# Overcoming Soft-Tissue Deficiency in Toe-to-Hand Transfer Using a Dorsalis Pedis Fasciosubcutaneous Toe Free Flap: Surgical Technique

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Reconstruction of combined finger and soft-tissue defects poses a technical surgical challenge. We present our experience with a hybrid flap: the dorsalis pedis fasciosubcutaneous-toe free flap. In a single stage, this flap solves the problem of medium-sized defects associated with digit losses in the hand. Donor-site morbidity has been minimal. (J Hand Surg 2005;30A:111–119. Copyright © 2005 by the American Society for Surgery of the Hand.)

**Key words:** Dorsalis pedis flap, hand coverage, metacarpal hand, microsurgery, toe-to-hand.

The association of finger loss and skin defect is not uncommon. For very small defects or under rare circumstances a skin graft may be acceptable. Otherwise a skin flap in combination with the toe transfer would be required. The most logical and straightforward approach—reconstruction in one stage with a single flap by harvesting the toe in continuity with skin web or a dorsalis pedis flap[1–9]—might result in intractable foot problems in the form of ulcerations, hyperkeratosis, recurrent infection, and pain.[10–12]

Leading investigators such as Chuang et al,[13] Wei,[14] Lister et al,[15] and May[16] recommended providing the hand stump with abundant skin by means of a pedicled groin flap in a first stage, later to be tailored during the digital transfer. Very few investigators have performed the reconstruction in a single stage by transferring 2 free flaps[17] because this was considered too risky and vessels available were limited. A single-stage reconstruction strategy was proposed by St-Laurent and Lanzetta.[18] They used an extended wrap-around but avoided donor site problems by covering the foot defect with an immediate lateral arm flap.

Willemart et al[12] described a conjoined flap[19] that

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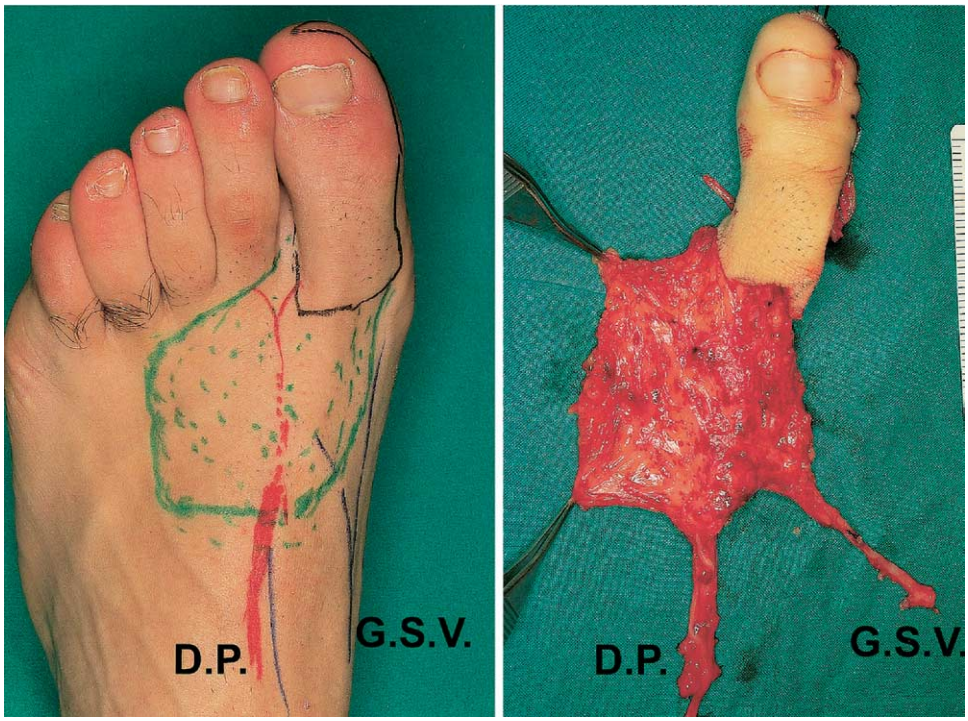


