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Clin Podiatr Med Surg
25 (2008) 623–639

CLINICS IN PODIATRIC MEDICINE AND SURGERY

Soft-Tissue and Osseous Techniques to Balance Forefoot and Midfoot Amputations

Monica H. Schweinberger, DPM, AACFAS,
Thomas S. Roukis, DPM, PhD, FACFAS*

Limb Preservation Service, Vascular/Endovascular Surgery Service, Department of Surgery, Madigan Army Medical Center, 9040-A Fitzsimmons Avenue, MCHJ-SV, Tacoma, WA 98431, USA

Amputation is largely considered an undesired end point when treating limb-threatening conditions of the lower extremity. Although all reasonable attempts to preserve a patient's foot and lower leg should be considered, the functionality of the limb and likelihood of recurrent ulceration or infection must be assessed. In some cases, a well-balanced partial forefoot or midfoot amputation will provide the patient with a more durable extremity that will better maintain their independence than minimalistic procedures aimed at preserving a deformed forefoot.

Historically, forefoot and midfoot amputations were received negatively secondary to numerous complications that patient and surgeon encountered with them. Delayed or nonhealing of incision sites, re-ulceration, and recurrent infection are commonly reported following these procedures [1–3]. Poor long-term results of hallux amputations have been reported with re-amputation rates ranging from 53% to 61% in two retrospective studies [4,5]. Equinovarus deformity is a widely recognized complication of transmetatarsal and Lisfranc amputations often leading to recurrent ulceration and more proximal amputation [1,2]. Failure rates for transmetatarsal amputations (TMA) have been reported from 17% to 44% [1]. In looking critically at these complications, the majority of them can be traced back to three potential etiologies: (1) non-compliance; (2) multiple co-morbidities; and

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* Corresponding author.
E-mail address: thomas.s.roukis@us.army.mil (T.S. Roukis).

0891-8422/08/$ - see front matter. Published by Elsevier Inc.
doi:10.1016/j.cpm.2008.05.006

(3) unaddressed pedal deformity [3]. Each of these is discussed in detail in this article.

Noncompliance

It is convenient at times to blame a patient's noncompliance with postoperative instructions for a poor outcome or undesired complication. Obviously, the patient must bear some responsibility if they willfully disregard their surgeons' orders despite warnings about the negative consequences, which include more proximal amputation. However, in many cases there may be barriers to compliance that should be identified preoperatively, or during the patient's hospitalization, and fully addressed [6]. The majority of patients undergoing amputation in the United States and Europe today are diabetic [7] and many are elderly, as well as, in poor physical condition. Postoperative, nonweight bearing restrictions may be impossible for these patient populations who therefore require alternative measures such as wheelchairs, total contact casts, or skilled nursing facility placement during recovery to protect the operative limb. If the patient lives alone at home, they may require a home health aide to help with their necessary activities of daily living, as well as, transportation to and from clinic appointments. Smoking cessation is imperative to improve the likelihood of incision healing [3] and patients may require referral to a smoking cessation support network to aid them in this process. Depression needs to be managed with counseling, support groups, or referral to a psychiatrist for evaluation and treatment, depending on the severity [3,6]. A social worker should be involved with every patient undergoing an amputation because failure to address the needs of the patient allowing them to maximize their ability to follow instructions will inevitably lead to postoperative complications.

Comorbidities

Medical comorbidities such as uncontrolled diabetes, peripheral arterial disease, chronic renal failure, and malnutrition all increase the risk of infection and nonhealing after partial foot amputation [3]. Uncontrolled diabetes impairs leukocyte function, which results in reduced host resistance and response to infection [8,9]. Peripheral arterial disease reduces the likelihood of incision healing secondary to inadequate perfusion of the surgical site [10]. Chronic renal failure causes proteinurea and resultant albumin deficiency, [3] which affects nutritional status and wound healing. Malnutrition can be precipitated by catabolism resulting from the presence of a wound or may pre-exist, before wound development. Regardless of the etiology, collagen synthesis is significantly impacted by inadequate nutrition [11].

In order to optimize the high-risk patient undergoing partial foot amputation and provide the most ideal conditions for successful postoperative healing without infection, multidisciplinary patient management involving endocrinology, infectious disease, internal medicine, nephrology, nutritional services, podiatric or orthopedic foot and ankle surgery, and vascular/endovascular surgery is required [12]. Significant patient education will likely be necessary to improve the patients overall health long-term.

Unaddressed deformity

Specifically in the neuropathic patient, ulcerations result from excessive, repeated pressure and shear on a concentrated area of the foot [13]. Deformities of the foot and ankle, such as equinus [14], hammer digit syndrome, hallux valgus, rigidly plantarflexed metatarsals, and Charcot neuro-osteoarthropathy deformity increase pressure and therefore the risk of ulceration. Neuropathic patients with deformity and a history of ulceration have a 36 times greater risk for re-ulceration than the general population [15]. Hallux amputations have been demonstrated to cause increased pressure plantar to the metatarsal heads and toes compared with the contralateral side [16]. In addition, the severity of deformity on the contra-lateral limb worsens with time, especially at toes two and three and metatarsophalangeal joints two through five [17]. The increased plantar pressure and shear caused by this progressive deformity can result in both fracture and ulceration with potential infection and repeated amputation [18].

