# ORTHOPLASTIC FOOT AND ANKLE RECONSTRUCTION PART II: Rotational Myoplasty for the Treatment of Osteomyelitis in the Foot

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A unified orthoplastic methodology for limb salvage and reconstruction, where the foot and ankle surgeon works along with the plastic surgeon, is often required in traumatic limb injuries, infections, and complex congenital and acquired foot deformities. The goals in the orthoplastic approach to limb reconstruction ultimately are twofold: 1) to achieve or restore maximal function to the limb; and 2) to restore or repair damaged or absent soft tissues. These goals are predicated on the idea that reconstruction is the best option for the patient and that the patient is a suitable candidate to undergo a potentially lengthy course of treatment.

The treatment for pedal osteomyelitis requires consideration of physiologic, psychologic, and anatomic factors to make a decision as to whether salvage and reconstruction is undertaken or palliative care is instituted. When reconstruction is chosen, the complexity of the case often requires a multi-disciplinary approach. Consequently, the efforts of the podiatric and plastic surgeons are complemented by the infectious disease specialist, internist, dietician, physical therapist, and even psychologist to optimize the patient's condition and potential for successful limb salvage.

## THE RECONSTRUCTIVE LADDER

There are several treatment options for surgical management of pedal osteomyelitis, which can be thought of as rungs on a ladder. The first rung on this reconstructive ladder is a "tissue inventory," which is an appreciation for and definition of the extent of osseous and soft tissue damage. This is achieved through history and physical examination as well as ancillary imaging modalities. This will dictate the direction for reconstruction and which further rung or rungs on the ladder will be employed. Osseous damage can include pathologic fractures, septic nonunions, osteomyelitis or infectious osteitis which can result in segmental bone loss. Concomitant soft tissue damage can be substantial, and is often greater than that which is initially apparent. Included in this assessment is damage to neurovascular structures, and their repair may take priority over osseous or other soft tissue reconstruction.

The next step is an adequate wound debridement. The goal of wound debridement is to convert a heavily contaminated wound with necrotic tissue to a clean, live wound that has the potential to heal. If the tissue inventory reveals complete obliteration of soft tissue and osseous substance beyond a level of which a successful reconstruction can be carried out, early amputation may be warranted. This should not be thought of as a failure but rather an aggressive and realistic treatment strategy. Amputation level is defined by the level above the tissue destruction at which there is adequate perfusion and where a reasonable return to function can be anticipated. This is particularly important in the foot where metabolic demand will increase with more proximal amputations.[1] If initial amputation can be avoided despite thorough debridement and there is a realistic expectation for a successful reconstruction, then this strategy should be attempted in most cases. Reconstruction can entail a lengthy course and require multiple operations. Therefore, the goals of reconstruction should constantly be evaluated throughout the treatment course in contrast to a swift, definitive, single-stage operation such as high-level amputation. Furthermore, amputation can always remain a treatment option should reconstructive efforts fail.

Hardware placement, either internal or external, may be required for limb stabilization. External fixators can span infected joints and large osseous segements while bone resection is carried out. In cases of localized osteomyelitis or osteitis the infected bone can be serially debrided with shavers and rotary burrs with care to preserve structural support until clean margins are obtained. Bone is debrided down to uniform cortical and cancellous bleeding.[2] Cavernous or segmental osseous defects (dead space) may be packed with antibiotic-laden methacrylate beads or calcium phosphate beads after initial debridement (empiric antibiotic) or during a secondary operation after initial culture results are obtained. Soft tissue debridement should be thorough and performed with the intent on eradicating infected, necrotic tissue and halting the progression of infection, while preserving a functional extremity.

After adequate debridement of all infected or questionable tissue, there may be several options for reconstruction of bone, soft tissue, or both. Osseous reconstruction begins with evaluation of existing support and type of bone that is lost. Bone defects can be filled through intercalary bone grafting or long bone transport using an Ilizarov external fixator. This latter method is performed after soft tissue coverage has been accomplished. Infected joints or pseudoarthroses can be fused after infection eradication.

