flap was used as a flow-through flap to reconstruct vascular defects (two ulnar artery, three radial artery). The lateral femoral cutaneous nerve was included into the ALT flap that was used as a neurosensory flap in five patients. Chen classification was used to evaluate functional outcomes at the end of the first year (Table II).[8]

Surgical technique

All operations were performed by two surgical teams. One of them prepared the flap while the other prepared the recipient area. The detection of the main perforating vessel, planning and dissection of the flap have been described previously.[7,9-12] A line was drawn between the anterior iliac spine and the midpoint of the superolateral border of the patella. The intermuscular septum between the vastus lateralis and rectus femoris muscles was also located with palpation (Fig. 1a). Near the midpoint of the above-mentioned line, the main perforating vessel and/or vessels were detected with a handheld Doppler probe (Dopplex D900 ®Huntleigh Healthcare Inc., NJ, and U.S.A) and mapped. The patient was placed in a supine position. A preliminary template was prepared according the size of the proposed defect. The template was inserted over the mapped perforators properly and flap margins were marked. An incision on the medial margin of the flap was made first down to the deep fascia. The flap was elevated to the midline in the subfascial plane for identification of perforators. The largest of the perforators was selected (Fig. 1b). Dissection began at the medial border of the flap and the dissection plane was chosen according to the fascial need. If a vascularised fascial graft was required, the dissection was performed into the subfascial plane under the tensor fascia lata. If a vascularised fascial graft was not required, then the flap was dissected suprafascially and the dissection plane was altered to the subfascial plane close to the perforating vessels (approximately 2 cm away from the vessels). All

TABLE I

Summary of the patients

No	Age/sex	Flap size (cm)	Injured structures	Complications	Functional results	Follow-up period (month)
1	42/M	6x12	Tendon, skin	–	Chen I	24
2	55/M	11x14	Tendon, skin	–	Chen I	34
3	18/M	10x14	Tendon, nerve, vessel, skin	Partial graft loss	Chen II	55
4	35/M	12x18	Bone, tendon, nerve, vessel, skin	Partial graft loss	Chen I	72
5	27/M	10x20	Tendon, nerve, vessel, skin	–	Chen II	38
6	40/M	13x16	Bone, tendon, nerve, skin	–	Chen III	44
7	32/M	12x20	Tendon, nerve, vessel, skin	Marginal flap loss	Chen II	37
8	20/M	11x10	Bone, tendon, skin	–	Chen I	60
9	34/M	10x16	Bone, tendon, nerve, vessel, skin	–	Chen II	60
10	40/F	14x17	Bone, tendon, nerve, vessel, skin	Marginal flap loss	Chen I	48
11	21/F	11x15	Tendon, skin	Partial graft loss	Chen II	36
12	39/M	9x15	Tendon, skin	Partial graft loss	Chen I	22
13	20/M	14x19	Bone, tendon, nerve, skin	–	Chen III	42

Chen: Chen classification.

mapped perforators were isolated and one or two of them were selected as the flap vessel according to their location and diameter. Other perforators were blocked with microvascular clamps. The clamped perforators were divided after the viability of the flap was checked and the retrograde dissection of selected perforators to the descending branch of the lateral circumflex femoral artery was performed (Fig. 1c). The motor nerve of the vastus lateralis muscle accompanying the vascular pedicle was identified and preserved. Dissection of the pedicle was continued until a sufficient length was obtained (Fig. 1d). If the flap was planned as a sensate flap, the lateral cutaneous nerve was found and included in the flap. The flap pedicle was transected after the flap circulation was checked for 10-15 minutes. A negative pressure drain was placed into the intermuscular septum. The donor site was closed with split thickness skin graft if primary closure could not be achieved.

RESULTS

Patients were followed for 22 to 72 months (mean: 44±14.6 months). All flaps survived totally except for two, in which only marginal necrosis was observed. These necrotic areas were treated by surgical debridement and daily dressings. The operation time ranged from four to nine hours with an average of six hours according the extent and complexity of the defect. Flap donor sites were closed primarily in four patients. Partial thickness skin graft was used in nine patients to reconstruct the donor site.

