# Management of Fingertip Amputations

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**Learning Objectives**

- Clarify the anatomy of the nail complex and finger pulp.
- State the epidemiology of fingertip injuries, including prevalence and distribution.
- Distinguish the different classifications of fingertip injuries and amputations.
- Elaborate on different treatment options of fingertip amputations from the least invasive to replantation.
- Review the treatment outcomes and complications of fingertip injuries.

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Injuries to the fingertips are among the most common injuries to the hand and result in approximately 4.8 million emergency department visits per year. Most injuries are lacerations or crushes; amputations represent a small but complex spectrum of injury. Treatments available cover a broad range of techniques with no single recommended reference standard for treatment. Although there is no consensus on how these injuries should be treated, the goals of treatment should include minimization of pain, optimization of healing time, preservation of sensibility and length, prevention of painful neuromas, avoidance or limiting of nail deformity, minimization of time lost from work, and provision of an acceptable cosmetic appearance. In this review we present a variety of options in caring for these injuries to help achieve these goals, and the available data that support the various treatment plans. *(J Hand Surg Am. 2014;39(10):2093–2101. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)*

**Key words** Fingertip, amputation, injury, replantation, classification.

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The fingertip is a specialized structure that allows fine motor activity and sensation during prehension, and also contributes to the aesthetics of the hand. As the first portion of the upper extremity to interact with the environment during exploratory and manipulative functions, the fingertip is particularly vulnerable to injury. Fingertip injuries affect soft tissue, bone, or nail distal to the insertions of the long digital flexor and extensor tendons of the fingers or thumb. Most fingertip injuries are lacerations or crush injuries; amputations represent a small but complex spectrum of injury with no single recommended reference standard for treatment. However, suboptimal management can result in persistent pain, abnormal sensation, nail deformity, joint stiffness in the involved digit, and reduced grip strength.

## ANATOMY

The fingertip is composed of multiple specialized structures (Fig. 1), all of which must be considered when evaluating and treating injuries. The nail is a prominent feature of the fingertip and fulfills a functional role by protecting the dorsal surface of the phalanges, improving sensory perception, facilitating pinch, and making scratching possible.[1] In addition, the fingernail has a cosmetic role. The nail complex itself is divided into specific parts: nailbed, nail plate, eponychium (cuticle), perionychium, and hyponychium. The nailbed consists of 2 parts: the proximal germinal matrix and the distal sterile matrix. The junction between these 2 parts is defined by the lunula. Only the germinal matrix produces ungula keratin; the sterile matrix's main function is nail plate adherence. The absence of dermis and subcutaneous tissue between the nail matrix and the underlying distal phalanx may increase the risk for osteomyelitis after open injuries. The nail plate is composed of onchyn, a keratinous substance produced by the death of the germinal cells as they are pushed upward from the germinal matrix. The proximal portion of the nail plate, concealed under the eponychium, is often referred to as the nail root. The eponychium and paronychium form the proximal and lateral soft tissue borders of the nail, respectively. The hyponychium is a plug of keratinous material situated beneath the distal edge of the nail where the nailbed meets the skin. The rate of nail longitudinal growth depends on the patient's age, sex, and habits; it averages 0.1 mm/d.

The epidermis of the fingertip is thick with deep papillary ridges that produce unique fingerprints. The deeper pulp consists of multiple fibrous bands extending from the dermis to the periosteum of the distal phalanx, the bony core of the fingertip, creating a latticework of separate septal compartments containing fat. The pulp constitutes over half of the fingertip volume and its intimate association with the underlying bone via the septa has a crucial role in grip.

Arborization of the digital arteries and nerves to the fingertip occurs near the distal interphalangeal (DIP) joint, where the nerve lies volar to the artery. The proper digital artery sends a branch to the nailfold, nailbed, and pulp. Each digital nerve sends a branch to the paronychium, tip of the finger, and pulp. As the primary organ of touch, the fingertip is abundantly supplied with sensory receptors including Pacinian and Meissner corpuscles, and Merkel cell neurite complexes.

## EPIDEMIOLOGY

Injuries to the fingertips are among the most common ones to the hand, accounting for 4.8 million emergency department visits per year.[2] In the pediatric population fingertip injuries account for two thirds of all hand injuries, with the most common mechanism of injury being a crush between a door and its frame.[3,4]

In contrast, in adults lacerations predominate, followed by crush and avulsion injuries. The most commonly involved digits are the index finger, thumb, and middle finger. The nondominant hand is most frequently involved and most injuries involve a single digit.

