TRAUMA TO THE NAIL BED AND ASSOCIATED STRUCTURES

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Acute injuries involving the nail plate and associated structures are commonly treated by the podiatric surgeon. Acute injuries of the toe-nail bed are caused by dropping heavy objects on the toes, or stubbing the toe into a solid object. Less common mechanisms of injury include puncture wounds, as well as lacerations sustained from lawn mower blades, axes, power tools or industrial machinery. Nail bed reconstruction and secondary procedures for perionychial repair commonly produce less than satisfactory results. For this reason, it is important that appropriate acute care of nail injuries be provided.

NAIL ANATOMY, PHYSIOLOGY, AND FUNCTION

The perionychium consists of the paronychium (proximal nail fold, medial and lateral nail grooves), the nail matrix, and the nail bed.[1] (Figure 1) The proximal end of the nail plate (NP) rests in the proximal nail groove, with the proximal nail fold (PNF) situated dorsally. The stratum corneum of the PNF forms the cuticle, which adheres to the dorsal surface of the NP. The NP consists of specialized keratin formed from the matrix cells located beneath the PNF and extending distally to the level corresponding to the distal margin of the lunula. The lunula is the whitish-appearing semilunar area of matrix extending distal to the PNF and cuticle. The nail bed (NB) consists of epithelial cells that do not add to the ventral surface of the NP, but form a relatively smooth, faintly longitudinally furrowed plateau on which the NP glides as it grows distally.[2,3]

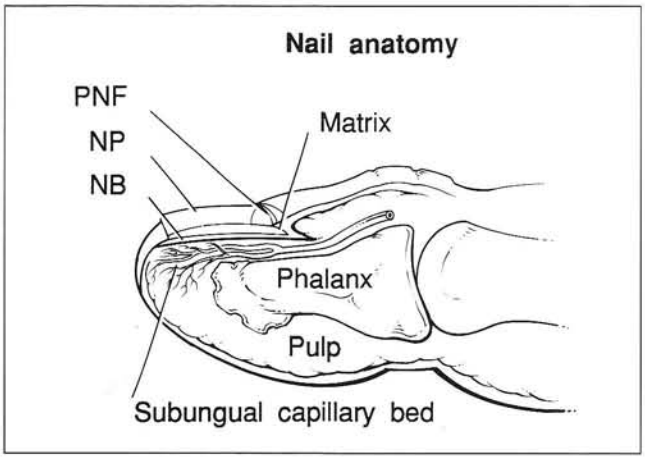

Figure 1. Nail anatomy and associated structures (*NP*, nail plate; *NB*, nail bed; *PNF*, proximal nail fold).

It takes at least five to six months to grow a new toe nail in a healthy adult. The subcutaneous region deep to the nail bed is highly vascularized, and the nail bed and matrix are situated almost immediately adjacent to the periosteum of the distal phalanx of the toe. In essence the nail bed anchors the nail plate to the distal phalanx. At least 5 mm of healthy nail bed distal to the lunula is necessary for nail plate stability.[4]

The nail plate and perionychium are subject to a variety of injuries ranging from minor contusions, to trauma causing severe tissue loss and the need for acute, and sometimes delayed, surgical reconstruction. Such injuries include subungual hematoma, simple NB lacerations, complex (crushing, stellate) NB lacerations, NB lacerations with distal phalangeal fracture, and a variety of NB and toe-tip avulsions, amputations, and degloving injuries. A complete review of the pertinent nail bed anatomy, mechanisms of injury, treatment protocols, and long term prognosis has been published.[5] Patients with NB injuries may present to the hospital emergency room or the local podiatrist's office. Accurate recognition of the extent of injury and proper initial treatment will greatly enhance the chance that post-traumatic sequelae will not develop.

SUBUNGUAL HEMATOMA

A potential space exists between the NP and the underlying NB and matrix. Digital trauma can often cause NB damage with a resultant subungual hematoma. Subungual hematoma may be overlooked because the pathology is hidden by the overlying NP which may be soiled or dystrophic (eg. mycotic). When a patient presents with a swollen toe and complains of throbbing pain following a digital injury, NB damage and subungual hematoma should be suspected.

