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Functional Outcome of Reverse Sural Artery Perferator Flap in Heel Reconstruction

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ABSTRACT

Introduction: The main goal of the heel reconstruction is to provide a durable coverage with a normal appearance, normal Range of Motion (ROM) and allow the patient to walk properly with normal shoes.

Patients and Methods: A total number of 10 patients were reconstructed with the reverse sural artery fasciomusculocutaneous flap between May 2012 and June 2015. Eight patients were men and two were women with a mean age of 20.35 years (range, 5.5-45 years). Six patients suffered from soft tissue loss of the heel with concomitant fracture calcaneous resulted after road traffic accidents, one patient suffered from potts fracture. One patient suffered from soft tissue loss of the heel after extirpation of malignant tumor. Each patient underwent soft tissue reconstruction using a reverse sural fasciomusculocutaneous flap with peroneal artery perforators except in one patient no gastrocnemius muscle cuff was harvested with the flap. The flap sizes ranged from 16 X 7cm to 18 X 9cm. The mean follow-up period was 19.3 months.

Results: All the flaps healed uneventfully. There was no major complication as total flap necrosis. Only minor complications occurred which were treated without surgical intervention. All the children's regained the normal plantar flexion-dorsiflexion of their ankles compared to the non operated side after a mean period of 1.5-2 months postoperative. The entire adult patients regained the normal plantar flexion-dorsiflexion of their ankles compared to the non operated side after a mean period of 2-3 months post operative except two patients ended up with a fixed equines deformity 10 degrees for which they needed constant heel lift. This is probably due to the stiffness of the tissues and lack of preoperative stretch exercises to tendoachillies. About 80% of the patients were functionally satisfactied and Aesthetic satisfaction about 60%.

Conclusion: The reverse sural artery flap provides an easy and reliable method for heel soft tissue reconstruction. It gives good functional and aesthetic outcomes.

Key Words: *Reversed sural artery flap – Heel reconstruction – Single-stage heel reconstruction – Reverse sural fasciomusculocutaneous flap – Peroneal artery perforators.*

INTRODUCTION

The reconstruction of the heel area is challenge for a plastic surgeon due to the specific structural and functional characteristics of this region to be reconstructed and also due to the paucity of local soft tissue that reduces the therapeutic options. The main goals of heel reconstruction are to provide a functional and aesthetic appearance with normal ROM to allow the patient to walk properly with ordinary shoes **[1]**.

Benito-Ruiz et al., **[2]** divide the heel into the anterior weight-bearing heel and the posterior non-weight-bearing heel. Many surgical procedures have been described to overcome this problem; like the instep flap, **[3-5]** the lateral calcaneal flap **[6]**, the dorsalis pedis flap **[7]**, the lateral supramalleolar flap **[8,9]**, the flexor digitorum brevis muscle flap **[10]**, the reverse sural flap **[11,12]**. With the development of microsurgery, many excellent free flaps have become available like radial forearm flap, and muscle flaps (serratus, gracilis, latissimus dorsi) with skin grafts. The free flaps are time-consuming and require microvascular expertise, which is not always available **[1,13]**.

The aim of this study to present and evaluate the function outcome of reverse sural artery fasciomuocutaneous flap with peroneal artery perforators as single-staged procedures for heel reconstruction. Functional reconstruction was assessed by using the Goniometer to measure both the passive and active Range of Motion (ROM) of the ankle when physiotherapy was finished.

PATIENTS AND METHODS

Patient demographic data:

A total number of 10 patients were reconstructed with the reverse sural artery fasciomusculocutaneous flap between May 2012 and June 2015. Eight patients were men and two were women with a mean age of 20.35 years (range, 5.5-45 years). Six patients suffered from soft tissue loss of the heel with concomitant fracture calcaneous resulted

run-over accident with a motor vehicle and one patient suffered from Potts fractures. One patient suffered from soft tissue loss of the heel after extirpation of malignant tumor (Marjolin's ulcer). All the soft tissue defects were in the heel include the anterior and the posterior heel. Fractured bones were reduced and stabilized where appropriate by orthopedic surgeons. Each patient underwent soft tissue reconstruction using a reverse sural fasciomusculocutaneous flap with peroneal artery perforators except one patient no gastrocnemius muscle cuff harvested with the flap (fasciocutaneous). The size of the flap varied from 16 X 7cm to 18 X 9cm (Table 1).

