McCraw and Arnold's Atlas of Muscle and Musculocutaneous Flaps

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Interplast
Healing Bodies, Changing Lives

Global-HELP
Publication

SOLEUS

ANATOMICAL CONSIDERATIONS

Surface Markings

The soleus muscle lies deep to the gastrocnemius muscle and can be easily palpated only in the distal calf. The cleft between the soleus and the gastrocnemius muscles is best observed in the medial calf between the Achilles tendon and the distal margin of the contracted gastrocnemius muscle. Superiorly the soleus muscle is both difficult to see and to palpate because it is completely covered by the gastrocnemius muscle.

Origin and Insertion

The soleus muscle originates from the upper-third of the dorsal and medial surfaces of the fibula and the midposterior tibia. More specifically, the soleus muscle arises from the upper one-third of the posterior surface of the fibula, from the soleal line on the posterior surface of the tibia, and from the medial border of the tibia. It also arises from a strong fibrous band, the tendinous arch of soleus, which stretches between the shafts of the tibia and the fibula. It inserts into the Achilles tendon over a five centimeter area, just anterior and distal to the insertion of the gastrocnemius muscle. The soleus muscle is a distinctly bipenniform (''double feather'') shaped muscle and its width encompasses the posterior two-thirds of the calf. It is a ''slow'' muscle which is used mainly in static standing. The isolated functional loss of the soleus muscle is usually unnoticed even in the athletic person.

Adjacent Muscles

The soleus muscle lies beneath the Achilles tendon and the two gastrocnemius muscular heads. All of the other calf muscles lie anterior to the soleus muscle, as it surrounds the posterior and medial compartments of the calf. The deep muscles of the calf are separated from the soleus muscle by the deep transverse fascia of the leg (fascia cruris). From lateral to medial, these deep muscles include the flexor hallucis longus, the tibialis posterior, and the flexor digitorum longus muscles. The peroneal vessels lie on the medial surface of the flexor hallucis longus muscle proximally. Distally the tibial artery and nerve pass between the flexor hallucis longus and flexor digitorum muscles and lie on the surface of the tibialis posterior muscle. Recognition of the relationship of the soleus muscle to these neurovascular structures is critical to both their protection and to the survival of the soleus muscle flap.

Vascular Pattern

The soleus muscle is a classic example of a broad flat muscle with a mixed blood supply. The proximal vasculature arises directly from the popliteal vessels and can reliably carry all but the distal four to five centimeters of the muscle. The distal muscle is supplied by numerous segmental perforating vessels from the posterior tibial artery. As expected, the proximal vasculature is dominant and much more reliable than the vasculature of the ''reversed'' muscle flap, which is supplied by four or more distal deep perforating vessels. We have experimentally identified a vascular ''watershed'' in the proximal one-third of the muscle, but this does not seem to have any clinical significance. This is another case where functional flap physiology, if only on an empirical basis, contradicts the observed vascular anatomy of a muscle flap.

Motor Nerve

Tibial nerve.

USES

The proximal soleus muscle finds its predominant use in midtibial defects, and when it is completely elevated it will also cover the tibial tubercle. Although it will not consistently reach the lower one-third of the tibia as a proximally based muscle flap, it is a very reasonable consideration to explore the calf and determine whether or not the soleus is a possibility. When it is feasible to use the proximal soleus muscle, it provides a very simple solution to some difficult lower tibial wounds that would ordinarily be treated with a ''free'' flap. The ''reversed'' or distally based soleus muscle flap is seldom used because of its questionable viability. It is occasionally applicable to defects of the upper Achilles tendon area, especially in children. Even in these special situations, the ''reversed'' soleus flap can be seriously recommended only when the supplying vessels lie outside of the ''zone of injury.''

REGIONAL FLAP COMPARISONS

The proximal soleus muscle flap is clearly the most appropriate muscle flap for midtibial defects. The gastrocnemius muscle flap will better serve the upper pretibial area and the knee. Although fasciocutaneous flaps and the medial gastrocnemius myocutaneous flap can

provide excellent midtibial coverage, their skin-grafted donor sites are esthetically less desirable than a skin-grafted soleus muscle flap. When it can be used for distal pretibial defects, the proximal soleus muscle flap is truly a "bonus" local flap. Because our flap choices are so limited for lower one-third tibial defects, the "reversed" soleus muscle flap may be a reasonable option, particularly in children. The "reversed" EDC muscle flap will more predictably reach the lower pretibial area than the "reversed" soleus muscle flap. It should be noted that neither of these "reversed" muscle flaps can be extended to the malleoli or to the anterior ankle joint. The "island" dorsalis pedis flap will reach the Achilles tendon and the lower tibia after a formidable dissection, but the use of this sophisticated skin flap is generally limited to difficult defects of the malleoli or the dorsum of the foot. For small defects of the Achilles tendon area, the entire medial gastrocnemius myocutaneous unit can be advanced distally by dividing its origin from the femur and converting it into a pure "island" sliding myocutaneous flap. This will advance the distal cutaneous segment of the compound gastrocnemius flap by approximately four centimeters, but this small amount of additional length can make a critical difference. In general, the "ungraftable" Achilles tendon area and defects of the lower tibia and ankle are preferably treated with a "free" microvascular transfer rather than with a "reversed" soleus muscle flap or a distally based fasciocutaneous flap. Children provide the exception to this rule since our limited experience in children has been satisfactory with the "reversed" soleus muscle flap.

DISADVANTAGES

The dissection of the soleus muscle requires a friendly conversance with the anatomy of the gastrocnemius muscle and the other posterior muscle groups. The posterior tibial neurovascular bundle must be carefully protected throughout this dissection because it is adherent to the surface of the distal soleus muscle. The soleus muscle needs to be sharply separated from both the Achilles tendon and the gastrocnemius muscle, and the elevation of the soleus muscle away from the intermuscular septum may also be tedious. The distal four to five centimeters of the proximal muscle flap may not survive because of the known dual blood supply, but this can usually be recognized at the time of the flap elevation. If there is a question about muscle viability, the muscle flap inset and grafting should be delayed for two to three days.

The "reversed" soleus flap has a variable vascularity which cannot be known until the time of exploration. If the deep perforators lie within the "zone of injury," the flap probably should not be used at all. Certainly, four or more major deep perforators should be left with the distal soleus muscle flap, but as more perforators are retained, one is forced to accept a higher rotation point. Consequently, there is always a dilemma as to whether one should leave additional perforators to enhance the viability of a longer muscle flap or sacrifice more perforators and lower the rotation point. Presently, this is an unanswerable question.

ADVANTAGES

The proximal soleus muscle flap is relatively easy to dissect once one is familiar with the anatomical landmarks. It does provide good muscle coverage for the middle-third of the tibia, and it is truly a "bonus" flap for certain lower tibial defects. The donor site deformity is negligible, and the skin-grafted muscle usually has a very acceptable appearance. Like the gastrocnemius muscle, it can be thinned and tailored at the time of inset to provide a more pleasing contour. We have become much more aggressive with this tailoring, because experience has shown us that at least half of the excessive muscle bulk does persist. There has been no detectable functional deficit from the isolated use of the soleus muscle.

COMPLICATIONS, PITFALLS, AND DONOR SITE

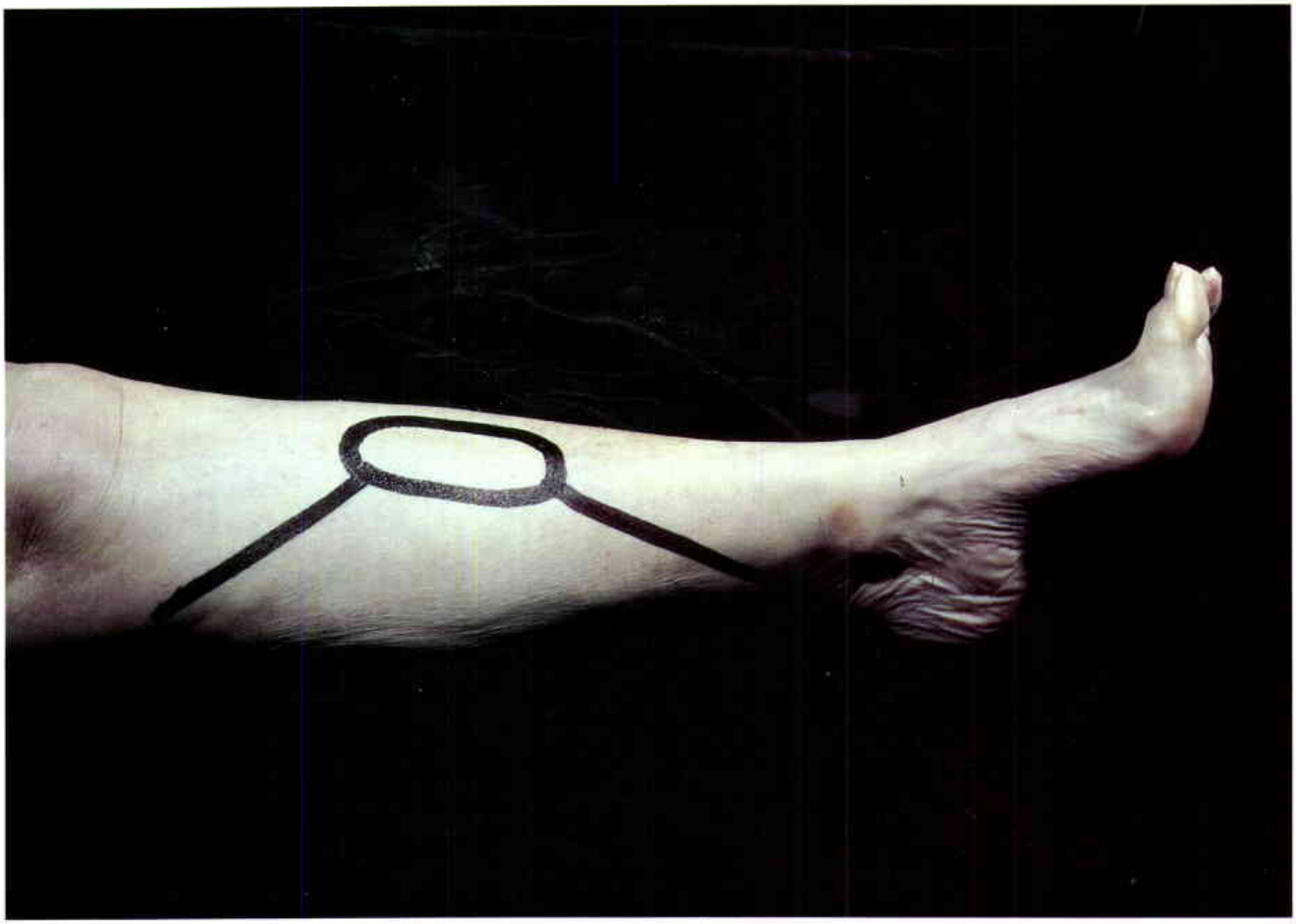
The complications are primarily related to errors of anatomical identification. Dissection in the wrong plane can easily lead to an injury of the surrounding structures, particularly to the posterior tibial neurovascular bundle. The Achilles tendon can be confused with the deep fascia of the leg and be accidentally divided unless the location of the gastrocnemius muscle and its muscular insertion into the distal Achilles tendon is clearly identified. One may also inadvertently elevate less than half of the medial head of the soleus muscle, and thereby leave the sustaining blood supply "behind" with the unelevated muscle. It is safer to elevate the entire medial head of the soleus muscle with a portion of the lateral head assuring that the dominant vasculature is included with the elevated muscle flap. The redundant lateral head of the soleus muscle can easily be trimmed following flap elevation. It is also important to preserve the soleus muscular fascia for purposes of suture retention.