Hemorrhagic NP discoloration will appear reddish-blue initially and brownish-black after five to seven days, and confirms the diagnosis of a disrupted NB. Radiographs of the digit should always be obtained during the initial evaluation of a subungual hematoma, as approximately 20-25% of these lesions are associated with an underlying phalangeal fracture.[6]

Treating subungual hematoma involves draining the blood to reduce subungual pressure. If the hematoma involves an area less than 25% of the visible NP, drainage can be obtained through the NP with the use of an 18 gauge needle, #11 blade scalpel, heated paper clip, hand cautery unit, or the podiatry drill with appropriate small ball burr.[1,6] (Figure 2) Appropriate antibiotic therapy and tetanus prophylaxis are also administered. Once the plate is penetrated, blood is expressed and pressure released. A water soluble antibiotic cream and a sterile dressing with appropriate splinting are then applied.

The patient is seen for a follow-up evaluation in 7-10 days. If the subungual hematoma involves greater than 25% of the visible NP and/or the plate has been avulsed into or through the proximal or lateral nail folds, a significant NB laceration should be suspected and direct visualization of the bed is recommended.[1] (Figure 3)

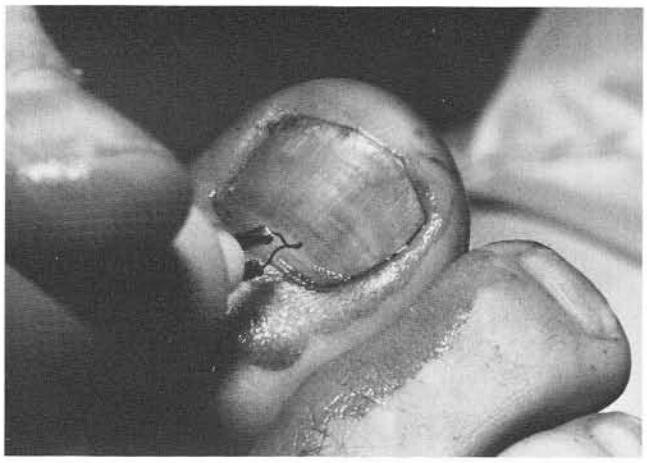

Figure 2A. Hand cautery unit used to penetrate nail plate.

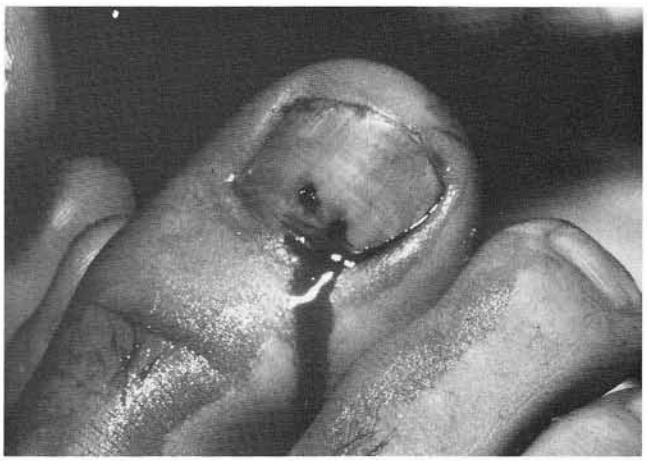

Figure 2B. Hemorrhage expressed through nail plate with relief of pressure.

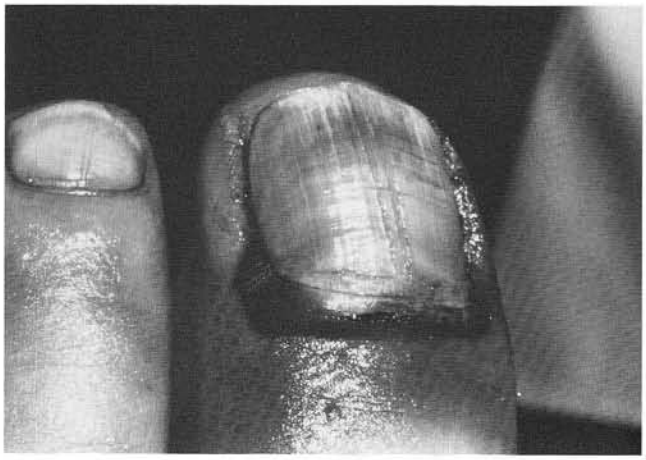

Figure 3A. 100% subungual hematoma following crush injury. Note the dissecting hematoma separating the proximal nail fold epidermis from underlying dermis.