Partial skin graft failures occurred in four donor sites. All of them were treated with daily dressings. The duration of the hospital stay ranged from 12 to 36 days with a mean of 17±6 days. Protective sensibility was regained in all flaps within 12 months. In two flaps, a secondary debulking was needed under local anesthesia. As a secondary procedure, a tendon transfer was per-

TABLE II

Functional evaluation according to Chen classification[8]

Grade I	Ability to resume original work. Joint motion 60% of normal. High grade recovery of sensibility, without excessive intolerance of cold. Muscular power of 4 to 5 on a scale of 1 to 5.
Grade II	Ability to resume some gainful work, but not the original work. Joint motion 40% of normal. Recovery of near normal sensibility without severe intolerance of cold. Muscular power of grades III to IV.
Grade III	Independence in activities of daily living. Joint motion 30% of normal. Poor but useful recovery of sensibility. Muscular power of grade III.
Grade IV	Tissue survival but with no recovery of useful function.

formed in three patients, tenolysis in two patients, wrist arthrodesis in one patient and neurolysis was performed in one patient. Satisfactory functional results were obtained in 11 patients (Chen I, n=6 and Chen II, n=5; Fig. 2a-d, 3a-d) whereas poor (Chen III) results were obtained in the remaining two patients (Table I). The aesthetic results were evaluated as acceptable in all patients except for one young woman.

DISCUSSION

The reconstruction of soft tissue defects of the hand becomes particularly more complex if an injury of the other hand structures such as the tendons, nerves, bones and vessels are accompanying these defects.[1] One-staged repair techniques permitting and providing early mobilization are desired methods.[1,2] Although there are multiple modalities, including local flaps and locoregional flaps to reconstruct hand defects, their surface area is limited to large defects and their vascular pedicles are usually in the trauma zone.[1-4]

In our study, the anterolateral thigh flap provided a large, thin and pliable skin to reconstruct the large and complex forearm and hand defects with a good functional outcome. Both the free fasciocutaneous flap and the muscle flap can be used for the reconstruction of large complex forearm and hand defects.[1] But when a muscle flap is used, donor site morbidity is inevitable since it requires the sacrifice of a muscle. Fasciocutaneous flaps seem to be more advantageous when compared with muscle flaps if functional muscle transfer is not required.[1] Moreover, muscle flaps lack sensation and may undergo fibrosis and scarring, which complicate secondary surgical procedures such as a tenolysis.[13] Although fasciocutaneous flaps do not cause any functional loss, they also have their own disadvantages: The radial forearm fasciocutaneous flap is a well-known and used flap in hand reconstruction,[14,15] but the drawbacks of this flap are the sacrifice of the radial artery and cosmetically unacceptable contour deformity at the donor site when compared with the ALT flap.[1,14,15]