Table (1): Patients' data and follow-up period.

No.	Age/sex year	Defects site	Defects size cm	Type of flap	Size of flap (cm)	Associated problems	Complications	Follow-up/month
1	5.5 M	• Rt. heel soft tissue loss, exposed prostheses	9/9	• Reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators.	17 X 9	Fracture calcaneous	• Perforation of the flap by lag screw.	34
2	45 F	• Recurrent Marjolin's ulcer in lt. heel since 2 years	9/9	• Reverse. Sural artery faciocutaneous flap with peroneal artery perforators.	18 X 9	Non	• NO	27
3	7 M	• Lt. heel soft tissue loss. exposed prostheses	9 X 7	• Reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators.	17 X 8	Fracture calcaneous	• Postoperative. Superficial epidermolysis of the distal edge of flap (1cm).	24
4	10 M	• Lt. heel soft tissue loss. exposed prostheses	8 X 7	• Reverse. Sural artery fasciomusculocutaneous flap with peroneal artery perforators.	16 X 8	Fracture calcaneous	• Hypertrophic scar on the graft edge and donor site incision.	22
5	8 F	• Rt. heel soft tissue loss with exposed prostheses	7 X 6	• Reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators.	16 X 7	Fracture calcaneous	• Delayed take of the PTSG-Hypertrophic scar on the graft edge and donor site.	19
6	15 M	• Rt. heel soft tissue loss with exposed prostheses	7 X 5	• Reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators.	17 X 6	Fracture calcaneous	• Hypertrophic scar.	17
7	33 M	• Rt. heel soft tissue loss	9 X 11	• Reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators.	18 X 9	–	• Hypertrophic scar.	15
8	26 M	• Total Lt Heel loss, exposed calcaneous, + necrosis in tendoachillies	9/9	• Reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators.	18 X 9	Potts fractures	• It was treated via AO. modular EX. Bridging the ankle with 2 Schanz screws fixed to the tibia and the other 2 Schanz screws fixed to first metatarsal bone of the foot.	11
9	19 M	• Rt. heel soft tissue loss	8/7	• Reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators.	16 X 8	Fracture calcaneous		9
10	35 M	• + partial calcaneal bone loss	8/7	• Reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators.	16 X 8			6
Mean	20.35	• Rt. heel soft tissue loss	9/11-7/5		18 X 9 16 X 7			19.3

Operative procedure:

All the 6 calcaneal fractures were open fractures graded by the Gustilo and Anderson classification as type IIIB where there was extensive soft tissue injury with periosteal stripping and bone exposure. All the initial emergent procedures were fulfilled both for the patient and the fracture. All the open fractures had local sterile irrigation, covered with a betadine-soaked sterile dressing and splinted. An Intravenous (IV) 3rd generation cephalosporin was administered with the induction of anesthesia. A tetanus booster was given. Plain X-ray and CT scans of the broken calcaneus were obtained to study the fracture and decide on the skeletal stabilization plan. We intended to use the "fix and flap" protocol whereby a formal radical debridement was done alongside with internal fixation of the fracture followed by covering the exposed calcaneus by a reverse sural fasciomusculocutaneous flap with peroneal artery perforators flap at the same setting by the plastic surgeons. We planned to use low profile implants to restore the calcaneal anatomy (width, height, Bohler's angle, crucial angle of Gisane) and reduce articular surfaces.

