



# Single-Stage Extensor Digitorum Tendon Reconstruction, Including Overlying Soft Tissue Defects of the Foot Dorsum with a Composite-Free Anterolateral Thigh Flap

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## Abstract

**Background** Loss of the extensor tendon with overlying soft tissue remains a complex reconstructive challenge. Successful reconstruction combines tendon repair with defect coverage by soft tissue flaps, meets the goals of approaching functionality, and achieves an esthetic result.

**Patients and Methods** From June 2016 to June 2022, our center submitted six patients to a one-stage procedure correcting the extensor tendon and skin defect using a composite-free anterolateral thigh (ALT) flap with fascia lata (FL).

**Results** The ALT skin paddle was from 10 × 8 cm to 26 × 13 cm, and all flaps included vascularized FL with an average of 12 × 9.5 cm, which was split and folded to reconstruct as a tendon. The extensor digitorum brevis tendon defects were reconstructed by fascia sheets in all patients. One patient had additional reconstruction of the extensor hallucis longus tendon. All the flaps survived completely, and no complication was reported. All patients received rehabilitation therapy starting in the third week postoperatively. The mean follow-up was 33.67 months (range, 10–60). The mean arc of ankle rotation between dorsiflexion and plantar flexion was 49.20 degrees (range, 40–55 degrees). After reconstruction, our patients showed good functional results, and these patients could walk, climb stairs, tiptoe again without support, and regular footwear could be worn.

## Keywords

- ▶ anterolateral thigh flap
- ▶ fascia lata flap
- ▶ foot dorsum
- ▶ extensor tendon defects
- ▶ soft tissue defect

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**Conclusion** A composite-free ALT flap with vascularized FL is a reasonable option for coverage of the extensor tendon and overlying soft tissue defects. It helps reduce the surgical risk and hospitalization time and provokes faster recovery and rehabilitation.

**Level of Clinical Evidence** Case studies, Level 4.

A massive in-depth injury in the foot dorsum, including loss of the extensor tendon with overlying soft tissue deficiency, brings difficulties to the reconstruction that demands the wound not only be covered but also be functional.<sup>1,2</sup> The management of each component can be achieved by single- or multistages, depending on the injury level and the surgeon's experience. Due to the complexity of the damage, it is sometimes tricky for conventional local or pedicle flaps to meet the requirement, and free tissue transfer is a reasonable choice for coverage of foot dorsum defects.<sup>3-5</sup> A composite-free anterolateral thigh (ALT) flap can achieve an excellent result of Achilles reconstruction with a fascia lata (FL) that combines simultaneous transfer of vascularized fascia and skin island. It also has the advantages of higher resistance to infection, faster healing, fewer adhesions, and better gliding capability.<sup>6,7</sup> The composite ALT flap with vascularized FL is a suitable treatment for reconstructing foot and ankle defects.<sup>8,9</sup> To the best of our research, there has been no report yet on the reconstruction of both extensor tendons and overlying soft tissue defects of the foot dorsum with a composite-free ALT flap. So, in this article, we want to present our experience reconstructing these structures in a single stage using a composite-free ALT flap with vascularized FL.

## Patients and Methods

From June 2016 to January 2022, six patients (two males and four females), ranging from 17 to 47 years old, underwent tendon reconstruction using a composite ALT flap. All the patients had no smoking history or comorbidities. The average body mass index (BMI) was 22.23 kg/m<sup>2</sup> (range, 20–24.03 kg/m<sup>2</sup>). Injury mechanisms were as follows: car accidents in four patients and burns in two patients. The average size of skin defect was 14.3 cm in length (range, 8–25 cm) and 8.67 cm in width (range, 6–12 cm). The anatomical injury area was the dorsum combined with the anterior ankle in three patients, dorsum and plantar defect in two patients, and only one dorsum defect singularly. All patients presented with loss of the extensor brevis tendon; one had an additional loss of the extensor hallucis tendon. There was a 7.67-cm average size of tendon loss (range, 7–8 cm). All patients underwent thorough initial debridement and bone fixation with K-wires. Then, the vacuum-assisted closure (VAC) system was applied for extra help until the subsequent reconstruction operation. The patency of the anterior and posterior tibial vessels was evaluated before surgery using a portable Doppler and angiography (computed tomography angiography or magnetic resonance angiography).