Equinovarus deformity seen after transmetatarsal and Lisfranc amputations performed without proper balancing often results in ulceration at the plantar-lateral aspect of the stump from excessive pressure [19,20]. Following transmetatarsal or Lisfranc amputation, the foot is reduced in length leading to overpowering by the gastrocnemius-soleus complex, and the transverse arch of the foot is structurally aligned in varus due to the loss of the metatarsal heads. Therefore, the foot automatically assumes an equino-varus posture (Fig. 1). The equinus deformity will worsen if unaddressed because of the elimination of extensor digitorum longus and extensor hallucis longus muscle function postoperatively, which causes an imbalance between the posterior compartment and the anterior compartment with resultant plantarflexion at the ankle joint [20]. Likewise, the varus deformity will worsen if left unaddressed secondary to the loss of intrinsic muscle function and disruption of the insertion of the plantar fascia causing subtalar joint imbalance and increased inversion pull of the tibialis anterior and posterior muscles, which overpower the eversion strength of the peroneus brevis muscle [1]. Prophylactic surgery to correct deformity and reduce the likelihood of ulceration in neuropathic patients has been suggested by some authors [9,15].

When performing amputations, the surgeon must evaluate the patient's global foot structure and determine the etiology of the initial problem and what potential deformities may occur postoperatively. If each of the patient's deformities and potential deforming forces is able to be surgically

Fig. 1. Clinical en fass view following transmetatarsal amputation performed at another facility demonstrating the universal forefoot varus deformity present if soft-tissue or osseous balancing techniques are not employed.

addressed, the likelihood of recurrent ulceration and amputation should be reduced. This paper focuses on specific techniques to appropriately balance transmetatarsal and Lisfranc amputations with tendon transfer, as well as joint stabilization to consistently provide a stable, plantigrade, and functional residual foot.

Indications

The appropriate amputation level for an individual patient is determined by vascular supply, available soft tissue coverage, and deformity or previous surgery. An ankle brachial index (ABI) of $\leq$ 0.45 is generally considered incompatible with healing, while transcutaneous oxygen tension of $\geq$ 30-mm Hg or greater indicates, but does not guarantee, the potential to heal [3]. When a patient's arterial supply is in question, a vascular surgeon or endovascular specialist should be consulted to determine if revascularization procedures are indicated. The partial foot amputation must be performed at a level with adequate perfusion to heal.

Large open wounds on the dorsal or plantar foot must be excised before definitive closure of an amputation, and they may necessitate more proximal amputation if adequate soft-tissue is not available for coverage, especially plantarly. Primary closure is preferred; however, alternate methods of wound closure can be used if necessary. Skin grafts are generally thought to be a poor choice for coverage on weight bearing areas, but can be used in nonweight bearing areas of the plantar foot or dorsally for wound closure

[21]. Some surgeons will use skin grafting in weight bearing areas if there is adequate underlying granulation tissue and the patient can remain non-weight bearing on the foot until complete healing and maturation of the skin graft occurs at which point the tissue is quite durable. After they are fully matured, skin grafts usually contract a great deal, especially thin split-thickness skin grafts that can be excised and primary closed. Local flap coverage of plantar wounds may be possible depending on the size of the defect, mobility of the regional tissue, and adequacy of arterial supply to the foot [21,22]. Free flaps have been described, but can leave excessive bulk that is difficult to shoe or brace and prone to breakdown from the shear forces between the native and transferred tissue [23]. Performing the amputation at a level at which primary closure can be performed will avoid the additional incisions and potential vascular compromise associated with alternate wound coverage techniques and thus, may ultimately lead to a more functional and durable result.

In general, when a patient requires or has undergone a hallux or partial first ray amputation in isolation, owing to the high postoperative re-ulceration and re-amputation rates discussed earlier; has had two or more ray amputations; or has significant forefoot deformity in the presence of recurrent ulceration or infection, then a TMA or Lisfranc amputation should be considered. The amputation is performed at the most distal level compatible with healing and wound closure as discussed above [24]. Proper balancing of the residual stump will generally provide a durable, stable, plantigrade, and functional foot.