After the orthopedic surgeon was finished from his work, the hand hill Doppler was used to detect the sites of peroneal artery perforators, the course of median superficial sural artery and Lesser Saphenous Vein (LSV). The peroneal artery perforators were marked on a line midway between the Achilles tendon posterior and the lateral malleolus anterior. There are 3-6 perforators, lying at 5-15cm above the tip of the lateral malleolus **[14-16]**. The pivot point was marked at about 5cm proximal to the lateral malleolus Fig. (1).

The operations were performed under general anesthesia for children and spinal anesthesia for the adult patients. After administration of anesthesia the patient was positioned prone on the operating table and the tourniquet was used Fig. (2A,B). The wound was debrided and copiously irrigated with saline 0.9%. A template from the defect was marked on the flap's donor area. The skin, with its size determined by the soft-tissue defect to be restored, was marked along the center line of the posterior aspect of the leg, at the location of the axis of Lesser Saphenous Vein (LSV), the accompanying superficial sural vessels, and the sural nerve. The adipofascial pedicle was approached through a lazy-S-incision over the distal part of the leg.

The cutaneous layer was dissected to expose the LSV, sural artery, and the sural nerve. After dissection of the adipofascial pedicle (about 4cm width), at the mid-calf where the sural nerve becomes deep under the deep fascia and within the intergastrocnemius groove, a midline cuff of the gastrocnemius muscle containing the sural nerve was harvested Fig. (2B). The pedicle containing the LSV, sural nerve, and sural artery were ligated and transected proximally. This fasciomusculocutaneous flap with its vascular pedicle were elevated, with the deep fascia, and rotated 180 degree toward the pivot point, about 5cm above the tip of the lateral malleolus, where the flap can reach the defect without tension. The tourniquet was then released to achieve haemostasis and ascertain good vascularity to the flap before insetting the flap. The flap transferred to the defect by incising the skin bridge. The flap was then inset, the muscle layer sutured to the surrounding periosteium with 4-0 Polyglactin (Vicryl) as a separate layer, deep fascia of the flap sutured to fascia and subcutaneous of the leg with 4-0 Polyglactin, finally skin with skin by 4-0 Polypropylene (prolene) (our modification, three layer in-setting of the flap). A negative suction drain was introduced underneath the flaps. Finally, the gastrocnemius muscle defect was closed by approximating the two heads of the gastrocnemius muscle. The proximal end of the severed sural nerve completely buried into the surrounding gastrocnemius muscles to prevent further neuroma formation. Immediate a split-thickness skin graft was laid on the donor site defect.

Postoperative, the patients continue to receive IV 3rd generation cephalosporin for 7-10 days (the dose adjusted according the body weight of the patient). The flap was checked for viability after 24 hours. The drain was removed after 84 hours. All patients were kept in bed for 1 week, preferably in prone position. The patients were discharged on the 10 to 14 day postoperatively after good take of the skin graft and followed-up at regular intervals.

Physiotherapy:

To return the patient to the pre-injury function level was of utmost importance. We aimed to return the patients to walk and run properly in normal shoes. In the first 4 weeks post-operatively, the patient walked in an air-cushioned boot to fix the ankle in 90 degrees (not to allow it to fall into equines) and at the same time not to put too much pressure on the flap. The patients were instructed to remove the boot frequently during the day and to move their ankles both passively and actively not past 90 degrees. After 4 weeks specialized

program of physiotherapy was started. It consisted of passive and active Range of Motion (ROM) exercises for the ankle, stretch exercises for tendoachillies and ankle plantar flexors, strengthening exercises for all muscle groups around ankle, and proprioception enhancement. Our aim was to regain normal ROM and power comparable to the other side and to return the patient to the pre-injury function level. We used the Goniometer to measure both the passive and active ROM of the ankle when physiotherapy was finished. We repeated measuring the ROM at 3 months point to make sure there was no delayed loss of ROM Fig. (2D).