**Figure 1.** Preoperative markings (left) and elevated (right) of a first trimmed toe-DPFSC flap (case 4). DP, dorsalis pedis artery and venae comitantes; GSV, origin of the great saphenous vein.

included the skin of the dorsum of the foot and the toe in the same vascular axis, but spared the web's skin, which in their opinion was the main source of foot sequelae. This flap much improved the situation; however, the dorsum of the foot was included with the flap and this in itself is a well-known source of iatrogenic morbidity.[11]

Ismail[20]introduced the dorsalis pedis fasciosubcutaneous (DPFSC) flap as a pedicled flap for coverage around the ankle. The flap includes the tissue underneath the dermis and above the extensor tendons and was pedicled on the dorsalis pedis artery and vena comitantes. A skin graft was used for covering the flap. To date no other refinements have been presented apart from its use as a free flap and in combination with an extensor digitorum brevis muscle.[21] Our purpose is to present a hybrid flap, including transferred toe plus fasciosubcutaneous extension, that allows single-stage toe-to-hand transfer with minimal morbidity.

## Surgical Technique

Before surgery the presence and location of the first dorsal metatarsal artery is studied with a unidirectional Doppler probe. In every case we used the method of Banis[23] of leaning the Doppler probe toward the sides in an attempt to investigate the location and depth of the first metatarsal artery. We do not use angiography. Preoperative anteroposterior radiographs of the donor foot (posteroanterior weight bearing of the toes) and posteroanterior and lateral radiographs of the normal and the injured hand are taken. Next the proper length of the proximal toe phalanx is measured. Any length discrepancy should be compensated to achieve a smooth digital arcade.[24] The flap size then is estimated by assessing the defect present in the hand and tissue covered by unyielding scar. It should be pointed out that the cover of the skin of the toe does not surpass the middle of the proximal phalanx volarly.

The design of the flaps includes the designated toe and the estimated proximal extension of FSC flap. Additionally the latter can be directed to one or the other side in relation to the transferred toe to match the hand defect (Fig. 1). The skin included with the toe never surpasses the classic limits, that is, for a second toe or a first-trimmed toe the web on the sides, and even less for a tandem second and third toes,[25] so as to allow primary closure at the web.

Under tourniquet and after exsanguination of the leg by elevation the FSC portion of the flap is first raised. A zig-zag incision is made on the dorsum of

