Adipofascial, Transposition, and Rotation Flaps

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INTRODUCTION

Dorsal defects of the digits pose a unique challenge for reconstruction. The skin is thin, and any damage or defects would immediately expose the underlying extensor tendon, bone, and joint. Early soft tissue cover is important to avoid permanent damage to the critical structures beneath.

Anatomy of the finger is unique with thick glabrous skin on the palmar side and thin, pliable skin on the dorsum. There is an elaborate network of vessels crossing over from each side of the proper digital artery to the back of the digit. Numerous local skin flaps have been described based on this vascular network. These flaps can be divided based on their movement into transposition and rotation flaps and on their composition into skin and adipofascial flaps. Local flaps like transposition, rotation, and perforator-based local flaps provide stability but lack the mobility and pliability features of adipofascial flaps.

A layer of adipofascial tissue lies between the dorsal skin and the extensor tendons, containing the dorsal veins within. This layer is the basis of an adipofascial flap. It is a flexible layer that can be folded to add bulk and fill dead spaces. The vascular basis of this flap is the branches of the proper digital artery and its anastomoses with the dorsal metacarpal system. These flaps can be designed as proximally based, distally based, or laterally based. These flaps need to be covered with a skin graft, and the excellent vascularity usually results in good take of the graft. The other advantage of this flap is the minimal donor site morbidity as compared with regular skin flap.
The design of transposition and rotation flaps on the finger usually requires some modification to the classical design because the fingers are cylindrical compared with the flat surfaces over the trunk, limbs, or the face. Longitudinal defects exposing tendons or bones can be covered with a long unipedicled transposition flap or a bipedicled straplike flaps from uninjured sides. However, these flaps need skin grafting for the donor defects. Small circular defects around the joints can be easily covered by rotation flaps.

**HISTORICAL PERSPECTIVE**

Hynes\(^1\) in 1954 showed that deepithelialized skin, when turned upside down, will readily take as a free graft. Ivan Pakiam\(^2\) in 1973 applied the same principle and used reverse dermis flaps to cover defects over dorsum of digits, ankle joint, dorsum of the foot, and even a deltopectoral defect following a forelimb avulsion. Erdogan Atasoy\(^3\) in 1978 has been using the same principle to reconstruct full-thickness dorsal skin defects with reverse cross finger flaps. Thatte and colleagues\(^4\) in 1982 also used these turnover flaps to cover defects over the palmar aspect of the fingers. The formations of epithelial cysts, as a result of buried hair follicles, were seen following the use of deepithelialized skin which has led to the modification in 1991 by Lai,\(^5\) who used random pattern adipofascial turnover flaps without deepithelializing. Most of these flaps were designed to cover semicircular or ovoid defects. Yii and Elliot\(^6\) described the homodigital bipedicle strap flap that used the uninjured dorsolateral tissues of the digits to cover longitudinal defects over the dorsum of digits.

The classical description of dorsal digital arteries running longitudinally and supplying the skin over the dorsum of proximal phalanx seen in older anatomic texts was challenged by Levame and colleagues\(^7\) in 1967. They proposed that the proper digital arteries give rise to obliquely running branches supplying the entire length of the dorsal skin of the fingers. Based on these findings, Smith in 1982 described an obliquely oriented sliding flap to cover the dorsal skin defects.\(^8\)

Numerous studies came up in the second half of the twentieth century describing the dorsal arterial system.\(^9-11\) In 1990, Strauch and de Moura\(^12\) proposed that the dorsal skin vessels are constantly present, branching from the proper digital artery. They concluded that the skin over the dorsum of each phalanx has the potential to be used as a pedicled flap. Braga-Silva and colleagues\(^13,14\) established that there were 2 constant dorsal branches that originated from the proper digital artery in the proximal and middle phalanx at fixed distances from the proximal interphalangeal joint. Vuppalapati and colleagues\(^15\) in 2004, through their clinical and cadaveric studies, highlighted the utility of the reverse dorsal digital artery flap to cover more distal defects on the dorsum of fingers.