## DIAGNOSIS

In addition to patient-related factors such as age, hand dominance, general health, occupation, and hobbies, the history should also include the time and mechanism of injury. Any conditions that could compromise regional blood flow and thereby limit reconstructive options, such as diabetes, tobacco use, or vasospastic disorders, should be duly noted. The injured finger should be evaluated to determine size, location, and geometry of any pulp defect, degree of nailbed involvement, and the presence or absence of exposed bone. After sensory evaluation, a more thorough examination may require analgesia and establishment of a bloodless field. A digital block will usually be adequate but in select individuals this may require supplementation with opioids. Local anesthetic may safely be used for this block with or without epinephrine.[5] Radiographs should be obtained of the injured finger, and also of the amputated part if replantation is being considered.

To facilitate documentation and treatment planning during evaluation of fingertip amputations, several

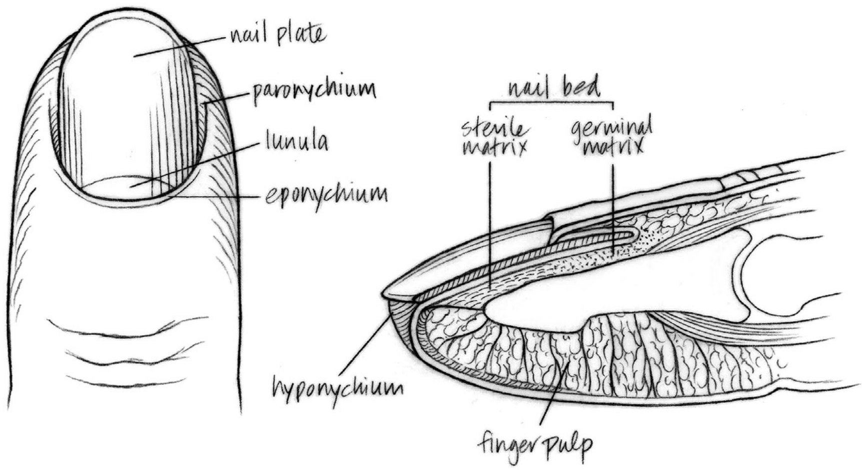


**FIGURE 1:** Anatomy of the fingertip.

classification systems have been proposed. Two simple systems are the Allen[6] and Fassler[7] classification schemes (Fig. 2). The classification by Allen is based on the level of amputation whereas the Fassler system is based on the geometry of pulp loss and whether bone is exposed. Both these systems can be useful for communication or documentation but have limitations in guiding treatment because they fail to define the blood supply at the level of amputation. Vascular supply is defined in the classification by Tamai,[8] which identifies 5 zones within the digits, of which zones 1 and 2 (Fig. 3) represent levels of injury within the anatomical area encompassed by the fingertip. More proximal zones in the Tamai classification include zone 3 between the base of the proximal phalanx and interphalangeal joint of the thumb or between the midsection of the middle phalanx and the DIP joint of the other fingers. Zone 4 consists of the classic flexor tendon zone 2 where the 2 finger flexor tendons overlap between the palmar crease and the proximal interphalangeal joint flexor crease, and zone 5, which is the level proximal to the base of the proximal phalanx of the thumb or proximal to the metacarpophalangeal joint in the fingers.

Recently, the more detailed PNB classification system was described by Evans and Bernadis,[9] based on damage to the 3 main components of the fingertip: pulp (P), nail (N), and bone (B) (Table 1, Fig. 4). By assigning single digit grades to each of these 3 anatomical components the system allows for generation of a 3-digit code that describes the extent and type of injury in more detail. The PNB system has been used successfully by 1 group to differentiate injuries that could be managed conservatively from those that required operative intervention.[10] However, in another study the PNB classification was thought to be too complex for everyday clinical use, and interobserver reliability was questioned.[11]

## TREATMENT

The goals of treatment should include minimization of pain, optimization of healing time, preservation of sensibility and length, prevention of painful neuromas, avoiding or limiting nail deformity, minimizing time lost from work, and providing an acceptable cosmetic appearance. To accomplish these goals, treatment should be individualized based on the mechanism of injury, amputation level, and orientation of the wound.

Replantation of fingertip amputations is a technically challenging but effective method of treatment.[12] Contraindications to replantation include lack of microsurgical capability, lack of suitable vessels, and crush injuries. The type of injury most amendable to this is a sharp clean amputation at Tamai level 2. This treatment can also be applied successfully to oblique pulp level amputations extending into Tamai level 2 (Fig. 5) and to Tamai level 1 amputations.[13] These distal level replantations required little or no formal rehabilitation because at Tamai level 1 no joints or tendons are involved, and at Tamai level 2 the DIP joint can be fused.

