CHAPTER **41**

CHARACTERIZATION OF THE PERONEUS BREVIS MUSCLE FOR CLOSURE OF LOWER EXTREMITY DEFECTS: A Cadaveric Study and Case Report

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Closure of soft tissue defects of the lower extremity can be a challenging problem. The primary goal is both closure of the defect and limitation of morbidity, while maintaining or limiting loss of function. Many authors have described the criteria for utilization of various flaps for closure of soft tissue defects of the lower extremity. Holden[1] described the importance of good vascularity for vascular ingrowth to the bony cortex of exposed or injured bone. Muscle coverage of exposed bone can be performed by the use of either local muscle transposition[2-4] or microsurgical free muscle tissue transfer.[5,6] Benacquista et al[7] reported a 10% failure rate of free muscle flaps to the lower extremity.[8] Of those that failed, 22% went on to amputation. However, Guzman-Stein et al[2] recommended the use of muscle flaps for exposed bone, coverage of post radiation wounds, exposed prostheses, or wounds due to chronic osteomyelitis. Moreover, Recalde Rocha et al[9] warned of utilizing the muscles of the lower leg due to their segmental nature of blood supply, which could lead to an unacceptable failure rate. They proposed utilizing fasciocutaneous flaps based on the anterior tibial artery. Touam et al[10] also described a number of distally based fasciocutaneous flaps for coverage of the lower leg, foot and ankle.

Many authors have described the use of local muscle tissue transposition for closure of soft tissue defects of the lower leg.[2,8,11-17] The purpose of our study was to further characterize the peroneus brevis muscle, including its dimensions, number, and location of pedicles. Arteriography was also performed at each pedicle to show the extent of muscle filling. These findings may aid in choosing which kinds of defects can be covered utilizing this muscle flap for closure of soft tissue defects. A number of authors have studied and used the peroneus brevis muscle for closure of lower extremity defects.[11-17]

Hughes et al,[14] in a cadaveric study of twenty limbs, found an average of 3.9 ± 2.4 pedicles to the peroneus brevis muscle, with an average 0.85 ± 1.37 above the medial malleolus with a range of 0-4 cm. The area covered with this muscle ranged between 12-21 cm^2 and averaged 15.6 cm^2. They recommended this muscle for coverage of the upper half of the lateral malleolus, the adjoining part of the fibula, and small areas in the lower part of the middle third of the leg.

Lyle et al1[13] presented the results of eight cases where the peroneus brevis muscle was utilized. The average defect size was 7 x 3 cm. The average age of the patient was 52.4 years, and 7 were smokers. They reported an 87.5% success rate. The one failure in their series was a diabetic smoker with PVD. They characterized this muscle as a type II Mathes-Nahai.

Vasconez et al[16] also recommended the use of the peroneus brevis and longus muscles for closure of lateral tibial defects. Elyssel et al[17] utilized this muscle for coverage of fibular soft tissue defects after osteosynthesis.

Eren et al[11] described a distally pedicled peroneus brevis muscle flap. They presented a series of nineteen patients with an average age of 51 years. Primary healing was obtained in 84% of their patients. The distal pedicle was generally three fingerbreadths proximal to the tip of the fibula. They recommended this flap for closure of defects in the distal leg region.

MATERIALS AND METHODS

Nineteen fresh frozen cadaver limbs (ten right and nine left) were used. Average age of the donor was 79.8 years (range 60-93 years). Each limb was dissected in order to characterize the following: 1) total length of leg from the knee joint to the tip of the fibula; 2) distal most extent of the peroneus brevis (PB) muscle in relation to the tip of the fibular malleolus; 3) the location where the superficial peroneal nerve pierced the deep fascia in relation to the tip of the fibular malleolus; 4) the maximum width of the PB muscle belly and the location from the tip of the fibular malleolus; 5) the location and number of arteries that supply the PB muscle belly, and; 6) The total freeable length of the PB muscle (Figures 1A-D). The same surgeon performed each dissection (Table 1).

One limb was fully dissected to show the arterial network supplying the PB muscle (Figures 2,3). Each of the pedicles was cannulated with a 22-gauge angiocath with the aid of a Zeiss OPMI 1-FC dissection microscope (Figures 4,5). Arteriography was then performed to show the extent of muscle filling at each site. Isovue®-300 intravenous radiopaque dye was injected and flat plate radiographs with extremity film were taken to show muscle filling (Figures 6-8).