Soft tissue reconstructive options for the lower extremity range from primary closure to microsurgical free flaps and staged reconstructions.[3] Clean wounds without ragged edges under minimal to no tension can be closed directly, appropriately termed "linear closure." Primary closure more accurately describes a wound closed without the use of borrowed tissue. Smaller wounds may be initially debrided and packed open, then allowed to close secondarily or through delayed primary closure. The next rung on the ladder includes the use of a split-thickness skin graft for closure of a clean wound that is too large for primary closure without excessive wound tension. In cases of significant soft tissue loss a fasciocutaneous or myofasciocutaneous flap may be required which is the next rung on the ladder. These can take the form of random flaps of skin and subcutaneous tissue (rotation, advancement, or transposition) for smaller defects. For larger, deeper defects, for regions with little vascularity, or regions of tissue loss involving the plantar aspect of the foot, muscle can be rotated with or without its overlying cutaneous tissue. Finally, if no local tissues are available then microsurgical free flaps (i.e., latissimus dorsi) can be used for reconstruction.

## GUIDELINES FOR SOFT TISSUE RECONSTRUCTION

The foot and ankle reconstructive surgeon must create a stable osseous frame around which the soft tissues are manipulated. Therefore consultation with the plastic surgeon prior to definitive osseous management is critical. For example, decisions regarding the use of an external fixator versus internal fixation may change the plastic reconstructive options since the choice of fixation may limit access to the wound or prohibit mobilization of large local flaps. Likewise, initial incision placement for access to infected or fractured bone may preclude the use of a preferred local flap for a less optimal flap. Repeat bone debridement or remodeling may be necessary to allow local soft tissue rotation for osseous coverage (i.e., bone shortening).

Once the underlying osseous segment is prepared several options exist for soft tissue coverage including muscle flaps, fasciocutaneous flaps, or free tissue grafts. The decision for the use of one type of flap for coverage over another is dependent on numerous factors although several generalizations can be made. Ideally the same type of tissue that is lost is used for replacement. The choice of reconstructive method however is not always ideal, and depends on both local and systemic factors. Local factors include the location, size and type of defect and the presence of vascular disorders. The arc of rotation for certain local flaps in the foot and ankle may prevent their usage in reconstruction. Concomitant vascular damage, whether secondary to general vascular disease or local tissue destruction, can limit the effective portion of an otherwise useful flap. Moreover, additional early and late deformity can result from local tissue usage. General or systemic considerations include the patient's overall medical/nutritional status and their functional expectations.

The ideal flap will cause the least morbidity while providing the best mechanical, functional, and cosmetic result. If primary closure of a wound is possible it is preferable to close in this fashion, however closure in this fashion when dealing with osteomyelitis historically has been successful less than 50% of the time.[4,5] If direct skin edge apposition is not possible fasciocutaneous flaps or skin grafts are used. When significant soft tissue defects exist or underlying bone is exposed, muscle is incorporated into the flap. Local flaps may be preferred to distant free flaps for smaller defects because of the inherent decrease in morbidity, although this depends on the availability of acceptable local tissue. Innervated flaps are preferable in mechanically exposed areas such as the bottom of the foot, although the argument for the use of sensitive flaps in the neuropathic foot is debatable.

## ROTATIONAL MYOPLASTY

Muscle flaps in general are an excellent option for foot and ankle reconstruction and infection management. They are an excellent vascular conduit, carrying to the wound necessary nutrients, white blood cells, and systemic antibiotics. They are also generally more resistant to ischemia than fasciocutaneous flaps. They can be molded to fill a defect, provide adequate osseous padding or bulk, and provide a wound bed which can immediately accept a skin graft. The downside to using rotational muscle flaps is the expected loss of the donor muscle function and potential for increased disability and dysfunction with the affected limb.

Muscles have one of five types of blood supply as outlined by Mathes and Nahai.[6] Type I muscles receive input from a singular vascular pedicle. Type II muscles receive their vascular input from one primary pedicle at or near the muscle origin and from several smaller pedicles along the muscle belly. Type III muscles receive input from two major vascular pedicles from two separate arteries, while type IV muscles receive their blood supply from several segemental pedicles along the entire course of the muscle belly. Each pedicle serves a specific region of the muscle and without which that portion of the muscle could not survive. Finally, type V muscles have one dominant pedicle at the origin and several smaller pedicles at the insertion. Of these five patterns, type II and type IV muscles predominate in the lower extremity. The latter pattern is seen in most of the lower leg muscles.[7] Consequently, for type IV muscles, the ability to rotate the muscle is restricted by the number of vascular pedicles that can be severed and still maintain the viability of the muscle. Type II muscles on the other hand have one dominant pedicle that can generally sustain the rotated muscle despite ligation of the smaller segmental pedicles. This pattern is seen with most muscles in the foot, allowing for their use in rotational myoplasty in this region.