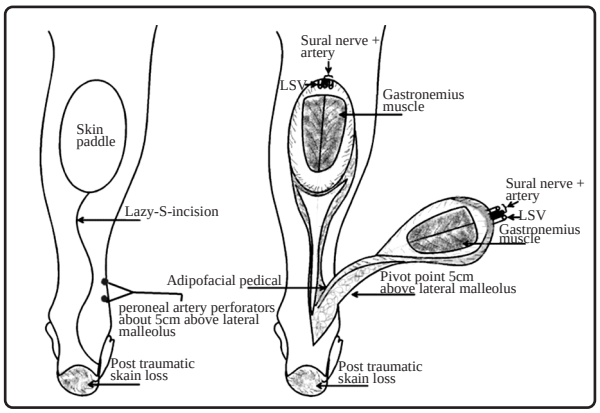

Fig. (1): Schematic drawing of distally based fasciomusculocutaneous flap with adipofascial pedicle.

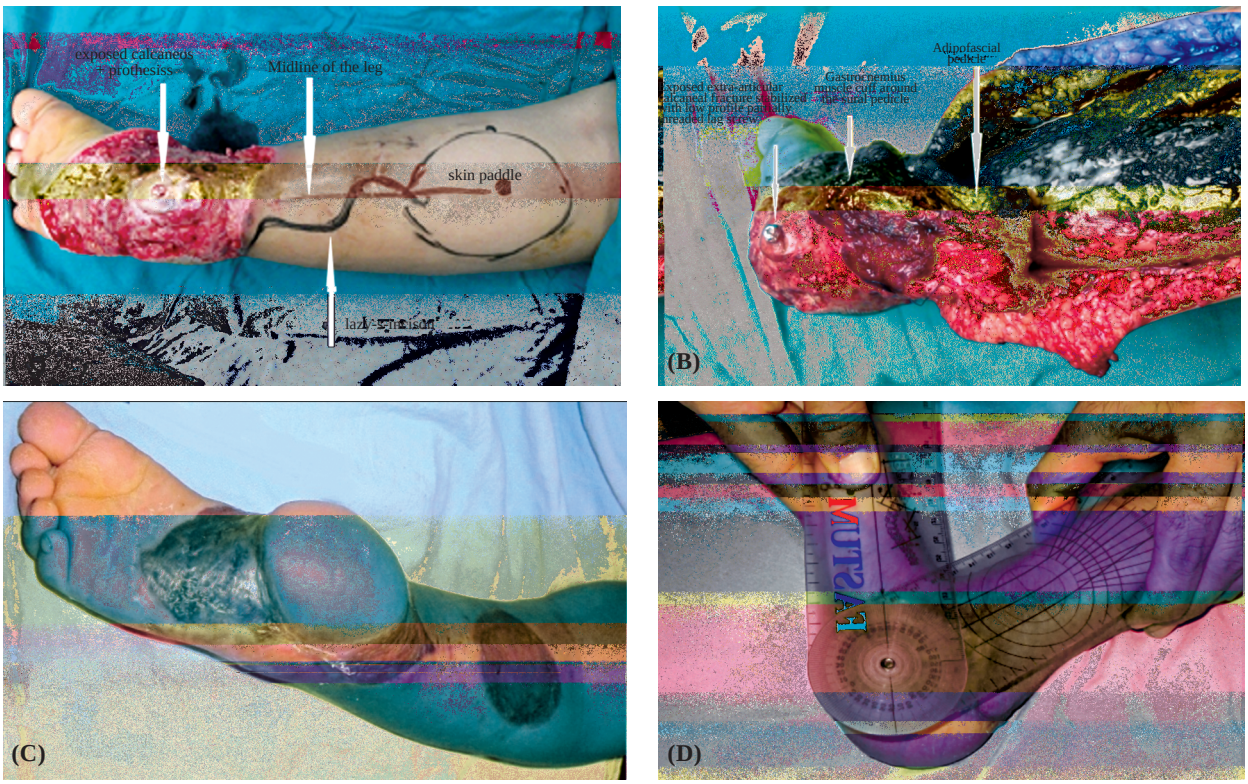

Fig. (2): A male child 5.5-year old presented with post traumatic loss of the soft tissue of the heel with fracture calcaneous with exposed prosthesis, the wound after debridement and marking of the sural flap, (B) The same patient, intra-operative, after flap elevation with gastrocnemious muscle cuff with the flap, (C) The same patient, one month postoperatively, d. The same patient, postoperatively, Goniometer to measure ROM of the ankle after physiotherapy was finished.

RESULTS

A total number of 10 patients were treated with reverse sural fasciomusculocutaneous flaps with peroneal artery perforators from May 2012 and June 2015. Eight patients were men and two were women with a mean age of 20.35 years (range, 5.5 -45 years). Six patients, suffered from soft tissue loss of the heel with concomitant fracture calcaneous resulted after road traffic accidents and one patient suffered from Potts fractures. One patient suffered from soft tissue loss of the heel after extirpation of malignant tumor (Marjolin's ulcer). All the defects were in the heel include the anterior and the posterior heel. All the patients underwent single stage soft tissue reconstruction using a reverse sural artery fasciomusculocutaneous flap with peroneal artery perforators after fixation of

the fractured calcaneous and Potts fractures. The size of the flap varied from 16 X 7cm to 18 X 9cm. All the flaps were successful with minor complications as delayed take of the partial thickness graft in two patients, superficial epidermolysis of the distal edge (1cm) of two flap, transient congestion immediately after inset of the flap was seen in two flaps which resolved within a few days with no adverse sequelae on the flap survival and hypertrophic scars at the edge of the skin graft in donor and recipient site.