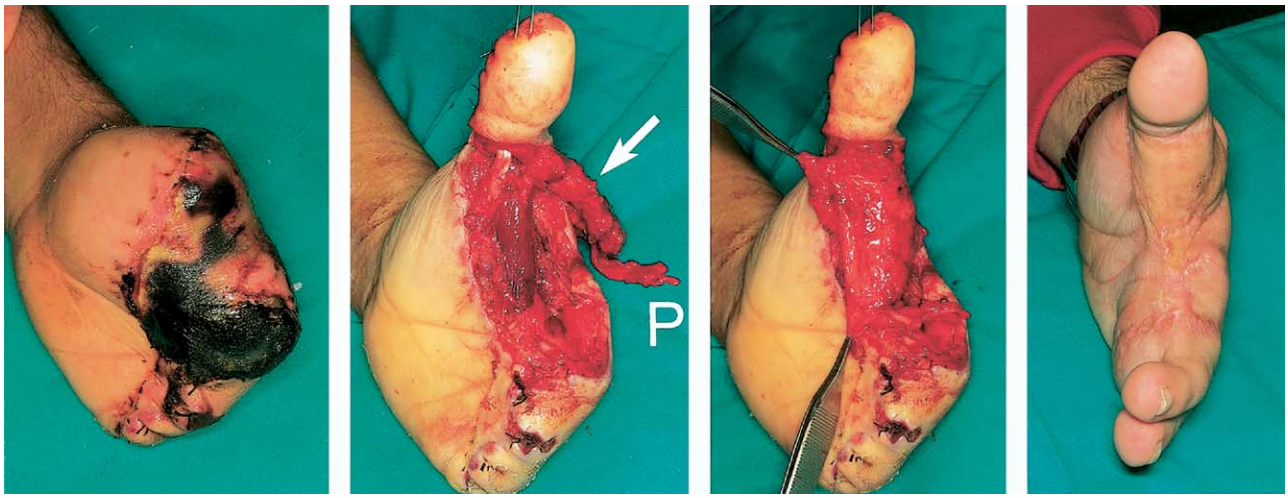


**Figure 2.** (A) Preoperative condition at referral (case 4). On the left the stump is covered by a necrotic flap evolving to dry gangrene. (B) The first toe is now in position and the large palmar defect with exposure of tendon repairs and nerve repairs is seen clearly. The FSC flap lies behind (arrow). P, pedicle. (C) The flap has been swung around to cover all the palmar structures. (D) Full-thickness skin graft was used to cover the fasciosubcutaneous portion of the flap.

the foot over the first web with a knife and dermal flaps are elevated to at least .5 cm more than the outer limits of the planned flap to allow for some retraction. These dermal flaps are composed of the dermis and the superficial layer of veins and are the mainstay of the procedure. Proximally the donor artery is isolated for the required length (see later). Vena comitantes also are isolated and traced but in most cases a large subcutaneous vein was relied on as the main drainage. Once the vessels are isolated the dissection of the flap proceeds by deepening at the sides and the flap is elevated toward the first web by following the plane above the peritenon of the extensor tendons. Once the first web is approached utmost care should be taken not to cross the web from one side to the other, leaving the first dorsal metatarsal artery behind, because this error may entail flap necrosis. This risk is higher when the artery is partially covered by the fascia or muscle of the first dorsal interosseus (Gilbert types IB, IIA, IIB).[26] To overcome this difficulty the first dorsal metatarsal artery is located both at its take-off point from the dorsalis pedis (or deep plantar) proximally and dorsal to the intermetatarsal ligament distally. The surgeon then proceeds safely by elevating the artery under visual control going proximally and/or distally until it is included fully with the flap. Once the FSC portion is isolated the dissection of the toe proceeds in the usual manner. Great care is taken not to include too much fat around the distal communicating artery to ensure an aesthetic fit when transferred to the hand. The first plantar metatarsal artery then is ligated. Proximally the dorsalis pedis or first dorsal metatarsal artery and the veins are dissected as necessary. In our experience, the donor artery has been the dorsalis pedis in 4 cases and the first dorsal metatarsal has been the donor artery in 2 cases. The surgeon should take into account that flap adaptation to the recipient site may place the vessels at some distance from the planned anastomotic area, and this should be compensated by dissecting some extra length of donor vessels. There is a substantial amount of dissectable pedicle available.

The tourniquet is deflated at this stage to assess the blood supply to the toe, the FSC flap, and the dermal foot flaps. Bleeding at the edge of the dermal flaps always is noticed. Profuse oozing also is noticed throughout the surface of the flap. The flap is transferred and revascularized by anastomosis to the radial artery end-to-side with the dorsalis pedis or end-to-end to a common palmar digital artery when using the first dorsal metatarsal artery. The venous drainage always should be accomplished by at least one subcutaneous vein of the dorsum of the foot, supplemented in some cases with a vena comitante or another large subcutaneous vein distant to the first. The decision to perform more than one venous anastomosis is done taking into account the availability in the recipient site or, in the case of a larger flap, to supplement the venous drainage.

Covering of the fat is performed by thick or full-thickness skin grafts taken from the groin. The latter

**Figure 3.** The pliability of the web can be appreciated in this postoperative picture. The palmar portion of the second and third tandem toe was covered by wrapping the flap and applying a meshed skin graft, which does not match the skin as well as the other flap that was covered by a full-thickness skin graft.

is used to minimize retraction and to improve appearance for web or dorsal defects (Figs. 2, 3).

The dermal foot flaps are approximated in a single layer with a nonresorbable intradermal stitch. A suction drainage is placed in the space corresponding to the first web. A dorsal plaster slab immobilizes the foot for a week (Fig. 4).