### Abductor Digiti Minimi Rotational Myoplasty

The abductor digiti minimi pedicle flap can be utilized for coverage of lateral column and heel defects based on the proximal lateral plantar artery major pedicle.[8, 9] The muscle takes its origin from the lateral tubercle of the calcaneus, deep to the origin of the flexor digitorum brevis. It is the most lateral muscle of the foot. On the medial aspect of the muscle lies the lateral intermuscular septum proximally and flexor digiti minimi brevis distally. Inferior to the muscle is the lateral band of the plantar fascia. Superiorly lies the peroneus longus tendon sheath proximally and fifth metatarsal distally. It course distally along the lateral margin of the foot to its insertion on the base of the proximal phalanx of the fifth toe, which it shares with the flexor digiti minimi brevis muscle of the third plantar layer. The muscle can flex and abduct the fifth toe at the metatarsophalangeal joint, counter-balancing the pull of the long extensor of the fifth toe and the medial interossei and lumbricale musclature. The muscle is supplied by the lateral plantar artery and nerve. Several small vascular pedicles of this type II muscle can be found on the medial aspect of this muscle along its course. The dominant vascular pedicle can be found closer to the muscle origin several centimeters distal to the calcaneal tuber.

The approach for a proximally-based muscle flap is through a linear incision directly over the body of the muscle, from the calcaneus to fifth metatarsophalangeal joint. The muscle is first identified distally near its insertion, where the dorsal and plantar aspects of the tendon are easily visualized. It is followed proximally with care not to violate the deep fascia overlying the muscle belly. The plantar fat pad is thick and separates easily from the deep fascia overlying the muscle belly and is retracted inferiorly with large atraumatic retractors. The tendon is then tagged distally with suture and the tendon is released from its insertion. Meticulous dissection is carried out under loupe magnification revealing several small pedicles supplying the muscle belly on its medial aspect. These can be ligated utilizing bipolar electrocautery while dissection is continued proximally. Once the dominant vascular pedicle is identified, the remaining constricting fascia is freed and further proximal dissection ceases. The muscle can then be folded backwards to assess its fit in the soft tissue defect. Kinking of the vascular pedicle is always a concern with muscle rotation and careful placement and handling of the muscle is critical. The color of the muscle should be carefully monitored throughout the procedure and treatment course. Loss of vascularity to the muscle will reveal a gray, dusky muscle belly within minutes.

The muscle is secured in place with 5-0 gauge absorbable monofilament (Monocryl®) suture within the periphery of the recipient site. Once the muscle is well seated a split-thickness skin graft is applied directly over the muscle and secured to the wound periphery. Appropriate dressings are then applied with mild, even compression over the graft and flap.

## ILLUSTRATED CASE SERIES (Figures 1-24)

### Flexor Digitorum Brevis Rotational Myoplasty

Soft tissue defects of the heel pad or osteomyelitis involving the plantar calcaneus can be managed with rotation of the flexor digitorum brevis muscle on the medial plantar artery vascular pedicle. The muscle takes it origin from the plantar aponeurosis, medial and lateral intermuscluar septa, and from the medial tubercle of the calcaneus. The muscle courses distally and divides into four tendon slips, each to a lesser toe along with a tendon from the flexor digitorum longus. The tendons cross the metatarsophalangeal and proximal interphalangeal joints and therefore act to plantarflex the lesser digits. This muscle lies immediately deep to the plantar fascia and superficial to the long flexor tendon proximally and lumbricale tendons distally. Medially and laterally the flexor digitorum brevis is confined by the respective intermusclar septae.

The muscle is approached from a linear or curvilinear plantar midline incision that is carried through the plantar fascia. The foot is then divided into medial and lateral halves, and care is taken to minimize the subcutaneous dissection superficial to the plantar fascia. The lateral border of the muscle is approached first distally and followed along the lateral intermuscular septum. Each tendon slip is identified distally. The plantar neurovascular bundles to the digits are found between tendon slips and should be carefully and atraumatically retracted. Each tendon slip is then transected and tagged. The muscle is then separated from the medial intermuscular septa and reflection of the muscle proximally towards the medial vascular pedicle is carried out. Once adequate length has been obtained, the muscle is folded backwards and tagged into the defect. A split-thickness skin graft is used for cutaneous coverage.

