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Research Article

Combination of Perforator Flaps for Reconstructive Surgery in the Lower Leg: A Clinical Study on High-Risk Patients with Posttraumatic Osteomyelitis

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Abstract

Introduction: Several studies report good results of single perforator flap transfers for reconstruction of soft-tissue defects at the lower leg and the foot. The novel aspect of our study is application on combination of hinged perforator flaps transfers in high-risk patients with post-traumatic osteomyelitis.

Materials and Methods: The study was conducted as a retrospective clinical trial from 2006 to 2014. In sixteen patients, a total of 35 distally hinged sural, saphenous and supramalleolar perforator flaps were used in multiple fashion as a planned combination or reconciliation of unsuccessful initial flap transfers to cover the soft tissue defects on post-injury chronic osteomyelitis in the distal tibia.

Results: The soft tissue defects were large; mean 48 cm2 (SD 20). Most patients had severe osteomyelitis, Cierny-Mader (CM) grade III or IV. A total of 13 sural, 14 saphenous, eight supramalleolar and two Ponten flaps were transferred with a failure rate at the first stage of surgery at 19% (95% CI 9 - 36); at the second stage of surgery all flaps healed. The osteomyelitis severity was a risk factor for flap failure: no failures were observed in CM grade-III patients while 24% of the flaps failed in patients with CM grade-IV (85%CI diff 3 - 40).

Conclusion: A combination of perforator flaps is useful in the management of post-traumatic osteomyelitis in the distal lower leg. With a multi-flap approach, bifocal separated soft tissue defects can be covered, and second-stage transfer of a flap based on the neighbour angiosome may mend unsuccessful initial flap transfers.

Keywords: *Perforator Flaps; Post-Traumatic Osteomyelitis; Saphenous Flap; Supramalleolar Flap; Sural Flap; Reconstructive Surgery*

Introduction

The management of soft tissue defects in the distal third of the lower leg and foot due to post-traumatic osteomyelitis in high-risk patients remains a persistent challenge in reconstructive surgery. For a long time, free flap transfer was the operation of choice where the local tissues were severely compromised [1]. The studies of septocutaneos vessels in the leg by Manchot [2], later by Salmon, Cormack and Lamberty [3,4] set the stage for reconstruction by perforator flaps in the distal third of the leg. Further progress in the studies of the microcirculation, especially the concept of angiosomes [4,5] laid the ground for neurovascular flap technique and pedicle neuro-adipo-fascial perforator flaps [6,7]. Furthermore, the anatomical study by Nakajima grouped distally hinged fasciocutaneous flaps into venoadipofascial pedicled fasciocutaneous flap (VAF), neuroadipofascial pedicled fasciocutaneous flap (NAF) and veno-neuroadipofascial pedicled fasciocutaneous flap (V-NAF), showed that supplementary vascularisation originates from nerves and their commitant arteries and veins [8,9]. The "Perforator - Plus - Concept" combines the (V-NAF) flap with perforating source vessel (Figure 1). This flap is nourished by two sources, by the perforator artery at the pivot point plus the veno-neuroadipofascial vessel in the base of the flap [10]. The genuine anatomy of the vascular territories in the leg makes it possible to use a combination of flaps to heal soft tissue defects in the distal third of the leg. With a multi-flap approach, major soft tissue or bi-lobed defects around ankle joint can be covered, or second-stage transfer of a flap based on the neighbour angiosome may mend unsuccessful initial flap transfers.

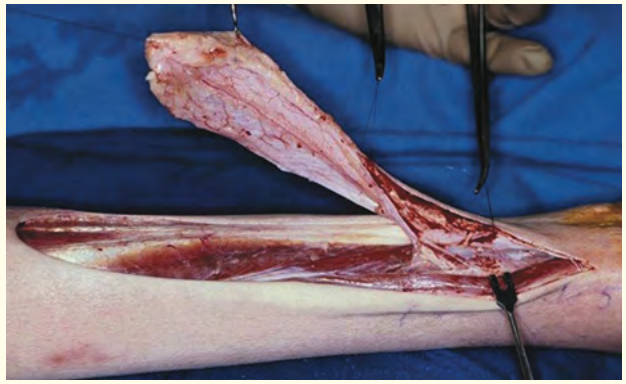

Figure 1: *"The Perforator - Plus - Concept" combines the (V-NAF) flap with perforating source vessel.*

Patients with post-traumatic osteomyelitis in the distal tibia and the foot should be considered high-risk cases for reconstructive surgery due to longstanding soft tissue derangement in advance to the systemic physiological compromise. The aim of the actual study was to explore the capacity of the angiosomes in distal leg using perforator flaps in combination fashion on patients with post-traumatic osteomyelitis where reconstructive microsurgery has been contraindicated.