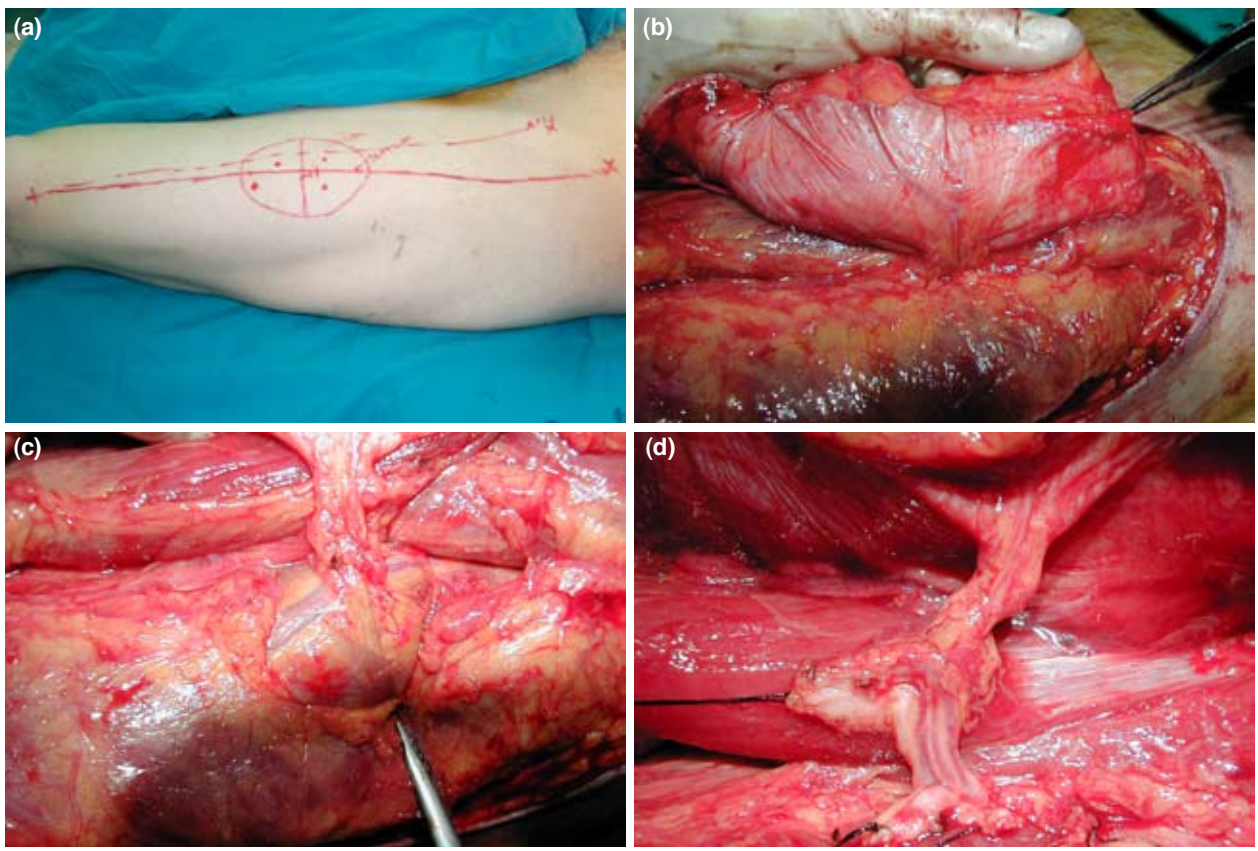

Figure 1. (a) Preoperative planning of the flap, **(b)** identification of the main perforator, **(c)** descending branch lateral circumflex femoral artery and accompanying veins and nerve is seen in intramuscular septum, **(d)** the view of the pedicle before separating from the donor site.

The scapular flap is another fasciocutaneous flap choice, which is not appropriate for a two-team approach since it is harvested in the lateral decubitus position. Moreover, its texture is not as good as the ALT flap for hand reconstruction because of its thick skin and subcutaneous tissue.[1] The lateral arm flap is among the most recommended flaps for upper extremity reconstructions and is used for small to moderate sized upper extremity defects.[1,16,17] Constant vascular anatomy, good skin texture, good vessel diameter for vascular anastomosis, ease of flap dissection and not needing to sacrifice a major artery are among the advantages of this flap.[1,16,17] Besides, two teams may work simultaneously when this flap is used for a forearm and hand reconstruction. On the other hand, it is smaller in size than the ALT flap and does not have a vascularized tendon segment as large as the ALT flap,[1] so that this size is often not adequate for larger defects and the flap does not have enough vascularized tendon segments if more than one tendon injured. Donor site scarring is another major disadvantage of the lateral arm flap, when compared with the ALT flap having a better concealed donor site.

In the chimeric flap principle, the ALT flap can be combined with the adjacent muscles and fascia lata.[10-12] The flap is potentially sensate when the lateral cutaneous nerve is included in the flap and it has a long vascular pedicle with a large diameter. Donor site morbidity is minimal, and the scar is easily concealed.[10-12,18,19] Furthermore, from the same donor area, an additional nonvascularized fascia lata strip graft can be taken in any size required for the reconstruction of multiple tendon defects. The vascular anatomy of the flap is suitable to reconstruct the vascular defects in extremities and it can be used as a flow-through flap.[1,8,11,18] In our series, five ALT flaps were used as flow-through flaps and the reconstruction of the vascular defects without any vein grafts could be achieved successfully in these cases. Through this way, the operating time and vascular donor-site morbidity were reduced

