Original Article

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Plastic Surgery Section

Perforator Plus Fasciocutaneous Flaps in the Reconstruction of Post-Burn Flexion Contractures of the Knee Joint

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ABSTRACT

Background: A post-burn flexion contracture of the knee joint is a disabling condition which interferes with an upright posture and a bipedal locomotion. Islanded perforator flaps have been used to resurface the tissue defect which is produced as a result of the contracture release. Despite their various advantages, they are limited by an increased tendency to undergo venous congestion. Perforator-plus flaps can be used to overcome this limitation, while retaining the merits of the islanded perforator flaps.

Methods: Ninteen patients with post flame burn flexion contractures of the knee joints underwent surgical releases and coverages by various local fasciocutaneous perforator-plus flaps. The patients were followed up for 6 months and the various aspects of the functional and the aesthetic rehabilitations were assessed.

Results: All the local fasciocutaneous perforator-plus flaps resurfaced the tissue defect over popliteal fossa with good colour and texture match and maintenance of the contour. None of the flaps had any significant early or delayed complications (which included venous congestions) which necessitated reoperations. All the patients were satisfied with the functional and aesthetic outcomes.

Conclusion: Local fasciocutaneous perforator-plus flaps can be considered as one of the primary treatment modalities for the surgical release and reconstruction of post burn flexion contractures of the knee.

Key Words: Perforator-plus flap, Fasciocutaneous flap, Peninsular flap, Post-burn contracture, Knee joint

INTRODUCTION

With a steady decline in the mortality of burn patients over the past six to seven decades, addressing the issue of disabling post burn sequelae has become more vital, for adequately rehabilitating the victim in society [1]. A burn patient who receives the best of treatment, which includes an early physiotherapy, an adequate splintage in the position of function and an early debridement with skin grafting, is expected to heal without any significant contractures. However, post burn contractures are distressingly common in India and other developing nations. The incidence of burn cases has been estimated to range from 60-70 lakhs annually in India [2]. In the emergency setting, most of the cases are treated in ill-equipped peripheral units by inadequately trained staff. This, in turn, gives rise to the enormous burden of post-burn contractures and deformities, which have to be dealt with, in the comparatively few tertiary care centres [2].

The post burn scar contractures over the major joints of the body are characterized by the presence of a single-celled, highly fragile neoepithelium, which may be associated with a long-standing shortening of the underlying musculotendinous units and the neurovascular structures, as well as tightened joint capsules and ligaments. The knee is the largest joint of the human body and it is involved in the maintenance of an upright posture and a bipedal locomotion. An adequate incisional or excisional release of the flexion contracture of this joint leaves large skin defects and it often exposes bowstringed hamstring tendons, major vessels and nerves in the popliteal fossa, which require soft tissue coverage. Those cases which are resurfaced with skin graft need a prolonged splintage and a rigorous physiotherapy for a minimum period of 6 months [3,4]. This leads to a poor patient compliance. Therefore, the rates of recontracture is more, which needs re-operations and this increases the patients' morbidity and the burden on the already stressed infrastructure .These shortcomings can be overcome by the use of flaps. However, the lower limb has been known to be a site of a less reliable vascularity, poor wound healing and scarcity of flaps. Before the advent of free flaps, only few reconstructive options were present, like conventional local flaps and cross-leg flaps, which required immobilization for weeks [5]. Several muscle or musculocutaneous flaps have been used to repair the soft tissue defects around the knee [6-8]. However, they are bulky, they cause varying degrees of functional loss to an already crippled extremity and they also cause poor aesthesis of the donor site. The random cutaneous and conventional fasciocutaneous flaps are simple and reliable and they provide a durable pliable coverage with a better donor site aesthesis and less morbidity. However, they are restricted by a limited length : breadth ratio, a need of delays and limited mobility and reach. The delicate balance between the flap vascularity and the reach in the lower limb was somewhat achieved with the advent of islanded perforator flaps [9,10]. It was recognized that the skin which overlay the muscles could be reliably transferred separately from the muscles as an islanded flap, based only on the dissected musculocutaneous perforators [9,10]. The donor site has minimal functional compromise and better aesthesis. They provide a thin, pliable coverage with tissues of similar colour and texture and an immense freedom of movement and they maintain the functional integrity of the muscles and the nerves, while safeguarding the main vascular trunks. But an important pitfall of such flaps is venous compromise. This is