## Operative Technique

We designed a composite ALT flap and FL flap to reconstruct extensor tendons and soft tissue defects simultaneously. The patients were in supine position, and a straight line was drawn between the anterior superior iliac spine and the superolateral border of the patella on the donor's thigh. The line was then divided into 16 parts, and a circle with 2.5 cm radius was drawn around the midpoint. Next, we used a handheld Doppler to locate and map the perforators. We designed an appropriate outline of the skin paddle for the skin defect. An incision was started on the medial side of the skin flap. The dissection continued in the subfascial plane until the descending branch of the lateral circumflex femoral artery (LCFA) and its perforators were located. We then chose one or two perforators from the descending branch for the composite flap, including the skin paddle and FL flap. The perforator was then dissected to expose it freely. Based on the size of the defect, we harvested ALT and FL flaps with one or two perforators centered on the flap. A rectangular design is outlined for the strip of FL. The size of this strip, in length, is calculated by the length of the tendon defect. To effectively reconstruct the extensor tendon on both sides, the FL was taken approximately 2 cm longer than the length of the tendon loss. In width, the strip of FL is the same as the skin paddle. The FL is then incised and dissected from the subcutaneous tissue in both ends, approximately 3 cm each. The flap pedicle was then ligated from the descending branch of LCFA, and the composite flap was elevated completely.

The flap was transferred to the recipient site, and end-to-end or side-to-end anastomosis was performed to the anterior or posterior tibial vessel. The anastomosis was performed before inserting the flaps into the defect. After confirmation of blood reperfusion, we reconstructed the extensor tendon. Each end of the FL was folded two or three times to create a tendon-like structure and then subsequently attached to the remaining tendon (extensor digitorum brevis tendon [EDBT] or anterior tibia tendon) using 2–0 Prolene simple interrupted sutures. The distal end of FL was separated into three to five strips, and each strip was folded and sutured to the distal remaining EDBT. Finally, the skin paddle covered the skin defect, and silicone drainage was applied. All the donor sites can be closed primarily or by skin graft. Postoperatively, the ankle was immobilized in 90 degrees dorsiflexion for 3 weeks, and then a passive motion started, followed by a dynamic range of movement during the next week. Patients can walk again after 3 to 4 weeks.

## Results

The detailed information and reconstruction results are shown in ►Table 1. The ALT skin paddle was from

**Table 1** Patient data

| Pt. | Sex/<br>age (y)<br>Side | Etiology     | Previous<br>surgical<br>Procedures | Position of<br>skin defect | Size of<br>STD<br>(cm) | Extensor<br>tendon<br>injured | TD<br>size | Flap size<br>(cm) | FL size | Pedicle<br>length<br>(cm) | Number of<br>perforator | Type of<br>anastomosis | Result    | AAR    | Follow-up<br>(mo) |
|-----|-------------------------|--------------|------------------------------------|----------------------------|------------------------|-------------------------------|------------|-------------------|---------|---------------------------|-------------------------|------------------------|-----------|--------|-------------------|
| 1   | M/39<br>R               | Burn         | Debridement                        | Dorsum                     | 7 × 10                 | 2, 3, 4                       | 8          | 8 × 10            | 10 × 12 | 8                         | 1                       | ATA<br>End to end      | Excellent | 55 deg | 12                |
| 2   | F/25<br>L               | Crush injury | Debridement<br>VAC                 | Dorsum<br>Anterior ankle   | 6 × 8                  | 2, 3, 4                       | 8          | 8 × 10            | 10 × 10 | 8                         | 2                       | PTA<br>End to end      | Excellent | 45 deg | 48                |
| 3   | F/23<br>L               | Crush injury | Debridement<br>VAC                 | Dorsum<br>Plantum          | 8 × 14                 | 1, 2, 3, 4                    | 8          | 8 × 16            | 11 × 12 | 8                         | 2                       | ATA<br>End to end      | Good      | 40 deg | 24                |
| 4   | F/17<br>L               | Crush injury | Debridement<br>VAC                 | Dorsum<br>Plantum          | 7 × 14                 | 2, 3, 4, 5                    | 7          | 8 × 15            | 9 × 11  | 9                         | 1                       | ATA<br>End to end      | Good      | 50 deg | 60                |
| 5   | F/47<br>L               | Crush injury | Debridement<br>VAC                 | Dorsum<br>Anterior ankle   | 12 × 25                | 2, 3, 4, 5                    | 7          | 13 × 26           | 8 × 14  | 10                        | 2                       | ATA<br>End to end      | Good      | 50 deg | 48                |
| 6   | M/41<br>L               | Burn         | Debridement                        | Dorsum<br>Anterior ankle   | 12 × 15                | 2, 3, 4                       | 8          | 13 × 18           | 9 × 13  | 11                        | 3                       | ATA<br>End to end      | Good      | 55 deg | 10                |

Abbreviations: AAR, arc of ankle rotation between dorsiflexion and plantar flexion; ATA, anterior tibial artery; F, female; FL, fascia lata; M, male; Pt., patient number; PTA, posterior tibial artery; STD, soft tissue defect; TD, tendon defect; VAC, vacuum-assisted closure.