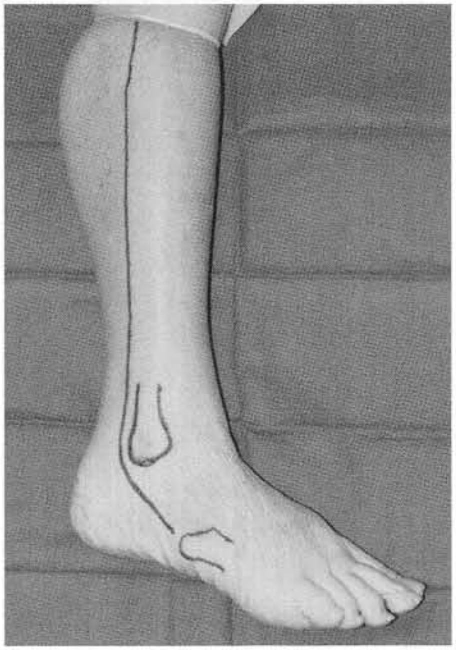

Figure 1A. Anatomic landmarks include the styloid process, fibular tip, and lateral surface of the fibula.

Figure 1A. Subcutaneous tissue removed off the deep fascia reveals the location where the superficial peroneal nerve pierces the deep fascia.

Figure 1C. Incision of the deep fascia and peroneal retinaculum allows access to the peroneal muscles and their tendons as they course inferior to the fibular malleolus.

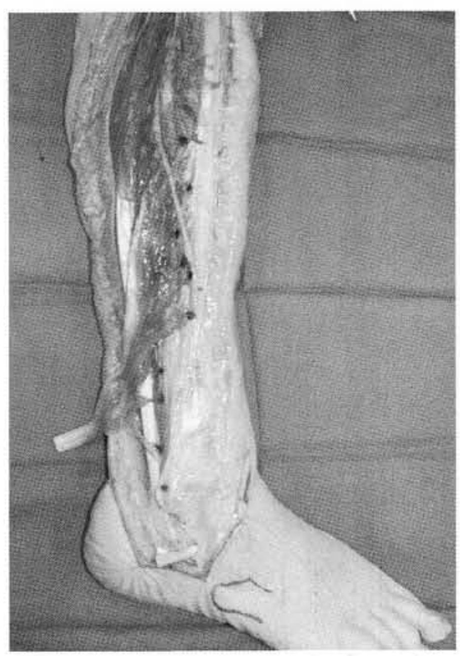

Figure 1D. The peroneus brevis tendon was transected distal to the inferior extent of the muscle belly. Each perforating artery entering the muscle was then marked with a skin scribe.

Table 1

Right or Left Leg	Length of Leg	Distal Extent of Muscle	Location of Superficial Peroneal Nerve	Maximum Muscle width, location	Location of Arterial Supply	Freeable Length of Muscle
Right	38	0	15	5 @ 13	4, 10.5, 23.5	17.5
Right	39	2	17	4 @ 15	6, 14.5, 28	21
Left	40	1	18	4 @ 13	6.5, 15, 21	23
Right	35.5	0	11	5 @ 10.5	5.5, 13.5, 21	20
Left	37.5	0	13.5	4.5 @ 11.5	8, 13.5, 25	18
Right	39	1	15	5 @ 14	4.5, 12, 21.5	21
Right	43	3	13	6.5 @ 15	7, 12, 19	20
Right	37.5	0	11	5 @ 13.5	5, 8.5, 13.5, 16	16
Left	40	2	13	5 @ 12.5	4, 10, 16, 18	18
Right	38	2	15	4.5 @ 14	4, 8.5, 15, 21	19
Right	43	1	16	8 @ 13	5, 8.5, 13, 15.5, 18.5, 21	21
Left	36	1	12.5	5 @ 11	5.5, 11.5, 14, 23	18
Left	38	0	11	4 @ 13	4, 12, 23	23
Right	39	0	14	4 @ 11	8, 12, 21	21
Left	43	3	15	7.5 @ 14	5, 8, 13, 18, 23	23
Left	37	2	10, 18	5.5 @ 13	3, 5, 9, 19, 20	17
Left	44	3	14	5 @ 15	7, 16, 28	24
Right	38.5	-1.5	13.5	5 @ 14	4, 7, 8.5, 10, 12, 13, 14, 15, 17, 19.5, 21, 23	22
Left	38.5	-2	14.5	4.5 @ 14	2, 4, 5, 6.5, 7, 10, 14, 14.5, 16, 18, 20, 24.5	23
	Avg Length = 39.18	**Avg Distal Extent = .92**	**Avg location of nerve = 14**	**Avg Max width and location = 5.10 @ 13.16**	**Avg location of: 1st = 5.15 2nd = 10.08 prox. = 22.13**	**Avg freeable length = 20.29**

