THE KITE FLAP IN THE TREATMENT OF FINGER TIP AMPUTATIONS
Case Report

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ABSTRACT

Background. Fingertip injuries are extremely common. Out of the various available reconstructive options, one needs to select an option which achieves a painless fingertip with durable and sensate skin cover. The present analysis was conducted to evaluate the management and outcome of fingertip injuries. In contrast to amputations of a single finger, bone shortening and wound closure usually should not be considered for thumb soft tissue defects. In general, the thumb should never be shortened. The flap has a consistent arterial supply, good sized veins, and terminal branches of the superficial radial nerve.
Case report. Male 42 years old with traumatic amputation at the right thumb. Suffered since 5 days before admitted to the hospital due to livestock string roll attraction that happens suddenly. There is thumb tip loss at the level of IP joint, bony expose, swelling, skin and soft tissue defect at the level of mid shaft of the proximal phalanx. Radiographic study shown that there is loss of distal phalanx of thumb.
Procedure. The kite flap for thumb tip defect or amputation. Flap is raised from the dorsum of the first phalanx of the index finger, including the metacarpophalangeal (MTP) joint.
Conclusion. The treatment needs to be individualized and all possible techniques of reconstruction must be known to achieve optimal recovery. The results showed preservation of finger length and contour, retention of sensation and healing without significant complication. Thumb tip defects should be aggressively treated to preserve thumb length, which is more important to the thumb's overall contribution to hand function than joint flexibility, in contradistinction to the fingers. Accordingly, the rectangular volar advancement is the preferred option for small thumb tip defects as it brings sensate durable skin to the thumb tip. Larger full-thickness defects of the thumb require sensate resurfacing with either the dorsum of the first phalanx of the index finger or kite flap.

Keywords: Fingertip injury, thumb tip defect/amputation, kite flap.

INTRODUCTION

An amputation is the removal of an extremity or appendage from the body. Amputations in the upper extremity can occur as a result of trauma, or they can be performed in the treatment of congenital or acquired conditions. A person with a fingertip amputation has lost a part of the fingertip, caused by an injury. Amputations may involve the skin, the nail, tissue beneath the skin, or bone.

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In contrast to amputations of a single finger, bone shortening and wound closure usually should not be considered for thumb soft tissue defects. In general, the thumb should never be shortened. The flap has a consistent arterial supply (the first metacarpal artery), good sized veins, and terminal branches of the superficial radial nerve.

PREVALENCE

Fingertip injuries / amputations are extremely common since the hands hold a wide array of objects. In 2001, the approximately 10% of all accidents in the United States referred for Emergency Room consults involve the hand. Hand injuries are frequently the result of job injuries and account for 11–14% of on the job injuries and 6% of compensation paid injuries.

ANATOMY

The fingertip is the portion of the digit distal to the insertion of the flexor and extensor tendons on the distal phalanx. From the periosteum of the distal phalanx, fibrous septae anchor the skin and palmar pulp to the bone. The volar pulp is also stabilized by the Grayson and Cleland ligaments, extending from the flexor sheath and distal phalanx volar and dorsal to the neurovascular bundles, respectively. The volar surface of the fingertips contains grooves and ridges, uniquely patterned for each individual, termed fingerprints.

The digital arteries and nerves arborize or trifurcate near the distal interphalangeal joint. The proper digital artery crosses the distal interphalangeal joint, sending a branch to the nail fold, nail

bed, and finger pad. Each digital nerve trifurcates near the distal interphalangeal joint, sending branches to the perionychium, fingertip, and volar pad. The digital nerves lie volar to the digital arteries near the fingertip. The fingertip is the organ of touch and feel and is abundantly supplied with sensory receptors, including Pacinian and Meissner corpuscles and Merkel cell neurite complexes.

The dorsal surface of the fingertip comprises the nail fold, nail bed, and nail plate. The perionychium includes the entire nail bed and paronychium complex. The paronychium is the skin surrounding the nail plate radially and ulnarly. The eponychium is the epidermal shelf at the base of the nail. The lunula is the white semicircle at the base of the nail bed. The fingernail is a specialized epidermal structure, like hair.

The proximal one third of the nailbed, from the nail fold to the edge of the lunula, is the germinal matrix. It has two components, the dorsal and intermediate nail. The two thirds of the nailbed distal to the lunula is the sterile matrix or ventral nail. Fingernail production occurs in 3 areas of the nailbed, the dorsal nail and intermediate nail of the germinal matrix and the ventral nail of the sterile matrix. Of these areas the intermediate germinal matrix produces 90% of nail volume. The remainder of the nail substance is produced by dorsal nail of the germinal matrix and ventral nail of the sterile matrix.

The dorsal roof of the germinal matrix deposits cells on the nail surface. The two thirds of the nail bed distal to the lunula, the ventral nail or sterile matrix, acts as a conveyor belt for the advancing nail and adds squamous cells to the nail, making it thicker and stronger.4 The nail is not merely attached to the bed but rather is a continuum of a single structure from basilar cells in the nail bed. Nail growth occurs at a rate of 3-4 mm a month. It takes 3-4 months for growth to full nail length and 1 year for the nail to achieve maximal pre-injury smoothness.