Materials and Methods

The actual study is a retrospective controlled clinical study conducted from 2009 to 2014 at Trauma Centre Berufsgenossenschaftliche Unfallklinik in Frankfurt am Main, Germany and University Hospital of Northern-Norway.

Study Population

The study was conducted according to a surgical protocol established by the senior author (RW). During the study period a total of 16 patients 35 flaps were managed by distally based saphenous, sural or supramalleolar perforator flaps. All of the 16 patients underwent planned multi-flap reconstructive surgery (Table 1).

Variables and data gathering

The following risk variables were registered: age, delay of reconstructive surgery, area and localization of the defect, and osteomyelitis grading. Severity grading of osteomyelitis has been done according to the Cierny and Mader staging system [11], which classifies osteomyelitis according to both anatomical and physiological indicators (Table 2). As the main short-term outcome variable, we registered postoperative necrosis of the flap. Minor necrosis of less than one quarter of the flap area healing with split-thickness skin grafting was classified as no failures; all other cases with necrosis more than one quarter of the flap within four months after the actual reconstructive operation were classified as failures. There were complete data on the main short-term outcome indicator in all patients who had undergone combination flap surgery during the study period; we could thus include all cases, making up a study population of 16 patients with a total of 35 flap transfers. The end point study was conducted 5.5 years after the actual reconstructive long-term operation (SD 2.75years).

Gender, age	Defect localization, defect area and CM-grade	Co-morbidity BL, BS*	Outcome first stage	Outcome second stage STG/VAC**	Surgical approach
Female, 48	Distal ventro-lateral 100 cm² CM IV	BL	Sural: success Saphenous: success	- -	Planned combination One week interval
Female, 74	Distal ventral, lateral 60 cm² CM III	BLBS	Sural: success Supramalleolar; success	- -	Planned combination Two weeks interval
Male, 53	Distal ventro-lateral 75 cm² CM III	BL	Saphenous: success Supramalleolar: success	- -	Planned combination Simultaneous transfer
Male, 59	Distal ventro-lateral 115 cm² CM III	BL	Saphenous: success Supramalleolar: success	- -	Planned combination Simultaneous transfer
Male, 69	Distal ventro-medial 42 cm² CM III	BL	Sural: success Saphenous: success	- -	Planned combination, Simultaneous transfer
Male, 45	Distal ventral, lateral 35 cm² CM III	BL	Sural: success Saphenous: success		Planned combination Simultaneous transfer
Male, 64	Distal ventero-lateral 55 cm² CM IV	BLBS	Supramalleolar: sucess Sural: success		Planned combination Simultaneous transfer
Male, 60	Distal ventro-lateral 60 cm² CM IV	BL	Saphenous: success Sural: success	STG/VAC: success	Planned combination One week interval Partial saphenous necrosis (less then ¼)
Male, 50	Distal ventro-lateral 45 cm² CM IV	BL	Saphenous: failure Sural: success	STG/VAC: success	Planned combination One week interval Saphenous necrosis
Male, 59	Distal ventral 50 cm² CM IV	BLBS	Sural: failure Saphenous: success	STG/VAC: success	Planned combination One week interval Sural necrosis
Male, 44	Distal posterior 35 cm² CM II	BL	Sural: failure Supramalleolar: success	STG/VAC: success	Planned combination One week interval Sural necrosis
Female, 72	Distal ventro-lateral 50 cm² CM III	BLBS	Saphenous: failure Sural: success	STG/VAC: success	Planned combination One week interval Saphenous necrosis