Figure 1. Lateral Zwipp-type incision dehiscence after open reduction and internal fixation of joint depression type calcaneal fracture.

Figure 2. Full thickness apical necrosis with underlying hardware exposure. The hardware was removed and the bone was biopsied revealing osteomyelitis confined to the lateral calcaneal wall.

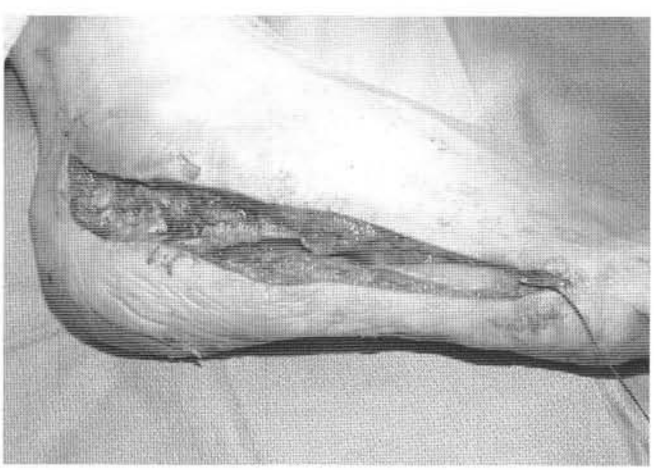

Figure 3. Thorough debridement of the lateral calcaneal cortex and surrounding soft tissue was carried out. The abductor digiti minimi muscle was chosen for rotational myoplasty. The original incision is continued over the muscle belly to the level of the metatarsophalangeal joint.

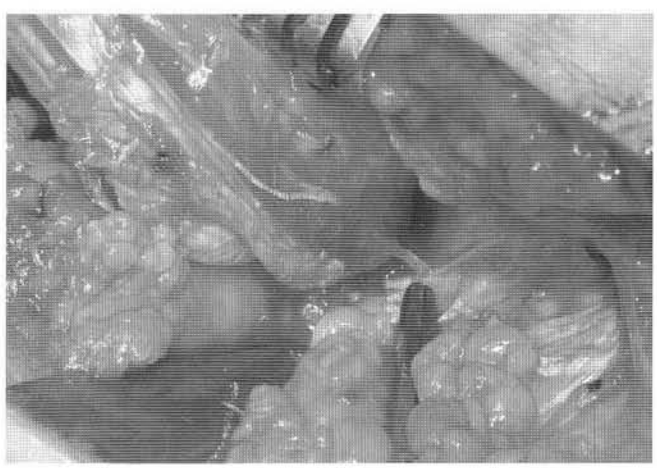

Figure 4. The muscle is reflected from the lateral intermuscular septum and small vascular pedicles to this type II muscle are coagulated with bipolar cautery. Several of these pedicles will be encountered along the medial face of the muscle belly.

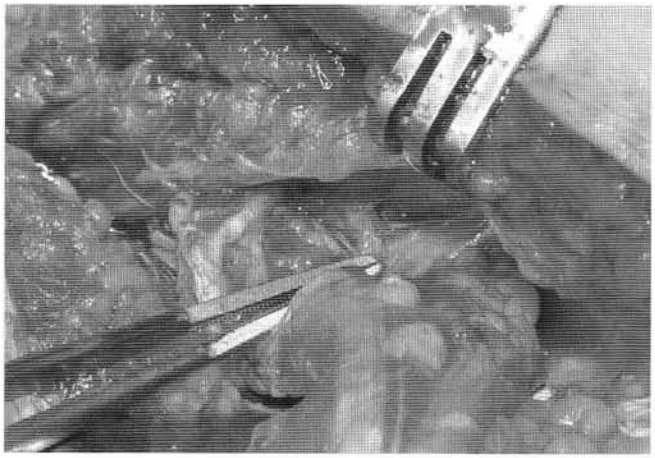

Figure 5. The primary vascular trunk from the lateral plantar artery is identified and preserved. This pedicle is encountered at the proximal cuboid level.