Constriction of the muscle by a compressive skin bridge is the major cause of muscle flap loss. This source of failure can be prevented by properly designing the access route or by avoiding a skin bridge altogether. This intolerance to constrictive pressure probably represents the same pathogenic sequence of the Volkmann's incident when muscular swelling leads to a decreased

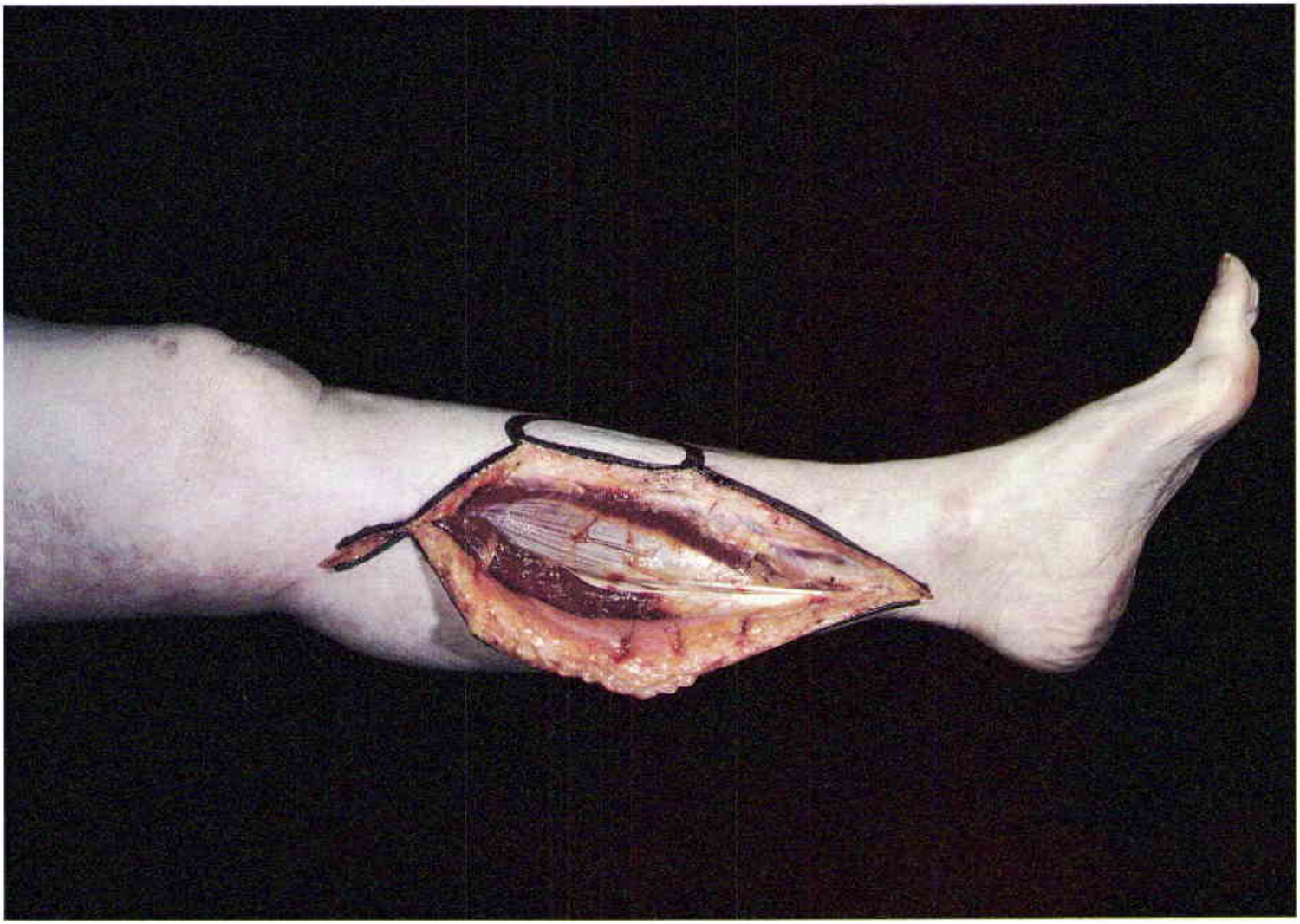
venous outflow. This muscular swelling then becomes self-perpetuating and eventuates in a fatally decreased arterial inflow. This same intolerance of constrictive pressure precludes the use of a "stent" to secure a skin graft on the surface of the soleus muscle flap.

If there is any question about the viability of the muscle, it should be placed on the recipient site and left ungrafted for a few days. An immediate skin graft may obscure the nonviability of the muscle flap for five to seven days because one may be erroneously led to believe that the skin graft is "taking." In this situation, it is better to observe the muscle directly for two to three days. Any nonviable muscle can be electively trimmed and the skin graft can be placed in a delayed fashion.

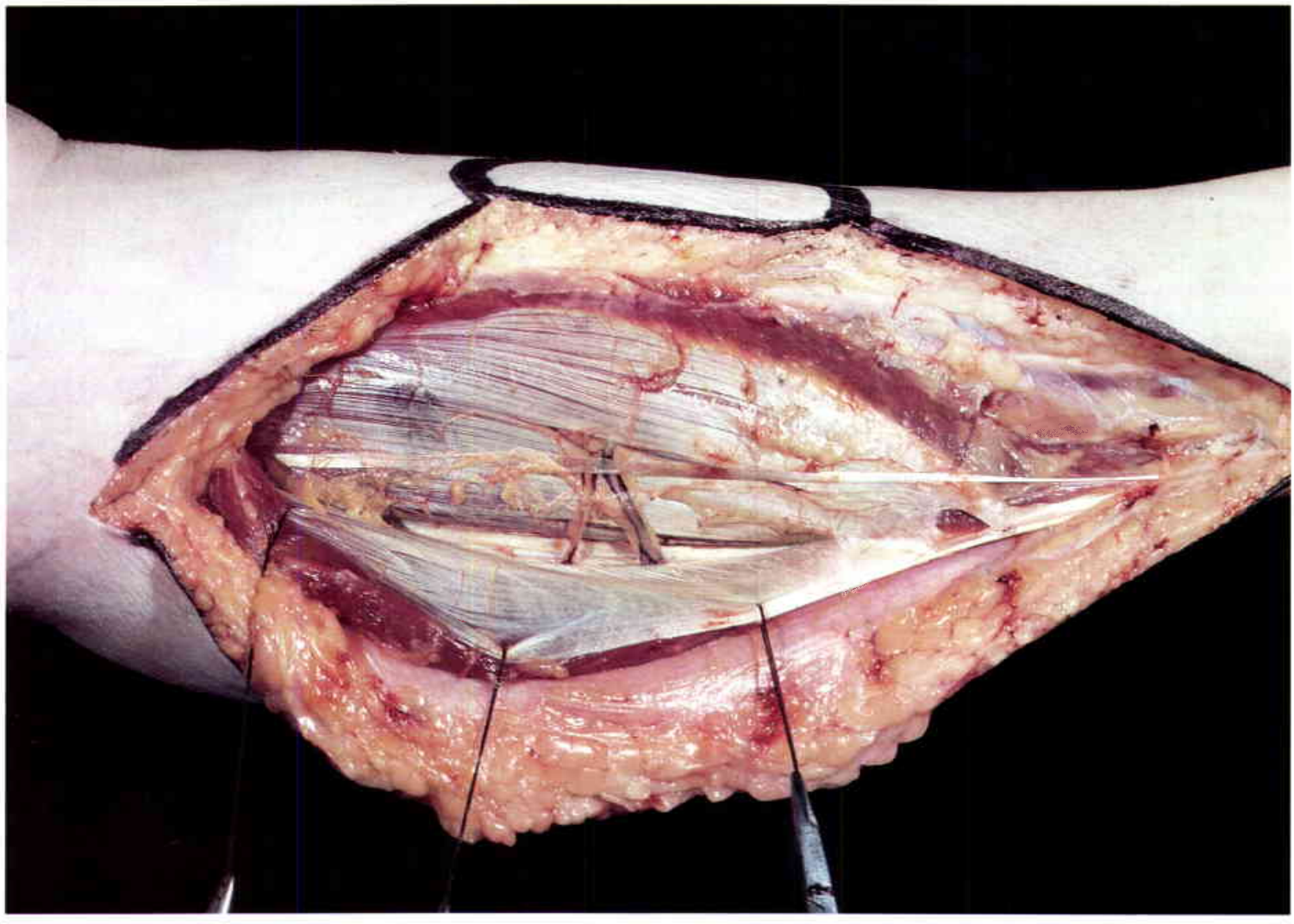
Hematoma and seroma formations have been unusual, but they will occur if the wound is not properly drained by suction catheters. The donor site is inconsequential both from functional and esthetic standpoints.



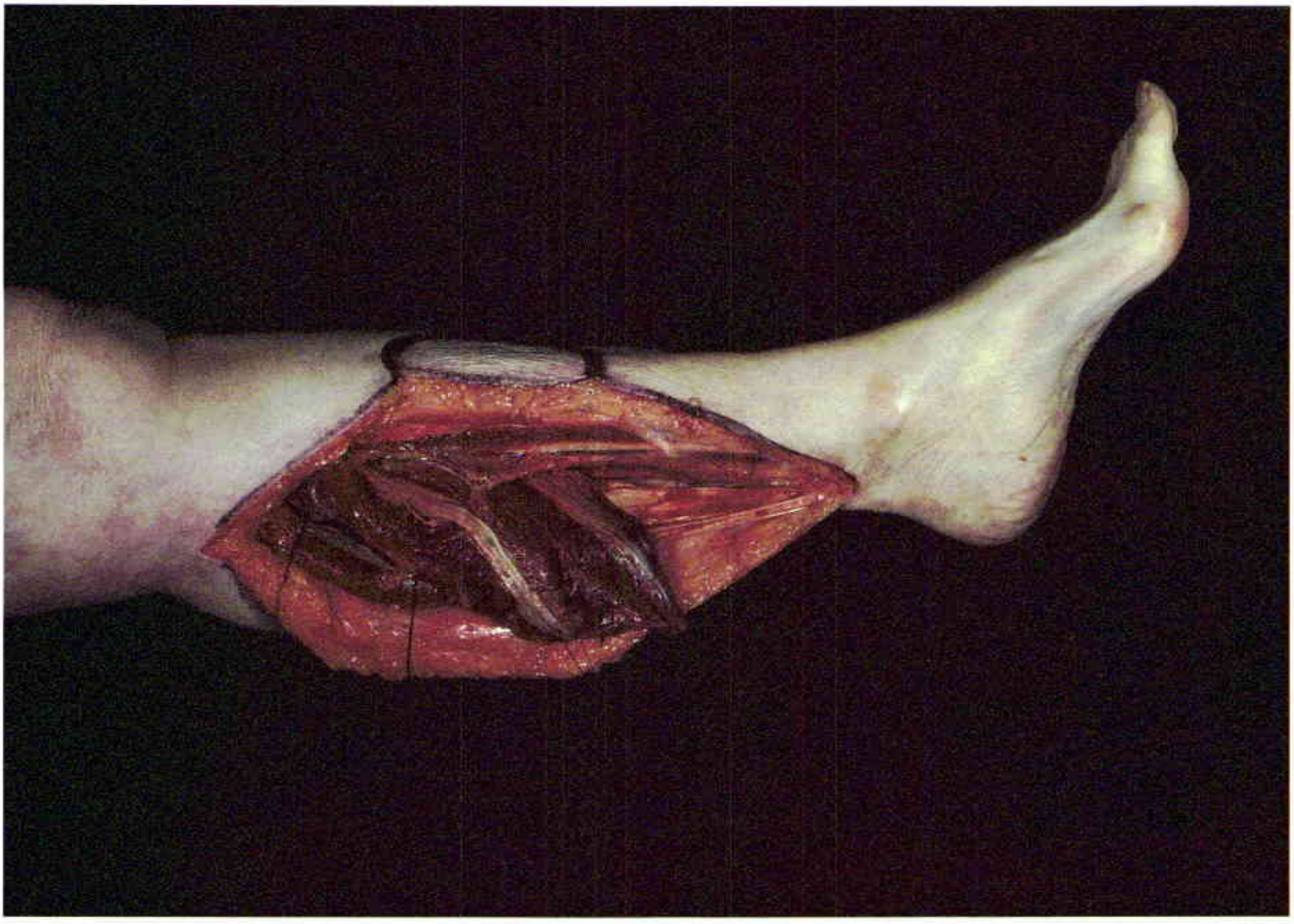
1
Medial approach to the soleus muscle with a "typical" area of coverage circled in the midtibial region. This direct approach to the muscle avoids a constricting skin bridge over the transposed muscle flap.