because the thin walled veins with lower vessel wall elasticities and intraluminal pressures is more sensitive to the torsional forces than the perforator artery during the flap transfer and inset [11,12]. The concept of the perforator-plus flaps aims to combat this pitfall. This new method involves raising of the peninsular fasciocutaneous flaps, thus including and retaining one or more perforators in their base [13,14]. This provides a dual blood supply through the perforator and the subdermal plexus, as well as it reinforces the venous drainage. The pedicle may be narrowed by back cuts to facilitate the mobility and a tension free inset [14]. It has been determined that the perforator-plus fasciocutaneous flaps can be safely used in the knee and the upper and middle thirds of the leg [15,16]. Moreover, most of the cases of post burn contractures of the knee have limited loco-regional unscarred tissues which increase the chance of a flap failure. This is combatted by including a perforator in the flap base [17,18].

The aim of this study was to evaluate the applicability of perforator-plus flaps in the reconstruction of post burn flexion contractures of the knee joint .

METHODS

During the period from August 2010 to March 2012 , 19 patients with post-flame burn flexion contractures of the knee joint were operated in the Department of Plastic and Reconstructive Surgery of our institution. A clearance was obtained from the institutional ethical committee and written informed consents were obtained from all the patients. All the patients were managed by a complete incisional or excisional release of the contracture, followed by coverage with local perforator-plus flaps. The patients were advised to quit smoking at least 2 weeks prior to their surgeries. The degree of contracture was assessed with a goniometer and the extent of the defect which would be produced was approximately estimated by comparing the degree of contracture with the normal side (or limb of another subject of a similar stature and build, in case of a bilateral involvement). The type of fasciocutaneous flap which had to be raised was then planned, after considering the location of the defect and the quality of the surrounding tissue. Any perforator which supplied the proposed flap territory was marked with the help of a hand-held Doppler with an 8 Hz probe. It was considered as preferable but not mandatory to identify the perforator pre-operatively. The approximate dimensions of the flap were determined by planning in reverse . The length of the flap from the identified perforator (which marked the location of the base) was equal to the distance of the distal-most margin of the defect from that perforator, plus one centimetre, to allow a tension-free inset. After the induction of anaesthesia, the contracture was released completely, without any damage to the underlying vital structures, under a tourniquet control. The final planning in reverse was done with a piece of lint and the modified outline was marked out. The flap was then raised by the combination of a sharp and a blunt dissection, thus preserving the supra and the subfascial plexuses. The perforator(s) at the flap base with a strong intra-operative Doppler signal(s) and a visible pulsation(s) was/were preserved. They were dissected, retaining a cuff of the areolar tissue around, in order to ensure the flap mobility and reach. The skin pedicle was narrowed with back cuts if it was needed, to facilitate the reach and inset without significant dog-ears.The flap inset was then accomplished without any tension on the pedicle. The placement of a suction drain under the flap was considered as optional. The donor site was covered by a split-thickness skin graft. The flap was covered by a light dressing and the limb was kept elevated post-operatively. Prophylactic antibiotics were given for 5 days. No special post -operative drugs or monitoring techniques were needed. The dressing over the graft was removed on the 5th post-operative day and the sutures were removed on the 10th day. No post-operative splinting was applied. The limb mobilization was began after 1 week and gradual weight-bearing started two weeks post-operatively . The patient was followed up two weekly in the first month after discharge and monthly thereafter, for 6 months.