When performing these distal replantations at least one artery should be anastomosed, and a vein whenever possible. In the absence of acceptable veins at the time of initial replantation, use of leeches, continuous exsanguination through pulp puncture or nailbed abrasion, or planned reexploration within 24 hours when veins often become more visible are all viable options. Most reports supporting fingertip replantation originate from countries other than the

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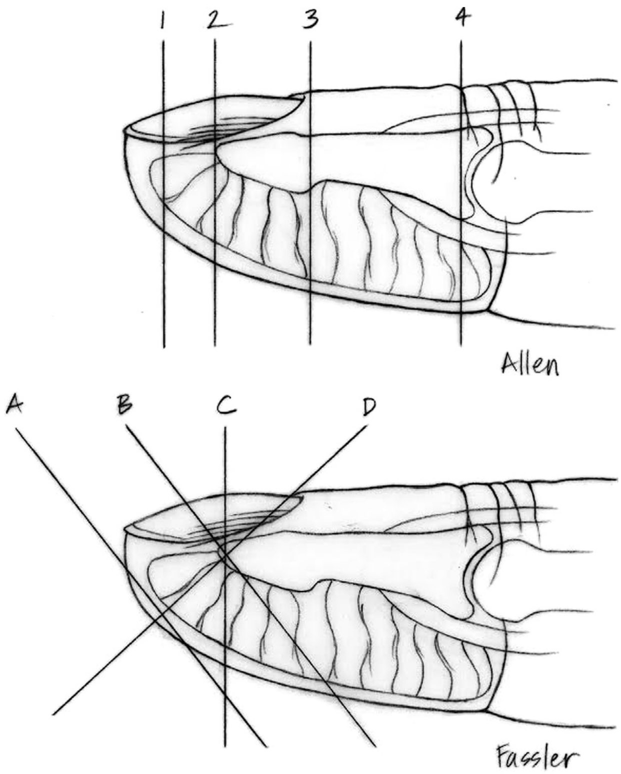


**FIGURE 2:** Allen and Fassler classifications for fingertip amputation. Allen 1 has no suitable vessel or anastomosis; Allen 2 preserves at least one-half of the nailbed and has no dorsal vein available for anastomosis; Allen 3 is similar to Allen 2 with regard to vascular supply, and when treated other than by replantation it has a high incidence of hook nail deformity if the remaining nailbed is not ablated; and Allen 4 is proximal to the nailfold and a dorsal vein can usually be found that is appropriate for anastomosis. Fassler classification is descriptive of injury geometry. Orientation in Fassler A and B is volar oblique (A does not involve the nailbed and B does), in Fassler C it is transverse, and in Fassler D it is dorsal oblique.

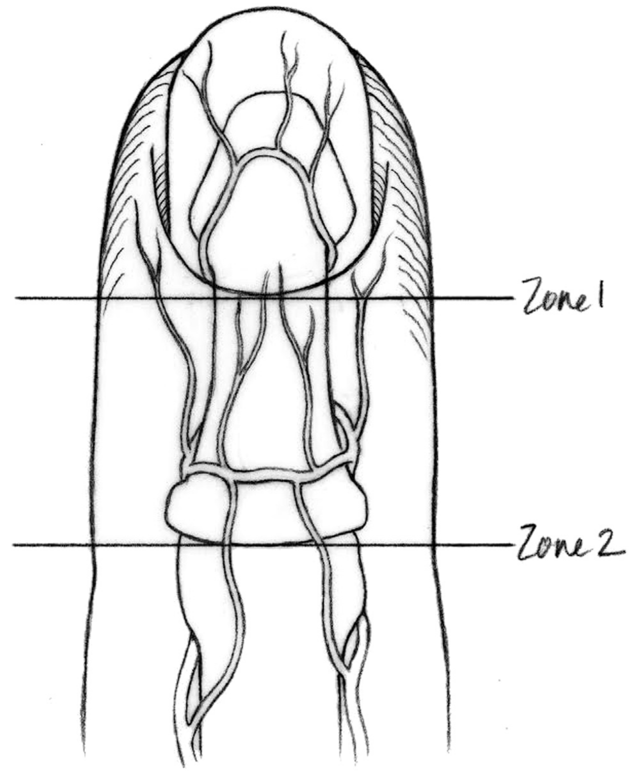


**FIGURE 3:** Tamai zone 1 is at the level of the lunula. Replantation at this level requires repair of either the central artery where it forms from the 2 digital arteries or at least 1 of the individual digital arteries. The subdermal palm veins are available at this level for repair. In addition, repair of the nailbed is required. Tamai Zone 2 is between the DIP joint and the nail matrix. Two digital arteries are consistently available at this level, as well as at least 1 dorsal central vein.