10 × 8 cm to 26 × 13 cm, an average of 15.8 × 9.7 cm. Otherwise, the FL flaps ranged from 9 × 11 cm to 11 × 12 cm, averaging 12 × 9.5 cm. The mean length of the pedicle was 8 cm (range, 7–9 cm). The extensor digitorum brevis tendon defects were reconstructed by fascia sheets in all patients. Two others also had different reconstructions of the extensor hallucis longus and extensor tendon of the fifth digit. The perforator was anastomosed in an end-to-end fashion in all six patients. The selected recipient vessels were anterior tibialis in five patients, with only one patient using the posterior tibialis vessels. All the flaps survived completely, and no complication was reported. The donor site was closed primarily in four patients, and in two patients with larger flaps, a skin graft was used. All patients received rehabilitation therapy starting in the third week postoperatively. The mean follow-up was 33.67 months (range, 10–60). The mean arc of ankle rotation between dorsiflexion and plantar flexion was 49.20 degrees (range, 40–55 degrees). All patients could stand and walk in their daily activities.

**Case Reports**

**Case 1**

A 39-year-old man (nonsmoker with a BMI of 22.9 kg/m<sup>2</sup>) presented with a stage 3 burn on the foot dorsum. After debridement, the skin defect measured 10 × 7 cm, and the extensor brevis tendon was lost at digits II to IV. An 8 × 10 cm ALT flap and 10 × 12 cm FL flap were harvested from the contralateral leg. The microvascular anastomosis was made between the flap pedicle and the anterior tibial vessels. A rolled FL strip was sutured to both central and peripheral remnants of the EDBT to perform tendon reconstruction. After 2 weeks, rehabilitation therapy could be started, followed by active movement with active mobilization. After 10 months, activity was excellent, with good foot plantar flexion. The skin flap was thin enough and did not require a secondary correction (►Fig. 1).

**Case 4**

A 17-year-old girl (BMI index of 21.3 kg/m<sup>2</sup>) was admitted for a left foot injury due to a car accident. Skin defect size was 7 × 14 cm, including the dorsum and anterior ankle, and a 7-cm extensor tendon loss from digits II to IV was identified. A composite ALT flap with 8 × 15 cm skin islands and FL 9 × 11 cm was harvested. An end-to-end microvascular anastomosis was performed on the posterior tibial artery. FL was split into four strips and sutured to the end of the remaining EDBTs. These patients could walk, climb stairs, and stand on their toes without support.

**Discussion**

The integrity of the anterior ankle structure ensures a good foot flexion function. The main muscle involved in foot extension is the tibialis anterior, which is long, large, and has the most suitable mechanical advantages. The extensor digitorum longus, extensor hallucis longus, and the peroneus tertius support this muscle. The extensor digitorum brevis



**Fig. 1** Case 1. (A) A 39-year-old man was presented with a stage 3 burning in the foot dorsal, including loss of the extensor digitorum tendons II to IV. (B, C) The composite ALT and FL flaps were harvested for the covering the skin defect and the repair of tendons II to IV. (D) Postoperative result 3 days. (E, F) After 12 months of follow-up. ALT, anterolateral thigh; FL, fascia lata.

and extensor digitorum longus muscles synergize in toe flexion. And when injured, it can lead to increased flexion to the sole due to the hypertonia of the muscles in the plantar. The skin in the foot dorsum is thin, with less subcutaneous tissue, making it more vulnerable and more challenging to recover when injured. Trauma in this area has increased exposure to deep structures, such as bones, tendons, nerves, and other tissues. This exposure quickly leads to infection, osteomyelitis, and tissue necrosis without proper covering. This complex wound represents a significant challenge for plastic surgeons.<sup>3,4</sup> Debridement and VAC are sometimes required to treat a complex injury with deep tissue exposure before reconstruction starts.<sup>5</sup> The complex skin and tendon loss injury can be reconstructed in single- or multistages. Multiple-staged operations increase the risk of complications such as infection, wound dehiscence, contracture, and prolonged rehabilitation time. And so that one-stage reconstruction is much preferable if available, as it helps obtain better functions, including improved range of movement, reduces surgical risk, reduces hospitalization time, and sooner the patient returns to the original life.