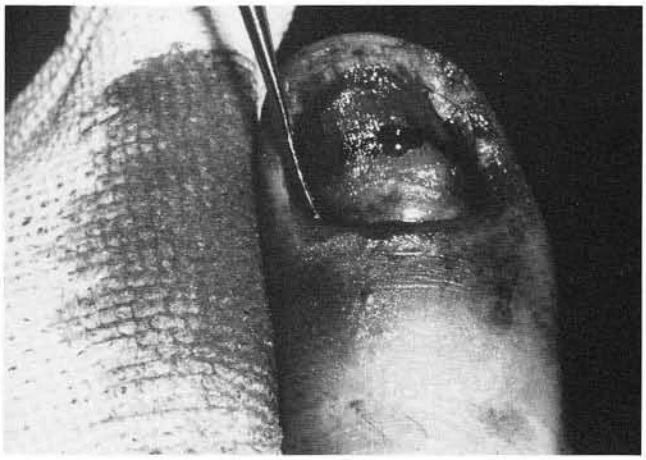

Figure 3B. Simple nail bed laceration observed following NP removal and lavage.

SIMPLE NAIL BED LACERATION

When a significant NB laceration is suspected, the NP is avulsed following digital block (proximal to any traumatized tissue) and a surgical prep. Tetanus prophylaxis and appropriate antibiotics are initiated. If indicated, a Penrose digital tourniquet may be used for hemostasis. If the toe is too edematous for further fluid injection, a more proximal regional block (Mayo block) is effected and the digital tourniquet is not used.

Once the NP has been removed, irrigation is used to flush away hematoma and debris, and the NB is inspected. NB debridement is performed and the margins of the laceration are then meticulously reapproximated using 5-0 or 6-0 absorbable suture on an atraumatic needle in a simple interrupted fashion. Lacerations of the proximal and lateral nail folds are repaired with 4-0 or 5-0 nonabsorbable simple interrupted sutures on a reverse cutting needle. Care must be taken to avoid driving the needle through the nail matrix. After the NB has been repaired, non-adherent gauze is used to bandage the wound and maintain the cul-de-sac nature of the PNF.[7] A digital splint may be indicated, and the patient is usually gait trained with crutches non-weight bearing on the affected side. The first redressing is performed three to five days later. Nonabsorbable sutures used to repair lateral or proximal nail fold injuries are removed after ten to fourteen days.

CRUSHING (STELLATE) NAIL BED LACERATIONS

Crushing nail bed lacerations are managed in the same way as simple NB lacerations. However, the degree of tissue disruption is greater in a crushing nail bed laceration. (Figure 4A-4D) Accurate reapproximation of the wound margins may be difficult, and post-traumatic sequelae due to NB scarification are common. Stellate lacerations of the NB frequently propagate through the nail folds thereby producing large segments of unstable tissue, and concomitant underlying phalangeal fractures are almost always present.

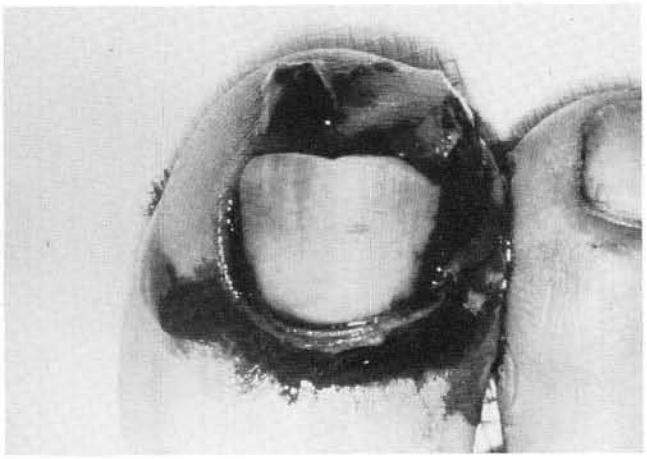

Figure 4A. Crushed hallux with subungual hemorrhage, displaced nail plate, and extensive proximal nail fold and pulp injury.