REPAIR TECHNIQUES

Multiple repair techniques have been described in the literature, including skin grafts, local or distant flap procedures, and partial toe transplantation. Many of these techniques are complex and can only be performed by specially trained physicians.

MANAGEMENT

The kite flap is raised from the dorsum of the first phalanx of the index finger, including the metacarpophalangeal (MTP) joint. It is considered to be a sensory flap. The main indication for the kite flap is the resurfacing of the dorsal aspect of the thumb. It is also used for the reconstruction of the first web when the defect is limited after release of a contracture.

CASE REPORT

PATIENT HISTORY

- Male 42 years old with traumatic amputation at the right thumb.
- Suffered since about 5 days before admitted to the hospital due to livestock string roll attraction that happens suddenly.
- History of unconsciousness (-), no abnormality of the general condition.

CLINICAL FINDING

- Skin and soft tissue loss at level of mid shaft of proximal phalanx
- Bony expose
- Swelling

PLAIN X-RAY

- Seem bone loss of the right thumb at level of interphalangeal (IP) joint
- Loss of distal phalanx of the right thumb
- No soft tissue swelling

No fracture

LABORATORY INVESTIGATION

- WBC : 11.2 x 10^3/ µl
- RBC : 4.34 x 10^6 / µl
- HGB : 12.1 gram / dl
- PLT : 264 x 10^3/ µl
- GDS : 90 mg / dl
- Urea : 18 mg / dl
- GOT : 22 µ / l
- GPT : 26 µ / l
- CT : 8’00”
- BT : 2’30”

SURGICAL PROCEDURE

1. Design of the flap.

2. Incision to expose the pedicle.
3. Exposing the subcutaneous tissue which contains the branch of the radial nerve and the artery.

4. The neurovascular bundle should not be dissected and should remain included in the subcutaneous tissue.
5. Perform a distally flap based island pedicle kite flap. The flap is outlined over the upper part of the first web.

6. Rotation allows coverage of all the dorsum of the thumb, the first web and palmar aspect of the first phalanx.

7. The donor site is covered by a full-thickness skin graft and the index finger is immobilized with the MTP joint flexed.

FOLLOW UP AFTER 2 WEEKS

DISCUSSION

As the terminal extension of the fingers and hand, the fingertips are the portions of the upper extremity through which we touch, feel, write, draw, and perform activities of daily living. With the advent of new technology, our dependence on our fingertips for everyday living continues to increase, as we more often surf the Internet, program handheld organizers, use smart phones, operate the TV remote control.

The question is much more complicated when there is loss of tissue. The main treatment objectives are:

1. Closure of the wound,
2. Maximize sensory return,
3. Preserve length,
4. Maintain joint function, and
5. Early return to work,
6. Achieve a satisfactory cosmetic appearance,
7. Early prosthetic fitting.

How these goals are achieved will depend on the amount of tissue lost, whether there bone exposed, and which finger is involved. Injuries can be classified according to where the amputation has occurred or whether the injury primarily involves the pulp (soft tissue) or nail bed.

The management of fingertip injuries is complex and not without controversy as a variety of treatment options are available. Goals of treatment in fingertip injuries include preservation of useful sensation, maximizing functional length, preventing joint contractures, providing satisfactory appearance and avoiding donor disfigurement and functional loss.

As fingertip injuries can be treated in different ways their management needs to be carefully individualized. If there is no or minimal tissue loss, the wound can be closed primarily with or without debridement. Healing by secondary intention or open technique by combination of wound contraction and re-epithelialization is applicable to small volarly directed fingertip wounds with no

exposure of bone. This is not preferred for wounds greater than 1 cm as it takes a long time to heal with the loss of volume. This approach has a definite place for fingertip injuries in children as they have good capacity of regeneration. If the wound is larger than 1 cm and volarly directed, without exposure of bone or tendon, skin grafting provides faster healing. Split-thickness grafts are favored as contraction results in a smaller defect. However, some authors favor full-thickness grafts as they re-innervate early and provide durable coverage. Composite tip grafts are often considered for young children below the age of six years but are not reliable for adults. When bone or tendon is exposed at the base of a fingertip wound, the use of skin grafts is not feasible and a local flap is necessary.

The type of flap reconstruction which is appropriate depends on the extent and configuration of the tip loss. In those amputations which are oblique, the direction and degree of obliquity also influences the choice of flaps. Local flaps if properly applied can provide a very satisfactory functional and esthetic result. The various local flaps used to reconstruct fingertips include volar V-Y, bilateral V-Y flaps, cross-finger flap, thenar flap and island flaps. Flap choice depends on the orientation and configuration of the wound, injured digit and sex of the patient. If the wound is small and involves a finger with a transverse amputation beyond the mid-nail level and dorsal oblique amputations beyond the proximal nail fold, the volar V-Y flap (Atasoy) gives good results. Bilateral V-Y (Kutler) flaps are best applied to volar and transverse avulsions with exposed bone when excess lateral skin is present. The cross-finger flap is preferable if the wound is volar-directed without sufficient volar pulp to facilitate V-Y flap. However, if local flap is not possible, a regional flap like thenar, cross-finger flap or neurovascular island flap may have to be considered. The thenar flap can be used for volar, transverse and dorsal injuries, specially for index and long fingers and is often preferred in females as it does not scar the visible dorsum.