Forefoot and midfoot amputation balancing

TMA and Lisfranc amputations are routinely performed in conjunction with a percutaneous Achilles tendon lengthening, open gastrocnemius recession, or endoscopic gastrocnemius recession to address the equinus deformity. Details regarding procedure selection and techniques for soft-tissue ankle equinus correction can be found in a separate article included in this issue [25]. Additional tendon or osseous balancing is required to address or prevent varus deformity in both TMA and Lisfranc amputations. Some authors have recommended tenodesis of the flexor and extensor tendons from the 4th and 5th toes, while the foot is held in neutral position, to oppose the deforming forces of the gastrocnemius-soleus complex and tibialis anterior muscles [24]. This form of balancing is not recommended by the author as it leaves dysvascular tissue in the wound bed and does not have the strength or stability to balance the tibialis anterior or gastrocnemius-soleus complex. Split tibialis anterior tendon transfer (STATT) has been described to address forefoot varus after TMA and Lisfranc amputation [1]; however, this procedure requires three incisions and may be contraindicated in patients who have undergone peripheral arterial bypass surgery secondary to the potential for disrupting or compressing the bypass site which can lead to dorsal tissue necrosis. Peroneus brevis (PB) to peroneus longus (PL) tendon transfer can effectively plantarflex the first ray while simultaneously everting the forefoot after TMA, thereby, correcting the forefoot varus deformity [26]. However, this procedure may be contraindicated in patients with peripheral arterial disease due to the additional incision required and potential for wound dehiscence and delayed or nonhealing. An intramedullary screw placed through the residual first metatarsal or medial cuneiform and driven into the talus while the forefoot is held in neutral alignment, similar to the techniques described by various authors for percutaneous Charcot stabilization [27–31], can also correct forefoot varus and provide good stability to the medial column without the need for additional incisions [32]. This technique is effective for both TMA and Lisfranc amputations especially in patients with peripheral arterial disease [32]. Finally, transfer of the tibialis anterior tendon into the medial cuneiform and the peroneus brevis tendon into the cuboid [1,19] following Lisfranc amputation can maintain a rectus position of the foot post-operatively.

The three most commonly employed techniques by the senior author, (T.S. Roukis) are: (1) PB to PL tendon transfer, (2) intramedullary screw placement, and (3) transfer of the tibialis anterior tendon into the medial cuneiform and the peroneus brevis tendon into the cuboid. Each of these is discussed in detail in the following sections.

Peroneus brevis to peroneus longus tendon transfer

The surgical procedure begins with the patient positioned in the supine position on the operating room table with a well-padded bolster placed beneath the ipsilateral buttock to control physiologic external rotation of the lower limb. The incision is mapped out at the midpoint between the posterior edge of the distal tip of the lateral malleolus and the dorsal edge of the posterior aspect of the 5^{th} metatarsal base and is approximately 3 cm in length (Fig. 2 A) [26]. A No. 10 blade is used to incise the skin approximately 1 cm in depth exposing the underlying peroneal retinaculum, which should be visible at the base of the incision. The peroneal retinaculum is then incised in line with the skin incision allowing visualization of the PL tendon inferiorly and the PB tendon superiorly. The intertendinous portion of the peroneal retinaculum is excised to facilitate the transfer. A clamp is placed about the PB tendon adjacent to its insertion on the 5^{th} metatarsal base. The PB tendon is then transected distal to the clamp and retrieved from the surgical site. Electrocautery is used to mark the location of two longitudinal tenotomy incisions to be performed in the PL tendon through which the PB tendon will be weaved. Two stab incisions are performed with a No. 10 blade and then a 90° angled clamp is placed from deep to superficial to advance the PB tendon through the PL tendon at the proximal

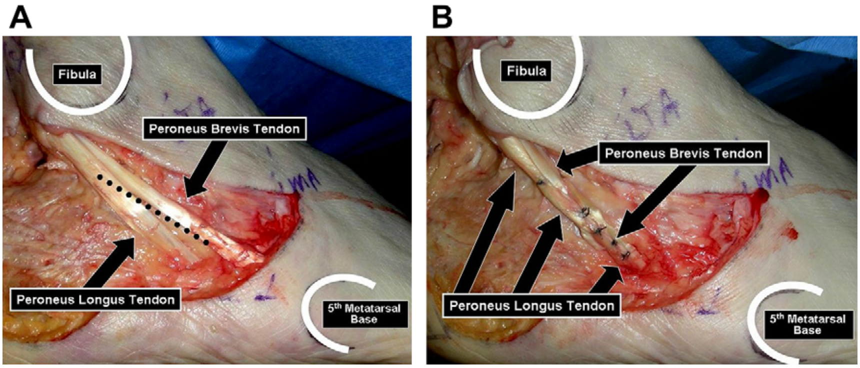

Fig. 2. (*A*) Photograph of a cadaveric specimen following resection of the soft-tissue about the hindfoot demonstrating proper skin incision placement (*black dotted line*) employed to access the peroneus brevis and peroneus longus tendons. (*B*) The peroneus brevis tendon has been weaved through the peroneus longus tendon and figure-of-eight locking sutures have been placed to maintain the transfer as discussed in the manuscript.