United States, where maintaining a hand normal in appearance and structure is of cultural importance.

Alternatives to replantation are many and include revision amputation with bony shortening and primary closure, allowing the stump wound to heal by secondary intention, composite grafting, skin grafting, or local and regional flaps. Many of these techniques can be done at the time of initial evaluation and performed in the emergency department or a procedure room with only local anesthesia. Alternatively, based on surgeon preference and equipment availability, the patient may be taken to the operating room for definitive care.

After determining that a replant is not indicated, treatment should be undertaken after an adequate digital block is obtained. Hemorrhage can be controlled initially by compression and elevation, but to achieve a bloodless field, application of a digital tourniquet constructed from a Penrose drain will probably be necessary.

Before or after application of the digital tourniquet the wound should be copiously irrigated with normal saline and then cleansed with an appropriate aqueous antiseptic solution such as povidone-iodine. This should be followed by debridement of all nonviable soft tissue although excessive debridement of the nailbed should be avoided to prevent scarring that can lead to nonadherence of the nail.[1]

Composite grafting is an alternative to microsurgical replantation in select instances.[14] In this technique the severed tip is sutured directly to the finger after appropriate cleaning and debridement to include defatting and often removal of residual bone. In the past, this technique was primarily recommended for children under age of 5 years; however, it has been suggested that success in adults may be enhanced by (1) maximizing contact area by shaping the graft into

**TABLE 1. Pulp, Nail, and Bone Classification for Fingertip Injuries**

| Pulp | Nail | Bone |
|---|---|---|
| 0: No injury | 0: No injury | 0: No injury |
| 1: Laceration | 1: Sterile matrix laceration | 1: Tuft |
| 2: Crush | 2: Germinal and sterile matrix laceration | 2: Comminuted nonarticular |
| 3: Loss—distal transverse | 3: Crush | 3: Articular |
| 4: Loss—palmar oblique partial | 4: Proximal nailbed dislocation | 4: Displaced basal |
| 5: Loss—dorsal oblique | 5: Loss—distal third | 5: Tip exposure |
| 6: Loss—lateral | 6: Loss—distal two-thirds | 6: Loss—distal half |
| 7: Loss—complete | 7: Loss—lateral | 7: Loss—subtotal |
| | 8: Loss—complete | 8: Loss—complete |

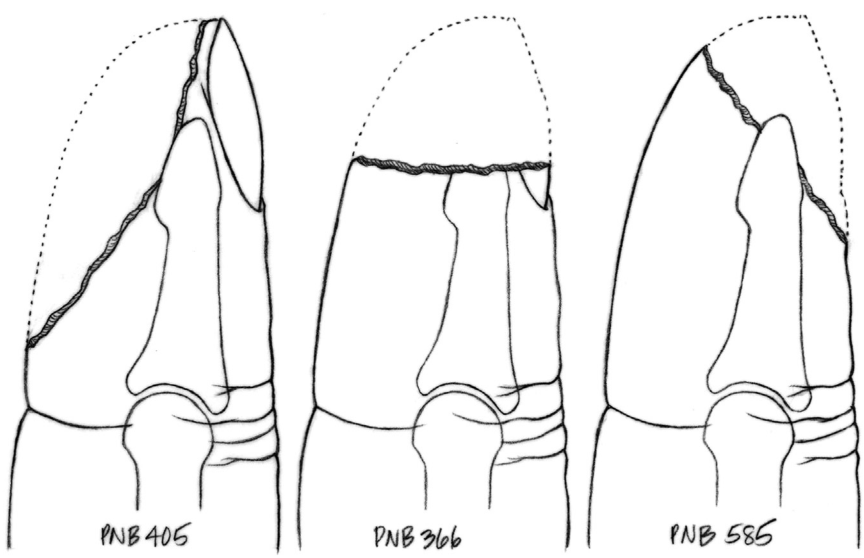


**FIGURE 4:** Examples of application of the PNB classification in fingertip amputation.

a cap that fits over the skeletonized distal phalanx of the injured finger, (2) cooling the graft with ice, (3) pharmacologic treatment, and (4) hyperbaric oxygen.[15] In adults, composite grafting may also be extended by subcutaneous pocketing of the amputated part, a technique initially described by Brent[16] in 1979 and recently modified to palmar pocketing with good success by Jung et al,[17] in whose study 9 of 10 tips had complete survival and 1 underwent 20% partial loss. In this recent study 2 cases extended to Tamai level 2 and all 10 cases resulted in cosmetically acceptable fingernail regrowth.

