MICROSURGERY

Microsurgery Technique in the Foot Reconstruction of Soft Tissue Defects: A Review of 4 Cases

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Background: The restoration of an intact covering is the primary surgical requisite following soft tissue defects in the foot because deep healing can be no better than the surface covering. Soft tissue defects that expose underlying bones, joints, and tendons pose challenging problems and require a free tissue transfer for a successful reconstruction.
Methods: Total of 4 flaps in the foot was performed between February 2009 to February 2010. We reconstructed soft tissue defects in the foot in 4 patients using 3 free anterolateral thigh (ALT) flaps and 1 free radial forearm (RF) flap. Trauma was the commonest cause in our patients.
Results: Free ALT and RF flaps provided stable and durable long-term wound cover in all patients. Complications were few and manageable.
Conclusions: Free tissue transfer has become commonplace in many centers around the world. The numerous advantages include stable wound coverage; improve aesthetic and functional outcomes, and minimal donor site morbidity. In our experience, we found that the using of free ALT and RF flaps in foot defects reconstruction, to be technically affordable, reliable and have resulted in excellent outcomes.
Key Words: *Foot defects, free anterolateral thigh flap, free radial forearm flap.*

Latar Belakang : Pemulihan penutup yang menempel pada kulit adalah syarat utama dari penutupan defek pada jaringan lunak pada kaki, sebab proses penyembuhan luka tidak lebih baik dari penutupan permukaan luka. Jaringan lunak yang terekpos dasarnya tulang, persendian, atau tendon menimbulkan masalah baru dan memerlukan transfer jaringan lepas untuk rekonstruksi yang maksimal.
Metode: Terdapat 4 total operasi flap kaki dalam selama Februari 2009-Februari 2010. Rekonstruksi defek pada jaringan lunak kaki pada 3 pasien menggunakan tiga flap bebas bagian anterolateral paha dan flap bebas lengan bawah radialis.
Hasil: Flap bebas anterolateral paha dan lengan bawah radialis memberikan hasil yang stabil dan menutup luka berdurasi jangka lama pada semua pasien. Komplikasi yang ditemukan sedikit.
Kesimpulan: Transfer jaringan bebas menjadi pilihan utama pada pusat-pusat kesehatan di dunia. Banyaknya keuntungan seperti penutupan luka yang lebih stabil, memperbaiki hasil akhir secara fungsional dan estetik, dan menekan morbiditas dari lokasi donor.Berdasarkan pelaopran kasus ini, penggunaan dari flap anterolateral paha dan lengan bawah radialis pada rekonstruksi defek kaki secara tekhnis terjangkau, dapat dipercayam dan menghasilkan hasil akhir yang baik.
Kata Kunci: *Defek pada kaki, free anterolateral thigh flap, free radial forearm flap.*

The overlying skin and soft tissue of the foot sole require a durable unshearable padding properties to sustain the body weight. Despite its specific and unique features, foot reconstruction has long been underestimated, and amputation was considered the treatment of choice for large foot defect until the last century [1]. Foot disease affects daily function, often requiring long care and expensive rehabilitation program. requiring long care and expensive rehabilitation programs. In regards to the reconstruction of

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large foot defects, consider two questions: (1) Can and should the foot be salvaged? (2) How to best recover functionality and morphology?

Extensive soft tissue defects on the lower third of the leg are particularly difficult, due to the associated exposed vessels, nerves, tendons, joint cavity, or bone. The plantar surface of the foot has highly specialized, densely adherent, glabrous skin, making functional replacement difficult, whereas the dorsum of the foot and toes has highly visible contours that are critical for proper shoe fitting[2]. Reconstructive options varies from grafts, local flaps, and distant free tissue transfer, with a single-stage effective reconstruction as the ideal target. Free tissue transfer offers the most versatile and reliable method at present, each with its own limitations. With the recent advances in techniques, skill, instrumentations, together with the knowledge of more reliable donor sites for free tissue transfer the success rate of foot defect closure have improved.

In 1984 Song and colleagues first introduced the anterolateral thigh (ALT) flap. ALT can contain muscle, fascia, skin, or any of these in combination, which have become one of the most reliable and versatile donor for free tissue transfer for the reconstructive surgeons[3]. Another reliable free tissue donor for foot reconstruction is the radial forearm flap (RFF) first described by Chang in China in 1978[4]. To provide sensation, the flap may include the superficial radial nerve or the medial or lateral antebrachial cutaneous nerves. RFF can also carry a segment of radial bone to create a vascularized bone graft, or be elevated as a fascia-only flap. ALT and RFF are fairly easy to harvest with their constant vascular anatomy, and not bulky eventhough various tissue components can be incorporated. Both are reliable with long and large pedicle, may include nerves and be used as a sensate flap, and can be harvested efficiently with a two-team approach.