tenotomy site. A second 90° angled clamp is placed from superficial to deep through the distal tenotomy incision and used to grasp the PB tendon and advance it through this incision site. Distal tension is applied to the PB tendon with the residual forefoot held with the residual first metatarsal plantarflexed and the entire forefoot in eversion, thereby correcting the forefoot varus deformity. With the foot held in corrected position and distal tension placed on the transferred PB tendon, 2-0 Nylon suture is placed in a figure–of–eight locking pattern at the proximal and distal tenotomy sites incorporating both the PB and PL tendons in each area (Fig. 2 B). Once complete, a 3 cm x 3 cm piece of biologic tissue substitute (OrthADAPT Bioimplant; Pegasus Biologics, Inc., Irvine, CA) is wrapped around the conjoined PB and PL tendons and secured in place with 2-0 Nylon in a vertical mattress suture through only the biological tissue and some surrounding adipose tissue and not the transferred tendons. The use of biological tissue, as described, limits the potential for adherence of the tendons to the overlying skin, as well as functioning as a neosheath, which allows unimpeded gliding of the tendons. The surgical site is irrigated, a suction drain secured in place, and skin closure is performed with a combination of 2-0 Nylon in vertical mattress fashion and metallic skin staples [26].

Potential complications associated with this procedure include nonhealing of the incision site, tendon rupture, reaction to the implanted biomaterial, and infection. The procedure is contraindicated in the dysvascular foot due to a significantly increased risk of wound dehiscence. Postoperative care consists of nonweight bearing in a sugar-tong plaster splint or total contact cast for 4 to 6 weeks postoperatively, or longer, dependent on the rate of incision healing at both the tendon transfer site and the amputation stump.

A retrospective, observational cohort study was performed by the Limb Preservation Service at the Madigan Army Medical Center, Tacoma, Washington involving seven high-risk patients (nine feet) who underwent PB to PL tendon transfer as described above in conjunction with TMA (five feet) or reconstructive forefoot surgery (four feet). Three of the four feet undergoing reconstructive forefoot surgery had infected ulcerations on presentation. One female and six male neuropathic patients with a mean age of 66.1 years (range: 59 to 75 years) and a mean of 6.57 comorbidities (range: 4 to 12) were included. Eight of the nine feet healed the tendon transfer incision primarily. Complete healing with suture removal occurred in an average of 50.1 days [median: 47 days; range: 34 to 90 days]. The one patient who failed to heal primarily actively used tobacco products and repeatedly disregarded nonweight bearing instructions post operatively, returning for evaluation on multiple occasions with a wet, disheveled, and fractured total contact cast. All feet had adequate correction of forefoot varus deformity as evidenced by a plantigrade forefoot and lack of recurrent or de novo forefoot ulceration at a mean of 14.6 months postoperative (range: 10 to 18.5 months). One patient developed transient eversion weakness post operatively, which resolved with performance of physical therapy training at home.

Intramedullary screw fixation

Intramedullary screw fixation is indicated for balancing of the residual forefoot after TMA and Lisfranc amputation in patients with peripheral arterial disease who have a high-risk of wound dehiscence and in whom additional incisions should be avoided [32]. The procedure can be performed through the amputation incision site and therefore does not add additional wound healing risk to the patient. This technique must only be used when the surgical sites reveal no cardinal signs of infection or necrotic tissue.

The procedure is performed upon completion of the amputation and before wound closure. An assistant holds the foot in corrected position with the medial column plantarflexed and the forefoot in eversion to create a plantigrade residual foot. A guide wire for a large diameter cannulated screw is then placed through the medullary canal of the exposed 1st metatarsal or first cuneiform depending on whether a TMA or Lisfranc amputation was performed, respectively. The guide wire is driven across the articulations of the medial column into the talus with care taken to avoid inadvertent penetration of the ankle joint, especially medially (Fig. 3 A and B). The position is verified by intra-operative image intensification visualization of the foot and ankle (Fig. 3 C). Once the position is deemed appropriate, the bone is countersunk, the length of the screw is determined, and an appropriate length 8.0 mm cannulated titanium screw (Asnis III, Stryker Orthopaedics, Inc., Mahwah, NJ) is inserted until the head of the screw engages the subchondral bone of the first metatarsal, if present, or seated within the first