**INDICATIONS AND CONTRAINDICATIONS**

Indications:
- Defects over dorsum of the fingers extending from the metacarpophalangeal joint to the tip of the fingers up to 20 × 10 mm in size
- Exposed joints
- Mid lateral defects
- Complete or partial pulp loss

Contraindications:
- Underlying comminuted fractures of the phalanges
- Fingers with compromised vascularity
- Partial degloving injuries
- Smokers

**VASCULAR ANATOMY**

On the dorsum of the finger, the extensor tendon lies closely opposed to the bone. Overlying the tendon is a vascularized layer of paratenon. Between the paratenon and dorsal skin lies a highly vascular and pliable adipofascial layer. This layer provides a gliding surface and is supplied by well-defined dorsal branches from the proper digital artery at specified intervals.

The vasculature of the dorsal surface of the fingers can be divided into 3 zones as suggested by Endo and colleagues.\(^16\) The terminal branch of the dorsal metacarpal artery and the dorsal branches of the proper digital artery form the source vessels. The 3 zones are as follows:

1. The region over the web and the metacarpal head.

   Two dorsal digital arteries arise from the dorsal metacarpal artery, one for each adjacent digit, at the level of metacarpophalangeal joint. These arteries join the proximal dorsal branch of the proper digital artery at the midpoint of the proximal phalanx.

2. The dorsum of the proximal phalanx.

   The proper digital artery gives rise to the proximal dorsal branch at the midpoint of the proximal phalanx just distal to the proximal finger crease. The size of the proximal dorsal branch is 0.3 to 0.6 mm. A distal dorsal branch arises from the proximal digital palmar arch, at the neck of the proximal phalanx.
3. The dorsum of the middle phalanx.

The proximal dorsal branch in this region arises from the proper digital artery at the level of the proximal third of the middle phalanx. The size of this artery is 0.3 to 0.5 mm. The distal dorsal branch arises from the distal digital palmar arch that is formed by an anastomosis between the radial and ulnar proper digital arteries. The distal dorsal branch gives rise to 2 notable branches, one forming an arch over the nail matrix and the other supplying the skin over the distal interphalangeal joint.

Strauch and de Moura\textsuperscript{12} studied the arterial system of the fingers in 141 human cadavers. According to them, the branches of the proper digital artery followed a consistent branching pattern in the proximal and middle phalanx. Each proper digital artery has a condylar branch, a metaphyseal branch, a dorsal skin branch, and the transverse palmar arch. The proximal and middle phalanx has a proximal and distal transverse palmar arch in close relation to the C1 and C3 cruciate pulleys, respectively. This pattern becomes a complex one in the distal phalanx, where there are proximal, middle, and distal nail matrix arches (Fig. 1). In summary, there are 2 groups of dorsal branches arising from the proper digital artery, arranged proximal and distal to the proximal interphalangeal joint.

In a cadaver study of 144 fingers, Braga-Silva and colleagues\textsuperscript{14} showed that the vascular system of the dorsum of the finger consisted of 3 dorsal branches of the proper digital artery over the proximal phalanx and 2 over the middle phalanx. The first dorsal branch over the proximal phalanx was inconsistent.\textsuperscript{14} The second dorsal cutaneous branch was consistently present 10 mm proximal to the proximal interphalangeal joint in all fingers. The mean diameter of this branch at its origin was 0.3 mm. The third dorsal cutaneous branch lies 4 mm proximal to the proximal interphalangeal joint. The 2 dorsal cutaneous branches over the middle phalanx lie 7 and 12 mm distal to the proximal interphalangeal joint, respectively. They concluded that defects in the middle and distal phalanges could be covered with flaps based on these dorsal cutaneous branches.

Flaps raised in close proximity to the nail fold must ensure the preservation of branches arising from the digital arteries approximately 10 mm proximal to the eponychial fold. Delia and colleagues\textsuperscript{17} showed that dissection distal to this point would hamper the vascular supply of the flap. Earlier Strauch and de Moura,\textsuperscript{12} have also stressed that the branch traveling from the middle transverse palmar arch, up to meet the proximal matrix arch, must be taken into account, in order to better preserve the vascularity of the skin.\textsuperscript{12}

**ADIPOFASCIAL FLAPS**

Two types of adipofascial flaps have been described in the literature to cover the dorsal digital defects. The random type adipofascial turnover flap described by Lai and colleagues\textsuperscript{18} is harvested from the dorsum of the injured digit and has its base along the edge of the defect. The flap can be used as a heterodigital or homodigital turnover flap and is safe as long as a length-to-breadth ratio of 1:1.5 is maintained. A pedicled type adipofascial turnover flap, described by Voche and Merle,\textsuperscript{19} is based laterally on one of the dorsal branches of the proper digital artery (Fig. 2).