Thumb tip defects need special consideration as preservation of thumb length is always a priority for optimal hand function. The rectangular volar advancement (Moberg) is the preferred option for smaller defects less then 1.5 cm as it brings sensate durable skin to the thumb tip. In thumb defects more then 1.5 cm first dorsal metacarpal artery flap or the

Littler flap are often required for glabrous and sensate resurfacing with preservation of thumb length. Large thumb defects are often best reconstructed with a free sensate flap from the great toe/first web space. Occasionally, a cross-finger flap from the dorsum of the index finger is required if the Littler flap and first dorsal metacarpal artery flap are not available for sensate resurfacing of the thumb. As the dorsal vascular anatomy is dependent on the proper digital vessels in digits, the Moberg flap should not be used in the digits.

TREATMENT CONSIDERATION

The approach to management of fingertip injuries is based on several factors, including, age, hand dominance, digit involvement, sex, preexisting medical conditions, mechanism of injury, occupation, and anatomy of fingertip defect. Obtain the patient's history to ascertain the treatment approach. The age of the patient can contraindicate certain treatment options, including crossfinger or thenar flaps, as the delay required before flap division can result in joint contractures in older patients. As the primary goal of treatment of an injury to the fingertip is a painless fingertip with durable and sensate skin, the knowledge of fingertip anatomy and the available techniques of treatment are of paramount interest.

Composite grafting is less reliable and discouraged for patients older than 6 years. Injuries to the dominant hand are occasionally treated more aggressively. Moreover, digit involvement can direct management in considering the importance of contribution to overall hand function and applicability of specific flaps (ie, thenar flaps work better for index and middle fingertip injuries; Moberg flaps, which are suitable for small thumb defects, are discouraged for finger injuries).

The sex and ethnicity of the patient can influence reconstructive options : cross finger flaps, which transpose hair-baring skin to the palmar surface, are discouraged for women. The use of a cross finger flap in a patient with dark skin can also lead to an aesthetically displeasing color mismatch. Preexisting conditions like Dupuytren contracture or rheumatoid arthritis are contraindications to cross finger and thenar flaps because of the risk for resultant joint stiffness. The mechanism of injury can influence availability of certain local flaps.

Occupation and hobbies can be an important determinant in selecting fingertip treatment options for those concerned with

returning to work. For example, a piano teacher is approached differently than a manual laborer. In performing the examination, the clinician must determine the size of the defect, the circulation of the remaining soft tissue, and the angle and level of the injury, as well as nail bed involvement. Noteworthy is bone or tendon exposure, which contraindicates certain treatment options. Radiographs should be obtained to evaluate for fracture or a retained foreign body.

The nail is unique to primates as a specialized structure on the dorsum of the distal portion of each finger, thumb and toe. The nail allows for increased sensory perception on the volar pulp by compressing sensory organs against the unyielding nail. The nail is vital for increased prehension which is so unique in primate function. In addition it protects the fingertip and also serves as a temperature regulator.

There are several local options for tissue rearrangement of volar skin over the amputation stump. These include fillet flaps, volar V-Y flaps, bilateral V-Y flaps, and homodigital island flaps. "Dog ears" in the acute traumatic amputation often should be left to eliminate tension and to prevent compromising the blood flow to the remaining flaps achieving closure, these dog ears disappear over time. If the wound is small, it can be allowed to heal spontaneously by contraction and epithelialization. Wounds smaller than 1 cm can heal spontaneously in a reasonable amount of time. Larger wounds may require a skin graft to heal quicker. Split-thickness grafts can be used for the benefit of wound contraction to result in a smaller area on the tip, which is not normal pulp.

Regarding the treatment of the bone in a digital amputation, the bone under the stump end must be smooth. Remaining bone chips and devitalized bone should be removed. The bone at the stump end can be smoothed by using a rongeur and file. Bone length is not as important as a stump with mobile nonsensitive coverage. The bone of the distal phalanx must be of adequate length to support the nail bed and nail growth. With digital amputations involving the thumb, length is important.

In addressing the nerve at the stump end, it is important to avoid neuroma formation in this location. The nerve end should be in a position away from the stump end or an anticipated point-of-contact pressure. To minimize the risk of

neuroma formation at the stump end, traction neurectomy of the digital nerve should be performed bilaterally for each digital amputation. The nerve is longitudinally distracted in the distal direction and then transected to allow for proximal retraction, leaving the nerve end 1-1.5 cm from the fingertip.

Amputations at the level of the distal interphalangeal joint can be closed over the articular surface of the middle phalanx. Local flaps can be used to provide soft tissue for closure over the middle phalanx, if needed. The volar V-Y flap is the standard local flap option for injuries at this level. The volar V-Y flap is fashioned with the apex of the V at the proximal interphalangeal crease. When amputations are through the middle phalanx, preserving the flexor digitorum superficialis insertion, which inserts on the middle third of the middle phalanx, is desirable.