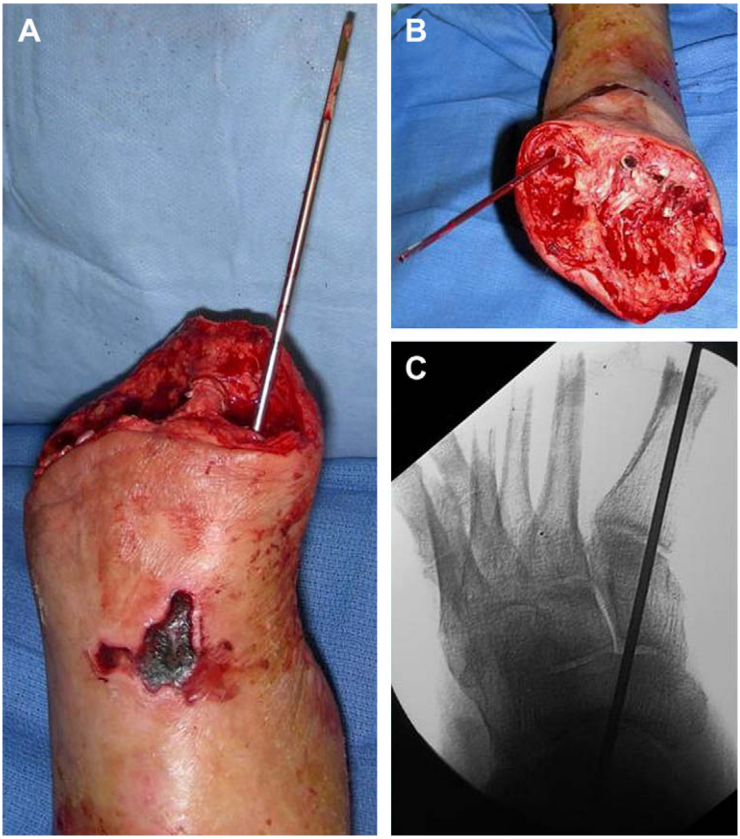

Fig. 3. Intraoperative anterior-posterior (*A*) and en fass (*B*) views following transmetatarsal amputation in a patient following below knee popliteal peripheral arterial bypass and percutaneous tendo-Achilles lengthening demonstrating insertion of a large diameter guide wire through the residual first metatarsal and into the talus. Note the gangrenous lesion overlying the dorsal midfoot that developed from pressure applied by a constrictive dressing over a 48-hour period. Intraoperative anterior-posterior image intensification view, confirming proper guide wire placement (*C*).

cuneiform in the case of a Lisfranc amputation. Drilling over the guide wire is not recommended before screw insertion as it will reduce screw purchase and stability. Allogenic bone graft (BioSet IC, RT Allograft Paste, Regeneration Technologies, Inc., Alachua, Florida) is placed over the implant and a biologic tissue substitute (OrthADAPT Bioimplant; Pegasus Biologics, Inc., Irvine, California) or the patient's abductor hallucis muscle is used to cover the end of the bone to protect the hardware from direct exposure in the case of wound dehiscence [32]. Alternatively, a 7.5 mm cannulated titanium threaded head screw (Charlotte Multi-Use Compression Screw System; Wright Medical Technology, Inc., Arlington, Tennessee) can be employed (Fig. 4), which has the added benefit of achieving

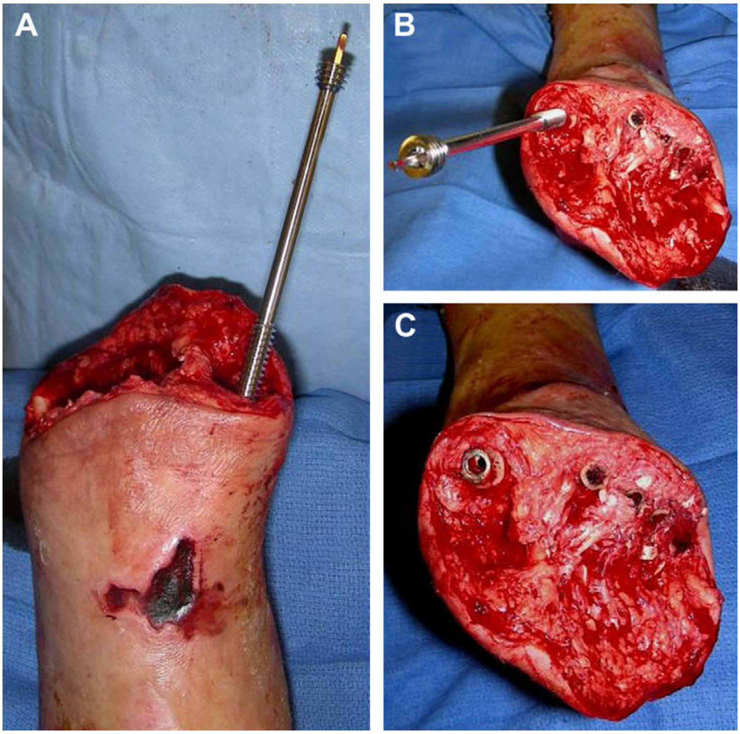

Fig. 4. Intra-operative anterior-posterior (*A*) and en fass (*B*) views demonstrating the proper length threaded head screw over the guide wire and fully seated within the residual first metatarsal (*C*).

compression across the medial column articulations without the need to fully seat the screw head and does not require the use of allogenic bone graft which reduces cost and complexity. Regardless of screw choice, the end result should be a stable and well-aligned forefoot (Fig. 5). Wound irrigation, suction drain placement, and skin closure is then performed as described above.

Potential complications of the procedure include infection, which could seed the retained hardware and spread along the cannulated portion of the screw into the hindfoot, as well as, iatrogenic fracture of the involved bones. Patients will have a stiff midfoot postoperatively, therefore, the hardware should only be placed after it has been verified that the foot is being held in fully corrected position. Nonweight bearing is required for 4 to 6 weeks postoperatively secondary to the adjunctive posterior lengthening performed, which is usually a percutaneous Achilles tendon lengthening (PTAL) rather than a gastrocnemius recession secondary to the patients poor vascular status [25] and to allow for incision healing at the amputation site.