All the patients complained of hyperesthesia and numbness of the lateral aspect of the foot after sacrifice of the sural nerve. All the previous complications were treated without surgical intervention. The follow-up period was 34 to 6 months, with the average being 19.3 months. The entire patients had no problems in wearing medical shoes with silicone heel pad. The operative times ranged from 80 to 120 minutes (mean, 95 minutes). The length of hospital stay ranged from 7-14 days (mean 8.9 days) (Table 2).

All the children's regained the normal plantar flexion-dorsiflexion of their ankles compared to the non operated side after a mean period of 1.5-2 months postoperative. The entire adult patient regained the normal plantar flexion-dorsiflexion of their ankles compared to the non operated side after a mean period of 2-3 months post operative except two patients ended up with a fixed equines deformity 10 degrees for which they needed constant heel lift. This is probably due to the stiffness of the tissues and lack of preoperative stretch exercises to tendoachillies. Healing was uneventful, and the function satisfactions about 80% and aesthetic satisfaction about 60% (Table 2).

Table (2): Patient outcome data.

No.	Mean
Operative time (minutes) mean	95
Hospital stay (days) mean	8.9
Complication	(40) %
Function satisfaction	8 (80%)
Aesthetic satisfaction	6 (60%)

DISCUSSION

In general soft tissue reconstruction of the foot and around the ankle is difficult because the exposed important structure (bone, tendons, and ligaments) are not candidate for skin grafting, and there is paucity of local skin to be mobilized as local flaps **[16-23]**. There are different modalities for reconstruction as muscle flaps, distally based fasciocutaneous flap, axial flaps, septocutaneous flaps, local transposition flaps and free flaps. Each flap has its own specific indications and drawbacks **[12,24,25]**.

Either peronial or posterior tibial arteries distally based perforator flaps, needs to maintain length-breadth ratio **[26]**. Lateral calcaneal flap can cover defect of 3cm in diameter, so it is not suitable for larger defects. Also cross leg flap is tedious and not candidate for elderly patients due to prolonged immobilization **[27]**.