The index finger is the most important digit other than the thumb; it is the primary finger used with the pinch function. If length, sensation, and mobility of the index finger are inadequate, the patient bypasses the index finger to preferentially use the middle finger for pinch functions. In this circumstance, an index stump can impede the function of the middle finger and the overall function of the hand. This is the primary indication for a ray amputation of the index finger.

The most critical digit to hand function is the thumb. Amputations of the thumb can be debilitating. The level of amputation determines the significance of the functional deficit. In general, the thumb is important as a post to which the fingers oppose. Therefore, in contradistinction to the length of the fingers, the length of the thumb is more important than active motion.

When the thumb tip has been amputated, replantation can provide the patient with the best return to function, even if interphalangeal joint fusion is required. In the event that replantation cannot be performed or is unsuccessful, minimal bone shortening should be performed to provide a smooth bone end over which to close the skin. In fact, the bone should not be removed only to obtain primary skin closure.

A volar rectangular advancement flap (Moberg) should be used to provide soft-tissue closure and preserve thumb length. The volar advancement flap is raised as a rectangle to include both

neurovascular bundles to the metacarpophalangeal crease of the thumb proximally, and then it is advanced in the distal direction.

The Moberg flap can be used to close 1- to 1.5-cm defects. If the amputation level is at or distal to the distal interphalangeal joint, the patient should not experience much functional loss. If the patient's amputation level is proximal to the interphalangeal joint, reconstruction with toe transfer or metacarpal lengthening and web-space deepening should be considered. If the amputation is at the carpal metacarpal level, pollicization can be considered if the index finger is not injured.

TREATMENT OPTION

The open technique involves allowing the wound to heal by secondary intention with wound contraction, which pulls innervated pulp into the wound. This technique is applicable to distal and volar directed fingertip injuries without protruding bone. Some small fingertip wounds with a minimal amount of protruding bone can be treated with the open technique if this bone is debrided with a rongeur. The open technique is discouraged for wounds larger than 1 cm because healing time exceeds 3-4 weeks and significantly delays return to work. This approach is suitable for fingertip injuries in children because of their increased capacity to regenerate soft tissues. The complications potentially encountered with the open technique include loss of volume and pulp.

Primary closure and revision amputation

Many fingertip injuries can be closed primarily or by recruiting adjacent soft tissues. Viability of the remaining soft tissues must be ascertained before application of a tourniquet. Occasionally, the fillet flap principle can be applied in reconstructing these wounds. Occasionally, bone shortening or revision amputation is required to allow tension-free primary closure of the soft tissues and adequate padding. Furthermore, in an effort to minimize recovery time and hasten return to work, some fingertip injuries are treated with revision amputation.

Skin grafts

Skin graft application is considered for distally located and volarly directed fingertip wounds without exposed bone or tendon. Controversy exists as to whether split- or full-thickness grafts are better. Advocates for split grafts maintain the take is earlier and more reliable and wounds

contract more, resulting in a smaller defect, while others favor full-thickness grafts for earlier re-innervation and more reliable, durable coverage.

In other words, split grafts may be preferable for wounds in which greater contraction is desirable. Full-thickness grafts can be obtained from the amputated tip by merely defatting the underside.

Split-thickness skin can be harvested from the hypothenar eminence using a Weck blade after infiltrating with 1% lidocaine containing 1:100,000 epinephrine. Full-thickness grafts are harvested in the configuration of an ellipse to allow for donor closure. The graft is secured circumferentially with 3-0 nylon sutures, which are left long to tie over an Adaptic gauze and a bolus of cotton, creating a bolster/stent. The finger is placed in a splint. This bolster dressing is removed at 5-7 days, and active range of motion is begun immediately.

Composite tip grafts

Reapplication of composite tip grafts, amputated parts containing bone fat or nail bed, can be considered for children younger than age 6 years. As composite tip grafts must initially survive by plasmatic imbibition until neovascularization, revascularization is not reliable for adults and tip grafts should not be reapplied for adults. The distal phalanx fracture is reduced and secured with internal fixation using a K-wire. The surrounding skin is approximated with absorbable chromic suture to avoid the hassle of suture removal in a child. Moreover, the child's upper extremity is placed in a soft splint using multiple Kerlix rolls from the hand to the upper arm. The splint is removed at 2 weeks.

Local flap options for the fingers

When bone or tendon is exposed at the base of a fingertip wound, a local flap is required. The various local flaps used to reconstruct fingertips include volar V-Y, bilateral V-Y flaps, crossfinger flap, thenar flap,14 and island flaps.15 Flap choice depends on orientation and configuration of the wound, injured finger, and sex of the patient. Surgeons can optimize the reliability of these local flaps by avoiding tension on the suture line and preserving the traversing sub-dermal blood vessels into the flap.

Volar V-Y flap

Though frequently termed the Atasoy flap, Tranquilli-Leali first described the volar V-Y flap in 1935.16,17 The volar V-Y flap is a triangular-shaped volar advancement flap outlined with its tip at the distal interphalangeal crease. The local flap is most applicable for transverse and dorsal avulsions when a relative abundance of pulp skin is present. The technique of raising the volar V-Y flap involves designing a V with the distal flap width at least as wide as the defect. Then the V is scored through the dermis only to avoid injuring the traversing vessels into the triangular-shaped flap.