Male, 68	Mid-distal, ventro-medial 68 cm^2 CM IV	BL	Saphenous: success Supramalleolar: failure	Sural: success	Planned combination Simultaneous transfer
Male, 86	Distal, ventro-lateral 55 cm^2 CM III	BLBS	Supramalleolar: failure Sural: success	STG/VAC	Planned combination One week interval Supramalleolar necrosis
Male, 59	Distal, ventro-lateral 55 cm^2 CM II	BL	Saphenous: failure Supramalleolar: success	STG/VAC	Planned combination One week interval Saphenous necrosis
Male 24	Medial ,lateral 52 cm^2 CM IV	BL	Saphenous: necrosis Suralis: success	STG/VAC	Planned combination Simultaneous transfer Saphenous necrosis

Table 1: *Study patient characteristics.*

** BL: Local Soft Tissues Compromised; BS: Systemically Compromised Host; BLBS: Local and Systemic Compromise*

*** STG: Split-Thickness Skin Grafting; VAC: Vacuum Assisted Closure*

Bone Involvement	Physiological grading
I - Medullary	A - Uncompromised
II - Superficial	BL - Local soft tissues compromised
III - Localized (< 5 cm, healed fracture)	BS - Systemically compromised host
IV - Diffuse (> 5 cm, non-union)	BLBS - Local and systemic compromise

Table 2: *Cierny-Mader (CM) classification of osteomyelitis.*

Operation technique

A team of plastic reconstructive surgeons and orthopaedic surgeons was responsible for preoperative planning, flap design and patient information. Doppler examination was not routinely used for perforator identification. Radical debridement of the actual osteomyelitis was done before flap surgery, and the patients were treated with systemic antibiotics plus beads of gentamycin-polymethylmethacrylate (PMMA). The chain beads were acting both as antibiotic and spacer under the flap coverage. In CM grade 3 osteomyelitis bone transplantation has been done four to six weeks after radical debridement and perforator flap surgery. Distraction osteogenesis in CM grade 4 osteomyelitis patients where done after soft tissues had healed.

Surgical technique for distally based sural perforator flap

The procedure is described in details in previous study [12] and only key features are highlight here. The area of inset is prepared and the flap base marked off with a finger-wide skin bridge between fibula and the lateral side of the Achilles tendon; the ratio of flap length to flap width is usually 4:1. The adipofascial pedicle carries a central skin stripe over the course of the sural nerve and the lesser saphenous vein expanding into a proximal skin peninsula. The skin peninsula is designed according to the shape of the defect, on each side overlapping the model of the defect by one centimetre and with a one to two cm wide adipofascial seam. An 8 - 10 cm exploratory incision is made at the anterior edge of the central skin stripe and the ventral rim of the skin with 2 mm subcutaneous tissue being carefully retracted forwards taking care to preserve the sural nerve and the small saphenous vein. The subcutaneous fat and fascia are then split over the fibula, and the fascia of the short peroneal muscle retracted on stay sutures to identify the septum of the soleus muscle in the sural neuro-fascio-cutaneous flap. At this point the surgeon should try to visualise the peroneal artery perforators, which in most cases are located 5 - 10 cm proximal to the tip of the lateral malleol. If perforating blood vessels cannot be identified neither from dorsal in the range of 5 - 10 cm from the mallolar tip, the pivot point should be set at 5 cm assuming that the flap will take its blood supply from the supramalleolar vascular plexus including the most distal perforators [13]. At the proximal end of the flap the sural nerve and lesser saphenous vein are identified and set off through a coronal mid-line incision. The skin peninsula is raised with its adipofascial seam subfascially to the base of its adipofascial pedicle, stepwise from proximal to distal and from posterior to anterior by sharp dissection. The flap is transposed to site of insertion through a separate incision, not by subcutaneous tunnelling. The donor defect is covered by artificial skin grafts or by split-thickness skin grafting. The bandage leaves the skin peninsula of the flap open for monitoring.