PATIENT AND METHODS

This article discuses four reconstruction cases of challenging soft tissue defects of the foot due to various etiology who presented to our clinic between February 2009 to February 2010 (Figures 1-4). Patients underwent reconstruction using either ALT or RFF.

The ALT flap was harvested in a standard fashion either as cutaneous, fasciocutaneous, or musculocutaneous flap. Ischemia time was recorded. Lavage of the vessels during anastomosis was by heparinized saline. Vessel anastomosis by 8.0-nylon interrupted sutures. In one case of post-traumatic vessel disease, a vein graft was and A-V loop was performed to achieve microvascular anastomosis with healthy proximal vessels. Nerve anastomosis was using 2-3 perineural stitches by 9.0 nylon. Donor site was closed primarily when possible, otherwise by the split thickness skin graft. Functional evaluation of knee extension before and after surgery was evaluated in patients who underwent ALT.

Before performing RFF, Allen test must ensure that vascularity of the hand can be maintained following sacrifice of the radial artery. Flaps were elevated from the non-dominant hand in a standard fashion, after exanguination and under tourniquet. The method of closure, particularly if a local flap is being used, is designed as the part of the skin incision. Specialized flaps can be designed, such as adipofascial flaps, composite flaps to include flexor tendons, or as osteofasciocutaneous flaps incorporating a segment of distal radius. The majority RFF flaps donor site require skin grafting either split or full thickness. Local skin flap based on the ulnar artery and its perforators can also be used.

Flap monitoring was performed every one hour for the first 24 hours, every two hours until the 72nd hour post-surgery, and regular observation until the end of the 12th postoperative day. Heparin was given only in the presence of: A-V loop, long venous interposition graft, intra-operative thrombosis, problematic anastomosis, cases of free flap revision, or exposure to irradiation. Aspirin tablet was given 80 mg two times daily during the first week, then once daily in the second week.

RESULTS

Three ALT and one RFF flaps were performed to reconstruct foot defect in 4 cases, all of which were successful and vital. Male to female ratio is 3 to 1, aged between 9 to 51 years. Two cases were due to trauma, the other half due to infection. The smallest defect was 10 cm

Table (1). Particular of Patients

No	Age/Sex	Primary Lession	Reconstruction	Flap size	Donor Site
1	29/F	Osteomyelitis in Metatarsal IV-V Pedis Sinistra	ALTF	15x11 cm	Primary Closure
2	9/M	Partial Skin Avulsion with Bone and Tendon Exposed in Pedis Sinistra	RFFF	12x6 cm	STSG
3	29/M	Pilon Fracture and Skin Loss in Ankle Dextra	ALTF	18x12 cm	Primary Closure
4	51/M	Diabetic Ulcer with Bone Exposed in Calcaneus Dextra Region	ALTF	10x5 cm	Primary Closure

ALTF : anterolateral thigh flap; RFFF : radial forearm free flap; STSG : split thickness skin graft

Table (2). Types of Microvascular Anastomosis

No	Age/Sex	Recipient Arteries	Diameter	Types of Anastomosis	Recipient Veins	Types of Anastomosis	Ischemic Time (minutes)
1	29/F	A.Dorsalis Pedis	1 mm	ETS	V.Comitantes	ETE	60
2	9/M	A.Radialis	1 mm	ETE	2 V.Comitantes + 1 V.Cephalica	ETE	40
3	29/M	A.Tibialis Anterior	1 mm	ETE	V.Comitantes	ETE	140
4	51/M	A. Dorsalis Pedis	1 mm	ETE	V. Comitantes	ETE	60

A: artery; V: veins; ETE: end to end; ETS: end to side

Table (3): Early Postoperative Complications

No	Age/Sex	Early Post Operative Complication	Complication Time After Operation	Fate
1	29/F	None	-	-
2	9/M	Partial necrosis	24 hours (compromised)	Debridement
3	29/M	Infection	8 hours	Bacterial culture, antibiotic therapy.
4	51/M	None	-	-

x 5 cm, the largest size was 18 x 12 cm. Two patients had bone as wound base. Patient's demography is presented in Table 1.