When replantation or composite grafting cannot be performed, the next branch in the decision tree is whether to allow the wound to close by secondary intention or consider alternative surgical techniques. Predictors of need for surgical closure include volar oblique injury, exposed bone, an associated distal phalanx fracture, and a soft tissue defect larger than 1.75 $cm^2$; occupation has not been found to be a determinant for surgical closure.[18]

When choosing to treat fingertip amputations by secondary intention several dressings have been recommended, including occlusive dressings, semiocclusive dressings, simple nonadherent sterile dressings,[19] and subatmospheric techniques.[20] Although it has proven effective for a variety of patterns of injury, this treatment method probably gives the best aesthetic and functional results when applied to Allen level I injuries.

A contributing factor in poor aesthetics with closure by secondary intention is bone shortening. Removal of bone results in loss of support for the nail, which is then further distorted by wound contracture, resulting in a hook nail deformity. To prevent this complication it has been recommended that the nailbed be excised for 2 mm proximal to the shortened bone.[21] However, the need for covering or cutting back exposed bone may not be

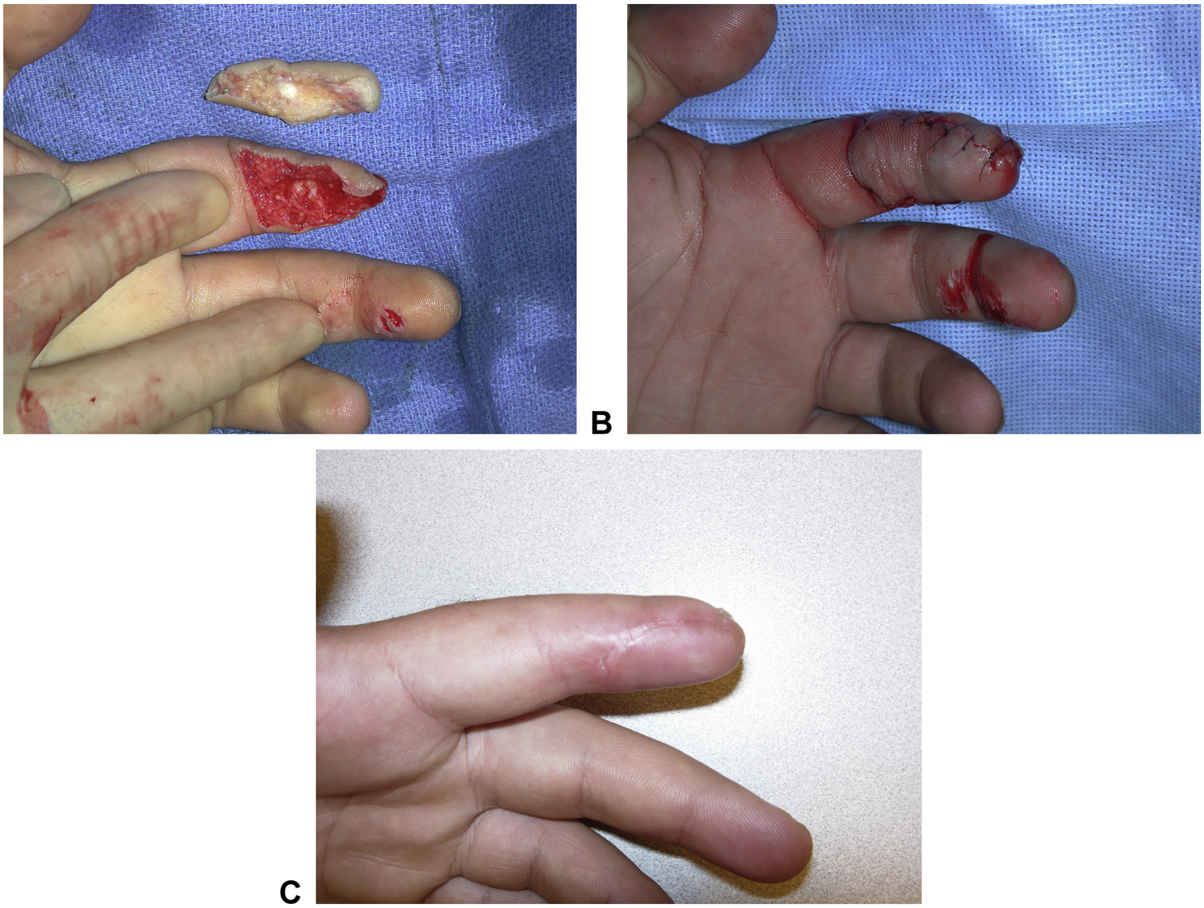

**FIGURE 5:** **A** Tamai level 2 volar oblique pulp amputation. **B** After completion of microsurgical replantation. **C** Four-month follow-up.