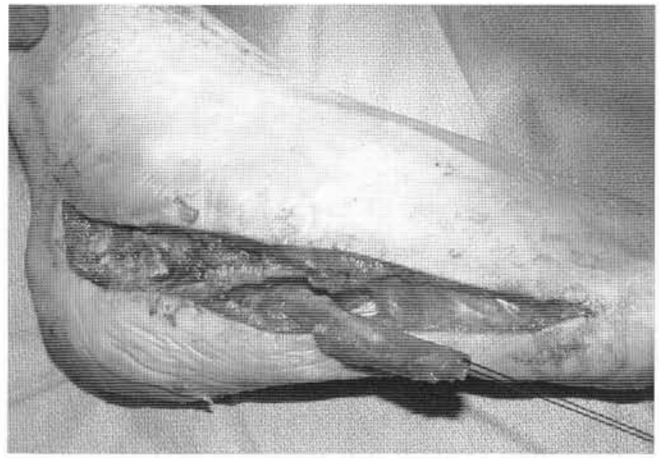

Figure 6. The muscle is rotated on itself proximally to fill the lateral defect. Care is taken not to kink the remaining vascular pedicle.

Figure 7. Adequate length has been achieved. Freedom of distal and inferior myofascial attachments is crucial for development of this flap.

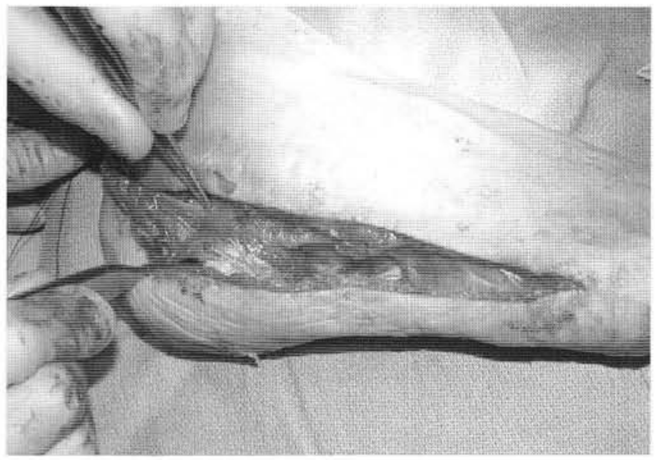

Figure 8. The muscle is contoured to the underlying osseous surface and tacked in to the wound edges. Any tendon is debrided. The muscle can be 'expanded' by gently teasing through the fascia over the muscle in a longitudinal fashion.

Figure 9. Small guage monofilament suture is then utilized circumferentially to secure the muscle flap in place.

Figure 10. The distal wound is closed directly and the muscle flap is covered with a split-thickness skin graft. Closed suction drainage is instituted to prevent hematoma and fluid collection in the dead space.

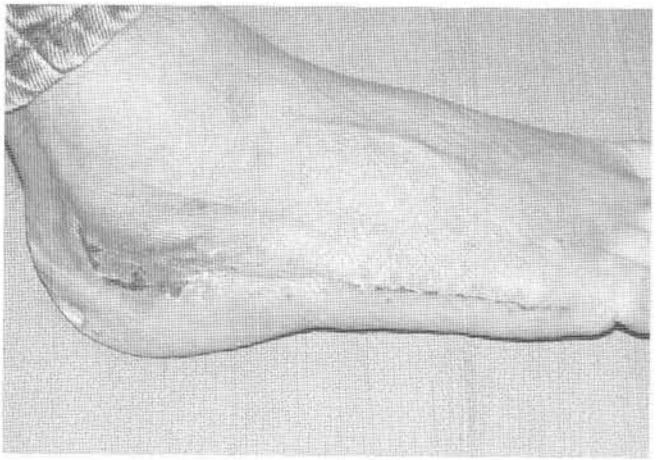

Figure 11. Patient 2 months post graft.

Figure 12. Scar revision was carried out 2 months later.

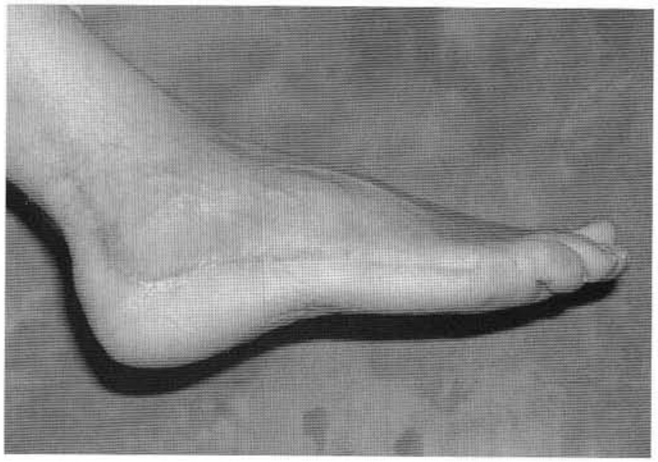

Figure 13. Final appearance of lateral wound.