Eventual incisional necrosis of the edges of the wound, although uncommon, may happen. In our experience (see Discussion section) they do not cause any residual morbidity. They should be managed conservatively. Patients should be seen every week and advised to take a shower every day and change the dressing (wet to dry). Once the wound is debrided spontaneously it should be dressed with petrolatum gauze until fully closed. Normal walking was allowed at 7 to 10 days regardless of the condition of the wound.

**Figure 4.** Donor site at 1 year.

## Discussion

Finger amputation and skin deficiency are common after trauma and pose a reconstructive challenge. The surgeon has to provide coverage with a flap because skin grafts alone are tolerated poorly in the hand and the foot alike. The problem is compounded because the skin cover of the second toe just reaches the distal half of the proximal phalanx on the sides, so the skin deficiency is always much larger than expected.[15] Lastly the hand is a prime aesthetic area, and after the face it is the most exposed part of the body. Hand coverage requires a like tissue (extra thin and pliable skin): chunky flaps have no role.

The dorsalis pedis fasciosubcutaneous-toe flap fulfills the criteria of including a toe and of being an extra thin flap. Additionally it has several advantages over the classic dorsalis pedis-toe counterpart. The dermal foot flaps allow good tendon excursion and skin gliding. This helps to dissipate the shearing forces that a graft directly applied over the periosteum would bear, such as in the classic dorsalis pedis flap (video 1 can be viewed at the *Journal's* Web site, www.jhandsurg.org). This has been related to chronic ulceration and shoe-wearing limitations.[11] Furthermore not having dermis makes the flap more pliable for easy contouring to the complex tridimensional hand defects. This decrease in stiffness allows the flap to adapt nicely to the contour of the finger on flexion. On the other hand the flap has to be skin

**Table 1. Demographics and Surgical Details**

| Case | Age (y) | Occupation | Toe | Flap Size (cm) | Requirements | Gilbert Type | Artery Donor ⇒ Recipient | Vein Donor ⇒ Recipient | Skin Graft Loss, % | Donor Site Complications |
|---|---|---|---|---|---|---|---|---|---|---|
| | 26 | Mechanic | Second toe | 7 × 6 | Cover defect | IB | DPA ⇒ RA (E-S) | GSV ⇒ Cephalic vein (E-S)<br>PeronSubc ⇒ Dorsal Subc (E-E) | 20 | Edge necrosis |
| | 25 | Press operator | First trimmed toe | 4.5 × 2 | Cover defect | IA | DPA ⇒ RA (E-S) | Subc vein ⇒ Cephalic vein (E-S) | 0 | None |
| | | | Second toe | 3.5 × 4.5 | Lengthening | IIB | FDMA ⇒ second PCDA (E-E)<br>SDMA ⇒ digital (E-E) | Subc vein ⇒ Dorsal Subc. (E-E) | 0 | None |
| | 19 | Machine operator | First trimmed toe | 6.5 × 5.5 | Cover defect | IB | DPA ⇒ RA (E-S) | GSV ⇒ Cephalic vein (E-S)<br>VC ⇒ Dorsal Subc V (E-E) | 0 | None |
| | | | Second and third tandem | 5 × 4.5 | Lengthening | IB | FDMA ⇒ 4° CPDA (E-E) | Subc vein ⇒ Dorsal Subc (E-E) | 0 | Minimal edge necrosis |
| | | | | | | | SPMA ⇒ 3° CPDA (E-E) | FDMA (vc) ⇒ Palmar vein (E-E) | 0 | |
| | | | | | | | TPMA ⇒ 2° CPDA (E-E) | | | |
| | 66 | Housework | Second toe | 3 × 2.5 | Lengthening | IA | DPA ⇒ RA (E-S) | Subc vein ⇒ Dorsal Subc. (E-E) | 0 | None |
| | | | | | | | SPMA ⇒ 4°CPDA (E-E) | | | |

DPA, dorsalis pedis artery; RA, radial artery; E-S, end-to-side; GSV, great saphenous vein; Peron Subc, subcutaneous vein on the fibular side of the foot; Dorsal Subc, one of the available dorsal veins of the hand; E-E, end-to-end; Subc Vein, one of the intermiddle layer of dorsal foot veins; FDMA, first dorsal metatarsal artery; CPDA, common palmar digital artery; SDMA, second dorsal metatarsal artery; VC, vena comitantes; SPMA, Second plantar metatarsal artery; FPMA, first plantar metatarsal arteries; TPMA, third plantar metatarsal artery.