Surgical technique for distally based saphenous perforator flap

The perforators of the posterior tibial artery emerge in the septum between the soleus and the flexor digitorum longus muscle and feed the axial suprafascial net of blood vessels accompanying the saphenous nerve and the greater saphenous vein (Figure 2c). The saphenous flap is designed following the course of the septum between the soleus and flexor digitorum longus muscle, the saphenous nerve and the greater saphenous vein at the ventral margin. The ratio of flap length to flap width is usually 3:1. An 8 - 10 cm exploratory incision is made at the dorsal edge of the skin stripe and the dorsal rim of skin with two millimetre subcutaneous tissue is elevated in the direction of the Achilles tendon, leaving the subcutaneous plexus of blood vessels to the lifted skin. The subcutaneous tissue and fascia are then incised for 8 cm along the ventral rim of the Achilles tendon and the fascia elevated dorsal to ventral from the soleus muscle up to the septum in order to identify perforator arteries. If no perforator is visualised, a second exploratory incision is made at the ventral rim of the skin stripe, elevating the skin with two millimetre subcutaneous tissue towards the tibia. When lifting the skin, the greater saphenous vein and the saphenous nerve should remain attached to the adipofascial pedicle. The subcutaneous fat and fascia are split along the dorsal rim of the tibia for about 8 cm, and the fascia over the flexor digitorum longus muscle elevated from ventral to the intermuscular septum. In most cases a perforator is visualised about ten cm proximal to the tip of the medial malleolus and the pivot point has to be adjusted to this perforator level. If perforating blood vessels cannot be identified neither from ventral nor from dorsal in the range of 5 - 10 cm from the mallolar tip, the pivot point should be set at 5 cm assuming that the flap will take its blood supply from the supramalleolar vascular plexus including the most distal perforators. Now the definite size and shape of the skin island is designed and the flap raised with a minimum of one cm wide adipofascial seam. Proximal to the skin peninsula the greater saphenous vein and the saphenous nerve are separated and the proximal stump of the nerve buried into muscle. From both the ventral and the dorsal side the fascia is elevated to the septum between soleus and flexor digitorum longus muscle and the septum is severed from proximal to distal. If more than one strong perforator had to be severed in order to transpose the flap, a delay of the transposition should be considered. The flap is transposed to the site of insertion by a separate incision and not by subcutaneous tunnelling. The donor area defect is managed by split thickness skin graft (Figure 2d).

Surgical technique for the supramalleolar perforator flap

The supramalleolar flap, described by Masquelet in 1987 is the third standard perforator flap used in the study for reconstruction of the lower leg and foot [14]. The flap integrates in the distal base a septocutaneous perforator from the peroneal artery as source vessel. An 8 - 10 cm exploratory incision is made at the ventral rim of the skin stripe to expose the perforator which pierces from dorsal to ventral 5 cm above the lateral malleolus and divides into two branches: ascending superficial cutaneous branch proximally and a deep descending branch distally [14,15-17]. The perforator pierces the interosseal memabrane from ventral to ventro-lateral some 5 cm above the lateral malleolus. The design of the flap follows the course of the superficial peroneal nerve, the ratio of flap length to flap width being 3:1 (Figure 2b). The flap is designed with a seam of one to two cm fat and fascia around the skin island. The medial rim of the adipofascial pedicle is incised longitudinally for 8 cm along the lateral rim of the tibia and the fascia elevated till the septum in order to identify the perforating branch of the peroneal artery. A second incision is made at the fibular rim of the skin stripe. When lifting the skin towards the fibula, the superficial peroneal nerve should remain attached to the adipofascial pedicle, if possible. The fibular rim of the adipofascial pedicle is split and the fascia elevated from proximal and dorsal to the septum between the lateral and the ventral compartment. After identification of the perforating branch of the peroneal artery the skin, fat and facia are incised in the proximal direction leaving an at least one cm wide adipofascial seam around the skin peninsula. Proximal to the skin peninsula the superficial peroneal nerve is separated and its proximal stump buried into muscle. The skin peninsula with its adipofascial seam and the pedicle of the flap are raised with the septum, separating the septum subperiostally at the distal end. The flap is turned around the perforating branch of the peroneal artery, mostly 5 cm proximal to the lateral malleolus. If the perforator calibre is small or if no perforator has been identified, the vascularisation of the flap may be at stake and delayed flap transfer should be considered. The donor area is managed as for sural flap. The flap viability is observed carefully for the first 48 postoperative hours.