2
The separation between the soleus and gastrocnemius muscles is first identified in the midcalf. This separation can also be found near the Achilles tendon, but the plane of dissection is less clearly defined. Note the plantaris tendon on the surface of the soleus muscle indicating that the plane of dissection between the two muscles is correct.

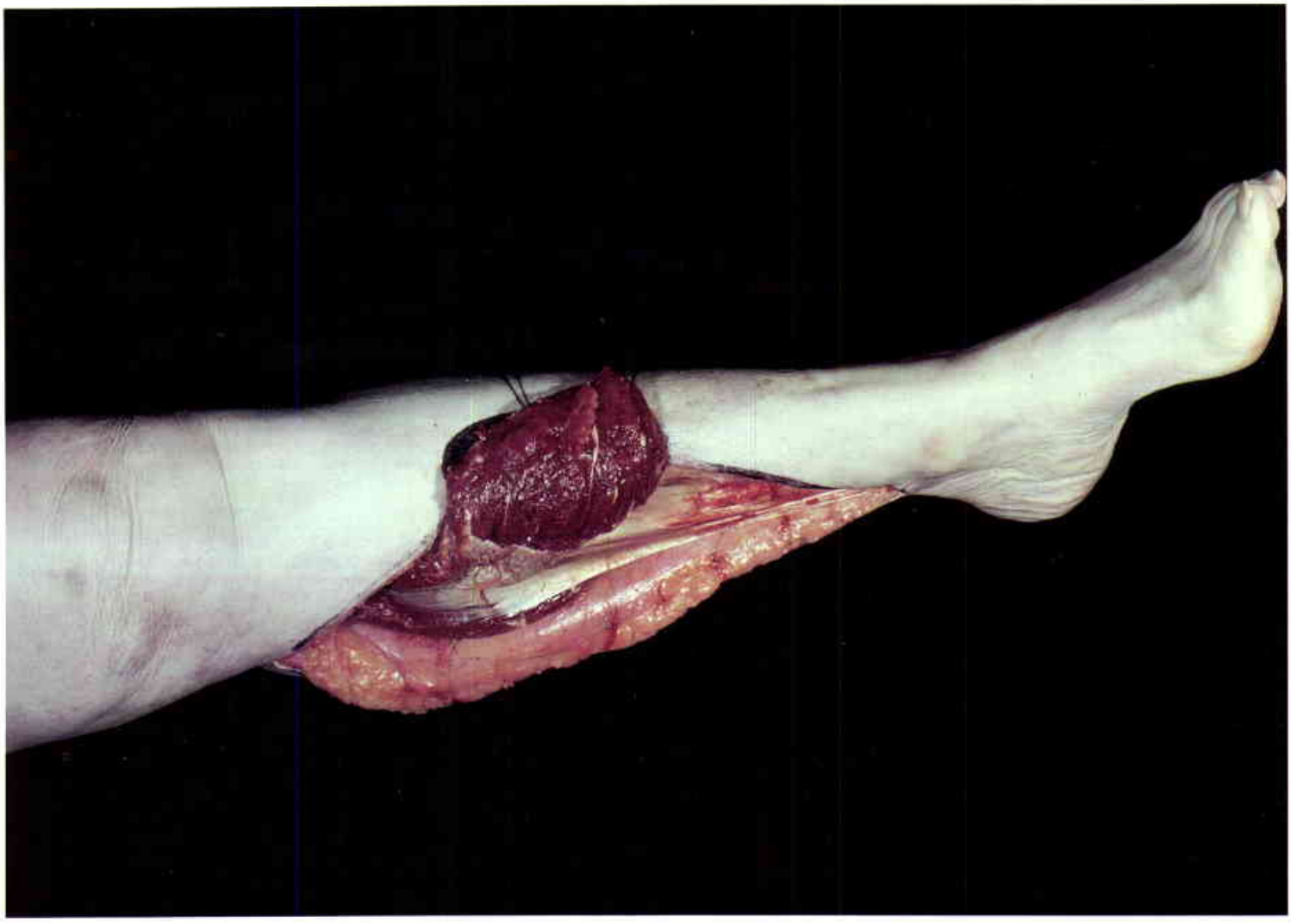


3
Close-up view of a deep muscular perforator passing from the soleus muscle to the undersurface of the gastrocnemius muscle, which is retracted with sutures. The soleus muscle is next separated from its medial attachment to the tibia starting at the point where the plantaris tendon crosses the distal muscle. In the area of the Achilles tendon, the soleus muscle must be sharply separated from the gastrocnemius muscle and the Achilles tendon.



4

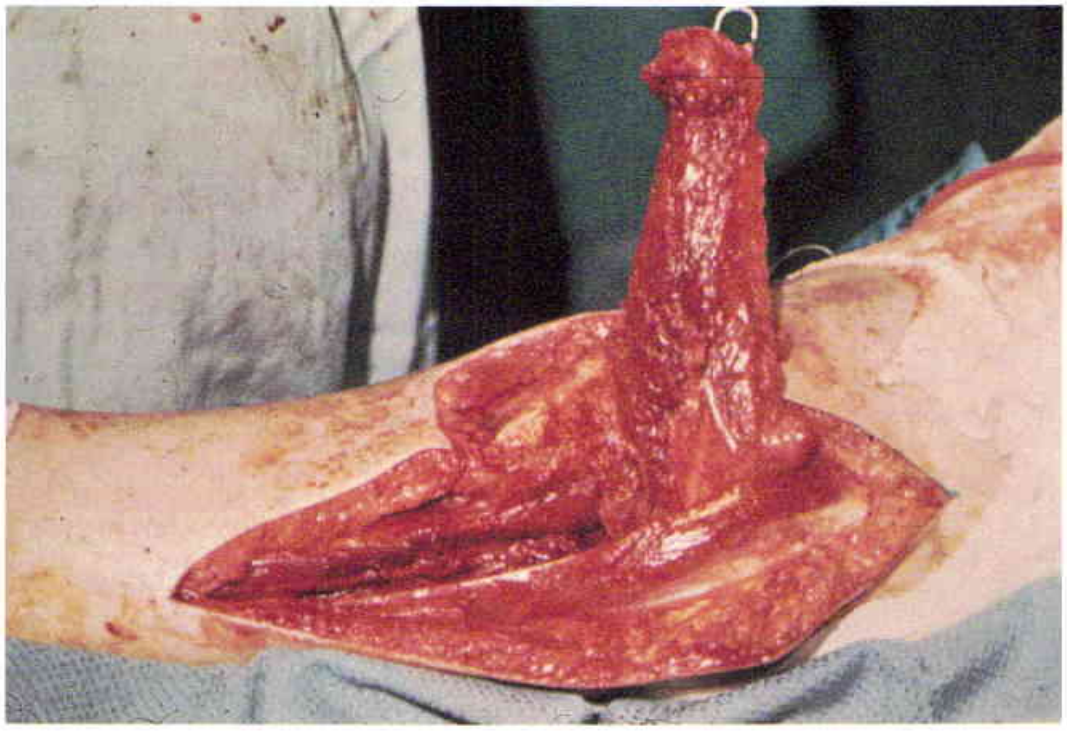
The soleus muscle has been separated from the Achilles tendon. It is still attached to most of the deep perforating branches from the posterior tibial artery. These deep perforators may be divided if it is necessary to increase the upward excursion of the muscle, but if they can be left intact, the blood supply to the muscle flap is obviously enhanced.



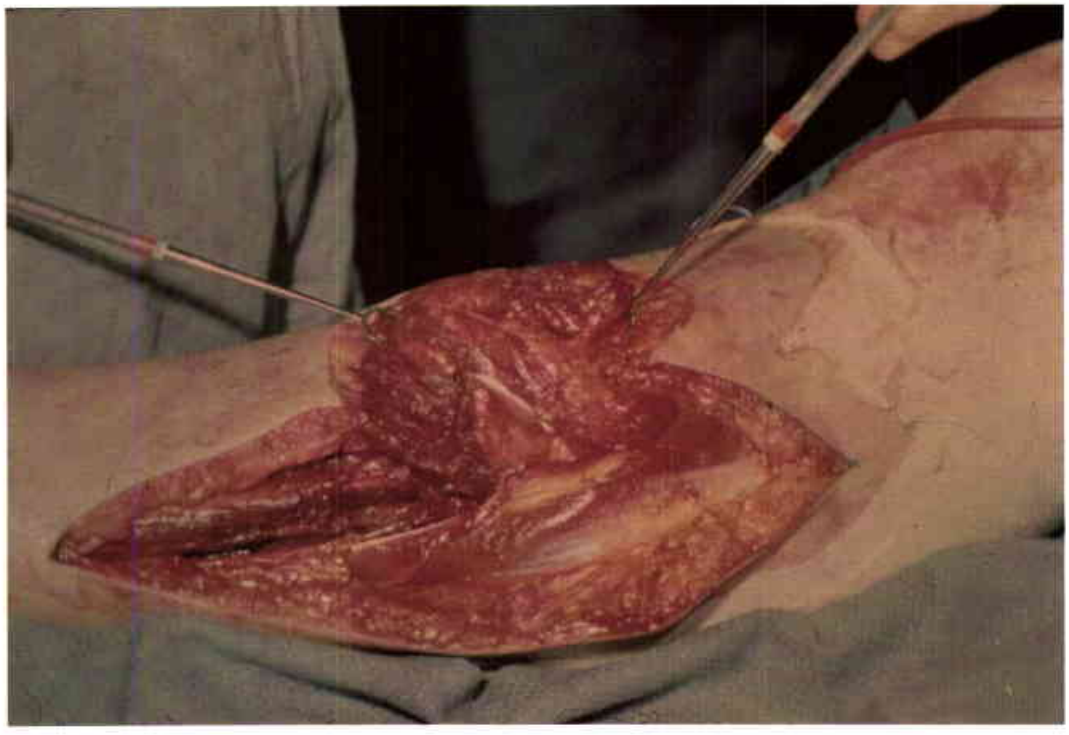
5

With this limited dissection the soleus muscle can be readily transposed into a midtibial defect. Coverage of a larger defect by the soleus muscle requires a more extensive dissection.

6
Twenty-two-year-old man with a superficial osteomyelitis of the tibia following an open fracture. This is a historical case for the authors since it was the first soleus muscle flap done at the Henry Grady Memorial Hospital in Atlanta. (Case of J.B. McCraw and L.O. Vasconez)



7
The soleus muscle is retrieved through a medial access incision following the debridement of the tibia.

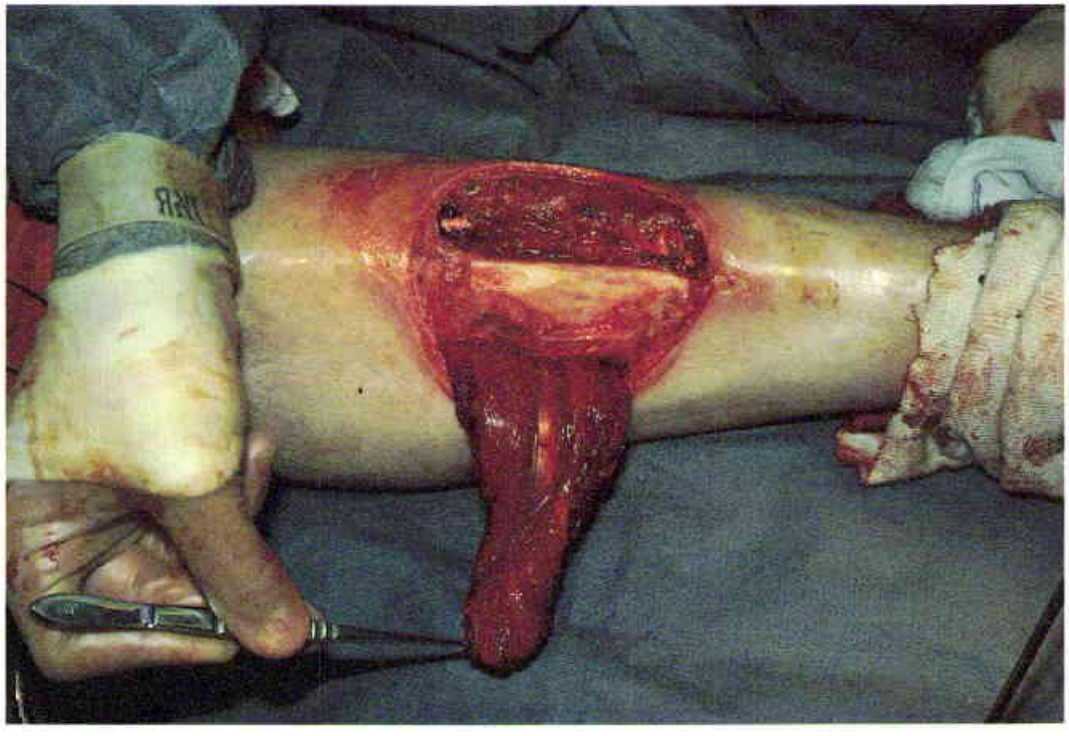


8
The soleus muscle is rotated into the pretibial defect. Skin grafting was delayed for two days.

9
Skin-grafted muscle flap and primary closure of the donor site. The skin closure must be effected without any muscular constriction since the soleus muscle is very sensitive to external pressure. It is remarkable that our methods have not changed since 1972. It is even more remarkable that this same method was used by Professor Stotz in World War I.