absolute, as shown by Hoigne et al,[22] who treated a series of 19 fingertip amputations distal to the DIP joint with semiocclusive dressing alone and observed regeneration of soft tissue thickness to nearly 90% of the baseline.

Skin grafting can be useful when the patient is unwilling or unable to manage an open wound for a month or more. Skin grafts still require time to mature and become durable coverage. They cannot be applied directly over exposed bone and normal graft contracture may contribute to hook nail deformity. Less contracture occurs with full-thickness skin grafts as opposed to split-thickness skin grafts but both have been used successfully. Unfortunately, although it is a simple technique that will result in a closed wound, skin grafting has provided inconsistent outcomes for fingertip injuries. Increased cold intolerance, lack of durability, and persistent tip tenderness are common problems after skin grafting; for these reasons this method of wound closure should only be used when other alternatives are not available.[19]

Other well-described surgical techniques for wound closure after fingertip amputation include a single volar V-Y advancement flap, combined radial and ulnar V-Y advancement flaps, the cross-finger flap, and the thenar flap.[23] Flap choice is usually based on wound geometry and size and finger involved. With transverse amputations at Allen level 2 or 3 a single volar V-Y advancement flap is used more commonly than combined radial and ulnar V-Y advancement flaps. The single volar V-Y advancement flap is best used for dorsal oblique (Fassler D) geometry and Allen 2 injuries and is often combined with some degree of bone shortening. Key points in elevating the volar V-Y flap are not extending the incisions proximal to the DIP joint flexion crease and not gaining flap mobility by incising deep to the epidermis, but instead by sharply releasing the fibrous septa from the distal phalanx.

Volar oblique/pulp amputations (Fassler B) that are not candidates for replantation can be efficiently covered by cross-finger flaps. Cross-finger flaps can also be used in transverse Allen level 2 and 3 injuries.

In brief, a flap is raised on the dorsum of the adjacent digit over the middle phalanx and is sutured to the primary defect. When raising the flap the paratenon covering the extensor apparatus is preserved. The dorsal secondary defect is covered with a full-thickness skin graft and the flap undergoes pedicle division and final inset in 14 days.

The thenar flap is another option for coverage of transverse Allen level 2 and 3 injuries to the middle and index fingers. Similar to the cross-finger flap, a 10- to 14-day period of immobilization in a non-anatomical position is required, and in most but not all instances the donor site requires skin grafting for closure.

Multiple alternative flaps to the heterodigital cross-finger and thenar flaps have been proposed. Flaps that eliminate the need for intrusion on adjacent digits by immobilization and creation of a donor defect are the reverse homodigital island flap[24] (Fig. 6) and the recently reviewed anterograde homodigital neurovascular island flap.[25]

The reverse homodigital island flap (Fig. 6) is based on the anastomoses that exist between the radial and ulnar digital arteries by the 3 transverse digital palmar arches that are constantly located at the level of the proximal cruciate ligament and distal cruciate ligament, and distal to the flexor digitorum profundus insertion. Venous outflow is provided by tiny venules and capillaries in the periarterial soft tissue. Of these 3 transverse arterial anastomoses the middle and distal are consistently large (almost 1 mm), which means that this flap is indicated for both Tamai zone 1 and 2 amputations or all Allen levels. In addition to providing coverage for multiple levels of amputation, the flap may also be harvested with a dorsal sensory branch of the digital nerve directly reinnervated by neurorrhaphy to a digital nerve stump at the level of amputation. The need for this reinnervation, however, remains controversial because the flap seems to comparably reinnervate without this step.

## COMPLICATIONS

Complications are common after fingertip amputation with most if not all reconstruction options. Complications include nail deformities, loss of pinch strength, loss of or alteration in sensation, cold intolerance, joint stiffness, painful neuromas, cosmetic concerns, and prolonged time away from work that often seems disproportionate to the magnitude of the injury. Successful replantation does not prevent many of these problems and most unfortunately cannot be adequately corrected.