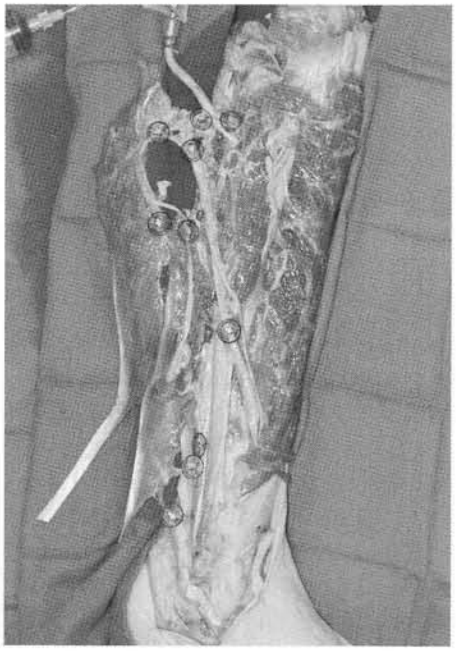

Figure 2. After removal of a portion of the fibula, each artery supplying the peroneal muscles were cannulated with an 22-gauge angiocath.

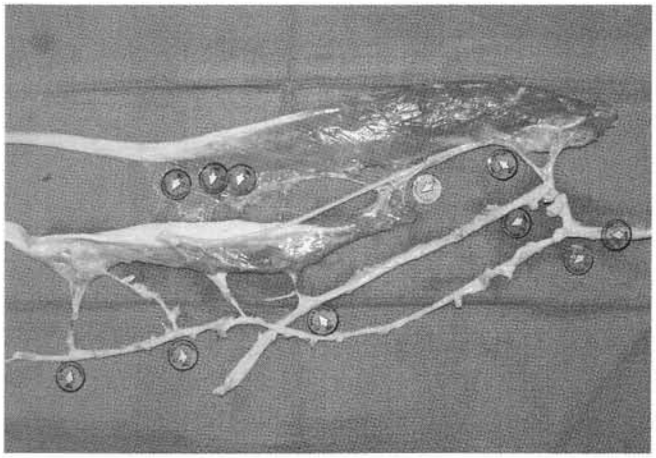

Figure 3. The peroneal muscles and their arterial supply have been completely dissected out. The major contributions include the peroneal artery (entering the proximal P. Longus muscle belly), the anterior tibial artery (entering the proximal to mid-section of the P. Brevis muscle belly, and contributions from the posterior tibial artery (entering the mid to distal P. Brevis muscle belly)

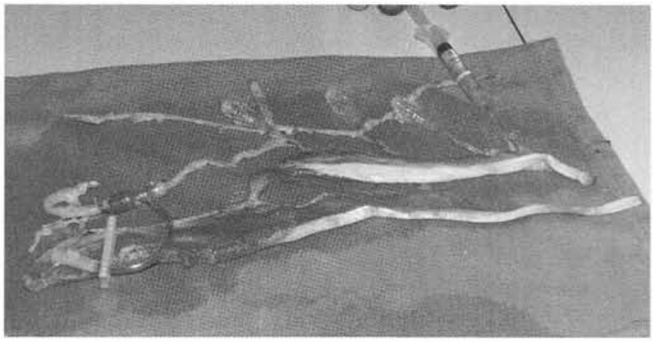

Figure 4. After cannulization of each of the contributing arteries (pedicles), Isovue-300 was injected into the distal-most pedicle to the P. Brevis, which arose from branches of the posterior tibial artery.

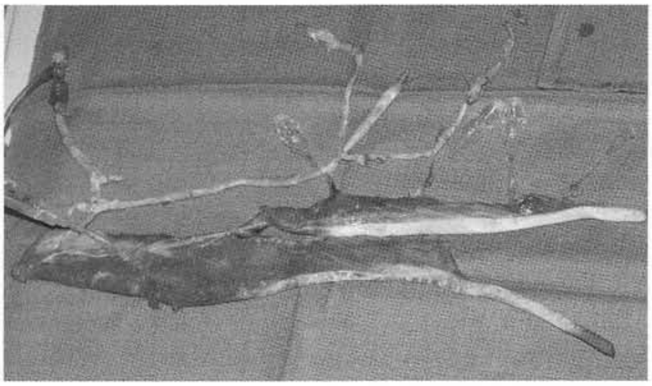

Figure 5. Injection of Isovue-300 into the main pedicle from the anterior tibial artery.

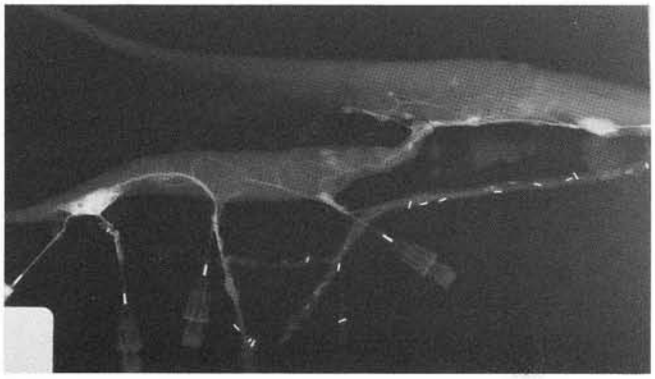

Figure 6. Flat plate radiograph demonstrating complete filling of the P. Brevis and P. Longus after injecting Isovue-300 into the peroneal artery.