10

Twenty-four-year-old housepainter who sustained a high voltage injury to both midpretibial areas while standing in contact with a metal ladder. The anterior compartment musculature was necrotic, and the tibia was exposed in both legs. Bilateral cross-leg flaps would have been quite difficult, and this 1975 case predated reliable "free" tissue transfers to the lower leg. (Case of J.B. McCraw)

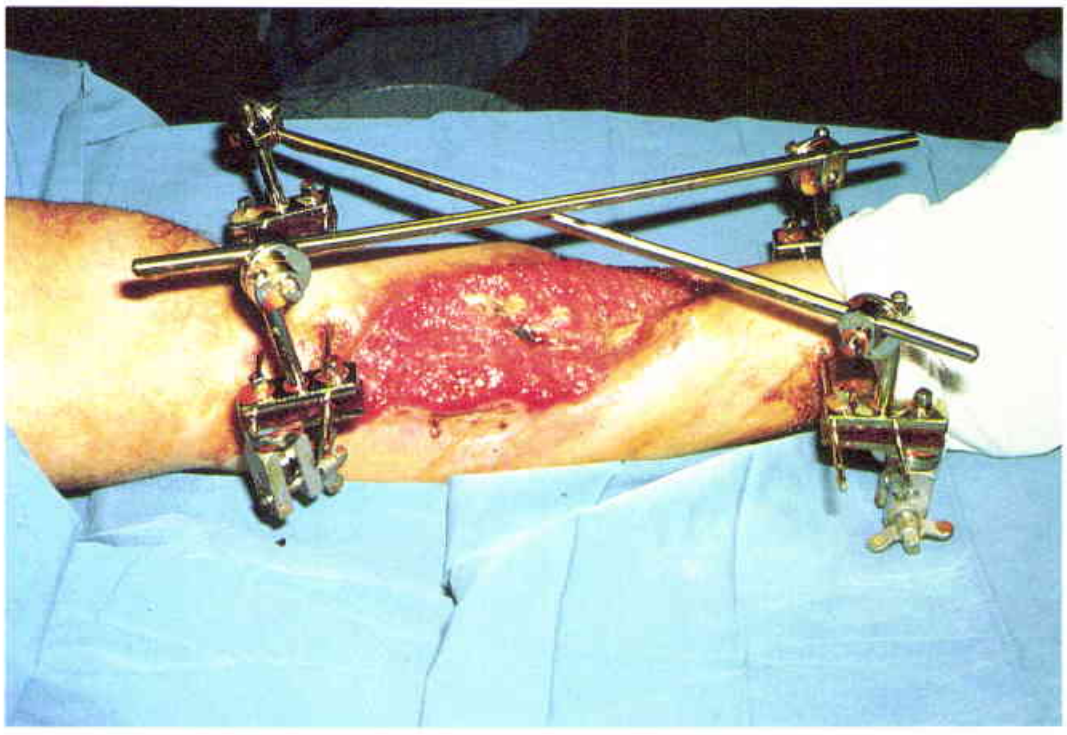


11

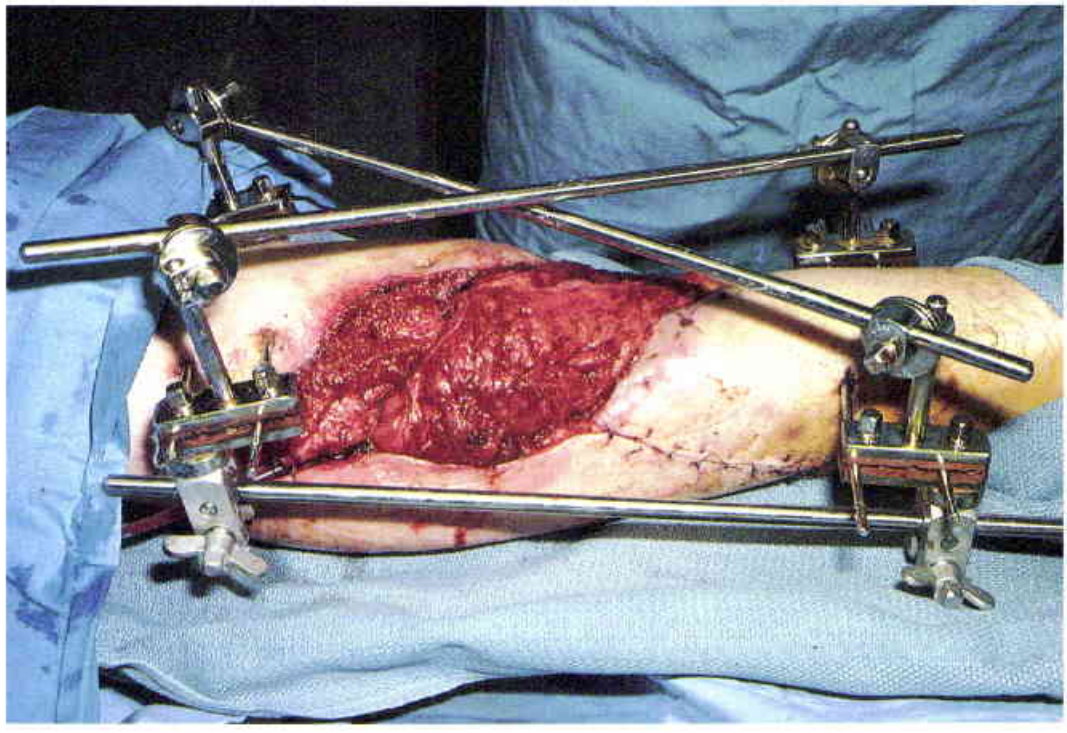
The tibial cortex was tangentially excised, and the necrotic anterior compartment musculature was debrided. It was possible to raise a soleus muscle flap at the time of the initial debridement because the viable margins of the injured tissues were adequately delineated.

12
Bilateral soleus muscles elevated and readied for transfer into the pretibial defects.

13
Early postoperative view of the skin-grafted soleus muscle flaps. The patient was very upset by the appearance of the flaps and threatened a lawsuit. He never recognized the potential gravity of his situation. Needless to say, the flaps were never revised.



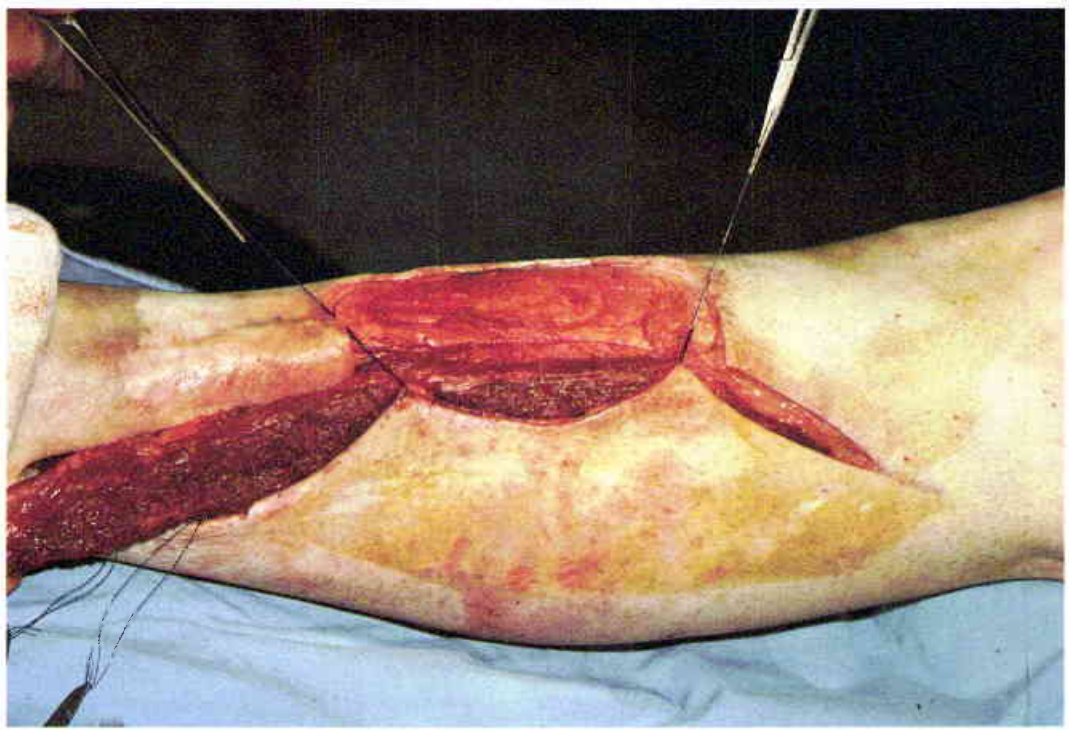
14
Nineteen-year-old man with active osteomyelitis in an unstable and exposed tibial fracture. (Case of P.G. Arnold)



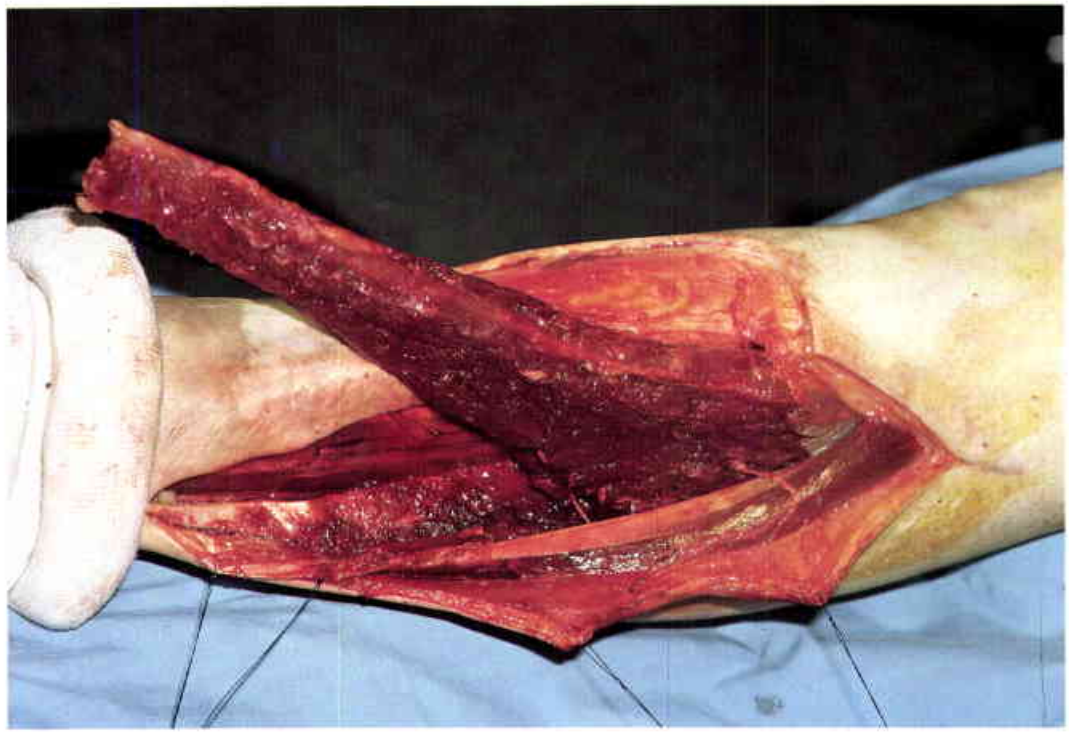
15
The soleus muscle was transposed at the time of the initial debridement. The external fixation device was not removed.