**Figure 5.** Worst donor site. From left to right: preoperative design (the flap is actually larger by 1 cm in all directions), at 4 weeks, and at 1-year follow-up evaluation (case 1). The skin glides over the bones and tendons (see video 1 on the *Journal*'s Web site, www.jhandsurg.org).

grafted and does not behave as a skin flap: it retracts. For this reason we do not recommend it for areas where any retraction could be a problem such as for correcting a first web contracture.

We have performed 6 free DPFSC flaps in 4 patients. They were performed in combination with a second toe (3 times), a first-trimmed toe (2 times), and a tandem second-third toe transfer (1 time) (Table 1). Two patients sustaining severe mutilating injuries received 2 flaps each (the transfers were separated by a week). All flaps except one were performed in the acute or subacute period. When they were transferred the stumps still were open or covered by necrotic flaps because no attempt was made previously to debride the stumps, on the contrary they were kept covered by the necrotic tissue in an attempt to avoid dissecation and further tissue loss.[22] The aim of the FSC flap was to cover an associated major defect in 3 cases, and/or to wrap the toe's proximal phalanx aiming to increase the length of the transferred toe in the remaining cases.

All 6 flaps survived in their entirety with no vascular complications. Partial skin graft loss of less than 20% occurred in 1 patient but did not require regrafting. The donor site healed primarily in 4 patients, however, in 2 patients partial necrosis at the wound edges occurred and healed by secondary intention closing in 4 and 7 weeks. The delay in donor site healing has been a nuisance but never a source of sequela. It should be emphasized that no tendon or vital structure stood under the area of the skin edge necrosis.

After a follow-up period of 1 to 5 years no complaints from the donor site or ulcerations have been registered. In every case it was possible to glide the skin and dermis over the tendon and bones underneath (see Fig. 5; also video 1 on the *Journal*'s Web site, www.jhandsurg.org). In the recipient area the goal of providing coverage was met in all cases.

Crucial to minimizing donor-site complications is to appreciate that the dermal foot flaps are super thin flaps[27,28] and behave as a flap not as a graft: they are composed of the dermis, a small amount of fat, and the superficial layer of veins (Fig. 6).[29] Hence too much thinning, for the sake of benefiting the fasciosubcutaneous portion, may compromise the blood supply of the dermal flap, entailing major necrosis. To help in this part of the dissection we have found it very useful to raise the dermal flaps with a cold knife, using the hair follicles as a landmark of the thickness of the dermal flap at the beginning.

Raising the DPFSC-toe combination does not take longer and is no more complex than a classic toe harvesting. The difficulty and time spent in dissecting the FSC portion is compensated by the easier dissection around the first dorsal metatarsal artery