The deep aspect of the flap is carefully elevated from the distal phalanx by releasing the fibrous septae with iris scissors. The proximal donor is closed as a longitudinal line to create a Y. This longitudinal limb is short and usually only needs two or three sutures. Distally, the flap can be repaired to the nail plate or nail bed. It is critical not to transect the arborizing vessels entering the flap in the subcutaneous plane and to avoid tension on the distal suture line to the nail plate. This flap can be mobilized to reconstruct distal transverse and dorsal oblique fingertip wounds smaller than 1 cm.

Bilateral V-Y flaps

In 1947 Kutler described the bilateral V-Y flaps for fingertip injuries. These local V-Y advancement flaps are harvested from the ulnar and radial aspect of the injured fingertip and advanced distally to cover the defect. This technique is best applied to volar and transverse avulsions with exposed bone when excess lateral skin is present. These flaps are designed along the midlateral line and should not extend proximal to the distal interphalangeal joint. In raising these flaps, the incisions are performed through the dermis only to preserve arborizing vessels.

The flaps are mobilized for distal advancement by dissecting fibrous septae from the distal phalanx. The proximal donor site is closed as a straight line creating a Y, and the distal edges are approximated in the mid line tension free. The disadvantages of Kutler flaps include partial or complete flap necrosis, risk for pincher nail deformity, and excess scar on fingertip risking hypersensitivity. These disadvantages are increased compared to other flaps.

Crossfinger flap

Originally termed the transdigital flap by Gurdin and Pangman in 1950,19 the crossfinger flap is commonly used for volar-directed tip injuries with exposed bone or tendon when insufficient pulp for the volar V-Y flap is present. Use of this flap is reserved for fingertip wounds associated with deficiency of local tissues, which would allow for a single-stage flap because the crossfinger flap involves two operations. Moreover, the fingers become stiff during the delay between these two stages. At the first stage, a template of the defect is fashioned from the Esmarch bandage and superimposed to the adjacent finger dorsum from which the flap will be harvested. Generally, the flap is harvested from the finger radial to the injury, except when reconstructing the index.

The flap is elevated from the adjacent finger dorsum in the plane above the peritenon to allow for grafting of the donor site. A full-thickness graft can be taken from the groin to close the donor finger dorsum. The flap is opened like a book cover, turned 180°, and inset into the fingertip defect. The fingers may be sutured together or even pinned to prevent flap dehiscence. During the delay, gentle active range-of-motion exercises are critical to prevent joint stiffness of both fingers. At 2-3 weeks, the flap is divided and inset and more aggressive active and passive range-of-motion exercises are begun.

Thenar flap

The classic description of the thenar flap by Gatewood in 1926 was proximally based.24 In 1976, Smith and Albin25 described the H-shaped modification of the thenar flap. With the H modification, both proximal and distal flaps are raised in the configuration of an H. These flaps are both sutured to the injured finger, but, at flap division, one flap is inset to the finger while the other is advanced to repair the donor site.

The thenar flap was classically elevated from the thenar eminence, which placed a potentially tender scar where we rest the hand. A better location for this donor scar is the metacarpophalangeal (MCP) joint flexion crease of the thumb. A 2 cm X 4 cm thenar flap can be harvested from the MCP crease and still allow primary closure of the donor site with thumb flexion. Care must be exercised in harvesting this thenar flap at the MCP crease to avoid injury to the neurovascular bundles and flexor pollicis longus tendon.

This flap can easily reach the index and long fingers and is preferred for women because it is hairless and does not scar the hand dorsum. The thenar flap can be used for volar, transverse, and dorsal injuries. The disadvantages of the thenar flap are that two operations are required with a 2-3 week delay and consequent risk for joint stiffness and contracture. Accordingly, the thenar flap is discouraged for older patients and the small and ring fingers.

Reverse homodigital arterial flap

The reverse digital flap is an arterialized homodigital flap described by Lai in 1989,27 which replaces injured tissue with like tissue from the same digit in a single stage. The flap is harvested from the lateral aspect of the proximal phalanx of the same finger, preferably the nonopposition side. The reverse digital flap is an axial flap based on collateral flow through the contralateral digital artery, thus it is only applicable to defects distal to the crossover communication from the contralateral digital artery.

The pedicle is harvested with a cuff of soft tissue to include the digital artery venae comitante. The digital nerve can be preserved. The pedicle is harvested to 5 mm proximal to the distal interphalangeal joint to capture crossover vessels from the contralateral digital artery. If doubt exists concerning reverse blood supply to the flap, the proximal digital artery can be temporarily clamped to evaluate retrograde flow to the skin island. The donor site usually requires a skin graft.

Homodigital arterial flap

This flap is similar to the reverse digital artery flap, as it is an island flap harvested from the same injured finger in one stage. This flap is harvested based on dorsal branches of the proper digital artery and venous supply within a 5-mm wide bridge of fat of the dorsal branch of the proper digital artery at the distal finger crease. This flap can be harvested with dorsal digital nerve branches to be a sensate flap. The donor site usually requires a skin graft. The arc of motion of this flap makes it difficult to reach the fingertip.