Table 2 summarizes the microvascular anastomosis detail. Diameters of the arteries in all flaps were 1 mm, with pedicle length between 12-15 cm. One or 2 veins accompanied the pedicle artery. The diameter of the veins varied from 1 to 1.2 mm. Acoustic Doppler examination was performed and found to be normal in all cases. Average operative time was 6-8 hours, and ischemic time until full anastomosis between 40 min to 140 minutes. Donor site closures in the ALT group were all primary. One patient who underwent RFF flap had split-thickness skin graft to close the donor area. In all cases, the microvascular anastomosis was performed proximal to the site of the defect. End-to-end (ETE) anastomosis was performed in 3 cases, end-to-side (ETS) in one case. Early postoperative complications was partial necrosis in one case, and infection in one case (Table 3). They were managed by debridement and antibiotic therapy and resolved.

Figure 1. Upper left: Case 1, with osteomyelitis of the meta-tarsal IV-V, dorsal view. Upper right: Plantar view of the same case. Lower left: intraoperative vascular anastomosis. Lowe right: primary closure of the ALT donor site.

Figure 2. Case 2, partial skin avulsion with exposed bone and tendon on arrival (left) and after immediate debridement (right).

Figure 3. Partial necrosis of the flap in Case 2. Appearance on day two (left) and day nine (right). Complications managed by debdridement of the necrotic poriton.

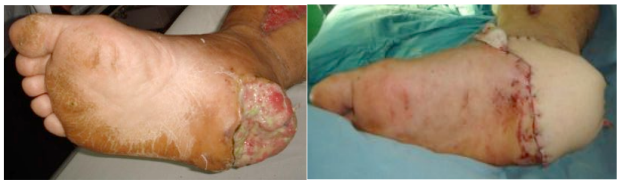

Figure 4. Case 4, a diabetic ulcer with calcaneal bone exposed (left), reconstructed using ALT with long vascular pedicle.

DISCUSSION

Reconstructive surgery for soft tissue defects of the foot ideally requires microsurgical expertise, versatility, and a significant awareness of the needs of the dynamic structure of this region. Before planning a foot reconstruction, evaluate the size and structure of the defect, adequacy of the vascular condition of the neighboring tissue, the vascular anatomy of the extremity, quality of the donor site, and the vascular pedicle length needed[6]. The characteristics of an ideal soft tissue free flap donor for foot reconstruction must incorporate large skin territory, has good color and texture match to the recipient site, provide a long and large caliber vascular pedicle, be reliable for different flap designs, constant pedicle anatomy and acceptable donor site morbidity, enable sensate reconstruction, be feasible for a two team approach, with no requirement for major artery or muscle sacrifice, be applicable as a flow-through flap, and can be used as a thin flap[7]. Our experience in Cipto Mangunkusumo Hospital showed that free ALT and RF flaps could meet the above criteria. Before the introduction of perforator cutaneous flaps, reconstruction of lower extremity defects used muscle flaps with split thickness skin graft or musculocutaneous flaps in which a whole functional muscle unit is[8].

The goal of reconstructing lower leg defect other than to obtain wound coverage, is to preserve function, which relies heavily on ambulation where the reconstructed sites will be subject to large stress loads. On weight-bearing areas, thin flaps or those with excess mobility may breakdown. In contrast, on the dorsal foot region and ankle, bulky flaps will interfere with proper shoe fitting and prevent efficient ambulation. Given the specialized and diverse regions of the foot and ankle, a subunit map as proposed by Hollenback will help the reconstructive surgeons in making decision[2]. Dorsal foot and ankle are well suited to the lateral arm, RFF, and scapular fasciocutaneous flaps. The toes have the least functional demand and may be left unreconstructed.

In this case series, 3 ALT flaps were used to reconstruct foot defects by anastomosis with either the dorsalis pedis or tibialis anterior artery. In Case 1, the primary lesion was located on the lateral foot region (Hollenbeck's dorsal subunit 1 and 3, and plantar subunit 2) which by algorithm would be optimally reconstructed using either RFF, lateral arm, gracilis with STSG, or ALT. Case 4 has full-thickness sole defect on the calcaneal region (Hollenbeck's subunit 5) due to diabetes, best reconstructed using ALT, gracilis and STSG, latissimus dorsi, scapular, lateral arm, and RFF flap. On both case, we opted the ALT flap and defects were satisfactorily covered.