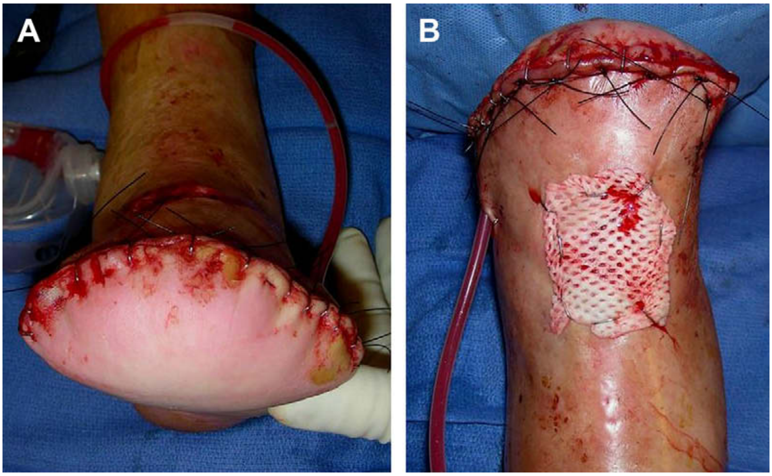

Fig. 5. Intraoperative en fass (*A*) and anterior-posterior (*B*) photographs following closure of the transmetatarsal amputation over a suction drain that has been sutured and stapled in place, as well as, débridement and coverage of the dorsal wound with a meshed cadaveric skin graft (GraftJacket Regenerative Tissue Matrix, Wright Medical Technology, Inc., Arlington, Tennessee). Note the rectus fore foot alignment achieved with the use of this technique.

Percutaneous extra-articular ankle immobilization can be performed in these patients to maintain the foot at 90° to the lower leg during healing of the PTAL procedure [33,34], because splint and cast application may be contraindicated after peripheral artery bypass surgery or due to prohibitive risk of ulcer development secondary to impaired arterial supply to the extremity. This procedure uses two smooth 2.8 mm Steinmann pins. The first pin is driven from the anterior-medial border of the distal tibia 5 cm proximal to the distal tip of the medial malleolus, posterior to the ankle and subtalar joints, and into the midportion of the posterior tuber of the calcaneus. The second pin is driven form the posterior-medial border of the distal tibia 5 cm proximal to the distal tip of the medial malleolus, anterior to the ankle joint, and ending in the neck of the talus or midsubstance of the navicular (Fig. 6) [34]. The pins are bent and capped or locked together with sterile self-adhesive dressing and then petrolatum-impregnated gauze is wrapped around the pin-skin interface followed by application of gauze between and around the pins. The patient must remain nonweight bearing on the extremity until pin removal at 4 to 6 weeks.

A retrospective case series was performed at Madigan Army Medical center involving five patients with diabetes and critical limb ischemia who underwent TMA for treatment of infected and or gangrenous toes with use of intramedullary screw fixation to correct forefoot varus deformity. Five males were included in this series with a mean age of 66.5 years (range: 59 to 75 years). The mean number of co-morbidities for this group was 6.5 (range: 4 to 8). All patients ultimately healed in a mean of 100 days (median: 85.5