Visor flap

The visor flap is a bipedicled dorsal finger skin flap that can be used to cover fingertip wounds after digital amputations proximal to the nail bed.28 Blood supply through this flap is provided through dorsal branches of the volar digital arteries and

this is more reliable distal to the proximal phalanx. In elevating the visor flap it is critical to preserve the extensor peritenon to allow this donor site to be skin grafted.

Local Flaps for Thumb

Rectangular volar advancement flap

Though often termed the Moberg flap, the volar advancement flap was first described by Littler in 1956 before being popularized by Moberg in 1964. This is a rectangular volar flap based on both neurovascular bundles. The flap is undermined in the distal to proximal direction to the MCP crease superficial to the flexor pollicis sheath and advanced in the distal direction. This flap can usually be advanced 1.5 cm distally.

Other manipulations that can improve distal flap advancement include flexion of the interphalangeal joint, Burrow triangles at the base, extending the lateral incisions into the palm past the MCP joint, and incising the skin at the base to create an island flap and skin graft the proximal defect. Larger thumb defects with exposed bone require consideration for Littler flap or first dorsal metacarpal artery flap. The volar advancement flap is discouraged for the fingers because the inclusion of both neurovascular bundles jeopardizes blood supply to the dorsum of the fingers and causes severe flexion contractures of the fingers.

Littler flap

The neurovascular island flap was first described by Littler in 1960. He termed it the interdigital flap. It is most applicable for large defects of the volar thumb. Rose in 1983 described use of the Littler flap for 6 wounds longer than 5.5 cm. Smaller defects are routinely reconstructed with the Moberg flap. The neurovascular island flap is harvested from the ulnar aspect of the middle finger or the radial aspect of the ring finger, basically on the common neurovascular bundle to the third web space within the median nerve supply. Before division of the distal branch of the proper digital artery, temporarily clamp to assess blood supply to the donor finger through what will be the remaining digital artery.

The advantage to the use of the Littler flap in thumb reconstruction is that it provides a large skin paddle with glabrous skin that is sensate, ultimately to preserve thumb length. The disadvantage is the donor site, which usually requires a skin graft and is prone to flexion contracture

deformity. The key to avoiding this donor flexion contracture is to design the flap confines to avoid harvesting across the flexion creases. In fact, the flap should be darted to avoid harvesting from the flexion creases. This excludes them from the flap to avoid flexion contracture of the donor finger. Also, if the donor defect requires a skin graft, a full-thickness graft should be used to decrease risk for donor finger contracture.

First dorsal metacarpal artery flap

The first dorsal metacarpal artery flap is a neurovascular island flap raised from the dorsum of the index proximal phalanx based on the first dorsal metacarpal artery and branch of the superficial radial nerve. The first dorsal metacarpal artery flap reaches defects on the volar thumb tip, thumb dorsum, first web space, the MCP joint of the small finger, and even the wrist and carpal joints. A second dorsal metacarpal artery flap can be used for defects on the dorsum of the other fingers or ulnar aspect of the hand.

The first dorsal metacarpal artery is a constant vessel arising from the radial artery just proximal to the point at which the latter pierces between the two heads of the first dorsal interosseous muscles in the apex of the triangular first interosseous space. In performing the dissection, the flap is designed over the index proximal phalanx and the knuckles of the PIP and MCP joint should be avoided if possible.

The pedicle is fashioned by elevating a narrow skin flap over the first interosseous space and subcutaneous tissue to include subdermal veins to drain the flap. The branch of the radial nerve to the index finger is frequently not visible as it courses at a slightly deeper plane than the subdermal vein plexus. The radial border of the second metacarpal bone must be exposed while performing the elevation of the pedicle, dissecting close to the periosteum of the metacarpal shaft.

The plane of dissection is deepened to expose the fascial layer of the first dorsal interosseous muscle, which is sharply incised and readily separated from the muscle in a radial direction, at which point the first dorsal metacarpal artery should be visible just superficial to this layer of fascia. Thus, the plane of dissection for raising the first dorsal metacarpal artery pedicle is subfascial over the first dorsal interosseous muscle to include the fascia through which the first metacarpal artery can be visualized.

Distally, the skin flap should be elevated in the plane superficial to the paratenon over the dorsum of the proximal phalanx to provide a bed appropriate for skin grafting of the donor site. Proximally, the pedicle is dissected from the paratenon of the tendon of the first dorsal interosseous muscle and then from the muscle itself in the distal to proximal direction. It is usually not necessary to skeletonize the first dorsal metacarpal artery back to its origin from the radial artery for the distal edge of the skin flap to reach the thumb volar tip.

The first dorsal metacarpal artery flap has several advantages over the Littler flap for sensate resurfacing of the thumb when the Moberg flap is not an option because the thumb tip defect is larger than 1.5 cm. The dissection of the first dorsal metacarpal artery flap is easier than the Littler flap and contains a more reliable venous drainage plexus than the mere venae comitante with the digital artery to the Littler flap. A larger and more reliable skin paddle can be elevated with the first dorsal metacarpal artery flap than with the Littler flap. The donor site of the first dorsal metacarpal artery flap is more desirable compared to the Littler flap.