Figure 14. Infracalcaneal ulceration of 2 years' duration. Evidence of prior skin graft is seen as hyperpigmentation in the plantar arch region.

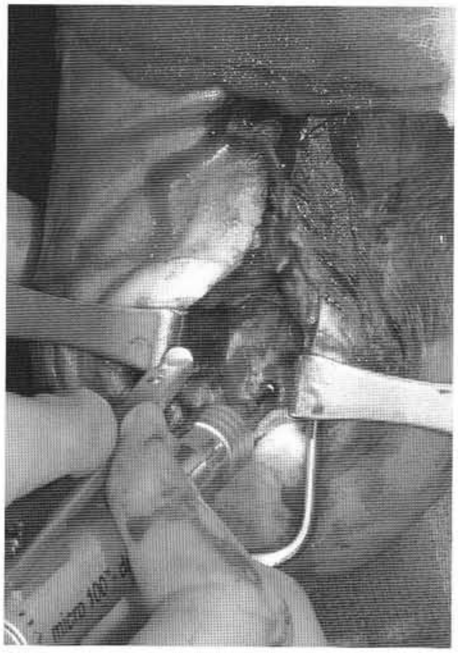

Figure 15. Bone biopsy indicates osteomyelitis localized to the inferior calcaneal cortex. Debridement of this cortical margin is carried out with high-speed rotary shavers under cool saline to healthy bleeding bone.

Figure 16. The flexor digitorum brevis muscle belly was elected for bone coverage and closure of the wound. Incision placement follows the direction of the muscle belly, with care not to violate the prior skin graft.

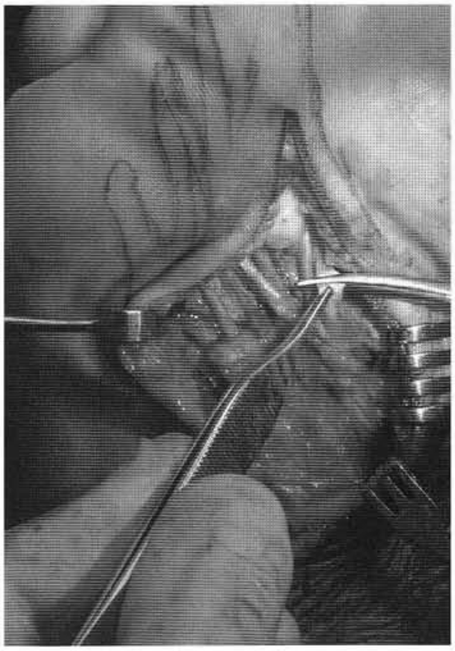

Figure 17. The tendon slips are identified distally and transsected. The neurovascular bundles to the respective digits are apparent between the tendon slips.

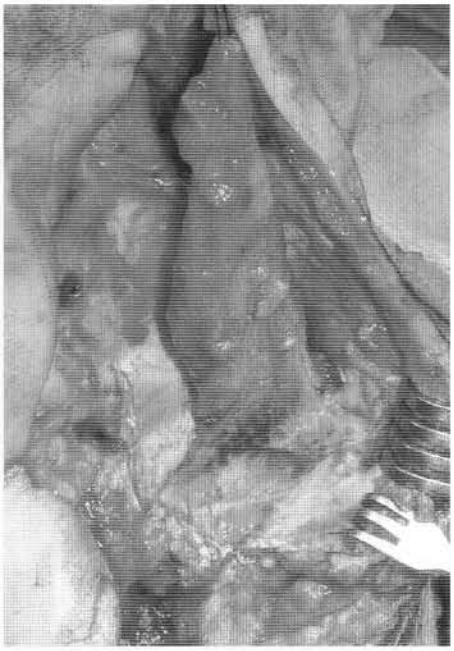

Figure 18. The muscle is dissected from the medial and lateral intermuscular septa. The anatomy of this region is distorted due to prior surgical procedures. Small vascular pedicles are coagulated to allow proximal dissection.