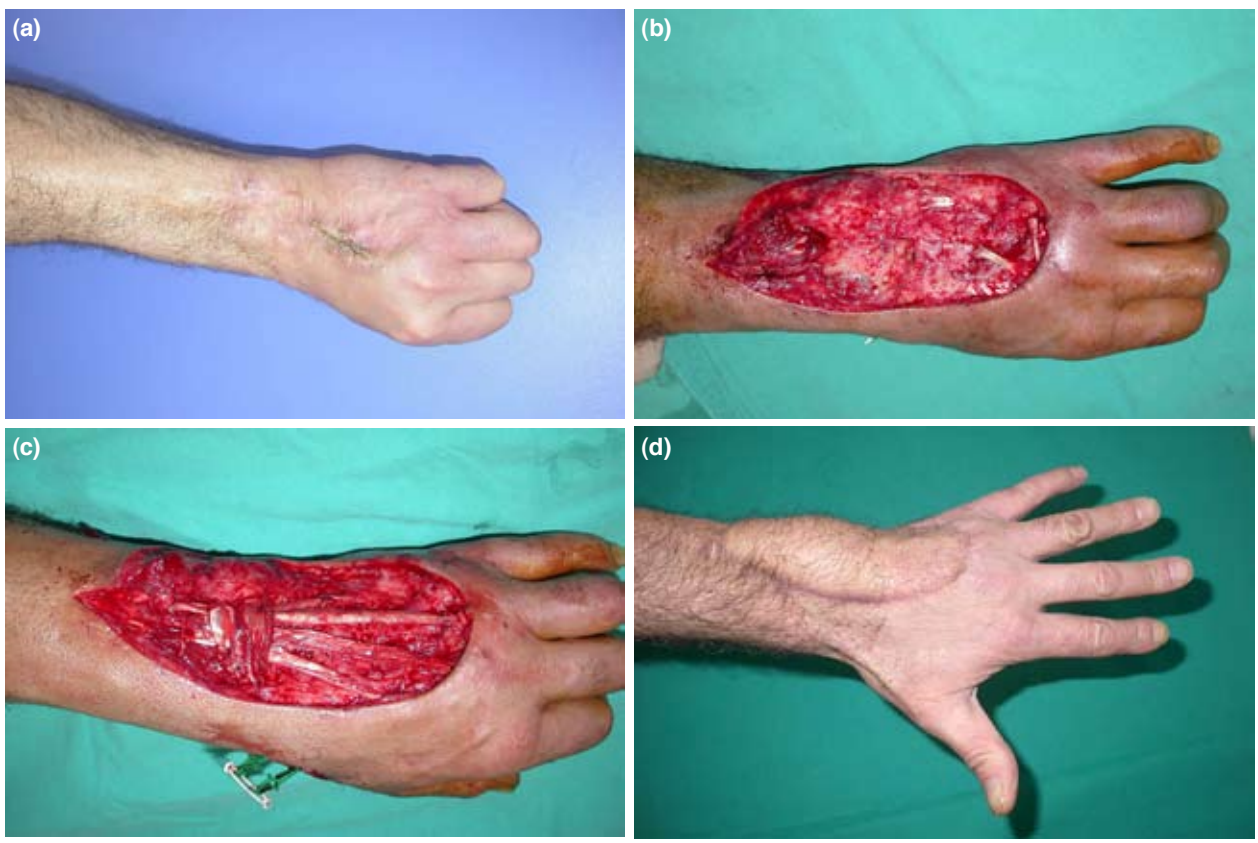

Figure 2. (a) Preoperative view of unstable scar, **(b)** The tendon defects due to previous injury and skin defect due to unstable scar excision are seen, **(c)** The view of the defect after tendon and extensor retinaculum repairs accomplished with tendon grafts from tensor fascia lata, **(d)** Funcional outcome one year after the surgery by reconstruction with a double layered vascularised fascial ALT flap.

and the circulation in the injured extremity was augmented.

The constant, thick, and vascularized fascial component of this flap provides a good gliding surface to the tendons and it can also be used as a vascularized tendon graft to repair tendon defects.[12,18] The fascial component of the ALT flap was used as a vascularized tendon graft in two patients and as a double-layered gliding surface in one patient, in which the functional outcome was good. In flaps used as a sensate flap, protective sensation was recovered earlier than non-sensate flaps. When compared to the other free flap alternatives, the latter is very advantageous in the repair of combined tendon, nerve, vessel, and skin defects since it can be used in the simultaneous reconstruction of these defects. Accordingly, we think that this flap should be called a "multifunctional flap". The ALT flap was used successfully as a multifunctional flap in the combined defects of tendons, vessels, nerves, and skin in our cases. The scar at the flap donor site could be well-concealed and functional impairment at the donor extremity was very minimal. In this series, the operation time was shorter since two operating teams could work simultaneously. Additionally, durable soft tissue could be provided although the defects were complex and large. Secondary surgical procedures could also be performed easily because there was no fibrosis or scarrin.