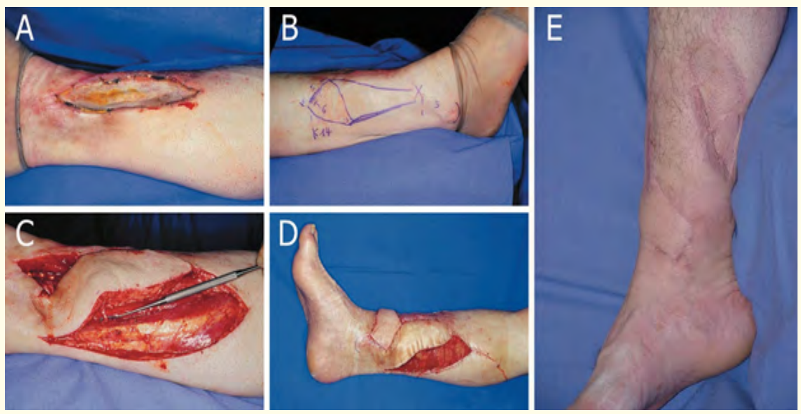

Figure 2: *A - A man (53 years old) was operated with open reduction and internal fixation for a closed distal pilon tibia fracture, and developed postoperative infection (CM-III type of osteomyelitis). Debridement left a soft tissue defect on the ventral distal tibia of 17 x 5 cm. After saucerisation, the soft tissue defect was covered with supramalleolar and saphenous flaps in a one-step procedure; B - Planning of the supramalleolar perforator flap. The pivot point is estimated five cm proximal to the tip of the lateral malleol; C - Perforator from posterior tibial artery supplying the saphenous neurofasciocutaneous perforator flap; D - Perforator flaps covering soft tissue defect on the bone; E - Six weeks after reconstruction with supramalleolar and saphenous flaps. The soft tissues healed without infection and acceptable esthetical outcome.*

Statistical platform

Continuous variables are expressed as means with standard deviations (SD) and proportions expressed by confidence intervals. Comparisons of means and proportions were done with significance level at 85% and 95%. We consider means and proportions different if the confidence interval for the difference (CI diff) does not include zero. Statistical analysis was performed in JMP (JMP 6.0.2, SAS Institute AS) and CIA software (CIA 1.2, British Medical Journal 1992).

Ethical Considerations

Data for the study were collected and processed according to guidelines set by the board of the Trauma Centre in Frankfurt (ref. no. BGU 6/21/8) and by permission of the Norwegian Social Science Data Service (ref. no. 13702). All endpoint data gathered in the questionnaire survey have been obtained following informed consent by the participants.

Results

The mean age of the study patients was 61 years (SD 11.5) and most patients were male (80 %). All defects were located at the distal tibia with a mean area-of-defect 48 cm^2 (SD 20); five patients had large soft tissue defects > 60 cm^2. Most patients had severe osteomyelitis; by Cierny-Mader (CM) classification, three patients had osteomyelitis of grade 2, six patients had grade 3, and seven patients grade 4.

Six patients underwent reconstructive surgery many years after the actual injury, the mean delay 33 years (SD 13); the other nine patients had reconstruction done within one year after injury. In all patients combined flap transfer has been planned and conducted at the initial stage in seven patients and in the secondary stage perforator flap has been done in nine patients. The uncertainty in primary flap blood perfusion has been the cause for a delay of transposition of the flap where no perforator has been identified in initial flap surgery (Figure 3). Of the 35 perforator flaps transferred, there were 13 sural flaps, 14 saphenous flaps, and eight supramalleolar flaps. The failure rate at the first stage of surgery was 19% (95% CI 9 - 36); at the second stage of surgery all flaps healed.

Figure 3: *Sural flap transferred. Delayed transfer of the supramalleolar flap in order to observe flap perfusion as no cutaneous branch from the perforating branch of the peroneal artery has been found.*