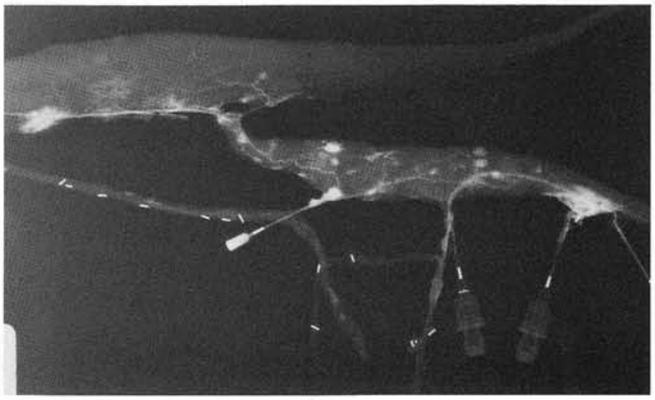

Figure 7. Flat plate radiograph demonstrating complete filling of the P. Brevis and P. Longus after injecting Isovue-300 into the anterior tibial artery.

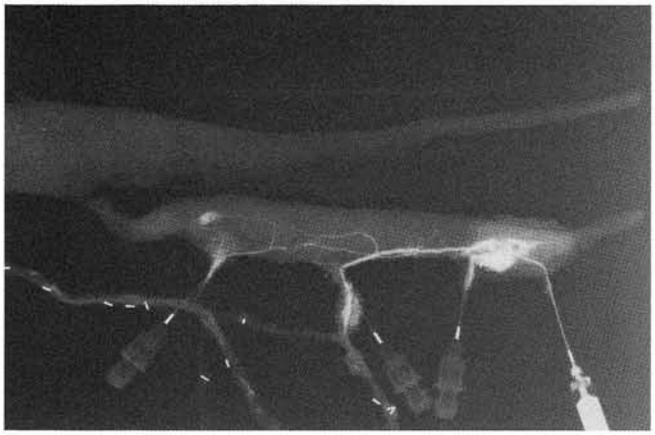

Figure 8. Flat plate radiograph demonstrating complete fill of the P. Brevis and P. Longus after injecting Isovue-300 into the distal-most pedicle arising from the posterior tibial artery.

RESULTS

Although cadaveric tissue does not handle in the same manner as living tissue, these findings still provide insight as to the dimensions and limitations of utilizing the PB muscle for closure of soft tissue defects of the lower extremity. On average, the distal most extent of the muscle was 0.92 cm distal to the tip of the fibular malleolus (range –2.0 to 3.0 cm). The superficial peroneal nerve pierced the deep fascia at an average location of 14 cm proximal to the tip of the fibular malleolus (range 10-18 cm). In one specimen the nerve was divided in two separate trunks, which pierced the fascia at 10 and 18 cm from the tip of the malleolus, respectively. The average maximum width of the PB muscle was 5.10 cm (range 4-8 cm) at an average of 13.16 cm (range 10.5-15 cm) from the tip of the fibular malleolus. There was an average of 4.1 pedicles to the PB muscle (range 3-12), which entered the muscle in a segmental fashion. However, the proximal pedicle was larger than the more distal ones. In all limbs, the most proximal pedicle came off the peroneal artery. The pedicles, which pierced the anterior intermuscular septum, were supplied from the anterior tibial artery and generally entered the middle portion of the muscle. The distal most pedicles often pierced the posterior intermuscular septum and were supplied by either branches of the posterior tibial artery or perforating peroneal arteries. The average location of the most distal pedicle was 5.15 cm proximal to the tip of the malleolus (range 2.0-8.0 cm). The average location of the second most distal pedicle was 10.08 cm from the tip of the malleolus (range 4.0-16.0 cm). The average location of the third most distal pedicle was 17.79 cm (range 5.0-28.0 cm). The average location of the most proximal pedicle was 22.13 cm (range 16-28 cm). The total freeable length was determined by how much of the muscle could be released without completely detaching it from the origin. The average freeable length was 20.29 cm (range 16-24 cm).

Anatomy, Blood Supply, and Function.