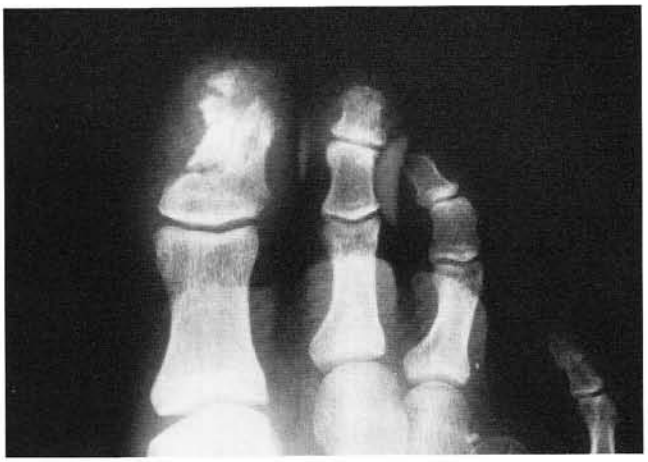

Figure 4B. Radiograph reveals comminuted distal phalangeal fracture.

NAIL BED LACERATIONS WITH FRACTURES

Distal phalangeal fractures, simple and comminuted, frequently result from crush injuries to the toe. (Figure 4A-4D) When the NB or surrounding nail folds are disrupted, these injuries represent open fractures and require appropriate local wound care, tetanus prophylaxis, and antibiotic therapy. Small fragments of bone that are exposed to the outside environment should be debrided. If the wound is obviously infected or heavily contaminated, further surgical debridement and delayed closure should be considered. Otherwise, fragments that are in good alignment with minimal displacement can usually be reduced and

stabilized by reapproximating the NB and splinting. Spontaneous reduction of a transverse distal phalangeal fracture occurs because of the intimate proximity of the NB to the periosteum of the phalanx. Large fragments that remain grossly unstable can be reduced with a single axial K-wire if necessary.

Figure 4C. Removal of nail plate reveals complex nail bed laceration.

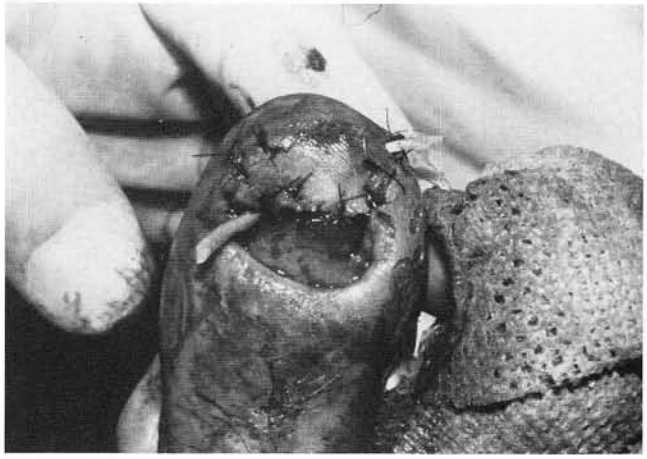

Figure 4D. After excision of bony fragments and debridement, nail bed and paronychium are reapproximated and rubber band drain is used.

Physeal Injuries

In young individuals, the status of the distal phalangeal physis should be assessed. The proximal center of ossification appears in the distal phalanx between three and six years of age, and the two centers are usually fused by eighteen years of age. Severe stubbing or plantarflexory injuries can create a laceration and fracture that propagate along the dorsal surface of the NP into the PNF, and through the physeal plate of the distal phalanx.[8] This type of injury often presents with the NP firmly attached to the NB and the medial and lateral folds. Following cleansing debridement, the phalanx can usually be realigned simply by reapproximating the soft tissues of the PNF and applying a surgical bandage. Splinting and a surgical shoe are used for three to four weeks. Antibiotic therapy should be administered, and the wound should be closely monitored for signs of infection. If drainage or other signs of infection develop, further debridement should be performed and consideration given to avulsion of the intact NP as it may be harboring microorganisms and promoting abscess formation.

NAIL BED AVULSIONS, AMPUTATIONS, AND DEGLOVING OF THE DIGITS

The chances of a good functional and cosmetic result following acute care decrease substantially with NB avulsion injuries and partial digital amputations. Treatment of such injuries varies with the level and direction of the tissue loss. Rosenthal[4] classifies these injuries as described in Table 1.