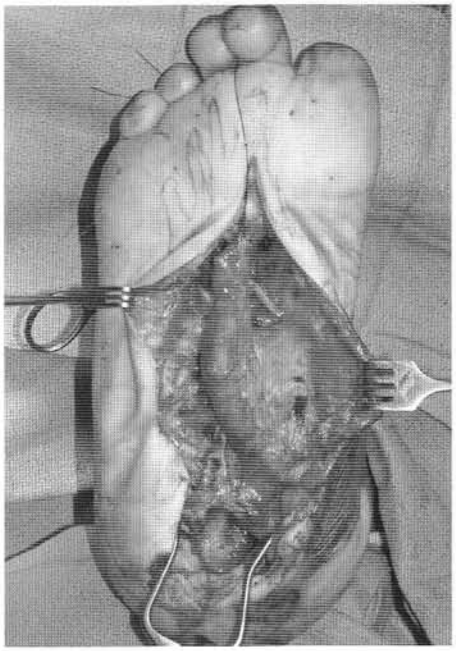

Figure 19. The distal tendon slips are ressected and the end of the muscle is tagged. The muscle is then rotated posteriorly to fill the soft tissue defect over the debrided calcaneus.

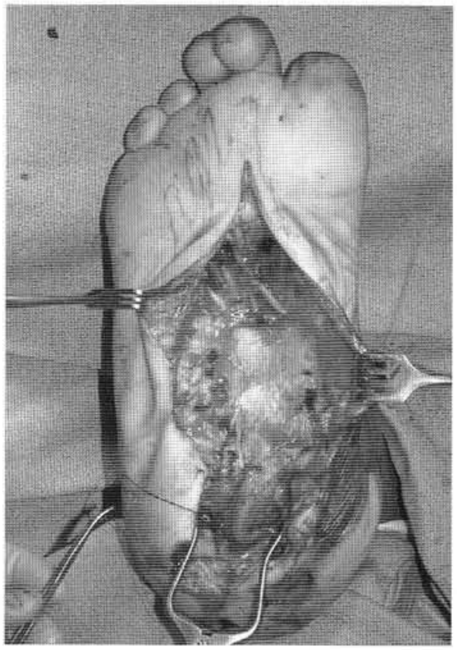

Figure 20. A small amount of contouring is required to fill the void.

Figure 21. The wound edges are opposed distally.

Figure 22. The distal wound is closed directly. A Keith needle is inserted into the heel from exterior to interior and purchase the muscle on its superior surface. The needle is then passed through the skin posteriorly and fastened to a nylon button over the skin. This will help maintain apposition of the muscle with the bone.

Figure 23. A meshed split-thickness skin graft is then applied over the muscle belly.

Figure 24. The infracalcaneal ulcer is healed after 3 months and the overlying skin graft has also become hyperpigmented. A small area of the previous skin graft has broken down distally due to irritation from the posterior splint. This wound will go on to heal uneventfully with local wound care.

## DISCUSSION

Management of pedal bone and soft tissue infection can require the expertise of both podiatric and plastic surgeons. There is an overwhelming emphasis in podiatric surgery to eradicate all bone and soft tissue infection, sometimes without deliberation for soft tissue reconstructive options. Maintenance or creation of a clean, stable, and healthy osseous frame is indeed central to the surgical approach to osteomyelitis. However, soft tissue coverage is paramount to a successful salvage and consequently should be included as a primary goal.

Rotational myoplasty in the foot is a useful tool in a staged reconstruction for pedal osteomyelitis. Pedicled muscle flaps provide vascularity, bulk, and protection to underlying bone after adequate debridement, and can allow for surgical closure earlier than more conventional wound care methods. There are also disadvantages to their use, including additional dysfunction and morbidity to the extremity. It has also been suggested that the rotated muscle flap may form a fibrotic scar and serve as a nidus for future infection.[4] Another author demonstrated that although initially apparent, the antibiotic carrying capacity of a muscle decreases over time, presumably a result of muscle scarring and loss of vascularity.[10]

Despite these arguments, this method has been shown to be effective as part of limb reconstruction. To assess the efficacy of muscle flaps for coverage of osteomyelitis in the lower extremity Anthony et al. evaluated 27 patients at least five years post reconstruction, 23 of whom had local flap coverage. In their series 89% were without recurrence of infection for a minimum of five years (mean 7.4 years).[11] Other authors have published similar results, with success using local flaps for lower extremity osteomyelitis ranging from 84 to 93%.[12-14] We have had a similar experience at Northlake Medical Center, supporting this staged method for dealing with pedal osteomyelitis in the appropriate candidate.

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