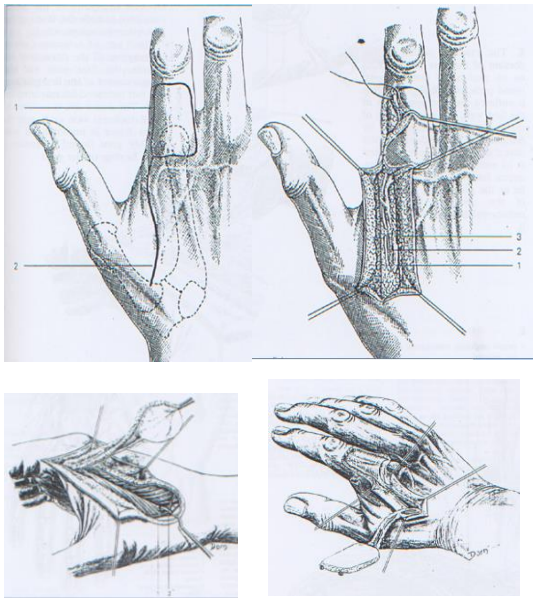
Sensation of the dorsal index finger skin is reliably provided by radial nerve branches to the level of the proximal interphalangeal joint but should be confirmed preoperatively by blocking the index finger digital nerves or median nerve. The sensation of the first dorsal metacarpal artery flap, as assessed by 2PD, rivals other modes of thumb reconstruction. The skin from the dorsum of the index finger has 3-7 mm 2PD.

Cross finger to thumb flap

On occasion, the Littler flap and first dorsal metacarpal artery flap are not available for sensate resurfacing of the thumb; a crossfinger flap from the dorsum of the index finger is required. The disadvantage to the use of this flap is that it requires two stages and a neurorrhaphy of the radial nerve branch to the ulnar aspect digital nerve of the thumb. Therefore, the Littler and first dorsal metacarpal artery flaps are preferred for larger thumb defects that cannot be reconstructed with the Moberg flap. The flap is harvested superficial to the paratenon of the dorsum of the finger to allow for skin grafting of the donor.

Kite Flap

The kite flap is raised from the dorsum of the first phalanx of the index finger, including the metacarpophalangeal (MTP) joint. It is considered to be a sensory flap. The main indication for the kite flap is the resurfacing of the dorsal aspect of the thumb. It is also used for the reconstruction of the first web when the defect is limited after release of a contracture.



SURGICAL PRINCIPLES

Several established goals exist in the treatment of fingertip injuries, including preserving useful sensation, maximizing functional length, preventing joint contractures, providing satisfactory appearance, and avoiding donor disfigurement and functional loss. Most fingertip injuries can be successfully treated in the emergency room with digital tourniquet and block. Crossfinger flaps, thenar flaps, and Moberg flaps can be performed in the emergency department but are probably best suited for the operating room in case a proximal tourniquet or bipolar cautery is needed.

In the emergency department, the whole forearm and hand are prepped and draped. A digital or intrathecal block can be used to anesthetize the fingertip. Alternatively, a superficial radial nerve and median nerve block can be used if a thenar flap or Moberg flap has been chosen as the reconstructive option. If multiple digital blocks are needed, a selective nerve block or wrist block may be more appropriate. A 5-mL syringe and 27-gauge needle are optimal for a digital block. The smaller syringe allows for better control and the smaller needle decreases the risk of irreversible, bilateral digital artery and nerve injury. The digital block can be performed dorsally or volarly. The dorsal approach allows for puncture through the less sensitive dorsal skin. Alternatively, an intrathecal block can be used specifically for fingertip injuries because this technique does not anesthetize the dorsum of the finger

proximal to the PIP joint. With the intrathecal block 1 mL of lidocaine is injected volarly into the flexor sheath, proximal to the A1 pulley.

Regarding tourniquet control, a 1-in Penrose can be placed around the finger base. The Penrose should be held flat to apply uniform pressure circumferentially around the finger base and a hemostat applied, pulling the drain just tightly enough to occlude arterial and venous flow.

COMPLICATION

Complications in the amputated stump related to the bone include formation of osteophytes and osteomyelitis. The risk for these bony complications can be minimized with appropriate bony debridement at the initial treatment.

Early postoperative complications include wound hematoma, infection, and necrosis. Hemostatic control of the amputation stump can be achieved initially with a tourniquet. Thoroughly irrigate and debride the amputation wounds to minimize the risk of postoperative infection. Devitalized skin, tendon, and muscle should be removed to minimize the risk of infection as well.

Postoperatively, patients can experience symptoms of pain in the amputated part or stump. Phantom limb is the sensation of feeling in the amputated part, and it is common after amputations. Patients should be informed of this potential complication preoperatively. The likelihood of developing phantom limb pain is highest after severely mutilating amputations, and it usually begins soon after the amputation. When made aware of this potential symptom preoperatively, patients seem to better tolerate this sensation.