16
Stable wound and healed fracture at nine months. The patient continues to do well after seven years.

17
Fifty-seven-year-old man with a traumatic full-thickness loss of an old burn scar. The burn was sustained as a child and had been allowed to secondarily heal by epithelization. (Case of P.G. Arnold)



18
The debridement denuded the central one-third of the tibia. The soleus muscle was exposed by "extending" the medial margins of the wound.



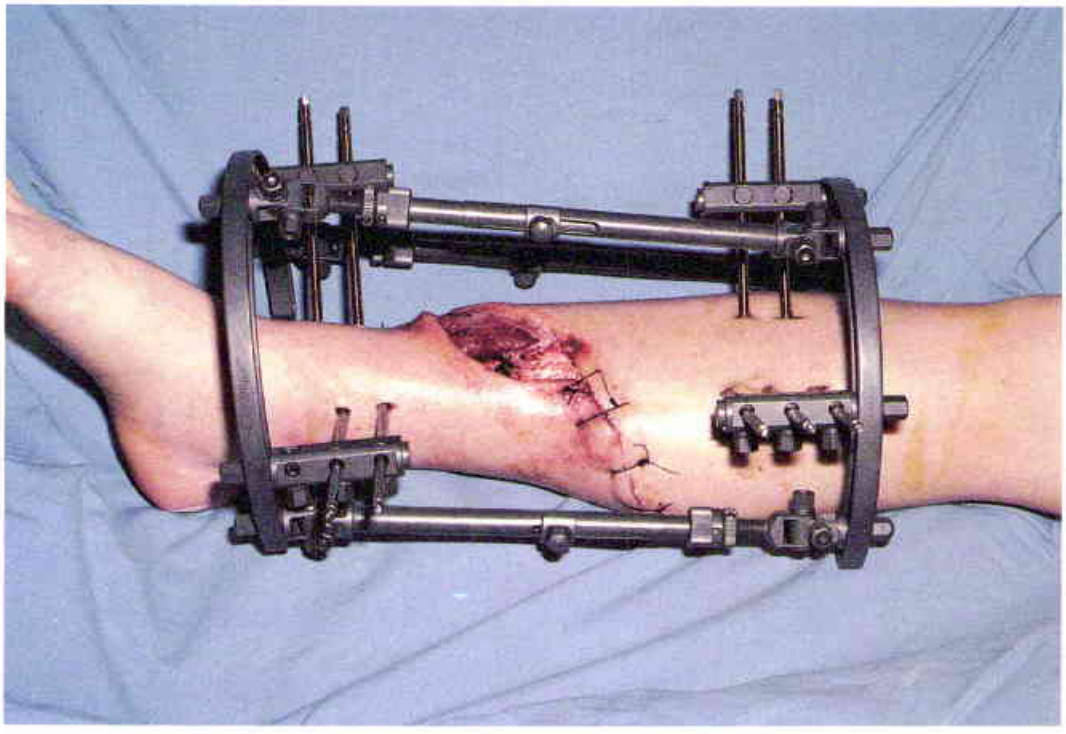
19
The distal soleus muscle was completely mobilized by sharply separating it from the Achilles tendon and the gastrocnemius muscle. Note the impressive length of the soleus muscle.

20
Three months following muscle transposition and skin grafting. The early graft appearance is irregular because the muscle was immediately grafted and the distal half of the graft was lost. A delayed skin graft would have been preferable. The wound has remained healed for five years.

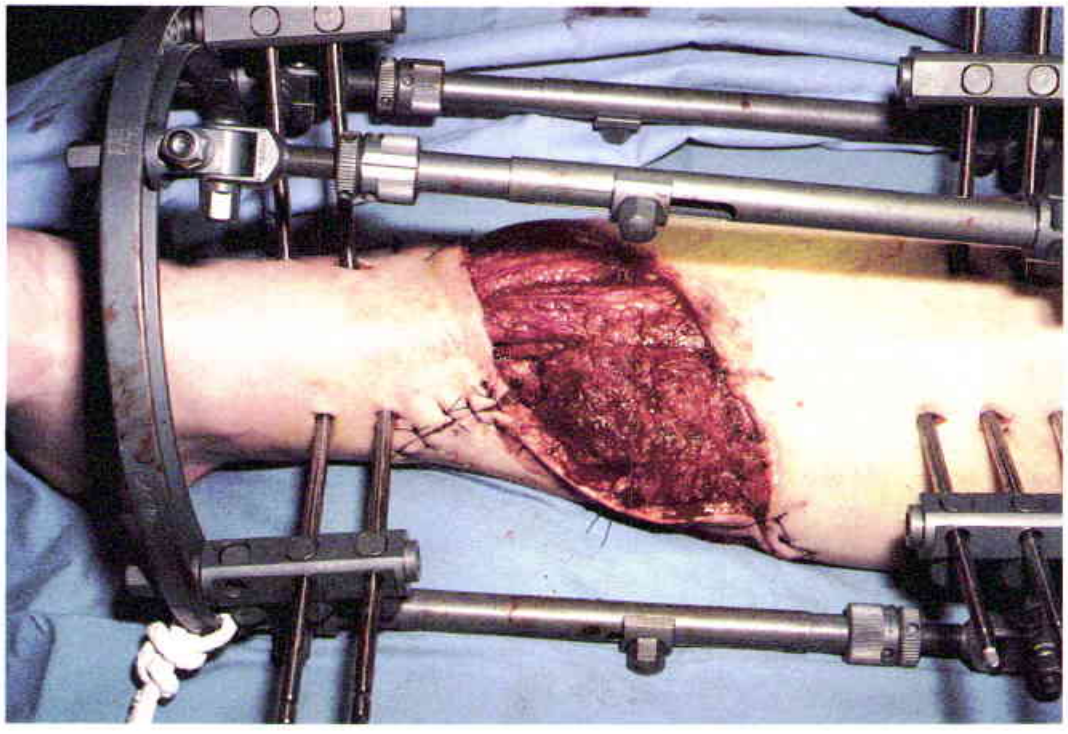
21
Osteomyelitis of the distal one-third of the tibia, which had continuously drained for five years. The surrounding venous stasis changes resulted from the complex injury of the tibia and fibula. (Case of P.G. Arnold)

22
The proximal soleus muscle was explored and found to be a reasonable choice for this low tibial closure. A skin graft was placed forty-eight hours following the muscle transposition.

23
Eighteen months following the muscle flap closure. The venous hypertensive disease has not progressed, and the osteomyelitis has not recurred over a five year period.



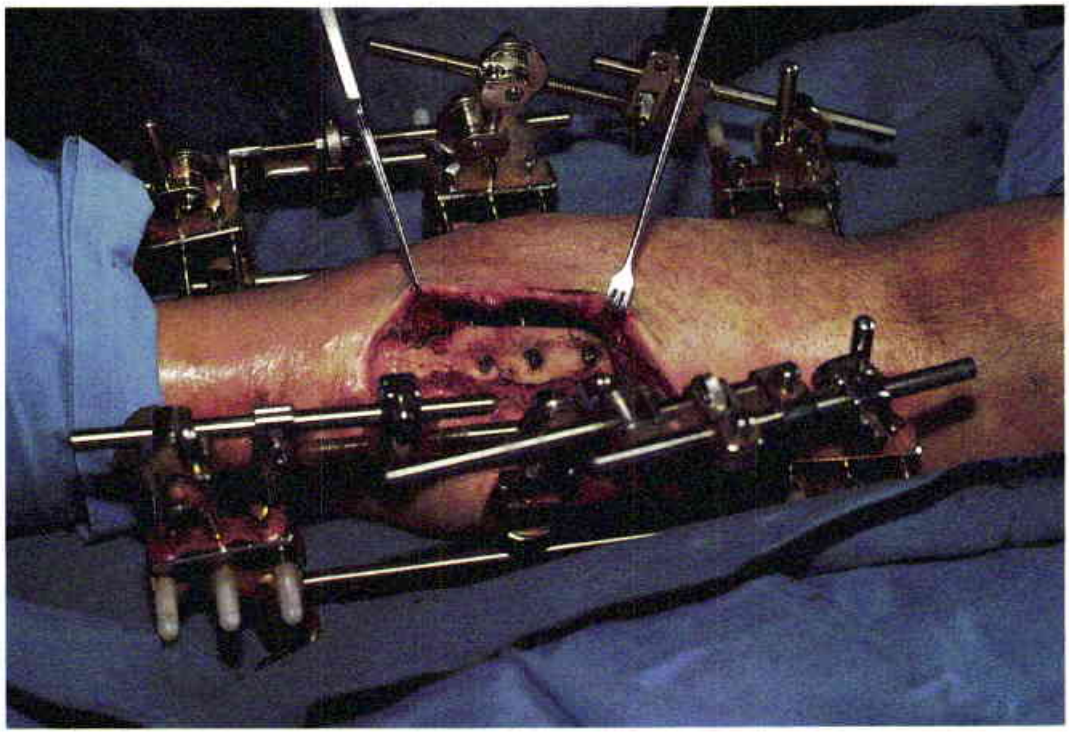
24
Nineteen-year-old female with an open tibial fracture forty-eight hours following the initial debridement and placement of an external fixation device. (Case of P.G. Arnold)



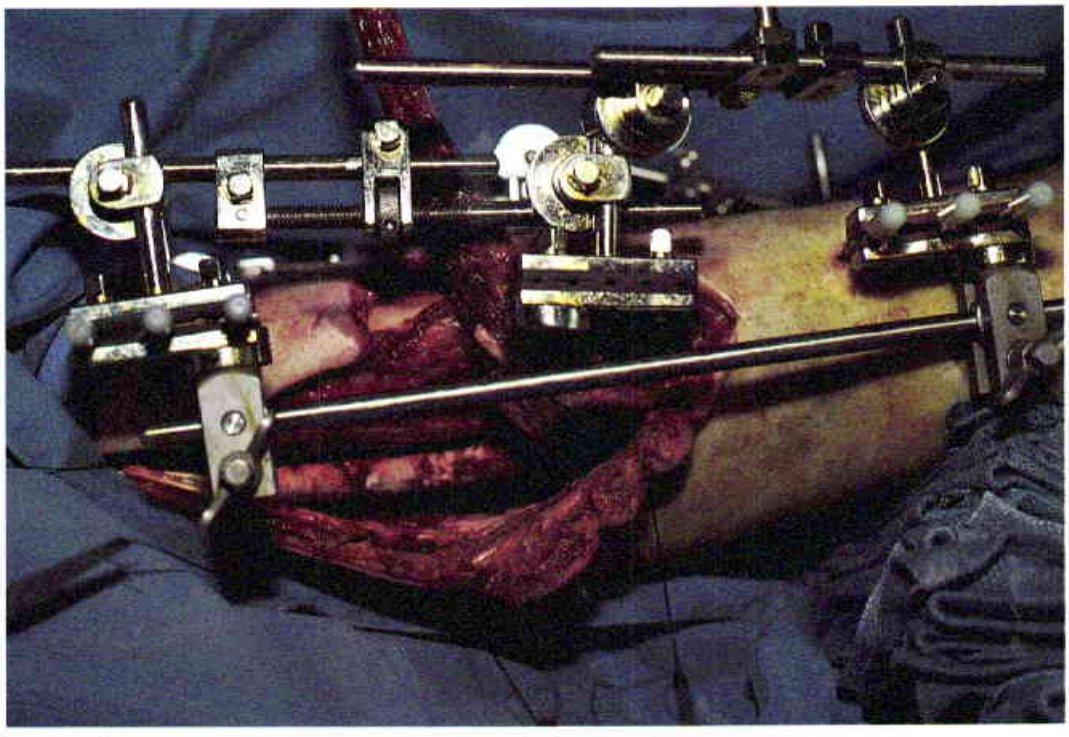
25
The proximal soleus muscle flap was explored and immediately transposed. Appearance of the muscle forty-eight hours following transposition at the time of skin grafting.