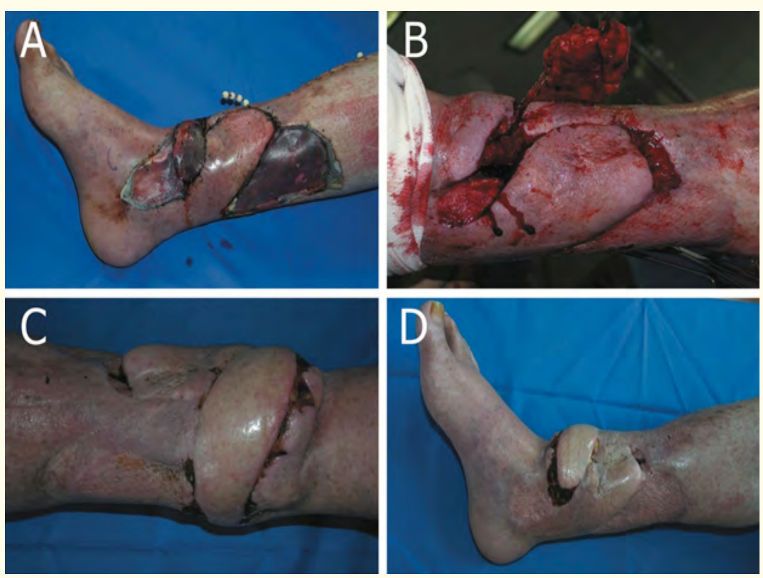

Figure 4: *A - Male (age 68), osteomyelitis grade III. Combination of saphenous flap first with supramalleolar flap. Healing saphenous flap and necrosis of supramalleolar flap; B - After loss of supramalleolar flap successful combination of saphenous flap with suralis flap; C, D - - Six weeks after reconstruction with suralis and saphenous flaps. The soft tissues healed without infection and acceptable esthetical outcome.*

There was a clear tendency that osteomyelitis severity, perforator recognised was a risk factor for flap failure: no failures were observed in CM grade-III patients while 24% of the flaps failed after the primary reconstruction in patients with CM grade-IV (85%CI diff 3 - 40). Data from the end-point survey demonstrate that most patients had satisfactory long -term results. One patient is still waiting for arthrodesis operation in ankle joint as a cause of post-traumatic arthrosis after severe pilon fracture. Of the 16 patients, all reported complete wound healing without oozing.

Discussion

The scope of our study was to report the versatility on combination of perforator flaps in reconstructive surgery on patients with post-traumatic osteomyelitis in the distal third of tibia. This group of study patients should be considered as high-risk cases owing to long-standing soft tissue derangement caused by chronic infection and also systemic physiological compromises. Consequently, they constitute a useful study population for a comprehensive examination of the viability and feasibility of multi-flap reconstructions once reconstructive microsurgical procedure is unwarranted, or else the defect is extremely minor [14]. The failure rate of combination flaps at the first stage of surgery was 19 % (95% CI 9-36) that is lower than the failure rate reported by the Hallock and his team where complication rate for fascia flaps has been 30% [15]. In the same retrospective review done by Hallock on 155 patients (184 flaps) complication rate was 39% for free flaps and 27% for local muscle flaps [14]. However, all primary combination flap failures in our cases managed by secondary operation with skin grafts, subatmospheric pressure and perforator flap came out successfully. Comparing the sturdiness of simultaneous with delayed perforator flap reconstructions in combination flaps we came to conclusion that these two techniques are clearly different. The simultaneous group where perforator has been detected and flaps transfers has been done in one step surgery had much better result than delayed combination perforator group where under the primary surgery perforator has not been recognised. Our study population was small and statistical comparisons should be done with caution. Anyway, there was a clear tendency that osteomyelitis severity (Table 2) with comorbid factors and previous operations together with no perforator recognised where risk factors for flap failure.

A total of eight study patients were managed by supramalleolar flaps, either at the first or the second stage of planned combination perforator flap surgery with an overall failure rate of 25 %. The actual sample is too small for statistical comparisons with results of other types of perforator flaps, but also Touam reports high rates of complications in supramalleolar flap transfers [15,18]. Clinical evidence indicates that the supramalleolar flap should not be the first choice for single or combination flap reconstruction in cases with extensive soft tissue derangement and posttraumatic osteomyelitis. A reason for the potential flaws of the supramalleolar flap may be that the vascular network supplying the flap is more vulnerable to traumatic damage; either direct blows or by displaced distal pilon tibia fractures. Another reason for higher vulnerability may be that the perforator arteries for the supramalleolar flap in general are of small calibre comparing to the sural and saphenous angiosome perforators.