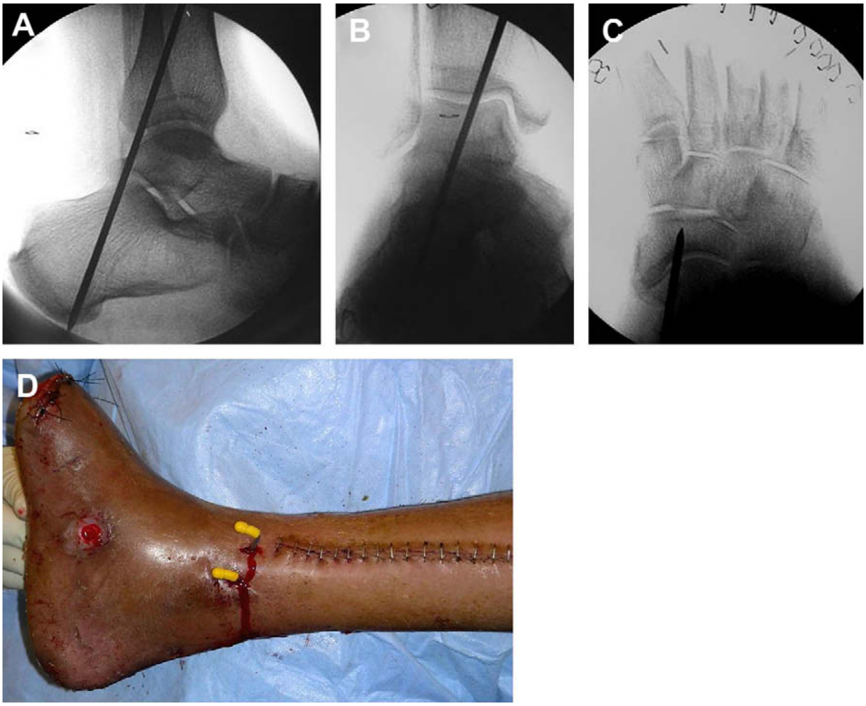

Fig. 6. Intraoperative image intensification lateral foot (*A*) and anterior-posterior ankle (*B*) views following insertion of the anterior-medial extra-articular pin, as well as, anterior-posterior foot (*C*) view following insertion of the posterior-medial pin in a patient who underwent a distal peripheral arterial bypass, percutaneous tendo-Achilles lengthening, and extra-articular pinning. Note the presence of a medial midfoot wound, which has been débrided and prepared for coverage with a meshed cadaveric skin graft (GraftJacket Regenerative Tissue Matrix, Wright Medical Technology, Inc., Arlington, Tennessee). Intraoperative medial view of the same patient following bending, cutting, and capping the extra-articular stabilization pins (*D*).

days; range: 52 to 180 days). Two of the five patients required a return to surgery for revision to a more proximal amputation secondary to ischemic complications of the residual forefoot. One had a re-stenosis of his posterior tibial artery and required repeat atherectomy before conversion to a Chopart amputation, as a result of ischemic compromise of the medial aspect of the plantar forefoot flap. Screw removal was necessary due to the proximal nature of the patient's final amputation level. It should be noted that the first dorsal metatarsal artery was transected during the original TMA and likely contributed to the patient's ischemic changes. Closure was obtained with application of a split-thickness skin graft over the distal stump. The second patient was converted to a Lisfranc amputation with maintenance of his medial column screw, which was simply advanced. Likewise, closure was obtained with application of a split-thickness skin graft over the distal stump. A third patient who was noncompliant with weight bearing restrictions, developed marginal

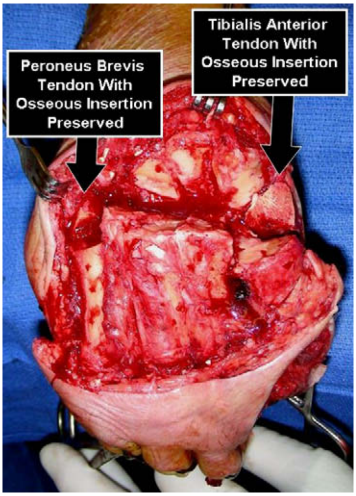

Fig. 7. Intraoperative en fass view of the foot following Lisfranc disarticulation with preservation of the tendinous insertion of the tibialis anterior and peroneus brevis tendons to the first and fifth metatarsal bases, respectively.

dehiscence of his incision and ultimately healed with local wound care while being treated at another facility. Each patient's foot demonstrated good correction of forefoot varus deformity upon postoperative evaluation and no hardware infections were encountered.

Anterior tibial and peroneus brevis tendon transfer

During amputations at the level of Lisfranc's joint, the insertions of the PB and tibialis anterior (TA) tendons are disrupted, which further weakens

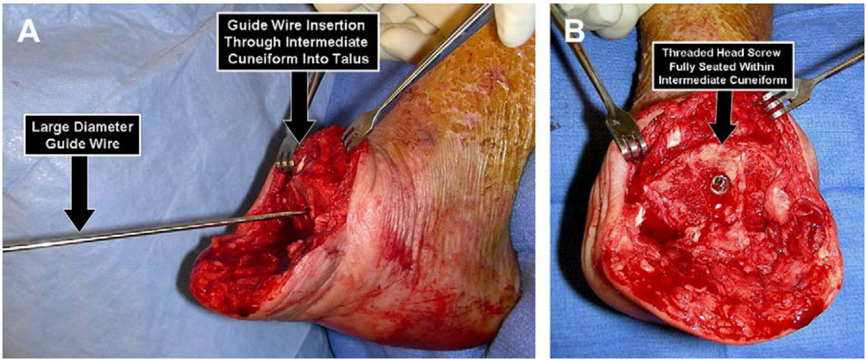

Fig. 8. Medial intraoperative view demonstrating proper placement of the guide wire through the intermediate cuneiform and into the talus (*A*) for a large diameter threaded head screw (Charlotte Multi-Use Compression Screw System; Wright Medical Technology, Inc., Arlington, Tennessee), which is recessed into the intermediate cuneiform (*B*).