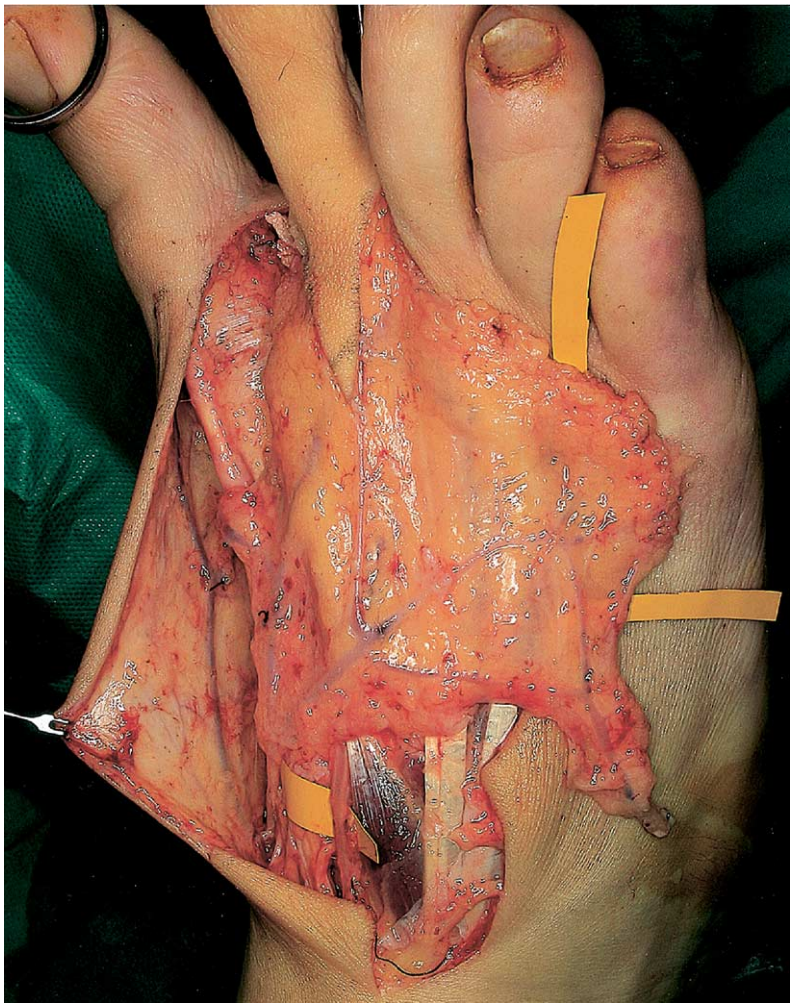

**Figure 6.** The flap composed of a second toe and the fasciosubcutaneous dorsalis pedis is now elevated and lies on its bed just before tourniquet release (case 1). The tibial dermal flap (elevated with a hook) includes a small amount of fat, the hair follicles, and the layer of superficial veins.

and distal veins. In a classic toe harvest the artery and veins need to be skeletonized very distally and tiny side branches need to be ligated. In the DPFSC many of those tiny branches actually go into the flap, and no time is wasted on its dissection–ligation. Additionally the pedicle is more protected by fat, so one can use the bipolar forceps with certain impunity, with much less risk for damaging the main pedicle or causing spasm.

The largest sized flap in this series was 7 × 6 cm, although we have had experience with flaps including all the FSC dorsum of the foot with total survival. This is not surprising if one takes into account the microarterial anatomy of the flap[30] and the vascular territory of the flap.[31]

Sacrifice of the dorsalis pedis could be avoided in 2 patients: feeding the flap by the first dorsal metatarsal artery only; obviously this modification is applicable only when a small flap is required. Finally, care should be taken to make sure that the first dorsal metatarsal artery is present and is located superficially or in between the first interosseus muscle (Gilbert types I or IIA and B).[26] If the first dorsal metatarsal artery is absent then the flap is unusable because the blood supply to the fasciosubcutaneous portion may be insufficient. We have not needed to resort to angiography but found the article by Banis[23] sufficient to assess the presence and approximate location of the first dorsal metatarsal artery. Furthermore we have moved over the years from the large vessels (such as the dorsalis pedis) to the small arteries[9] (first or second dorsal metatarsal arteries, first, second, or third plantar metatarsal arteries, or even digitals) if recipients have been available. The multiple anastomosis policy may be unnecessary[32] but they

might have the same effect as the artifice of including multiple arterial branches feeding the toe distally isolated on a common trunk proximally as described by Foucher[33,34] with much less destruction to the foot. Arterial foot anomalies also should be considered when planning this flap. The most common is the aberrant dorsalis pedis coming from the anterior branch of the peroneal artery.[21,35] We think that even this scenario, however, would not be a contraindication for using this flap. It is customary to ascertain the presence of the posterior tibial artery before sacrificing the dorsalis pedis: a positive Doppler at the medial malleolus while occluding the dorsalis pedis on the dorsum of the foot is sufficient in most instances. Venous drainage has been accomplished by a subcutaneous vein and at times supplemented by another or by vena comitantes. We believe that it is wise when using larger flaps to have a dual venous drainage, although we have insufficient data to support this statement.

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