26

Healed muscle flap and tibial fracture at one year. The length of the soleus muscle was adequate to accommodate this low tibial defect.



27
Thirty-one-year-old man eighteen months following an open fracture of the distal tibia. The fracture was first treated with an internal plate, but this was complicated by osteomyelitis and nonunion of the fracture. An external fixation device was placed at the time of our initial debridement. (Case of P.G. Arnold)



28
The soleus muscle flap is elevated with the fixation device in place. The necrotic tibia and the infected screw tracts were extensively debrided. A bone graft was not required.

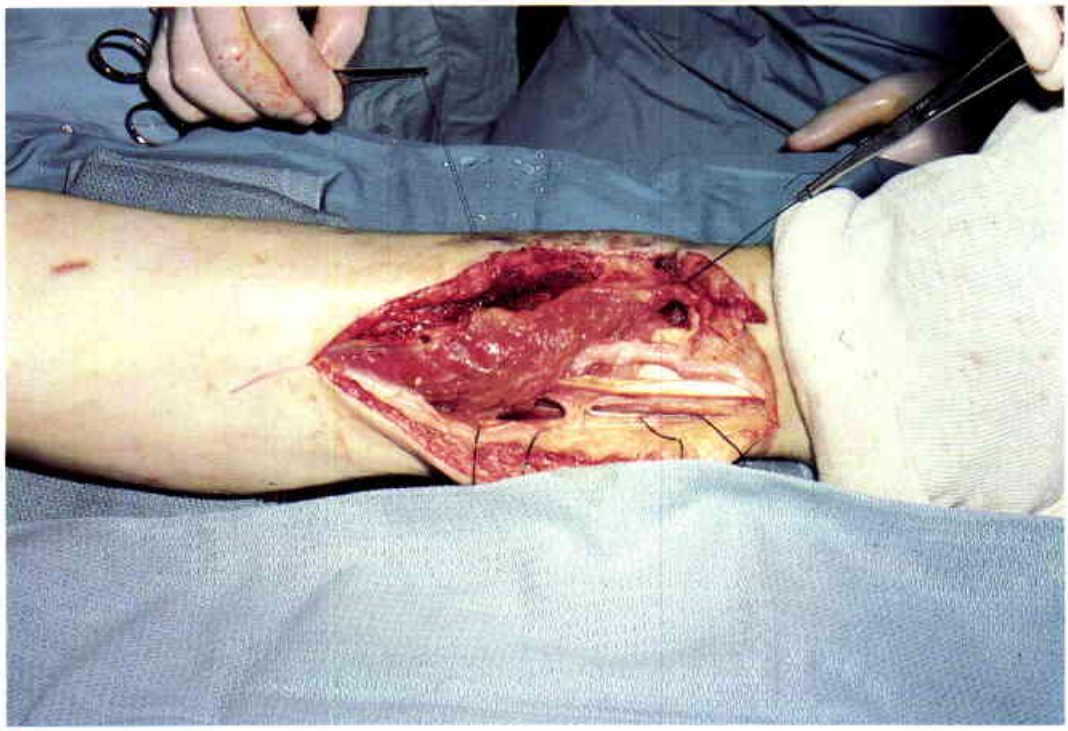
29

The tibia and the soleus muscle flap remain healed at two years. It is frequently worthwhile to explore the soleus muscle in these distal wounds, because it can offer a much simpler method of reconstruction than a "free" flap.

30
Thirty-two-year-old female with osteomyelitis of the distal one-third of the tibia fourteen months after an open fracture. (Case of P.G. Arnold)

31
The initial debridement resulted in an extensive soft tissue defect and a deep wound of the distal tibia.

32
A proximal soleus muscle flap was elevated at the time of the initial debridement.

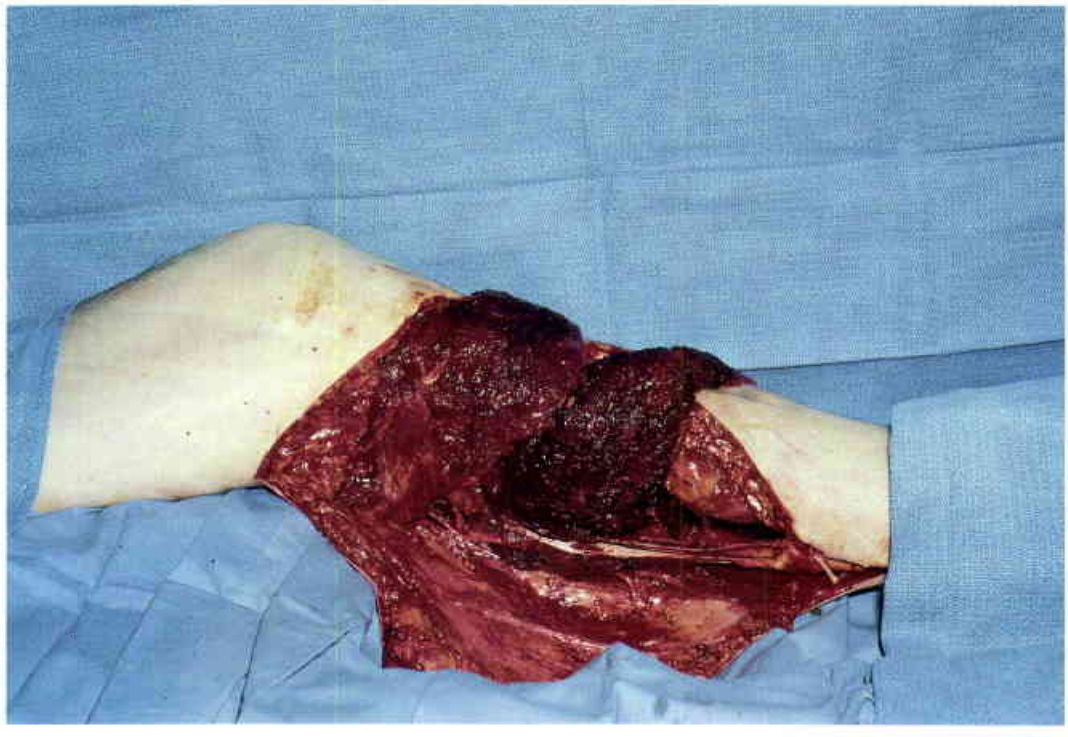


33
Transposed soleus muscle flap. Although the soleus muscle was small, it was adequate to fill the tibial cavity.

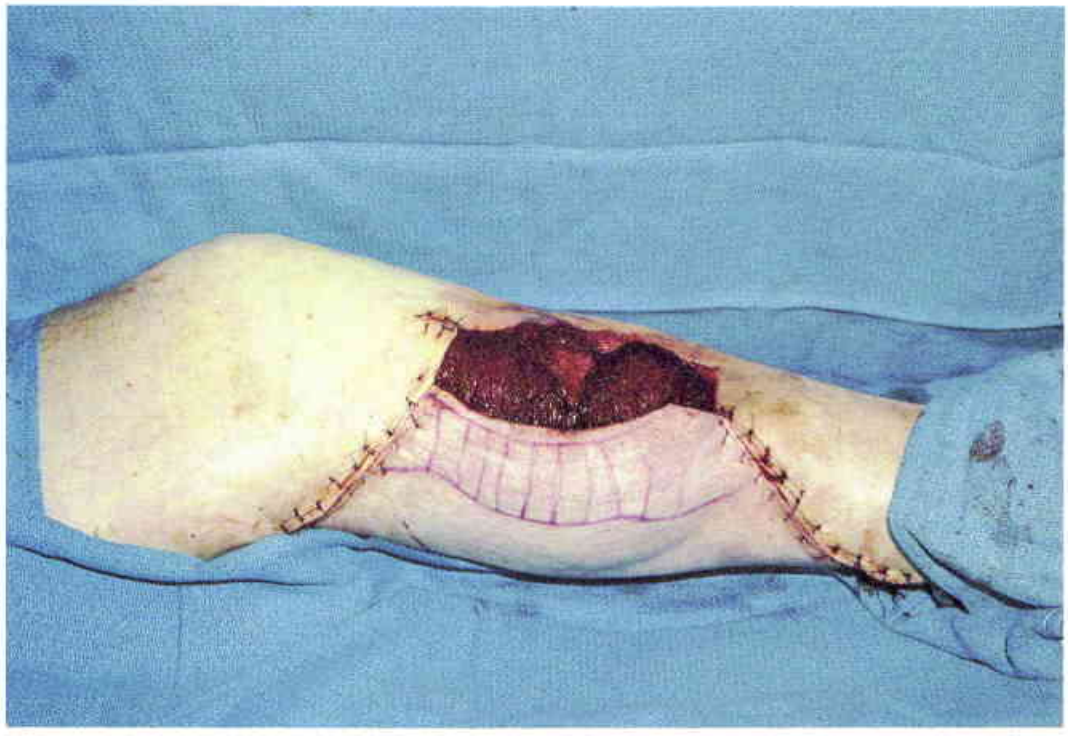
34
The patient was returned to the operating room for skin grafting after the viability of the muscle was assured.

35
Healed soleus muscle flap at eleven months. The wound has remained stable for eight years.

36
Severe osteomyelitis of the middle and upper tibia in a sixty-seven-year-old retired professional football player. The infection had been active for fifteen years. (Case of P.G. Arnold)

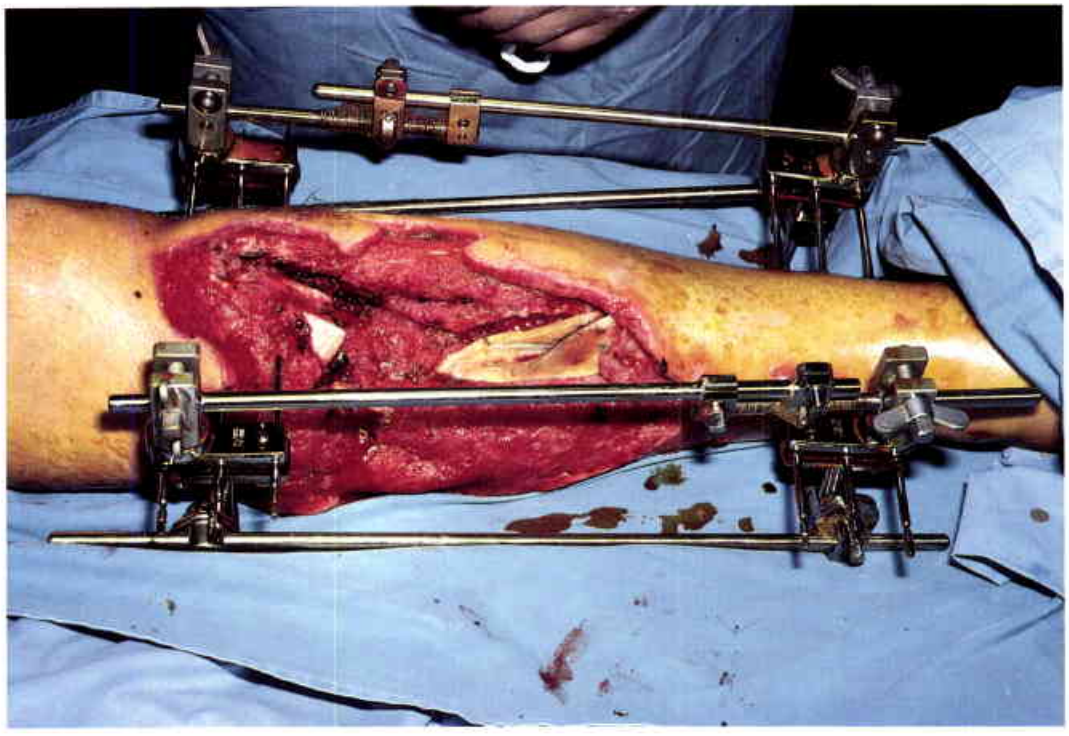


37
Because of the extensive nature of the soft tissue and bony defects, it was necessary to transpose both the soleus muscle and the medial head of the gastrocnemius muscle.