Stump pain is usually a result of a neuroma forming at the stump site. Sometimes, these neuromas have to be excised and buried into muscle or bone to minimize the local pain. Patients can have cold intolerance and hypersensitivity at the stump end. Usually, this is a self-limited process. Desensitization may hasten the resolution of these symptoms, and a transcutaneous electrical nerve stimulation (TENS) unit may be helpful. Neurontin may also be effective.

Contracture prevention is critical in the treatment of amputations. Local flap options for soft-tissue reconstruction often involve immobilization during a delay, which can result in contracture formation of an adjacent digit as with cross-finger or thenar flaps or of the shoulder, elbow, and wrist with the groin flap. It is imperative to begin early motion of the

amputated part to minimize the risk of contracture formation.

Finger tendon imbalance after finger amputations can result in a weakened grasp. When the flexor digitorum profundus is sutured over the stump end, the patient can develop a quadriga, which can result in the amputated finger beating the others to the palm because of the shorter tendon, thus limiting the range of motion of the uninjured adjacent fingers. When the flexor digitorum profundus tendon is allowed to retract proximally, this can result in the lumbrical plus posture (ie, the paradoxical hyperextension of the interphalangeal joints with flexion). The lumbrical plus posture can be treated by releasing the lumbrical or radial lateral band.

The most common complications encountered in the treatment of fingertip injuries, hypersensitivity and cold intolerance, are complications of the injury and not the treatment. The rates of hypersensitivity and cold intolerance approximate 50% regardless of the treatment, including healing by secondary intention, skin grafting, and local flap reconstruction. This hypersensitivity and cold intolerance is self-limited and almost always resolves after 1-2 years. Initial treatment includes scar massage, desensitization, and edema control.

CONCLUSION

The treatment of fingertip injuries can be complex and controversial, with more than one treatment option for most injuries. Treatment of fingertip injuries must be individualized to the patient's age, sex, configuration and composition of defect, digit injured, hand dominance, pre-existing medical conditions, occupation, hobbies, and mechanism of injury. This algorithm can serve as a guide to facilitate management of fingertip injuries.

The fingertip wound should be assessed for tissue loss. If there is minimal tissue loss the wound can be debrided and closed primarily. If the fingertip wound cannot be repaired primarily, no bone is exposed, and the wound measures less than 1 cm, consider open treatment or skin grafting. If the wound is larger than 1 cm, skin grafting would provide quicker wound healing.

If bone is exposed within the wound base, a local flap or bone shortening is required. If the wound is small and involving a finger with a transverse or dorsal oblique configuration, the volar V-Y flap can be used. If the wound is volar oblique without enough volar pulp for a volar V-Y flap, then a crossfinger, thenar, or neurovascular island flap (reverse digital artery or homodigital artery flap)

is preferred. Single-stage reconstructions with the volar V-Y flap, reverse homodigital artery, and antegrade homodigital artery, decrease the risk for finger contractures.

If the patient is older or has preexisting medical conditions that place him or her at risk for joint contractures during the delay of the two-stage flap procedures, avoid the crossfinger and thenar flaps. Patients with concerns about returning to work, those who are older, and patients with significant comorbidity may require revision amputations. In general, women should avoid crossfinger flaps to prevent an aesthetically unacceptable donor site on the hand dorsum and hair-bearing skin on the palmar surface of the hand.

Thumb tip defects should be aggressively treated to preserve thumb length, which is more important to the thumb's overall contribution to hand function than joint flexibility, in contradistinction to the fingers. Accordingly, the rectangular volar advancement is the preferred option for small thumb tip defects as it brings sensate durable skin to the thumb tip. Larger full-thickness defects of the thumb require sensate resurfacing with either the first dorsal metacarpal artery flap or the Littler flap. Alternatively, very large thumb defects can be reconstructed with a free sensate flap from the great toe or first web space of the foot.

The flap should be considered whenever bone or tendon is found to be exposed. The technical choice of flap is to be dictated by the anatomy of the tip loss. The volar V-Y flaps may be preferred in dorsally angulated amputations beyond the proximal nail level and transverse amputations beyond the mid-nail level. Bilateral (Lateral) V-Y flaps may be considered for the wounds with slightly volar and transverse avulsions with exposed bone with excess lateral skin. In the volarly directed wounds without sufficient pulp, cross-finger flap may be done. In obliquely directed amputations, oblique triangular flaps give satisfactory results. In females with transverse, volar and dorsal injuries, especially involving the index and middle fingers thenar flap may be preferred. In elderly patients, mentally unstable patients, osteoarthritic patients, uncontrolled diabetics and in unskilled laborers revision amputations can be considered.

In thumb tip defects less then 1.5 cm, the Moberg flap is preferable. In defects exceeding 1.5 cm first dorsal metacarpal artery flap/Littler flap may be considered. If the Littler and first dorsal metacarpal artery flap is not possible, a cross-finger flap from the dorsum of the index finger may be considered. Specialized flaps like the

oblique triangular flap, reverse digital flap, dorsal metacarpal and Littler flap should only be considered if technical expertise is available.

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