Table 1

Level of Injury

Zone I	Distal to bony phalanx
Zone II	Distal to lunula
Zone III	Proximal to distal end of lunula

Direction (Plane) of Tissue Loss

Dorsal (oblique)
Transverse
Plantar (oblique)
Axial (tibial or fibular oblique)
Central (gouge)

Distal digital injuries with NB defects within Zone I, without exposed bone, can usually be allowed to granulate closed by secondary intention. The injury is cleansed, mildly debrided and dressed, and the patient is allowed to ambulate to tolerance in a surgical shoe.

Zone I Injuries

If Zone I tissue loss is greater than 1 cm^2, skin grafting on an acute or delayed basis should be considered. Newmeyer[9] advocates using a split-

thickness skin graft on an acute basis, and has developed a simple and effective method easily performed in the office or ER. Clayburgh and associates[10] recommended reverse dermal grafts for filling large nail bed avulsion defects. The use of a skin graft requires intact periosteum upon which the graft is placed. Avulsed or amputated portions of adjacent digits too severely injured to be salvaged may be used as autogenous graft sources. Except for emergency coverage of a large defect with a split thickness skin graft, as described by Newmeyer, skin grafting is best performed on a delayed basis in the operating room.

Zone II Injuries

Zone II injuries are complicated by exposed bone and substantial nail bed loss. In the toes, local (adjacent) pedicle flaps are used for both acute and delayed repair of such injuries. The direction, or plane of the amputation dictates the type of flap to be used. The Atasoy-type plantar[11] or Kutler-type biaxial[12] neurovascular V-Y advancement flaps are best suited for toe reconstruction. These procedures can be readily performed in the emergency room or office. A small amount of bone reduction may be necessary to allow the flaps to cover the defect. Nail bed augmentation is best performed using the Atasoy-type plantar advancement flap following dorsal-oblique tissue loss. Central gouging Zone II defects typically require significant distal phalangeal reduction in order to create adequate plantar soft tissue flaps for wound coverage and proximal nail bed preservation. (Figure 5A-5D)

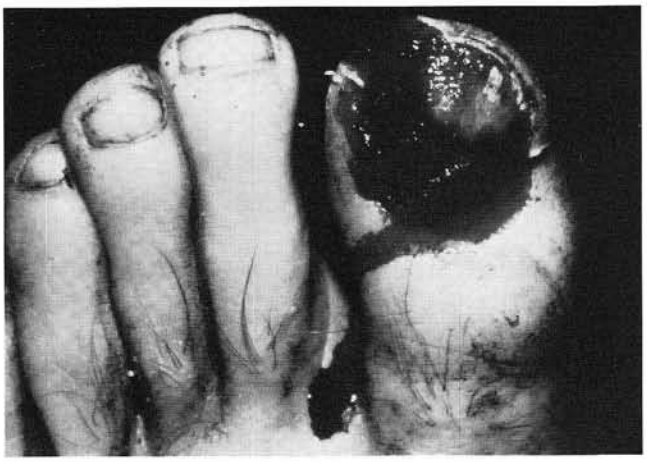

Figure 5A. Zone II central gouging defect secondary to axe injury through a shoe. Initial appearance 12 hours post-injury.

Figure 5B. Radiograph showing comminuted distal phalangeal open fracture.

Figure 5C. Appearance after several days of local care and systemic antibiotics. Note preservation of plantar soft tissue flaps and degree of osseous reduction.

Figure 5D. Definitive surgical repair of redundant tissues and delayed primary closure, following identification of negative bacteriology and good wound appearance. (Courtesy Thomas D. Cain, DPM)

Distant pedicle flaps are not typically feasible in partial amputations of the toes, unless the contralateral foot or leg is being considered as the donor site. In fingertip injuries, cross-finger and thenar distant pedicle flaps are commonly used. Because of the short length of the toes, distant pedicle grafts utilizing the ipsilateral foot or toes are not possible. Reattachment of the amputated tip of a digit as a free composite toe-tip graft is not recommended because results are predictably unfavorable. If too much of the nail bed has been lost (proximal Zone II injury) and subsequent nail plate instability is anticipated, then consideration should be given to ablation of the inadequate residual nail bed.

Zone III Injuries

Zone III injuries in the toes are generally not considered amenable to nail bed reconstruction. Proximal nail fold and groove damage is usually irreparable, and terminal ablation of the perionychium at an appropriate level is recommended. Primary amputation is usually performed in the operating room. Preservation of the distal interphalangeal joint and digital tendon function is attempted.

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