**Surgical Technique**

This flap is raised under tourniquet control. The wound over the dorsum of the finger is debrided thoroughly in 3 dimensions. The depth of the wounds especially over the joints is visualized and washed. If the joint is exposed and unstable or there is loss of central slip, a K-wire is used to stabilize the joint in extension. Any nonviable and undermined edges should be opened up, and the overlying skin is retained because the flap will fill the cavity. The flap is designed to be always

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**Fig. 1.** Vascular anatomy of the finger showing branches of the vessel.
more than the size of the defect in order to fill the cavity and the undermined edges. The length-to-breadth ratio of the flap is generally 1:1.5 if elevated as a random pattern flap and as 1:2, when elevated based on one of the dorsal branches of the proper digital artery proper (Fig. 3).

The initial skin incision can be made along the midlateral line or in the midline. The authors prefer the midlateral incision to avoid the adherence of the extensor tendons to the overlying suture line, which is encountered with dorsal midline incisions. The midlateral incision also allows the scar to be relatively concealed. In addition, exposure of critical structures following skin necrosis at the suture line can be avoided. A dermal thickness skin flap is raised below the level of hair follicles, leaving the dorsal vein uninjured in the bed. The adipofascial flap is then raised dividing the veins along the edges. The flap is raised superficial to the extensor tendon taking care to leave the paratenon intact, as done in the case of a classic cross finger flap. The flap is dissected until the pedicle is visualized and turned over to cover the defect (Fig. 4). For a wider defect, the flap is based on the source vessel lying along the lateral margin of the flap. The contralateral margin of the flap is divided, and the flap is transposed, rather than turned over. The transposition allows a greater reach of the flap (Fig. 5). It is important to handle this flap in an atraumatic manner. The authors have found that holding the flap with skin hooks instead of forceps reduces the degree of postoperative flap edema.

After flap elevation, the tourniquet is released; the vascularity of the flap is ensured, and hemostasis is achieved. The flap is inset, and the raw surface covered with split skin graft harvested from the ipsilateral forearm. The dermal flap is replaced and secured with 5-0 Prolene sutures. The authors have found that venous drainage and subsequent edema are a problem in adipofascial flaps, especially those with 180° of turnover. However, it will settle down over a period of 7 to 10 days. There may also be small areas of graft loss, but may epithelialize rapidly. When the defect is large, the reach of the flap can be increased by designing it in a curvilinear fashion.

Advantages:
- Simple, reliable, and single-stage procedure
- Pliable and thin; can be turned in any direction
- Minimal donor site morbidity
- Can fill small cavities and dead spaces
- The reach can be extended as per the need and size of the defect
- Sensation develops over a period of time
- Spares the proper digital artery
- Useful in multiple finger defects when traditional options like cross finger flap or neuro-vascular island flaps are not possible

Fig. 2. (A) Defect showing the dorsal composite loss of right ring finger. (B) Adipofascial turnover flap raised based on the vessels along the edge of the defect being turned over. (C) Flap inset into the defect covered with skin graft. (D, E) One year postoperative follow-up showing complete healing.
The amount of skin graft required is smaller, as the dermal flap can be replaced.

Pitfalls:
- Thinner dermal flaps can cause desquamation and later depigmentation of the replaced skin flap
- Including portions of dermis can lead to epidermal cysts
- Skin grafts need to be of moderate thickness
- Early mobilization to prevent stiffness

TRANSPOSITION FLAP

The design of transposition flaps for dorsal defects of the finger is different from other parts of the body because of the cylindrical shape of the finger (Fig. 6). The traditional transposition flap requires triangulation of the defect followed by transposition of the flap. Typically, these flaps cover the primary defect well but require skin graft for the secondary defect. In fingers, the transposition flap can be raised as

- Distally or proximally based
- Laterally based
- Bipedicle

Surgical Technique

Distally or proximally based transposition flap
Surgery is performed under pneumatic tourniquet control and with loupe magnification. Once the defect is created after thorough debridement, a template of the flap is designed based on the size of the defect. The skin flap adjacent to the defect over the dorsum of the same finger is raised superficial to the paratenon, along the midlateral line. In the fingers, the distal extent of the flap has to be designed beyond the defect in order to mitigate the tension generated across the flap.
when the fingers are flexed. The flap is raised with the base proximally or distally and transposed over the defect. The triangular donor defect is skin grafted (Fig. 7). When the secondary defect is narrow, resembling a release incision, it can be left alone and allowed to heal by secondary intention.