RESULTS

A total of 19 patients of post-flame burn flexion contractures of the knee joints were operated between August 2010 and March 2012 [Table/Fig-1 and 2]. Seven cases had involvement of the right side, 11 had involvement of the left side and 1 case had a bilateral affection [Table/Fig-3 and 4]. All the patients had flexion contractures of the knee joints, with a hypertrophic scarring and a hypopigmentation. Non-healing ulcers were present in 9 cases. Of the 19 patients in the study, 8 were males. The age range of the study population was 5-56 years (mean -29.6 years). The duration after the burn injury ranged from 6 to 15 months (mean -9.15 months). The degree of the flexion contracture ranged from 10-120 degrees, with an average of 52.75 degrees. All the cases were operated under spinal or general anaesthesia and they underwent incisional or an excisional complete releases in the prone position and coverage with local fasciocutaneous perforator-plus flaps. All the cases included a single perforator at the base. The pre-operative Doppler assessment of the perforator was done in all except 2 cases, where they were identified intra-operatively. The source vessel was the peroneal artery [Table/Fig-5] in 7 cases, it was the superior medial genicular artery [Table/Fig-6] in 5, it was the superior lateral genicular artery in 3, it was the lateral sural [Table/Fig-7] and the medial sural arteries in 1 case each and it was the saphenous/inferior [Table/Fig-3 and 4] medial genicular artery in 3. The flap dimensions ranged from 11.5x6 to 19x11 cm. All the flaps adequately covered the tissue defects over the flexural aspects of the knee joints. They were inset in a tension-free manner, with the maintenance of a good contour, colour and texture match. The operating time spanned from 75 to 105 mins (mean- 88.75 mins). None of the cases needed splintage and all the limbs were mobilized on the 7th post-operative day. The total duration of the hospital stay ranged from 10-17 days (average 12.1 days). Wound infection and dehiscence of the insetting sutures occurred in 2 cases. Only one case of the superior medial genicular artery perforator-plus flap developed marginal tip necrosis. There was no venous congestion in any flap. All the local complications were managed under local anaesthesia with debridement and by secondary suturing or healing by secondary intention. There were minor graft losses over the donor sites in 2 cases, which were treated conservatively. Apart from a single case of a superior medial genicular perforator-plus flap with paresthaesia over the antero-medial thigh, no other case had any significant evidence of a collateral damage like distal limb oedema, sensory loss or muscle weakness. All the patients were followed up for 6 months, except one, who was lost to follow up after 2 months. 8 cases had some evidence of a hyperpigmentation, an induration and/or a hypertrophic scarring over the grafted areas. However, since none of the patients had any grafts over the flexural aspects of the knees, there were no incidences of recontractures and hence, there was no need of reoperations. The flaps provided a long-term stable pliable coverage over the popliteal fossa with a good colour and texture match and maintenance of the contour. The flaps were not bulky and only one patient desired revision surgery for a dog-ear correction, which was accomplished on an

Serial No.	Age (Years)	Sex	Side	Duration Since Burn (Month)	Degree Of Contracture	Source Vessel	Flap Dimension (Cm)	Operating Time (Mins)
1	13	M	left	9	120	SMGA	19x11	95
2	5	M	left	6.5	100	SLGA	17x7.5	80
3	35	F	right	8	50	peroneal	14x6.5	80
4	27	F	right	6	10	lat. sural	17.5x8.5	75
5	56	M	left	8	45	peroneal	15x7	95
6	19	M	left	12	55	SLGA	14x7	100
7	26	F	left	11	85	SMGA	18x10.5	100
8	34	F	right	8	70	SMGA	17x10	80
9	33	F	left	15	25	peroneal	12x6	85
10	37	M	left	10	20	peroneal	14x6	100
11	31	F	right	7	90	peroneal	16x7	95
12	23	M	left	9	35	med. sural	11.5x6	85
13	18	F	left	10	40	SMGA	13.5x7	90
14	22	M	left	11	30	peroneal	13x7	80
15	31	F	left	8.5	25	saphenous	11x6.5	75
16	34	F	right	8	85	SLGA	15x8	100
17	45	M	right	9	35	saphenous	11x6	80
18	37	F	right	13	70	peroneal	14x6.5	90
19 left	36	F	left	7	30	SMGA	18x10	100
19 right	36	F	right	7	35	saphenous	15x8	90

[Table/Fig1]: Patient Profile and Intra-Operative Details
SMGA: superior medial genicular artery, SLGA: superior lateral genicular artery