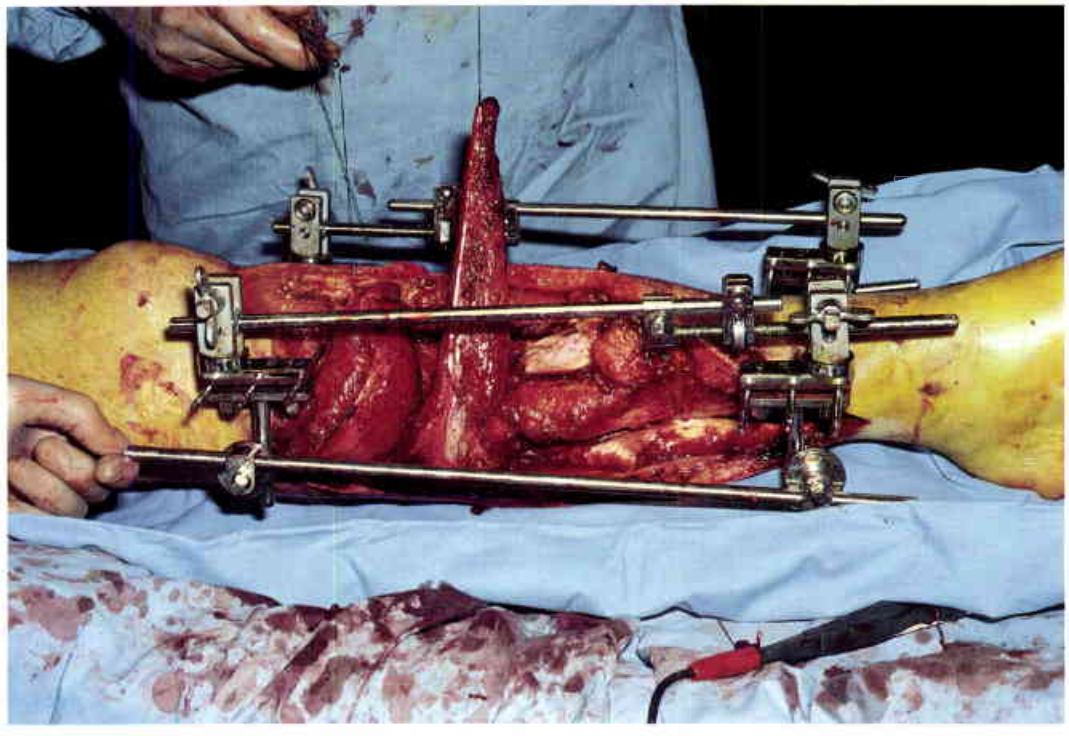


38
The patient was returned to the operating room for skin grafting forty-eight hours following the muscle flap procedure. The nonfluorescent medial calf skin (marked with cross hatches) was excised at this time.

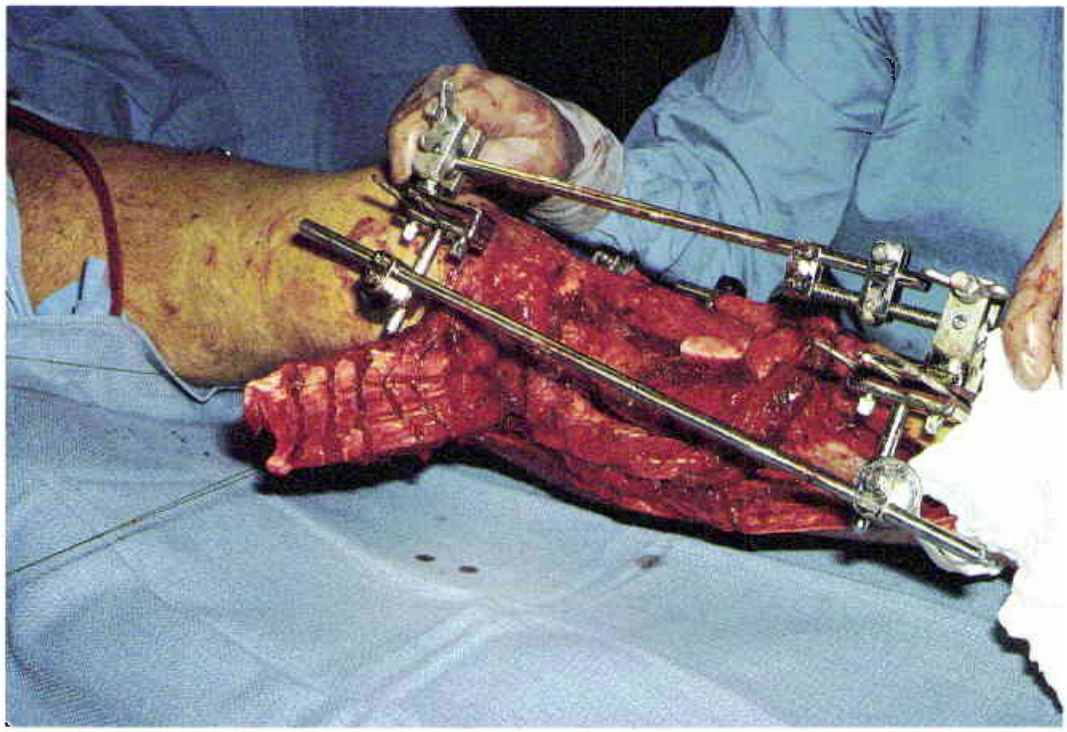
39
Healed wound eight months following the closure with soleus and gastrocnemius muscle flaps. As expected, there was no noticeable functional loss from the combined use of the soleus and gastrocnemius muscles. The osteomyelitis has not recurred over a seven year period.



40
Twenty-seven-year-old man six weeks following an open fracture of the tibia with a large segment of missing bone. This case predated the "free" osteocutaneous flap era. (Case of P.G. Arnold)

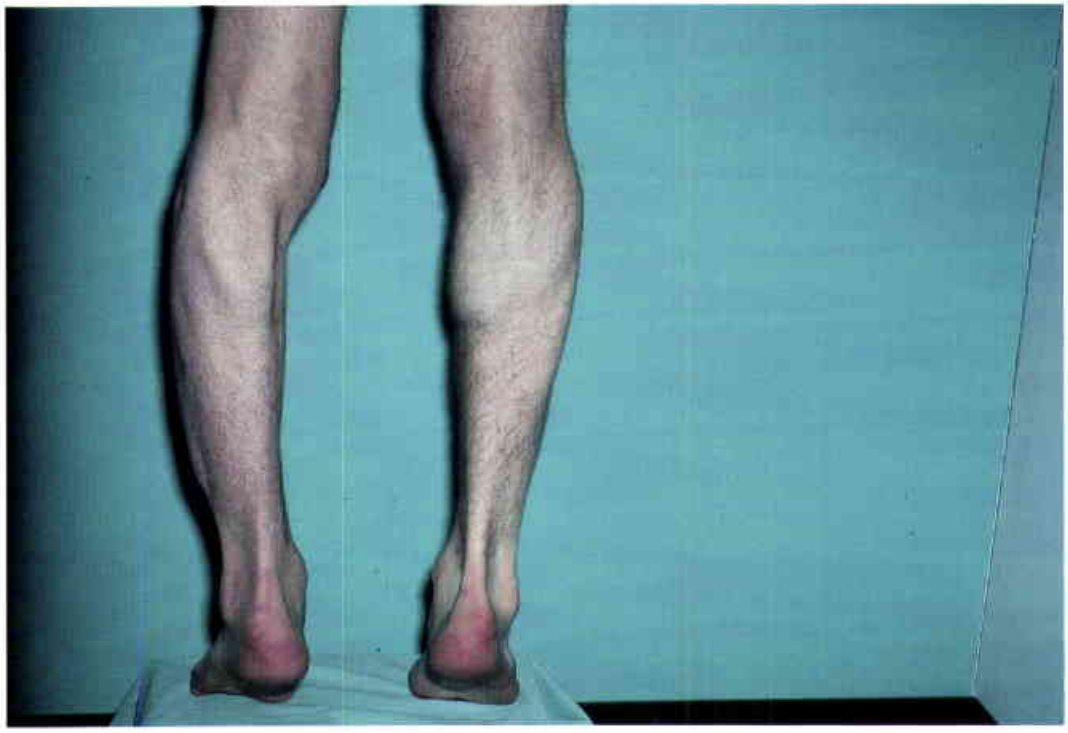


41
It was necessary to use the medial head of the gastrocnemius muscle as well as the soleus and tibialis anterior muscles to cover the massive tibial defect.



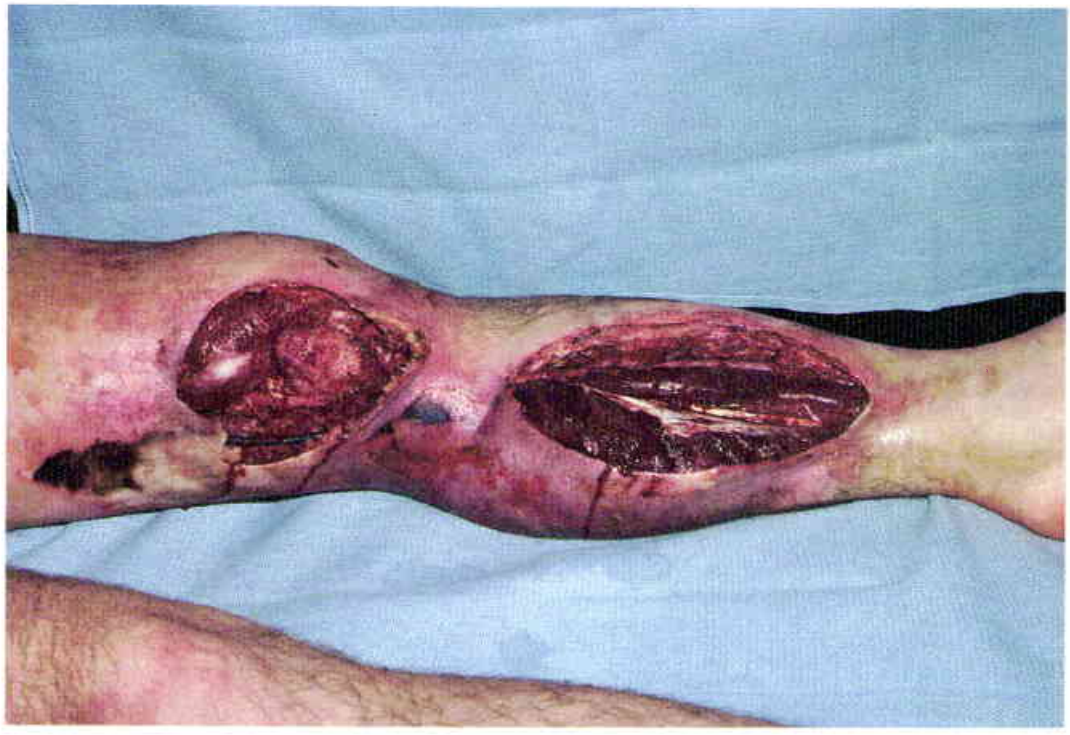
42
The deep fascia of the gastrocnemius muscle was "scored" to expand its coverage. It is just as easy to excise the muscular fascia. This also allows the "raw muscle" to be in direct contact with wound surface.

43
Appearance seven years following the surgery. The twenty centimeter tibial defect was reconstructed with a standard bone graft, which was introduced through a posterior approach after the muscle flap closure was secured.