Local flap coverage and free tissue transfer has been the corner stone of management for complex wounds in distal one-third of the leg and the foot. The free flaps are still superior to other modality due to they provide well-vascularized tissues for reconstruction. A multitude of free muscle, fasciocutaneous, and perforator flaps including radial forearm, anterior lateral thigh, gracilis and lateral arm flaps have been reported **[28-31]**. In addition, smaller perforator flaps from the groin, thigh and foot have been described **[32-33]**. Although the free tissue transfer is a reliable options for heel reconstruction, their drawbacks lie in the require expertise, sophisticated equipment, and requirement for advanced microsurgical technique **[34]**. It is a time consuming and it is costly procedure. They also are bulky flaps and create a remote donor area and disturb major vessels of an already traumatized limb **[15]**. When small to moderate-size defects require to be covered free flaps becomes a big procedure so the free flaps should be preserved for extensive defects. Free flap has a considerable failure rate even in the specialized centers. Considering these limitations pedicle flaps can be considered a first-line therapeutic option **[35]**. Masquelet et al., described the concept of neurocutaneous arteries and flaps. The distally based superficial sural artery flap is one of these neurocutaneous flaps, and its vascular axis depends on anastomosis of perisural vasculature with distal perforators of the peroneal artery near the lateral malleolus **[11]**. Since Masquelet et al., in 1992 introduced this therapeutic modality, the reversed sural artery island flap becomes the working horse for soft-tissue reconstruction in the distal third of the leg and foot. It is an easy and provides durable coverage of the defect; also, fortunately its pedicle is frequently preserved in most instances of superimposed vascular disorders and trauma **[27]**.

As long as the blood supply of the distal sural flap is reliable, that making this flap is safe, even in patients with distal arterial-insufficiency and

there is no major arteries scarification. So this flap can be used in traumatic legs with damaged major arteries. Since reverse blood flow through the peroneal perforators allowed repair of the reconstruction of the soft tissue defect without further compromising blood supply to the distal foot **[36]**.

The reverse sural artery island flap is an excellent choice for the reconstruction of the soft tissue loss of the heel. Because this flap is fasciomusculocutaneous, its durability is excellent, even in weight-bearing areas (anterior heel) or non-weight bearing area (the posterior heel). The under surface of the flap provides a good surface for gliding of the tendon.

It has wide arc of rotation 1800 for heel reconstruction and is easy to perform by less expertise surgeons. It can be completed in a short period of time with regional anesthesia, which is very advantageous for patients unfitted for general anesthesia due to poor medical condition.

Acikel et al., mentioned that the medial plantar and dorsalis pedis flaps are regional alternatives to free tissue transfer in Achilles tendon and heel injuries **[37]**. Nevertheless, these local flap options rely on major vascular pedicles that potentially compromise distal foot flow while the size of these flaps also limits their utility. Benito-Ruiz et al., reported in their algorithm of reconstruction of soft-tissue heel defects that the instep flap for anterior heel defects, and reverse sural flap for posterior heel defects are considered the first choice. Free flaps should be preserved in more complex wound when none of these flaps could be performed **[2]**. The reverse sural flap is indicated for posterior defects and for those cases where the instep flap cannot be used due to because the defect is huge, more than the instep area or vascular problems. The skin, fat and gastrocnemius muscle cuff harvested with the flap provide a good cushion to the weight-bearing areas.

The reverse-flow sural artery flap depends on four sources of retrograde blood flow: Peroneal artery fasciocutaneous perforators and posterior tibial arteries perforators, the LSV venous cutaneous perforators, and neurocutaneous sural nerve perforators **[38]**. The predominant blood supply comes from septocutaneous perforators from the peroneal artery with the most distal of these located 5-7cm proximal to the lateral malleolus **[39]**.