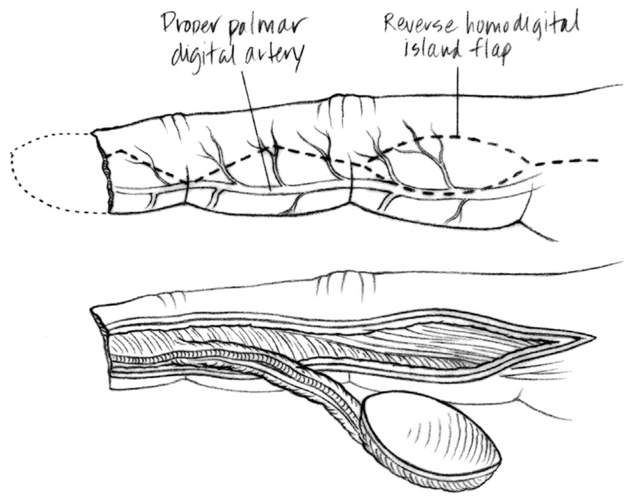


**FIGURE 6:** Depiction of reverse homodigital island flap.

Short nails and hook deformity are also common complications. Short nails may be lengthened by de-epithelializing a thin strip of dorsal skin proximal to the eponychium and advancing the dorsal fold to allow for more nail exposure (Fig. 7).[26] In the instance of a short nail associated with an amputation proximal to the distal edge of the lunula, nailbed ablation may be the only reasonable alternative. Hook nails can be corrected to a degree by the antenna procedure (Fig. 8).[27]

A variety of methods of treatment for painful terminal neuromas have been described and recently reviewed.[28] Those techniques most applicable to dealing with painful digital neuromas associated with fingertip amputations are resection and/or transposition to bone, centro-centralization, or flap coverage with neurorrhaphy of the inciting nerve to a nerve within the flap. The reverse homodigital island flap has been successfully used for the neurorrhaphy technique,[29] a finding that further supports its use as an innervated flap in primary repair of many fingertip amputations.

## OUTCOMES

Although the upper extremity is affected in one third of all traumatic injuries and hand injuries account for 5% to 10% of emergency department visits, outcome studies that directly compare the multiple reported methods of treatment for fingertip amputations are rare. Braun et al[30] in 1985 compared primary closure with split-thickness skin grafting in 100 fingertip amputations and found no significant differences in outcome. They did find that most problems presenting at 6 weeks persisted at 42 weeks, bone shortening produced a mobile amputation stump tip, and although not statistically significant, skin grafting only reduced

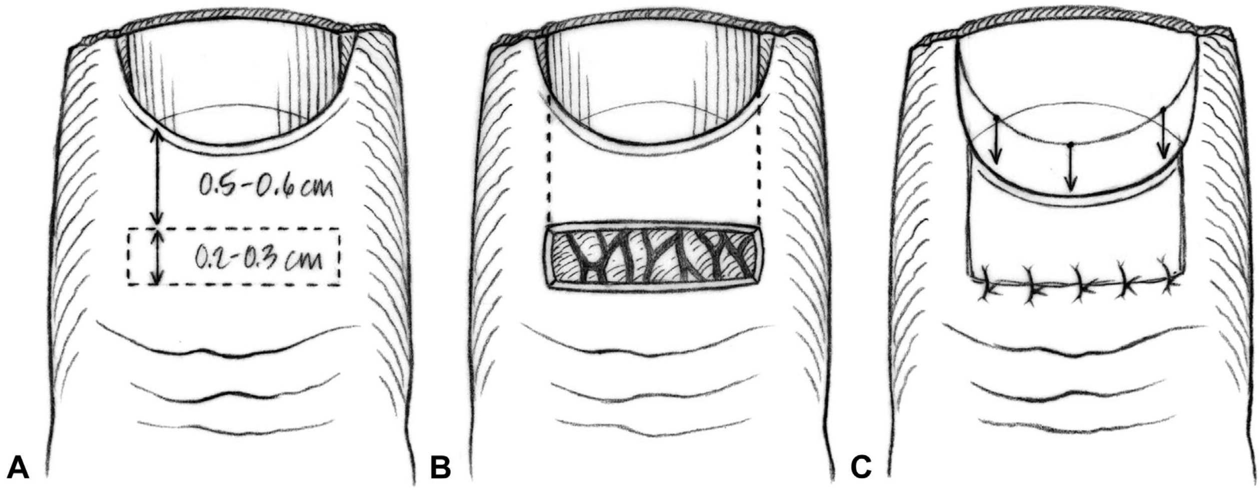


**FIGURE 7: A** Dorsal fold advancement flap design to increase nail exposure. **B** Proximal de-epithelialization of bed for flap advancement. **C** Following dorsal fold flap advancement into area of de-epithelialization.