The peroneus brevis is a thin, fusiform muscle, which lies in the lateral compartment of the leg. It takes origin from the fibula, anterior intermuscular septum, and posterior intermuscular septum. It arises from the distal two thirds of the leg and lies deep to the peroneus longus muscle belly. The tendon passes distally, posterior to the fibular malleolus through a groove in the posterioinferior fibula. It runs next to the fibula, deep to the tendon of the peroneus longus. Proximal to the peroneal tubercle of the calcaneus, both the longus and brevis tendons run within a common tendon sheath. As the tendons split, with the brevis passing superior and the longus inferior to the peroneal tubercle, the tendon sheath also splits into an inverted Y configuration. The peroneus brevis tendon continues distally to insert on the styloid process at the base of the fifth metatarsal. The peroneus longus continues distally to the peroneal notch within the cuboid, where it changes direction to course medially to its insertion on the plantarlateral base of the first metatarsal. The tendons pass deep to the superior peroneal retinaculum as they course posterior to the fibular malleolus, and then pass through the inferior peroneal retinaculum along the lateral wall of the calcaneus.

Both the peroneus longus and brevis muscles are innervated by the musculocutaneous branches of the common peroneal nerve, which arise from L4, 5 and S1.[18,19] Blood supply to the peroneal muscles arises from contributions from the peroneal artery, anterior tibial artery, and perforators from the posterior tibial artery, as described in the results section.

The peroneus brevis muscle has multiple functions. During locomotion it acts to stabilize the lesser tarsus and lateral column of the foot. It also acts as a stabilizing force to resist supination at the subtalar joint, and aids the peroneus longus in transferring body weight from lateral to medial.[20] Due to its location posterior to the ankle joint, it acts as a plantarflexor of the ankle joint and as an evertor of the foot.[18]

DISCUSSION

The choice of the best closure of a leg wound is as follows. Primary closure is preferred if adequate mobilization of tissue is available for closure over the defect. If only skin is lost, either a local fasciocutaneous flap or split-thickness skin graft is preferred.[1] If bone or hardware is exposed, a local muscle transposition flap with split-thickness skin graft is first considered. If the surrounding tissues have been overly traumatized, or an appropriate local muscle is not available, a free muscle graft with split-thickness skin graft is recommended.

Our findings of an average of 4.1 pedicles certainly correlate well with the findings of Hughes.[14] Some debate in the literature exists whether this muscle is a Mathes-Nahai type III[13,15] or IV[8] muscle. It has been stated that type IV muscles may be less reliable for flap closure due to their segmental nature of filling.[13] However, our findings would classify this as a type II muscle. The proximal pedicle from the peroneal artery was dominant with multiple pedicles entering the muscle more distally, with contributions from the anterior tibial and posterior tibial arteries. Each cannulated pedicle demonstrated equal filling of the muscle (Figures 6-8). Several authors have shown that the muscle could be detached from all but its proximal pedicle,[14] and rotated to cover defects of the lower third of the leg, or detached from all but its distal pedicle,[11] which allows for more flexibility in covering more distal wounds in the ankle and heel area. Our angiographic findings support the concept that as long as one pedicle is maintained, complete filling of the muscle can be accomplished.

Taylor et al[12] described the angiosomes of the lower extremity and identified the peroneal artery and anterior tibial artery as the only blood supply to the PB muscle belly. Lyle et al[9] described a dominant pedicle from the peroneal artery with distal minor pedicles from both the peroneal and anterior tibial arteries. Others have only described the peroneal artery[11,18,21] as the blood supply to the muscle. In our cadaveric study we found contributions from the peroneal, anterior tibial, and posterior tibial arteries. The peroneal contribution entered the muscle from its proximal origin and also supplied the peroneus longus muscle belly. In the middle portion of the muscle belly, contributions from the anterior tibial artery supplied the muscle and were noted to pierce the anterior intermuscular septum. More distally, there were contributions from the posterior tibial artery, which pierced the posterior intermuscular septum. Our angiographic findings showed that the whole muscle was filled with injection of each of the pedicles. It is from this distally based pedicle that Eren[11] based his muscle flap.

Patient age and activity level should be taken into account when selecting muscles for transfer[2] in order to maintain maximum function of the limb. Ideally, synergistic muscles should maintain their function.[8] In our case we utilized a local PB muscle flap for closure of a defect to the lower lateral leg. In order to help maintain stability of the lateral ankle, the distal stump of the PB tendon was anastamosed to the peroneus longus tendon. Tenodesis of the peroneal tendons is recommended in cases where grade II tears (>50%) of the PB tendon have occurred.[22-24] Tenodesis has also been utilized for stabilization procedures in cavus foot reconstruction.[25] A number of authors have described the use of the PB[11-17] muscle flap. However, in our review of the literature, no other author has described the technique of anastamosis of the peroneus longus and brevis tendons when utilizing either of these muscles for muscle flap wound closure. This simple procedure will allow for the peroneals to function as a unit, even though one of the muscles has been utilized for soft tissue closure.