Laterally based transposition flap

The difference between laterally based and proximally/distally based flaps is that the base is along the midlateral line on 1 side. The flap is broad enough to cover the defect. The pivot point is along the radial or ulnar lateral border of the proximal phalanx (Fig. 8). Along the base of the flap, small perforator vessels can be seen.

Advantages:
- Easy to raise
- Longer flaps can be raised with the robust blood supply
- Similar color and texture match
- More stable cover
- Preserved sensation

Disadvantages:
- Limited mobility and area that can be covered
- Can expose the extensor tendon and neurovascular structures
- Requirement of skin grafts for donor area resulting in contour defects

ROTATION FLAP

The flap rotates along the defect, and unlike a transposition flap, it does not have a secondary defect that requires skin grafting. Once the defect is marked on the finger, the flap needs to be designed, keeping the arc in such a way that the diameter is at least 3 to 4 times the diameter of the defect. A common mistake is to raise a smaller flap that is unable to cover the defect without significant tension.
Fig. 5. (A) Composite defect with bone and extensor loss over the distal interphalangeal joint. (B, C) Design of flap marked with raised dermal flap and adipofascial flap waiting for turnover. (D, E) Adipofascial flap based on proximal interphalangeal joint level perforator being folded on itself and filling the cavity. (F, G) Flap in situ with closure of dermal defect and split skin graft over the flap. (H, I) Long-term outcome showing well-settled flap.

Fig. 6. (A–C) Raising of the transposition flap.
Fig. 7. (A) Deep aggressive wound with loss of skin over thumb, index, middle, and ring fingers. (B) Transposition flap raised to cover the defects. (C) Long-term outcome.

Fig. 8. (A) Deep grinding machine injury with loss of nail bed complex and skin. (B) Transposition flap marked with base along the sides. (C) Flap inset into the critical area with skin graft of donor sites.

Fig. 9. (A–C) Raising of a rotational flap over dorsum of finger.
It is difficult to raise conventional rotation flaps in the fingers because of a lack of lax skin. Any rotation flap could be considered as having components of both transposition and advancement, and particularly in fingers, it lean toward the transposition end of the spectrum. These flaps are usually used to cover small circular defects over the metacarpophalangeal and interphalangeal joints. When planning a rotation flap, one should keep in mind that a larger flap will be required for defects over the joint to account for the excess skin requirements during flexion (Fig. 9). The lateral rotation flaps are marked with the distal margin extending to the midlateral line. Moving more distal on the dorsum of the finger, the size of the flaps reduces. Once the flap rotates (Fig. 10), there is a small “dog ear” noted along the proximal edge, which can be trimmed. Differential suturing usually permits linear closure of the donor defect in rotation flaps. However, one should not hesitate to skin graft the donor site, if there is excessive tension. A tie-over dressing is applied over the skin graft and will be removed after 7 days.

Advantages:
- Ideal for circular defects
- Avoids skin grafting of donor area
- Pliability of dorsal skin allows free joint movement
- Good vascularity

Disadvantages:
- Not suitable for larger defects

OUTCOMES

In terms of durability, skin flaps are better than adipofascial flaps. Adipofascial flaps do better when there is a need to fill dead spaces. In designing transposition flaps, one needs to consider limited tissue availability, cylindrical nature of the digit, the need to provide a supple and “tension-free” flap that allows good motion, and the donor defect. Even if the vascularity of the far extent of the flap is partially compromised, it has been observed to heal secondarily. Rotation flaps in the fingers are ideally suited for small circular defects and can be raised along the transfer axis. The results are good, but sometimes a back cut or skin grafting may be needed.

REFERENCES