Serial No.	Hospital Stay (Days)	Follow Up (Months)	Early Complications	Delayed Complications	Aesthetic Acceptability
1	14	6		hypertrophic scar, dog ear correction	average
2	10	2			good
3	11	6			good
4	10	6			average
5	12	6		hypertrophic scar	average
6	11	6			good
7	17	6	wound infection	hypertrophic scar	average
8	11	6	minor graft loss	paresthesia	average
9	14	6			average
10	13	6		hypertrophic scar	average
11	11	6		hypertrophic scar	average
12	10	6			good
13	14	6	minor graft loss	hypertrophic scar	average
14	15	6	wound infection		good
15	10	6		hypertrophic scar	average
16	11	6			good
17	10	6			good
18	10	6		hypertrophic scar	average
19 left	16	6	tip necrosis		average
19 right	16	6			good

[Table/Fig 2]: Post-Operative Results

outpatients basis. All the patients, at 6 months follow-up, were satisfied with the function and aesthesis of the limbs. They were able to maintain an unassisted symmetrical upright posture and a bipedal locomotion and they could squat without difficulty. Apart from 3 patients, the rest were able to sit cross-legged on the floor without much difficulty.

DISCUSSION

The contribution of perforators in the flap circulation was first suggested by Fujino [19]. Perforator flaps were later developed by Koshima [9,10] and Kroll and Rosenfield [20]. According to Taylor and Palmer's [21] concept of the angiosome (1987), almost all the tissues of an angiosome can be harvested on one adequate

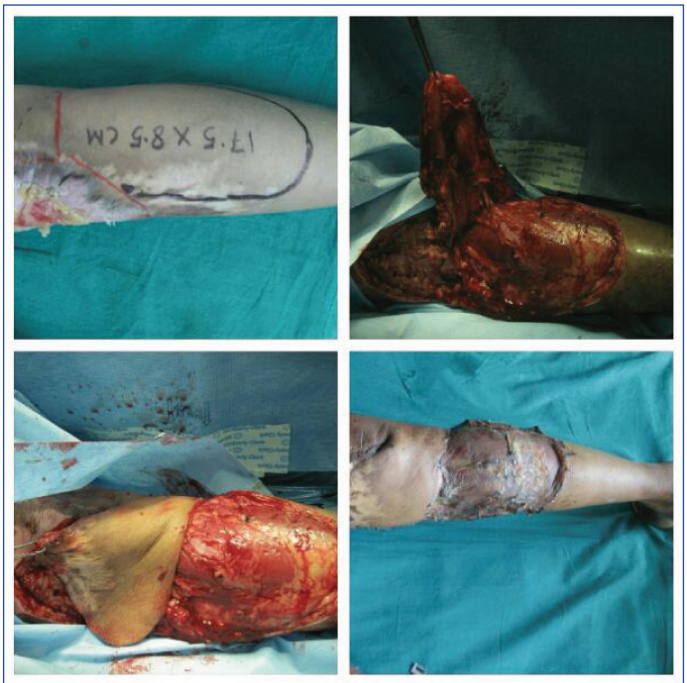
[Table/Fig-3]: Case no.19 (vide table 1): Bilateral contracture: Left-superior medial genicular artery perforator-plus flap, right-saphenous artery perforator-plus flap

[Table/Fig-4]: Case no. 19 post-operative day 10

[Table/Fig-5]: Case no. 3 (vide table1): Peroneal artery perforator-plus flap

[Table/Fig-6]: Case no. 1 (vide table 1): Superior medial genicular artery perforator-plus flap

perforator. Such perforators originate from one of the main axial vessels, they course through a muscle or septa, pierce the fascia and ramify in the suprafascial level within subcutaneous fat. The perforator-plus flaps were conceptualized and the nomenclature was coined in 2005 [13]. The terms, 'perforator-plus' and 'perforator-sparing flaps' have been used interchangeably for the same flap design [16]. In the classical rotation design, the moving tip is under tension if the donor defect is closed primarily. This can be prevented by designing oversized flaps or by making a back cut from the existing pivot point into the base. However, this might compromise the vascularity of the conventional flaps. The inclusion of a known or an identified perforator [16] in the base allows the greater freedom of a back cut, which shifts the pivot point closer to the defect and facilitates a tension free inset. This phenomenon is applicable to any design of a peninsular flap and it is the basis of a perforator-flap harvest [22].The peninsular design prevents kinking of the perforator vessels and it improves the venous outflow through the pedicle. The perforator-plus technique is being used in various conditions from lower limb trauma to pressure sores [15]. The evaluation of a series of different perforator-plus flaps for the reconstruction of post burn flexion contractures of the knee could not be found in the published literature till date. There is no conclusive evidence in the literature regarding the safe limit of harvest of the perforator or the perforator-plus flaps. However, it has been noted that there is a six-fold higher chance of an islanded perforator flap failure if the length is more than one-third of the total limb length [23]. It can be postulated that the larger dimensions of the perforator-plus flaps can be raised than the corresponding islanded perforator flaps, due to the dual blood supply. The knee joint has a rich vascular plexus around it, which gives rise to many