CONCLUSION

The goal of this type of surgical procedure is to afford closure of the wound while limiting morbidity. For this reason, a local muscle transposition flap is preferred, if available, as no donor site is necessary. Guzman-Stein et al[2] described the importance of not using muscles necessary for activities the patient performs, as this can lead to deficits in the ability to function. Mathes et al[8] stated that synergistic muscles should maintain their function to not leave the patient with a functional deficit. Although the PB muscle has been used by others for soft tissue closure,[11-17] the importance of tenodesing it to the peroneus longus has not been described in the literature. Peroneal anastamosis has been used in other types of reconstructive surgery of the foot and ankle[22-25] and functions well to limit the loss of function of the peroneal complex. For this reason we recommend a tenodesis of the peroneal tendons whenever the PB or peroneus longus are utilized for muscle flap closure of the lower extremity.

Eren et al's description of the location of the distally based pedicle[11] correlates well with our findings of the average location at 5.15 cm from the tip of the fibula. Three finger breadths on the author's ranges between 5-5.5 cm. The angiographic findings also support the use of either a distally based or proximally based pedicle for a PB muscle flap. This muscle could be used for closure of defects of the distal half of the leg. When using the distally based flap, it can be utilized for closure of wounds to the calcaneus and ankle region. When covering medial ankle wounds, the flap can be passed between the tibia and anterior Achilles tendon[26] to allow for a more direct route to the medial ankle region.

CASE REPORT

A 17-year-old male was seen in the emergency room one hour after sustaining an avulsion of the lower lateral leg (Figure 9). While pushing branches into a wood chipper with his foot, his boot was pulled into the chipper. A defect measuring approximately 4 x 8 cm at the lateral distal leg was noted with exposed bone. The patient could not remember his tetanus status. Both tetanus toxoid and immunoglobulin were administered. IV Ancef and Zosyn were given in the emergency room. A local field block was performed and the wound was cleansed and flushed with hibiclens and normal saline and wound cultures were obtained. Radiographs revealed scalloping of the lateral cortex of the fibula where the bone had been eroded by the wood chipper (Figures 10, 11). The medical history was unremarkable with the exception of tobacco (1 pack per day for 2 years), alcohol, and recreational drug use. The patient was taken to the operating room for debridement and irrigation of the wound. All devitalized tissue was removed and hemostasis was obtained. The superficial peroneal nerve was exposed within the anterior aspect of the wound (Figure 12). The subcutaneous tissue was separated off the deep fascia in order to provide soft tissue coverage for the nerve. The subcutaneous tissue was approximated around the nerve with a 3.0 Prolene suture. After debridement the wound measured 9 x 5.5 cm (Figure 13). Sterile Nu Gauze packing was placed within the wound and moist-to-dry sterile compressive dressing was applied. The patient was admitted for daily local wound care until the wound culture came back negative. An infectious disease consult was obtained and the Zosyn was discontinued. Seven days later, final closure of the wound was performed.

General anesthesia was used, supplemented with local anesthesia and epinephrine in a field block fashion at the donor site for the split-thickness skin graft. The packing was then removed from the defect in the lower lateral leg and all non-viable tissue was debrided. The Prolene suture maintaining the superficial peroneal nerve within the

Figure 9. Initial presentation of leg wound after injury in a wood chipper. Both the fibula and superficial peroneal nerve were exposed.

Figure 10. Anteroposterior radiograph reveals scalloping of the lateral cortex of the fibula.

Figure 11. Lateral radiograph reveals some bony fragmentation of the anterior portion of the fibula.

Figure 12. After the intial debridement, the superficial peroneal nerve was exposed in the anterior portion of the wound.

Figure 13. Subcutaneous tissues were mobilized and sutured with prolene over the nerve in order to prevent further damage to the nerve until final wound closure was performed.

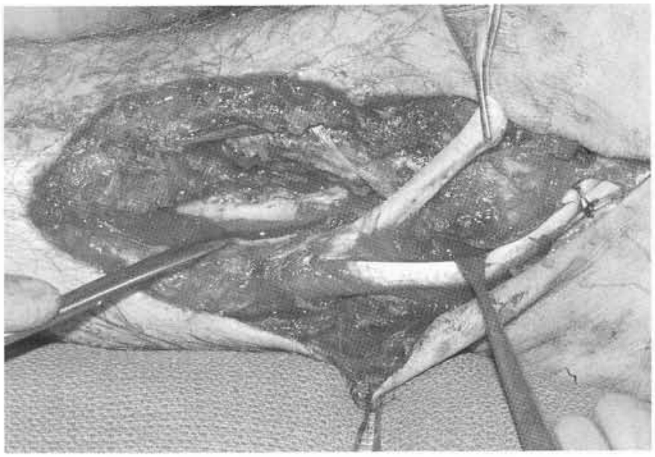

Figure 14. The peroneus brevis tendon stump was anastamosed to the peroneus longus tendon in order to limit loss of function of the peroneal complex.

subcutaneous tissue was removed. All soft tissues were then retracted and bony debris, which was still present, was removed. Pulse lavage was performed with two liters of saline with bacitracin.