For a long time, free flap transfer was the operation of choice where the local tissues were severely compromised. There is no doubt that significant lower leg wounds require soft tissue coverage using free muscle flaps [19,20]. However, there is increasing interest in last two decades in using advancement perforator flaps in covering the posttraumatic soft tissue defects in the distal third of the tibia [21-23]. Free flaps are useful in the management of high-grade osteomyelitis because the transferred muscle fills the dead space in post-sequestrectomy bone defects and cavities [21,22]. However, bone defects can also be filled from fascio-cutaneous perforator flap (Figure 5). Recent experimental studies indicate that adipose-derived mesenchymal cells and also muscle mesenchymal cells carry stem cell function and capacity for osteoneogenesis, provided the local blood perfusion is good [24]. One disadvantage of free flap transfers in post-injury reconstructions is that an already damaged vascular network may be further hurt if a local artery is sacrificed for the free flap anastomosis. Furthermore, free flaps either fail or they succeed, while in perforator flaps with partial necrosis the underlying granulation tissue can be used as a “biological dressing” and bed for secondary skin grafting after being managed by Vacuum-Assisted Closure [25]. The skin texture, color and tissue thickness of the perforator fasciocutaneous flaps shows superior aesthetical reconstruction and can thus, be specifically chosen to best replace a given defect using “like with like” tissues (Figure 2E).

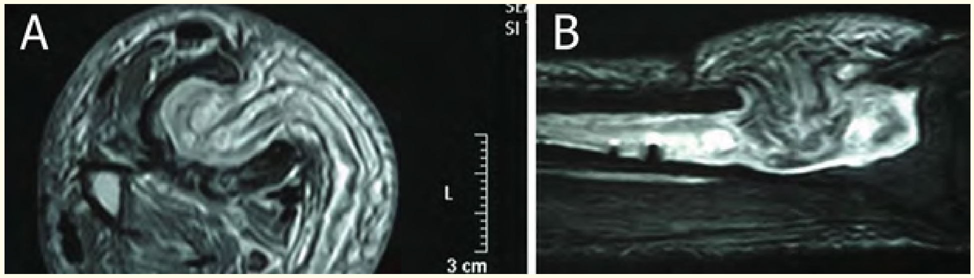

Figure 5: *5 weeks after transposition of the perforator flaps. MRI shows vascularisation of the adipofascial extension, which was implanted into the open medullary space of the tibia after sequestrectomy. A - front view; B - lateral view.*

Free flap microsurgical operations require a lot more input of hours, specialised human resources, and advanced equipment than a technically rather simple perforator flap operation. Especially in low-resource settings with high prevalence rates of orthopaedic trauma the perforator flaps thus represent a feasible strategy.

Comprehensive and complete debridement of the infected soft tissue and bone is the first and most important step in osteomyelitis surgery. Reconstructive surgery in severely compromised patients is a multi-disciplinary team effort; the orthoplastic approach management is crucial. Comprehensive and complete debridement of the infected tissues is the first and most important step in osteomyelitis surgery. For proper debridement, there are no standards and protocols: it takes clinical experience in the judgment of tissue viability. Even minor necrotic islands left over by the surgeon may lay the foundation for late exacerbations of the infection.

Conclusion

In the distal third of the lower leg three angiosomes for distally hinged perforator flaps may be used, provided that for each angisom a perforator has been found at the pivot point. Combining perforator flaps is a useful strategy in the management of the soft tissue defects in post-traumatic osteomyelitis in the distal lower leg once free flap is contraindicated. Local perforator flaps in the distal leg are most valuable for smaller defects and are often reasonable alternative to free flaps.

Conflict of Interest Statement

There are no prior publications, conflicts of interest, copyright constraints, or industry funding to report for any of the authors. The views expressed in this article are those of the authors and do not reflect the policy or position of any institution.

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Bibliography

1. Chang N and Mathes SJ. “Comparison of the effect of the bacterial inoculation in musculocutaneous and random pattern flaps”. *Plastic and Reconstructive Surgery* 70.1 (1982): 1-10.
2. Manchot C. „Die Hautarterien des Menschlichen Korpers“. Leipzig: FCW Vogel (1889).
3. Salmon M. “Les Arteres de la peau (The arteries of the skin)”. Paris: Masson (1936).
4. Cormack GC and Lamberty BGH. “The arterial anatomy of skin flaps”. Edinburgh: Churchill Livingstone (1986).

5. Taylor GI and Palmer JH. "The vascular territories (angiosomes) of the body: Experimental study and clinical applications". *British Journal of Plastic Surgery* 40.2 (1987): 113-141.