Treatment of the diabetic foot remains challenging due to the frequent ulcerations, infections, and osteomyelitis, risking patients for a proximal level amputations. Muscle flaps breakdown easier, and ulcers recur often due to the lack of pressure resistance. The interval required to achieve weight bearing is also longer, and secondary debulking procedures required to allow normal footwear. Use of fasciocutaneous flaps have shown excellent results as it reduce shearing, provide better contour, and increase the chance for reinnervation. However it is still anatomically insufficient to prevent gliding of the skin when pressure is applied. This can be resolved when using a thinned ALT perforator flap (3 to 4 mm) where the loosely organized fat beneath the Camper's fascia is discarded and the remaining thin layer of densely packed small fat lobules fat and compact fascial septa will adhere tightly and directly to the surface of the defect, reducing the gliding effect[9].

ALT offers thin flap with good contour, can cover for extensive defects because a large flap can be harvested, and has a fairly long vascular pedicle with large diameter. The ALT can be harvested from the ipsilateral leg, confining all surgery to one extremity, as was done upon our 3 cases ALT flaps.

The RFF free flap has become popular because of its thin pliable nature. In the lower extremity RFF can be used as conduit flap to provide vascular continuity in foot and limb salvage. When RFF is used for foot or limb reconstruction, early mobilization with early referral to physiotherapy for rehabilitation is a must. The overall survival and reliability of the RFF in foot and lower extremity reconstruction is higher than 96%. A major disadvantage of RFF relates to its donor site function and cosmetics. To minimize aesthetic drawbacks, the flap design is best confined in the volar aspect of the forearm, defect covered by full thickness in preference to split thickness graft. The main problem with RFF is the sacrifice of the radial artery, diminishing a main blood supply to the hand. Superficial sensory branch of the radial nerve should be identified and preserved to prevent painful neuorma and loss of sensation[3]. One patient in our series (Case 2) had his foot reconstructed using an RFF with donor site closure by split thickness skin graft.

The majority of surgical complications after microsurgery is related to vascular thrombosis, which usually occurs within 3 days of the surgery. Late thrombosis may still occur and is often associated with a local infection or mechanical compression of the vascular pedicle. Therefore, free flaps must be routinely monitored[10]. A portion of the flap's skin should be exteriorized and used to evaluate perfusion by noting the skin temperature, capillary refill, turgor, color and bleeding. This technique is one of the most accurate and reliable way to evaluate flap perfusion with 100% sensitivity, and 36% false-positive rate[10]. Arterial insufficiency is indicated by pale and cool skin which fail to bleed after a needle stick. Venous congestion usually results in edema and darkening of the skin color. During early venous obstruction, a needle stick will cause rapid bleeding of dark blood[10].

There were 2 early post-operative complications in our series. In Case 2, partial flap necrosis ensued 24 hours post-operative. Flap exploration and debridement were done, and successfully salvaged. In Case 3, partial flap necrosis and signs of infections developed,

successfully managed by surgical debridement, and antibiotic therapy.

No technology is yet universally accepted as a single flap monitoring device, but the hand-held Doppler is commonly used. It is limited, however, in differentiating between the recipient vessels with the flap's vascular pedicle hence it is best to accurately mark the location of the pedicle intraoperatively[10,11].

Whichever technique is utilized for flap monitoring, prompt surgical exploration is mandatory if a flap's vascular integrity is in question. The majority of tissue transfer complications are related to vascular pedicle thrombosis, occuring approximately in 4% cases, with 80% of occlusions arising in the first 48 hours. While arterial or venous occlusions may occur, venous thrombosis may evolve over several hours. Early detection of vascular occlusions is essential for flap salvage. Surgical re-exploration is mandatory and should be undertaken without delay, particularly with arterial problems. Flap survival after an arterial thrombosis and thrombectomy is only 15%. In contrast, after a venous occlusion and thrombectomy, the flap survival rate is 60%.

CONCLUSION

When soft tissue defect occurs on the foot, the restoration of an intact covering is the primary surgical target. Extensive soft tissue defects of the lower third of the leg and foot are particularly challenging. The advent of reconstructive microsurgery today has allowed reliable anastomosis of small or very small vessels, making free tissue transfers more commonplace in many centers around the world. The numerous advantages include stable wound coverage, improved aesthetic and functional outcomes, and minimal donor site morbidity. We found that using the free ALT and RFF for reconstruction of foot defects to be technically feasible, reliable, with satisfactory outcomes.
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