Attention was then focused on the anastamosis of the peroneal tendons. An incision from the inferior aspect of the existing wound was lengthened distally along the course of the peroneal tendons. Dissection was carried out to the level of the superior and inferior peroneal retinaculum with care taken to retract the sural nerve. The retinaculum was incised to gain access to the peroneal tendons. The paratenon was incised along the course of the PB and was also removed from the superior side of the peroneus longus tendon. The apposing surfaces of the tendons were roughened and they were sutured together with 2.0 Ethibond (Figure 14). The proximal tendon of the PB was transected proximal to the anastamosis site and dissected proximal to the fibular malleolus. A rotary burr was used to further smooth the lateral fibula, which was exposed (Figure 15). The PB was then freed approximately 12 cm proximal to the tip of the fibula. The majority of the tendon was removed, leaving only a thin strip on the muscle in order to secure it to the undersurface of the periosteum on the anterior fibula (Figure 16). The peroneal retinaculum and paratenon were reapproximated in a single layer with a 2.0 Dexon (Figure 17). The tendon was secured to the periosteum and over the lateral fibula with a 3.0 Dexon. The superficial peroneal nerve was then placed within a subcutaneous tunnel at the anterior of the wound and the subcutaneous tissues were held in place around the nerve with a 3.0 Dexon (Figures 18, 19).

Subcutaneous closure of the distal wound overlying the peroneal tendons was reapproximated with a 3.0 Dexon. Skin closure was performed with

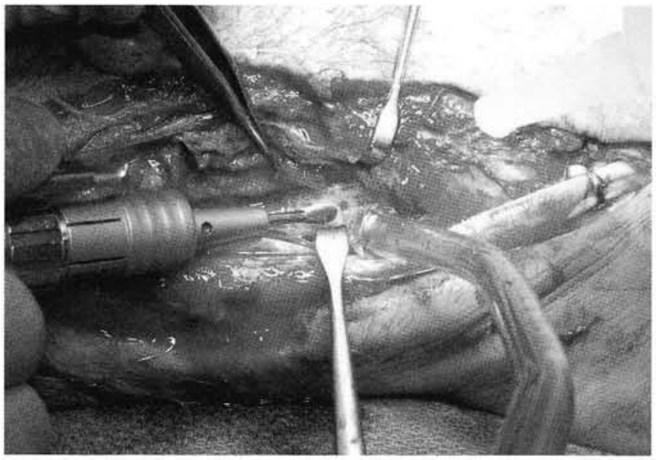

Figure 15. After the P. Brevis muscle was freed sufficient to cover the defect, the cortex was burred to prepare for the muscle flap.

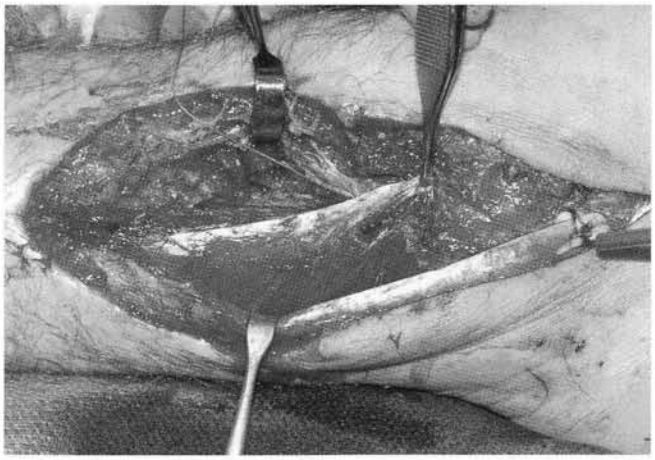

Figure 16. All but a thin strip of tendon was removed from the P. Brevis muscle. This tendon strip was used to suture the muscle to the under surface of the periosteum of the fibula.

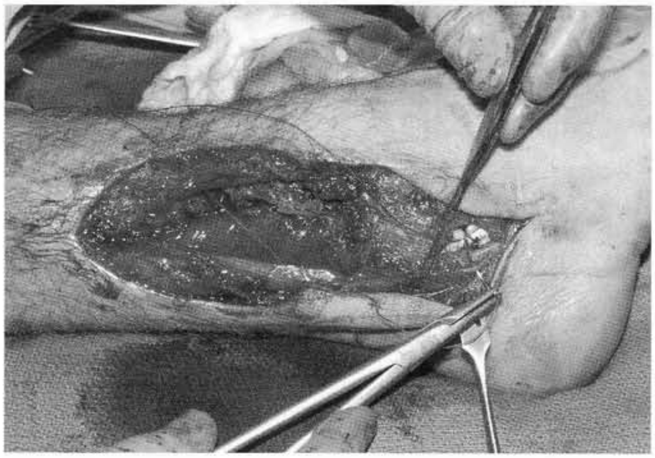

Figure 17. The peroneal retinaculum was reapproximated with a 2.0 absorbable suture.