The limitation of this study was related to the small number of the patients involved. However, we chose to enroll to this study only patients who had large and complex defects in the forearm and hand, instead of all the patients who had upper extremity reconstructions with an ALT flap.

In conclusion, the anterolateral thigh flap represents an excellent option for covering various complex defects in the forearm and hand. The flap not only provides a thin, pliable, vascularized tissue for covering the exposed tendons, nerves, bones, and vascular structures, but it also provides additional tendon, vessel and nerve sources to reconstruct deficiencies. The long term functional and aesthetic results are good in our series. We recommend the ALT flap as the first choice for the reconstruction of

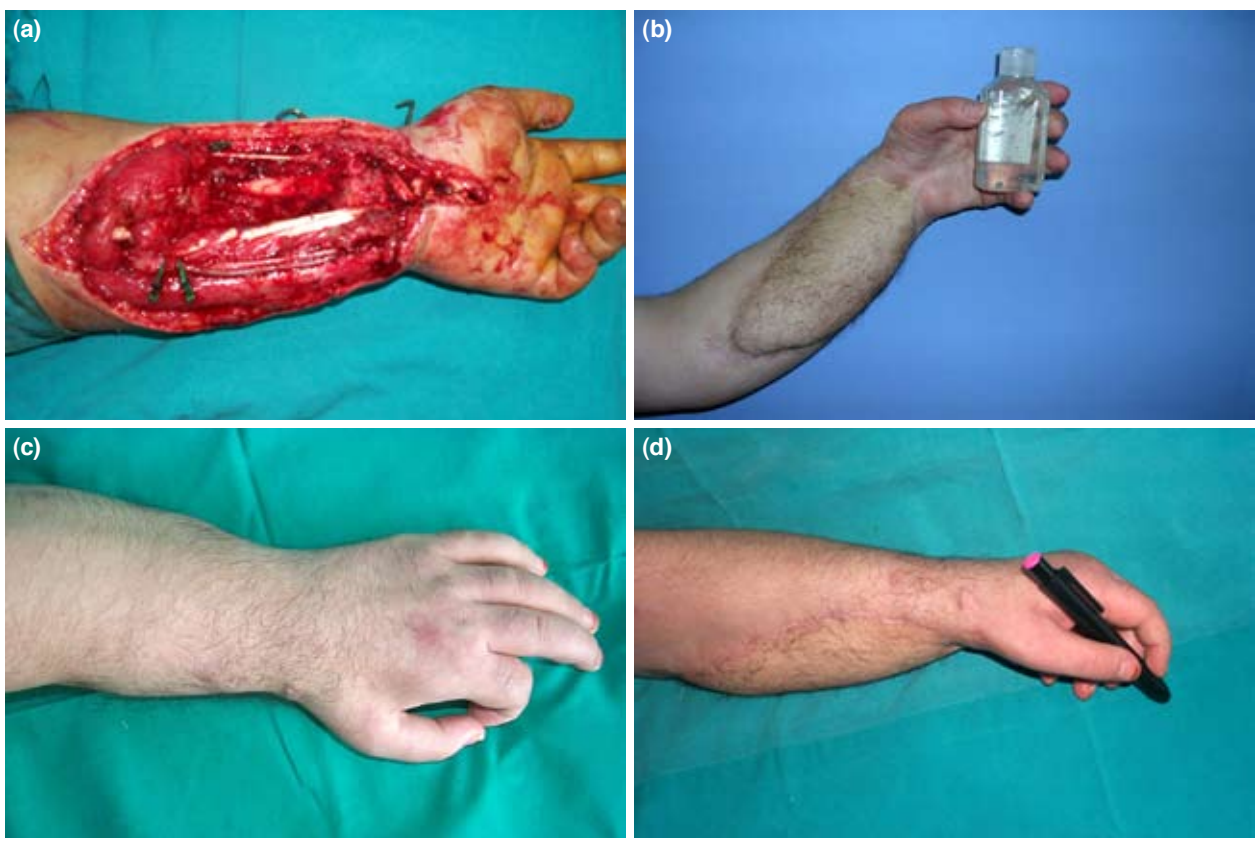

Figure 3. (a) The view of the severely injured left forearm after radical debridement. **(b-d)** The good functional outcome in the first postoperative year after reconstruction with a flow through ALT flap.

complex and large defects of the forearm and hand with combined tendon, nerve and vascular defects to achieve a good and functional outcome.

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