[Table/Fig-7]: Case 4 (vide table 1): Lateral sural artery perforator-plus flap.

prominent perforators and connects the femoral vessels which are above, with the popliteal and the tibial vessels which are below. An average of 93 perforators from 21 vascular territories supply the skin of the lower extremity. The mean diameter and the area which are supplied by one perforator are approximately 0.7 mm and 47 cm^2 respectively [24]. Perforator-plus flaps may be designed from various aspects of the distal thigh and the proximal leg to resurface the tissue defect over the popliteal fossa which is created by the contracture release. The antero-lateral thigh flap is based on the perforators from the descending branch of the lateral circumflex femoral artery, which are clustered within a 3 cm radius of the midpoint of a line which joins the anterior superior iliac spine and the superolateral patella. The descending branch anastomoses with the superior lateral genicular artery, which allows a distally-based flap to be harvested, with the pivot point 3-10 cm above the knee joint [25]. The anteromedial thigh flap is based on a major perforator from the rectus femoris branch of the descending branch of the lateral circumflex femoral artery, which is present in 51% individuals. It has a musculocutaneous course through the rectus femoris in 34% cases, while the rest are septocutaneous. The perforator is located about 3.2 cm medial to the midpoint of the line which joins the anterior superior iliac spine with the superolateral patella [26]. The cutaneous perforator of the superior lateral genicular artery is located within a triangle which is bounded by the superior border of the lateral femoral condyle, the anterior border of the short head of the biceps femoris and the posterior border of the vastuslateralis [27]. It is located about 7.4 $\pm$2.77 cm above the lateral femoral condyle [28]. In 60% of the cases, it traverses the lateral intermuscular septum of the thigh, while in the rest, it passes through the biceps femoris [6]. The saphenous branch of the descending geniculararetery originates 13 cm above the medial joint line and it courses along a line which joins the anterior superior iliac spine and the medial tibial condyle. Here, the vessel traverses deep into the sartorius and it gives septocutaneous perforators on either side of the muscle. The terminal branch of this artery anastomoses with the collateral vessels around the knee, like the inferior medial genicular artery, which forms the basis of the reverse flow distally based flaps [29]. The cutaneous perforators of the superior medial genicular artery are located in a small triangle which is bounded by the superior border of the medial femoral condyle, the anterior border of the adductor magnus and the posterior border of the vastusmedialis [30] . The medial and the lateral sural arteries originate from the popliteal artery. 1-5 medial sural artery perforators were detected in 100% cases in an Asian population. But the lateral sural artery perforators were absent in 57% of the cases. These perforators are located between 5 cm above and 17.5 cm below the popliteal crease, within a range of 0.5 to 4.5 cm from the midline raphe of the gastrocnemius [31]. The vascular axis of the posterior tibial artery lies along a line which is ~4.5 cm medial and parallel to the line which joins the tibial tuberosity and the midmalleolar point [32]. The septocutaneous perforators which arise from it are arranged in three clusters, the most proximal of which is 3.6-10.8 cm below the joint line [33]. The peroneal artery perforators [34] are situated along an oblique line, behind the posterior border of the fibula, along the intermuscular septum, between the soleus and the peroneus longus. Proximally, they are 0.25 cm away, while distally, they are 1.7 cm behind the posterior fibular margin. Based on this anatomic knowledge on the perforator distribution around the knee joint and the popliteal fossa, robust and pliable perforator-plus flaps can be harvested to cover the tissue defects, following a surgical release of the knee contracture. With the advent of freestyle perforator flaps [35] the applicability of the perforator-plus flaps can be further broadened with lesser restrictions on the flap axiality and design. However, the maximum safe dimension of the harvest of such flaps has to be ascertained.

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