Figure 18. The superficial peroneal nerve was still exposed in the anterior portion of the wound.

a 4.0 Prolene suture in a horizontal mattress fashion. A split-thickness skin graft was then harvested from the anterior thigh and meshed 1.5 to 1. It was then sewn in place with a 5.0 gut suture in a running locked fashion (Figure 20). A Wound V.A.C. KCI was then applied to the lateral leg (Figure 21), and a Tegaderm(dressing applied to the donor skin graft site. The patient was readmitted to the hospital and kept strictly non-weightbearing with the foot of the bed elevated.

On postoperative day 5, the first dressing change was performed. It was noted that there was 100% graft take (Figure 22). The Wound V.A.C. KCI was reapplied and the patient remained non-weightbearing with the foot of the bed elevated. On postoperative day 9, the second dressing change was performed and there was still 100% graft take (Figure 23). At this time the patient was placed in a below-knee non-weightbearing cast with a window cut out to allow for local wound care. He was instructed to remain strictly non-weightbearing for a total of 6 weeks to allow the peroneal tendons to tenodese. At 3 weeks postoperative, it was noted that there was mild draining from the distal most aspect of the wound and anterior edge of the wound, however the graft was firmly adherent (Figure 24). The patient remained non-weightbearing until 2 months postoperative when his cast was removed. It was noted that there was 100% take of the graft (Figure 25). At this time he was allowed to return to normal shoes and begin ambulation.

At 3 month postoperative, the patient was ambulating without problem. He maintained strength in the peroneal complex, with the ability to evert the foot. He did not report any ankle instability. The skin graft had taken 100% with complete closure over the original defect.

Figure 19. Appearance after the superficial peroneal nerve had been placed within a subcutaneous tunnel, which was gently sutured around the nerve.

Figure 20. Appearance of the wound after a split-thickness skin graft was sewn into place.

Figure 21. A Wound Vac by KCI was placed over the skin graft and incision site.

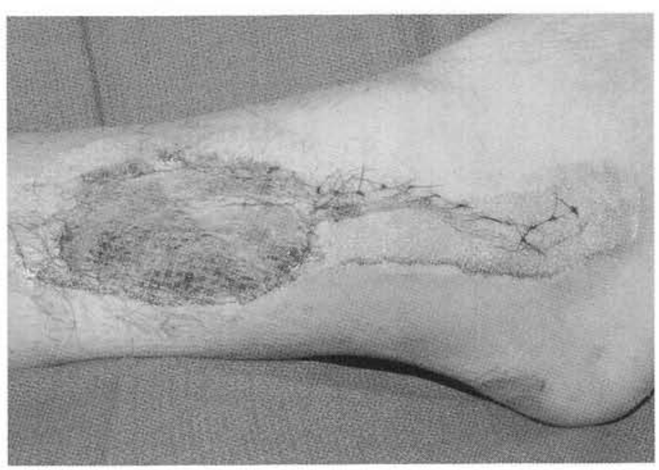

Figure 22. First dressing change at 5 days postoperative with 100% graft take.

Figure 23. Second dressing change at 9 days postoperative with 100% graft take.

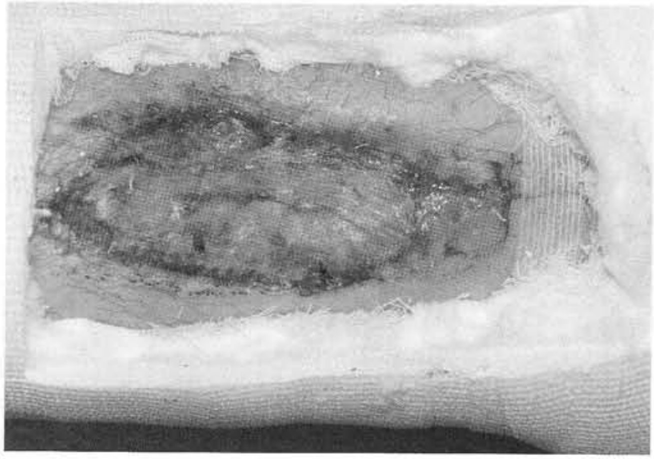

Figure 24. The cast was windowed to allow for daily dressing changes, and at three weeks postoperative, there was still 100% graft take.

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Figure 25. At two months postoperative there is 100% graft take, and the patient was allowed to start weight bearing.

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