6. Ponten B. "The fasciocutaneous flap: Its use in soft tissue defects of the lower leg". *British Journal of Plastic Surgery* 34.2 (1981): 215-220.

7. Blondeel NP., *et al*. "Perforator flap anatomy. Technique & clinical applications". St. Louis Missouri: Quality Medical Publishing (2006).

8. Nakajima H., *et al*. "Three-dimensional analysis and classification of arteries in the skin and subcutaneous adipo-fascial tissue by computer graphics imaging". *Plastic and Reconstructive Surgery* 102.3 (1998): 748-760.

9. Nakajima H., *et al*. "Accompanying arteries of the cutaneous veins and cutaneous nerves in the extremities: Anatomical study and the concept of the venoadipofascial and neuroadipofascial pedicled fasciocutaneous flap". *Plastic and Reconstructive Surgery* 102.3 (1998): 779-791.

10. Mehrotra S. "Perforator-plus flaps: a new concept in the traditional flap design". *Plastic and Reconstructive Surgery* 119.2 (2007): 590-598.

11. Cierny G, *et al*. "A clinical staging system of adult osteomyelitis". *Contemporary Orthopaedics* 10 (1985): 17-37.

12. Tajsic N., *et al*. "Sural perforator flap for reconstructive surgery in the lower leg and foot: a clinical study of the 86 patients with post-traumatic osteomyelitis". *Journal of Plastic, Reconstructive and Aesthetic Surger*y 62.12 (2009): 1701-1708.

13. Zhang F., *et al*. "Distally based sural neuro-lesser saphenous veno-fasciocutaneous compound flap with lower rotation point". *Annals of Plastic Surgery* 62.4 (2009): 395-404.

14. Masquelet AC., *et al*. "Skin island flaps supplied by the vascular axis of the sensitive superficial nerv: anatomic study and clinical experience in the leg". *Plastic and Reconstructive Surgery* 89.6 (1992): 1115-1121.

15. Touam C., *et al*. "Comparative study of two series of distally based fascio-cutaneous flaps for coverage of the lower one-fourth of the leg, the ankle, and the foot". *Plastic and Reconstructive Surgery* 107.2 (2001): 383-392.

16. Hallock GG. "Utility of Both Muscle and Fascia Flaps in Severe Lower Extremity Trauma". *Journal of Trauma* 48.5 (2000): 913-917.

17. Hallock GG. "A Paradigm Shift in Flap Selection Protocols for Zones of the Lower Extremity using Perforator Flaps". *Journal of Reconstructive Microsurgery* 29.4 (2013): 233-240.

18. Oberlin C., *et al*. "La couverture par lambeaux despertes de substance cutanee de la Jambe et du pied: a propos de 76 cas". *Revue de Chirurgie Orthopédique* 74.6 (1988): 526-538.

19. Mathes SJ., *et al*. "Use of the muscle flap in chronic osteomyelitis: experimental and clinical correlations". *Plastic and Reconstructive Surgery* 69.5 (1982): 815-829.

20. Zumiotti AV., *et al*. "Treatment of post-traumatic tibial osteomyelitis using microsurgical free flaps". *Journal of Reconstructive Microsurgery* 19 (2003): 163-171.

21. Nenad T., *et al*. "Saphenous perforator flap for reconstructive surgery in the lower leg and the foot: a clinical study of 50 patients with posttraumatic osteomyelitis". *Journal of Trauma* 68.5 (2010): 1200-1207.

22. Tajsic N., *et al*. "Distally based perforator flaps for reconstruction of post-traumatic defects of the lower leg and foot. A review of the anatomy and clinical outcomes". *Injury* 45.3 (2014): 469-477.

23. Hallock GG. "In an era of perforator flaps, are muscle flaps passé". *Plastic and Reconstructive Surgery* 123.4 (2009): 1357-1363.

24. Bella D., *et al*. "Bone regeneration in rabbit critical-sized skull defects using autologous adipose-derived cells". *Tissue Engineering Part A* 14.4 (2008): 483-490.

25. Rinker B., *et al*. "Subatmospheric pressure dressing as a bridge to free tissue transfer in the treatment of open tibia fractures". *Plastic and Reconstructive Surgery* 121.5 (2008): 1664-1673.

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