Al-Qattan has described a gastrocnemius muscle cuff technique around the sural pedicle allows the maintenance of a “mesenteric” connection between the buried sural pedicle and the flap in the upper part of the leg, hence improving the blood supply of the flap also improves the survival rate of this flap even in patients with diabetes **[40]**. Recently, a sural artery delay procedure improving the results in patients with risk factors such as age over 40 years, diabetes, venous insufficiency, and peripheral vascular disease **[41]**.

The advantages of the reverse sural artery fasciomusculocutaneous flap include easy and fast elevation, a reliable blood supply, long vascular pedicle, one-stage procedures. The well-vascularised muscle component also fills effectively a deep soft-tissue defect or bony cavity, thereby improving the regional vascularity, increasing resistance to bacterial inoculation, act as a soft tissue pad in heel reconstruction and promoting bone healing. Also there is no major arteries scarification of lower limb. In fact, this flap can be used in traumatised legs with damaged major arteries with patent peroneal artery.

The main drawbacks of this flap are the use of a skin graft in the donor site in flaps wider than 4cm, adherence of the skin graft to the underlying muscles in the donor site, it is not sensate, the sacrifice of the sural nerve leading to loss of sensation in the lateral part of the foot and the fifth toe and sural nerve neuromas in proximal nerve stump. Hyperesthesia and numbness of the lateral aspect of the foot after sacrifice of the sural nerve are frequent complaint of all patients. However, 1 year after reconstruction, the hyperesthesia was considerably less.

Kalam et al., reported some limitations to the reversed sural flap, as maximum safe length-breadth ratio not defined. There is deficiency of resches regarding maximum flap dimension (specifically, width) and safety, but usually a relatively large flap can be harvested with little donor site morbidity. They harvested a large flap measured 14 X 12cm. Without any complications **[27]**.

In the current series, a total number of ten patients were reconstructed with the reverse sural artery fasciomusculocutaneous flap after total heel loss. Six patients suffered from soft tissue loss over the heel with concomitant fracture calcaneous resulted after road traffic accidents. One patient suffered from soft tissue loss of the heel after extirpation of malignant tumor with safety margins (Marjolne ulcer). All the flaps were successful with minor complications as delayed take of the partial thickness graft in one patient, superficial epidermolysis of the distal edge of one flap (1cm), transient congestion immediately after inset of the flap

was seen in two flaps which resolved within a few days with no adverse sequelae on the flap survival and hypertrophic scars at the edge of the skin graft in recipient site. Mean follow-up period was 19.3 months.

All the children regained the normal plantar flexion-dorsiflexion of their ankles compared to the non operated side after a mean period of 1.5-2 months postoperative. The entire adult patient regained the normal plantar flexion-dorsiflexion of their ankles compared to the non operated side after a mean period of 2-3 months post operative except two patients ended up with a fixed equines deformity 10 degrees for which they needed constant heel lift. This is probably due to the stiffness of the tissues and lack of preoperative stretch exercises to tendoachillies as the patient walking in here tips of the fingers for two years preoperative. The outcome in acute cases is better than chronic cases. Functional reconstruction can be obtained if specialized program of physiotherapy was started 4 weeks post operative especially in children's. Healing was uneventful, and all the patients were highly satisfied with the outcome.

The current study coincides with the Kalam et al., in their series; thirty patients with exposed Achilles' tendon (posterior heel) were treated with superficial sural artery flap with excellent outcome. They concluded that the superficial sural artery island flap can be used as a good alternative to microsurgical reconstructions **[27]**.

Conclusion:

Although this study is limited by a relatively small number of patients and the absence of a comparison group, we conclude that the reverse sural fasciomusculocutaneous artery flap considered an easy, one-stage surgery, a reliable blood supply, fast elevation, a long vascular pedicle with large arc of rotation, and provide a long-lasting reconstruction. It is a reliable method for heel reconstruction. It also considered as a good alternative to free tissues transfer in mild to moderate defect in the foot. It gives good functional and aesthetic results. Functional outcomes can be obtained if specialized program of physiotherapy was started in appropriate time postoperative especially in children's.

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