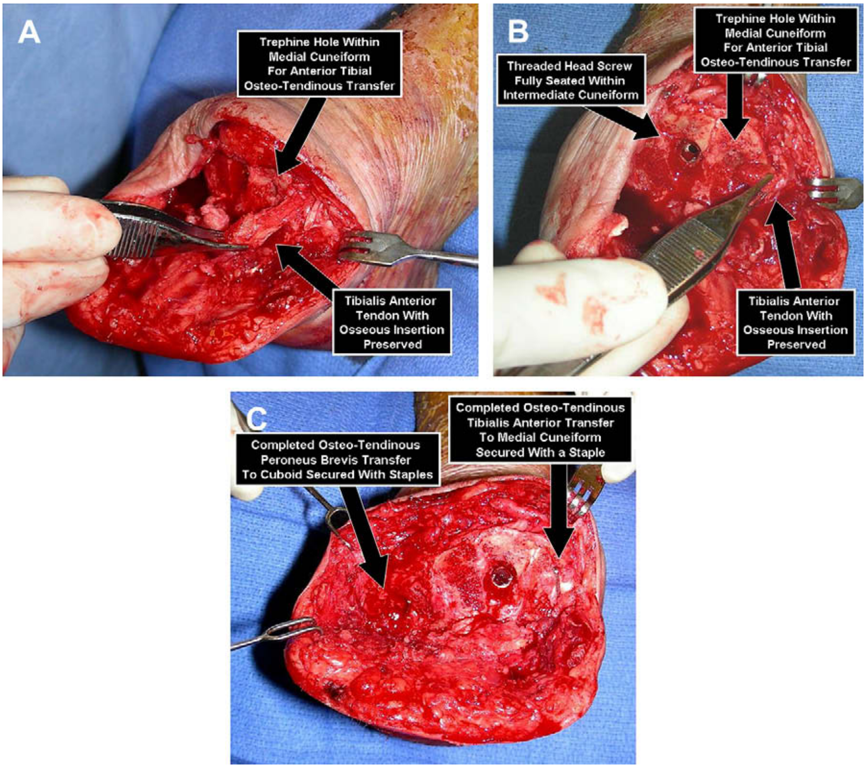

Fig. 9. Intraoperative views demonstrating distal traction on the anterior tibial osteo-tendinous transfer (*A*) followed by insertion into the trephine hole within the medial cuneiform (*B*). The same technique is employed for the osteo-tendinous peroneus brevis transfer into the cuboid. The osteo-tendinous transfers are then secured with one or more staples (Quick Staple, Wright Medical Technology, Inc., Arlington, Tennessee) to prevent pull-out (*C*).

the anterior compartment against the strong plantarflexory strength of the gastrocnemius-soleus complex. In addition, there is significant reduction in eversion strength because of the loss of PB muscle function with subsequent inversion of the residual stump by the unopposed force of the posterior tibial muscle. This reduction in strength can be prevented by PB and TA tendon transfer. Careful dissection is performed to disarticulate the tarsometatarsal joints while sparing the PB and TA tendon insertions. A sagittal saw can be used to osteotomize the base of the first and fifth metatarsals while preserving the attachment of the PB and TA tendons (Fig. 7). The remaining segments of the first and fifth metatarsals not attached to the tendons are removed from the surgical site along with the second, third, and fourth metatarsals. A large diameter screw is then inserted through the intermediate cuneiform and across the midfoot articulations into the talus using the technique described above to provide a stable midfoot (Fig. 8). With the foot held in corrected position and 90° to the lower leg, the PB and TA tendons are held taught and laid against the anterior aspect of the cuboid and medial cuneiform respectively to determine the appropriate location for attachment to provide adequate tension for tendon balancing. A trephine is then used to bore a hole into each of these areas and portions of the remaining bone from the first and fifth metatarsal bases are remodeled to fit into each respective bone tunnel. With the foot is held in corrected position the first metatarsal fragment, with TA tendon attached (ie, osteo-tendinous segment), is tamped into the medial cuneiform. The fifth metatarsal fragment with the PB tendon attached is then tamped into the cuboid [35]. One or two metal staples (Quick Staple, Wright Medical Technology, Inc., Arlington, Tennessee) are placed over the tendon transfer site and inserted to add additional tension and limit the potential for dislodgement of the transferred tendons (Fig. 9). Maintenance of the osseous insertion of these tendons allows bone-to-bone healing, which is more reliable and timely than tendon-to-bone healing, as well as technically more simple to perform. Wound irrigation, suction drain placement, and skin closure is then performed as described above (Fig. 10).

Complications associated with this procedure are fixation failure with loss of correction and delayed or nonunion of the transferred bone. Patients must remain nonweight bearing in a splint or cast, if indicated, postoperatively for 4 to 6 weeks or longer dependent on the rate of incision healing.

Fig. 10. Postoperative en fass (*A*) and medial (*B*) views following a well-balanced, rectus Lisfranc amputation using the soft-tissue and osseous techniques employed in the manuscript.

Summary

Performing a well-balanced transmetatarsal or Lisfranc's amputation as described here in a high-risk patient with multiple comorbidities can provide long-term mobility and independence. The lower energy expenditure required to ambulate with a partial foot amputation as opposed to a trans-tibial or trans-femoral amputation reduces cardiac stress, which may reduce mortality rates [1,36,37]. Avoiding multiple surgical procedures to amputate and re-amputate portions of the foot and the cumulative lengthy recovery time associated with this form of treatment, as well as the negative psychosocial impact to the patient, can also reduce perioperative morbidity. Proper surgical planning for the individual patient with involvement of social services and a multidisciplinary approach should provide the highest likelihood of success.

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