The distal pedicled fasciocutaneous flap of the calf or distally based lateral supramalleolar adipofascial flap was used to cover skin defects of the foot.<sup>10–13</sup> As microsurgical techniques progressed, free tissue transfer revealed unexplored possibilities for coverage of foot defects.<sup>14</sup> Song et al first described the ALT flap in 1984.<sup>15</sup> The ALT has low donor-site morbidity, ease of harvest, and versatility, so it has become the workhouse flap for soft tissue reconstructions from head to toe. This flap is mainly harvested as a fasciocutaneous type, including FL, overlying adipose tissue, and skin.<sup>8,9,16,17</sup> It can also be harvested in chimeric flap type to increase the flexibility in covering foot and ankle defects.<sup>18,19</sup> Much research about the perfusion of the FL has shown that it has a reliable vascular supply, which enables the harvest of a free FL flap.<sup>20,21</sup> The FL as a fascial component of the ALT flap is preferred particularly for tendon reconstruction of lower and upper limbs. The composite ALT with FL flap is a good option for better reconstruction of knee extensor and Achilles and overlying skin defects.<sup>22–27</sup> A chimeric ALT with an FL flap can be defatted and shaped during a primary procedure.<sup>6,7</sup> So far, a literature search revealed no previous



**Fig. 2** Case 4. (A) A 17-year-old girl was admitted for left instep injury due to a car accident. Loss of the extensor digitorum II to IV and the extensor hallucis longus. (B) The composite ALT and FL flaps were harvested. (C) Postoperative view. (D) After 2 years of follow-up. ALT, anterolateral thigh; FL, fascia lata.

reports of a single-stage reconstruction with a composite-free ALT flap for the extensor tendon and overlying soft tissue defects of the foot dorsum. The composite ALT and FL flaps were associated with a fascial and a skin paddle component, which both have the same perforator vascularization and came from the descending branch of LCFA. In this technique, the vascularized FL flap will become a tendon substitute and have the advantages of early and rapid healing, higher infection resistance, and increased tendon mobility, ultimately in a single operation.

The FL sheet design is performed along the thigh axis. As the elevation of the composite flap, FL adheres to the center of the skin paddle. The length of the FL token is usually shorter than the skin paddle; however, the FL width is harvested as the same as the skin paddle so that we can reconstruct as many tendons as possible simultaneously. The fascia is dissected from the skin paddle at two ends of the flap, and the proximal part will be rolled up and fixed to the center end of the remaining tendon. The distal portion is split into two to four strips and sutured to the end of each remnant digitorum tendon. All the fascia strips are folded into a tendon-like structure. We prioritize reconstructing the digitorum tendon to the first four digits, as these are responsible for the extensor function of the foot. When fixing the tendon, we flexed the foot at 90 degrees and determined that the FL length was enough to stretch and not be redundant. Tendon reconstruction is performed after the reperfusion of the flap. The size of the ALT skin paddle is estimated to cover the entire skin defect. The skin flap covering is not too tight to prevent flap necrosis, and it is also not redundant to avoid a thick flap, which affects the extensibility of the ankle.

There was no complication registered. The patients started to practice increasing ankle mobility from the third week, exercise to complete range from weeks 4 to 6, and altogether removing the splint, strength training from weeks 7 to 12. Evaluation of the movement range of the dorsiflexion and plantar flexion showed promising results. All the patients could walk, climb stairs, and tiptoe again without support; regular footwear could be worn.

The limitation of this study is that the composite ALT flap, in some cases, especially for women, is quite thick. Thick flaps affect the esthetic results and motor function of the ankle, which the thickness affects walking. Secondary thinning can be performed to ensure the esthetics of the foot. As

the skin flap and fascia share a common vascular pedicle, it is impossible to do primary thinning in the first operation. Only when using chimeric ALT flap type with free FL flaps, we can do the flap thinning method.

## Conclusion

The composite-free ALT flap with vascularized FL offers a reliable option for a single-stage extensor tendon reconstruction, including the overlying soft tissue defects. This flap makes the recovery process faster, reduces surgical risks, and the patients can quickly return to normal life activities sooner. We suggest that a secondary procedure for flap thinning in the female individual is sometimes necessary to achieve more esthetic and functional results.

## Ethical Approval

This study was performed in line with the principles of the Declaration of Helsinki. This study was approved by the Research Ethics Committee of our institution.

## Informed Consent

Informed consent was obtained from all individual participants included in the study. The authors confirm that human research participants provided informed consent for publication of the images in ►Figs. 1 and 2.

## Funding

None.

## Conflict of Interest

None declared.

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