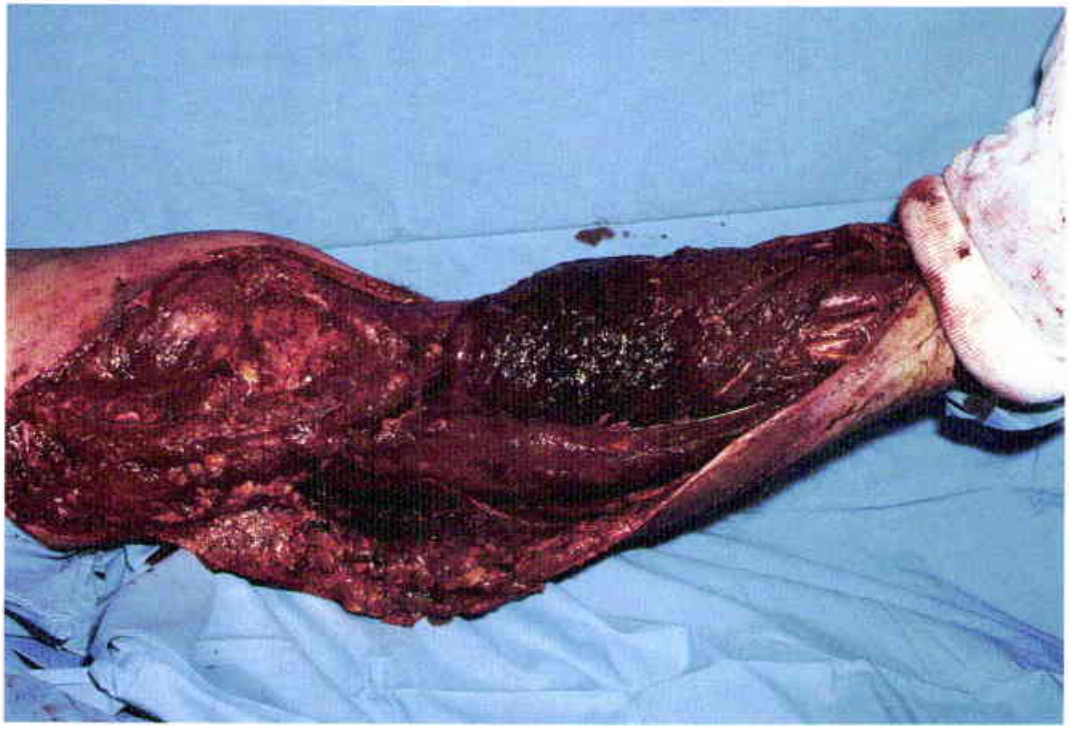


44

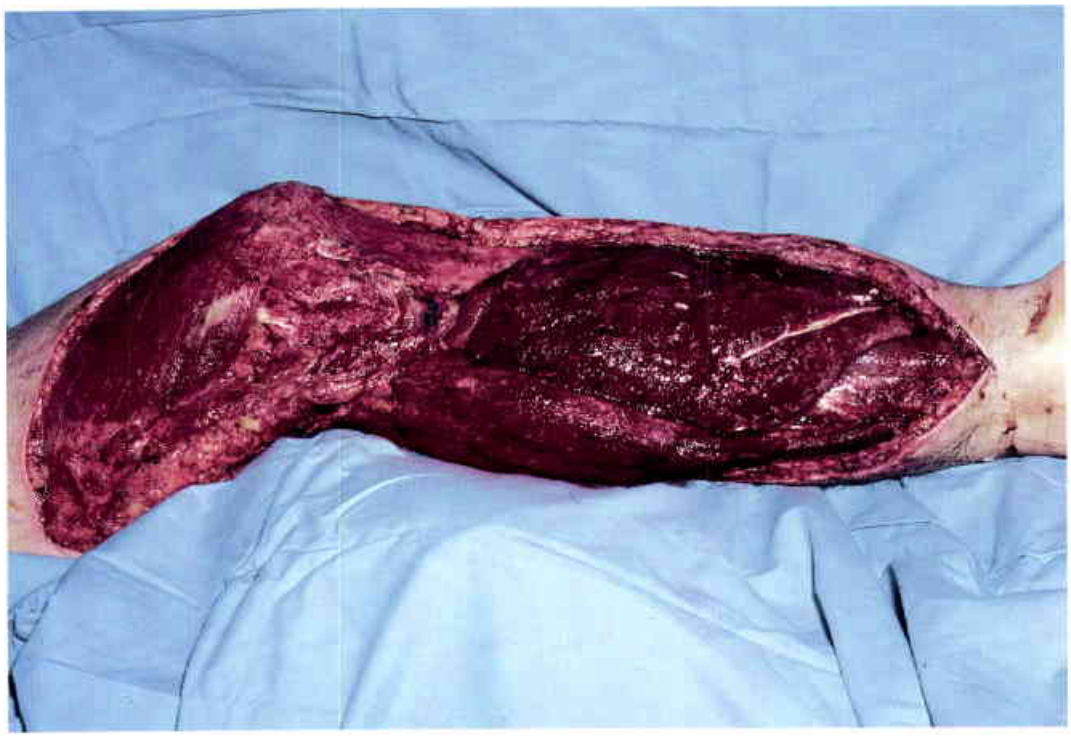
Patient standing on tiptoes to demonstrate the hypertrophy of the remaining left calf muscles. It is remarkable that the tibial length has been maintained. The patient walks with a normal gait.



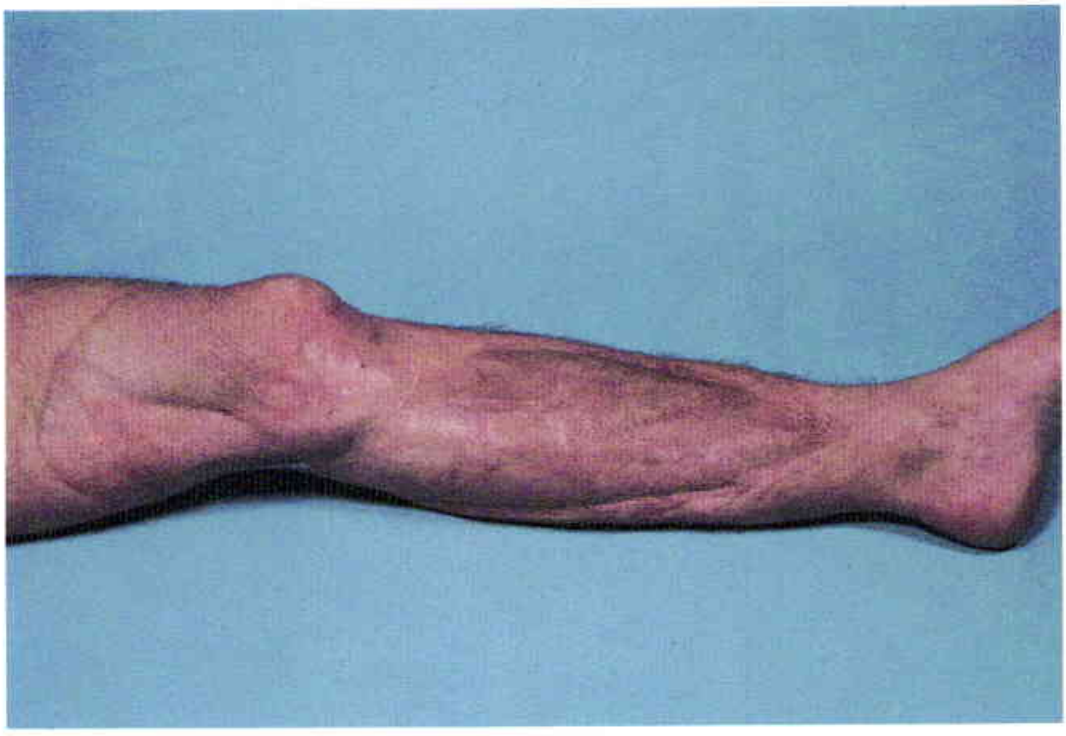
45
Fork lift injury in a thirty-two-year-old man. The entire middle portion of the tibia was exposed. None of the discolored thigh or calf skin fluoresced. Note the thrombosed saphenous vein in the upper wound. (Case of P.G. Arnold)



46
The infected tibia was debrided and covered with the soleus muscle. Because of the large size of the soleus muscle in this patient, it was not necessary to also use the gastrocnemius muscle. The surrounding nonviable skin was excised.



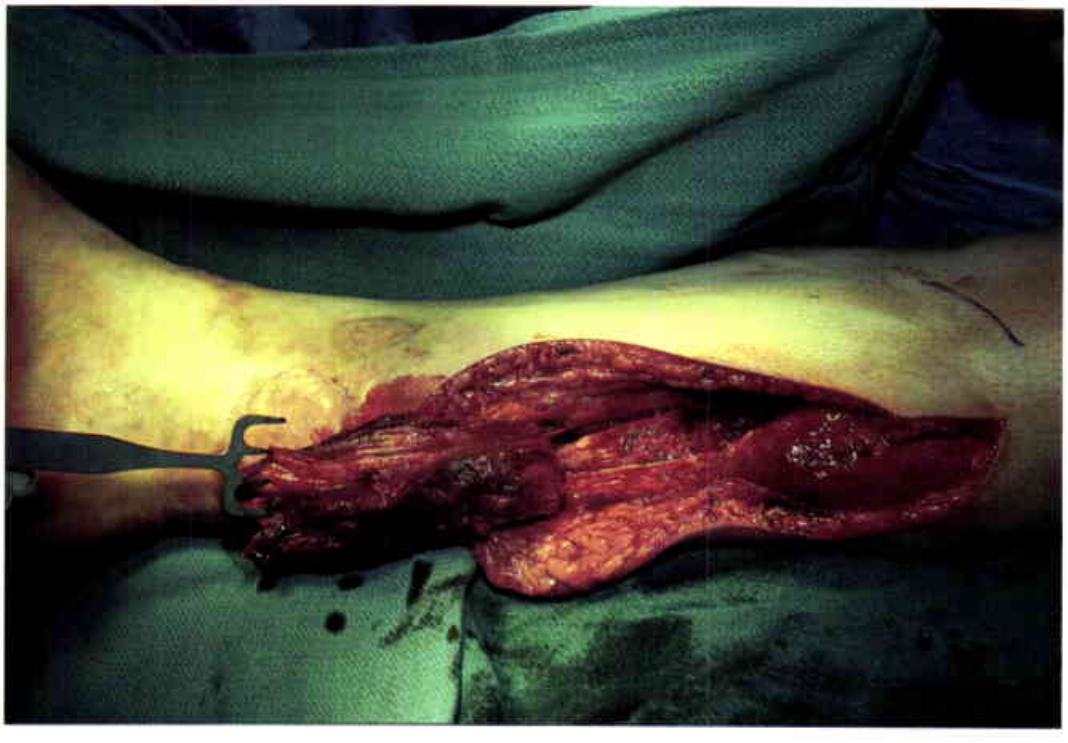
47
Repeated debridements were required to prepare the extensive surface wound for skin grafting.



48
One year following injury. The skin grafts have provided a durable surface for seven years.

49
The patient returned to vigorous athletic activities.

50
Chronic ulceration of a burn scar in the Achilles tendon area in a twenty-four-year-old man. The patient had undergone skin grafting on numerous occasions, but none had been successful. (Case of J.B. McCraw and D. Gilbert)



51
A "reversed" soleus muscle flap was rotated into the area of the scar excision. A high rotation point was chosen to include more deep muscular perforators with the muscle flap.

52
The skin-grafted soleus muscle flap has provided a durable surface for five years.

53
Riding lawnmower injury in a ten-year-old boy. The Achilles tendon and the posterior half of the os calcis were lost. (Case of W. Magee)

54
The Achilles tendon was reconstructed with a plantaris tendon graft and the superficial muscular fascia of the "reversed" soleus muscle flap.

55
"Reversed" soleus muscle flap rotated inferiorly with its deep surface visible.

56
Skin-grafted muscle at five months. The wound has been stable for six years. The patient returned to full athletic activities, including competitive soccer.

SOLEUS

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