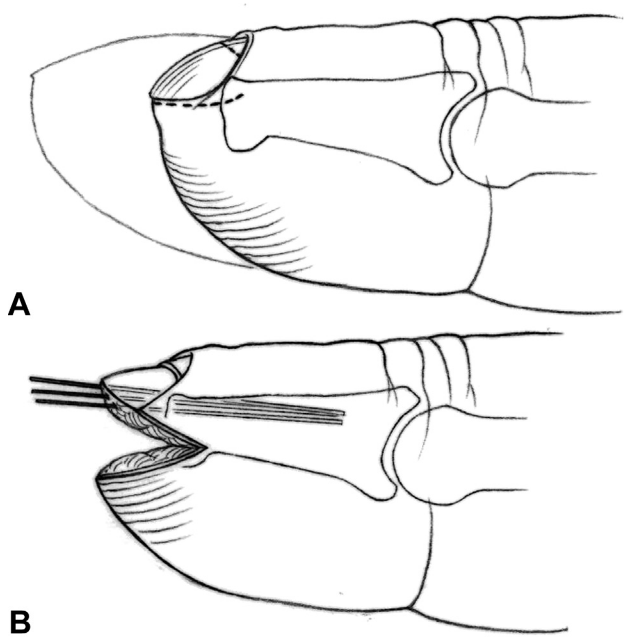


**FIGURE 8: A** Hook nail deformity following fingertip amputation treated with bony shortening. **B** Completed elevation of nail bed by antenna procedure. Pulp may then be reconstructed with a V-Y advancement flap.

time away from work by 6 days compared with primary closure with residual skin flaps. A more recent study from Japan directly comparing amputation closure with replantation equally distributed among 46 amputations found that the Disabilities of the Arm, Shoulder, and Hand score of the replant group was significantly better.[31] All replant patients were highly or fairly satisfied with the results, whereas only 14 patients in the amputation closure group were highly or fairly satisfied. The tradeoffs for this increased patient satisfaction were increased hospital stay and greater time away from work.

A retrospective study from The Netherlands further explored outcome with treatments other than replantation by comparing 59 Allen 2, 3, and 4 amputations in 53 patients treated by reconstruction, bone shortening and primary closure, and wound dressings alone (conservative group).[32] The reconstruction group included full-thickness skin grafts, composite grafting, and a variety of flaps. No statistically significant differences were found with regard to strength, reduction in mobility, cold intolerance, nail deformities, aesthetics, or time away from work. Cold intolerance occurred in 84.7% of the fingers and nail deformities were present in 89.8% of the digits, with hook nail deformity accounting for the deformity 47.5% of the time.

Another recent retrospective study tried to determine indications for operative intervention and whether it offered any advantage.[18] The study looked at 100 tip injuries (including 18 thumbs) classified by mechanism of injury (crush, laceration, or avulsion) and Fassler orientation. The investigators found that patients requiring operative intervention had a significantly longer time to return to work than those not receiving surgery (4.33 vs 2.98; $P = .001$). Surgeries included nail plate removal, full-thickness skin graft, completion amputation, and cross-finger, V-Y advancement, thenar, and first dorsal metacarpal artery flaps. Patients requiring surgery were more likely to have volar oblique (Fassler B), exposed bone, an associated distal phalanx fracture, and a larger soft tissue defect. Multivariate analysis failed to show exposed bone to be an independent predictor of need for surgical intervention.

In conclusion, the fingertip represents a complex anatomic unit that is susceptible to a high rate of injury because of its function as the initial point of contact with our environment. Treatment of fingertip amputations to this point has been largely individualized based on the characteristics and mechanism of the amputation; level of amputation; individual needs and desires of the patient; cultural values; and skill, beliefs, and experience of the treating surgeon. However, despite the frequency of this injury, there has been no reference standard for treatment established.

What few comparative treatment data that exist seem to indicate that more consideration should be given to replantation whenever possible because functional outcome appears to be better than amputation closure. Flap reconstruction also seems to offer little advantage in general over closure by secondary intention except in special instances that are poorly defined to date. One exception is primary use of the homodigital island flap, not only because it largely confines donor morbidity to the injured digit but also because it has evolved as a possible treatment for stump neuroma, a complication that other forms of treatment, with the exception of replantation, do not prevent.

Further development of injury classifications such as the PNB with high interobserver validation that are linked to treatment algorithms will help make treatment more uniform and less based on individual beliefs.

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