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Soft Tissue Defects of Lower One Third of Leg: Options for Flap Coverage

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ABSTRACT

Background: Lower one third of the leg is more prone to trauma and more susceptible to develop exposed bone that necessitate coverage with flap, the decision to choose flap is difficult and depends on different factors, we tried to compare 3 sets of flaps used for coverage.

Patient and Methods: 33 patients were divided into 3 groups according to the type of flap coverage, most of our patient were males and mean age was adult age group. 3 methods for coverage; group I free LD flap used, group II crossed leg flap used, and group III coverage done with perforator flaps.

Results: Most of the patient had rood traffic accident as a cause of injury, most common defect in this study was at the lower third leg, the LD flap group has the largest flap size but it has long hospital stay and longer operative time, also all cases require 2ry procedure, highly trained plastic surgical team, the other 2 group had shorter operative time, in group II, 2ry pedicle separation for all cases, easy and versatile flap, difficulties for position fixation for 3 weeks, in last group III had shorter operative time, shorter hospital stay, single operative procedure but has limitation due to smaller flap size and cannot be done if degloving injury occurred.

Conclusion: Flap coverage for lower one third leg defect is difficult question to answer, a lot of flaps could be used each method has its pros and cons, perforator flap is easy and versatile with learning curve it can be used for small to moderate size defects, cross leg flap remain as easy and versatile flap and can be used as backup plan for other methods, free LD flap provide large flap size used for large defects.

Key Words: *Perforator flaps – Free LD flaps – Crossed leg – Lower third leg reconstruction.*

INTRODUCTION

Lower one third of the leg has a special anatomy, makes the coverage of soft tissue defects a difficult problem **[1]**. This area is deficient from muscles and vascularity of tissues is minimal in comparison with other areas of the body. The skin and superficial fascia on the tibia are thin stretched on the bone, so the bones of the lower third are more vulnerable to injury, and exposure **[2,3]**.

All these factors preclude to loss of soft tissue once traumatized, with exposure of bone, tendons, plate and screws or even ankle joint. Soft tissue repair of this defect may be with local flap, fasciocutaneous pedicled flap, or free tissue transfer **[4,5]**.

As regard flap with random pattern territory in lower part of leg proved to be ineffective, because these flaps are usually small in dimensions, and range of mobilization of the flap is limited **[6]**.

With more complexity of the injuries, more complex procedures for reconstruction will be necessary **[7,8]**.

Three principle vascular systems supply the leg, posterior tibial, anterior tibial, and peroneal, they pass in closed compartment, with less significant communication between them. Based on this vascular territory, a lot of perforator flaps can be elevated. But in degloving injuries these perforators may be lost and cannot be used **[9]**.

Free tissue transfer is recommended as the best solution for soft tissue defects in distal lower leg **[10]**. Reconstruction with free flap provides healthy tissue for reconstruction, but many times leads to sacrifice of one of the major vessels of leg **[11]**.

Perforator flap concept entail a part of skin associated or not with subcutaneous fascia, supplied by a branch from main arteries. This branch (perforator), may pass through muscle (musculocutaneous perforator flaps), or (septocutaneous perforator flap). After the wide application of these perforator flaps, the concept of considering free flap the basic tool for soft tissue reconstruction of lower leg decreased **[8,12-16]**.

In many cases local tissues are so severely damaged that there are no possibilities for local flaps harvesting or free flaps transfer due to the

absence of available recipient vessels **[17]**. The cross-leg flap was described by Hamilton 1854, after that it was used for soft tissue coverage in the distal leg, After diffusion of microsurgery since 1970, cross-leg flaps for lower limb wound coverage have been replaced by free flaps, but in specific conditions the cross-leg flap still considered a simple and effective alternative **[18]**.

In some clinical situations in which local fasciocutaneous and myocutaneous flaps are not available. Occasionally, a free flap may also have failed because of technical errors or damaged vasculature. In these situations, a cross-leg flap is the best choice. The inclusion of fascia in the flap makes length-to-breadth ratio 3: 1 perfectly safe. This allows much greater area of skin to be transferred with much more freedom of leg position. The flap provided stable coverage for different defects with few complications **[19]**.

In this study we will compare the 3 flap reconstruction commonly used for coverage of lower one third leg; free LD muscle flap, cross leg flap and medial/lateral septocutaneous perforator flaps. We compare these different methods as regard the hospital stay, operative time, flap size, flap failure, associated complications, and secondary procedures.

PATIENTS AND METHODS

In the period from January 2014 to March 2016, a total number of thirty three patients (27 males and 6 females) presented with lower limb soft tissue defects (19 in right leg and 14 left leg). The soft tissue defects in twenty five cases were caused by rood traffic accident (RTA), run over accident in six patients, street driller machine in one case and falling from height in one case.

The soft tissue defect ranged from most of the leg; lateral side of the ankle (7 cases), distal one third of leg (9 cases), medial side of distal leg, ankle and foot (4 cases), dorsum of the foot and ankle (3 cases), volar side of distal leg (6 cases), lateral side of distal leg (3 cases), Around ankle and foot (1 case).

The Patients were divided according to the reconstructive procedure done into three groups: Free latissmus dorsi flap (group I), cross leg flap (group II) and medial/lateral septocutaenous perforator flap (group III).

In group I (Free latissmus dorsi flap), eleven patients (9 male and 2 females), their age ranged from 7 to 60 years (29.91±12.89). Defect size ranged from 6X13 to 14X 30Cm. All patients received blood transfusion intraoperative and three of them received also postoperative blood transfusion, the blood transfusion volume ranged from 500CC to 3000CC (1545.45±690.59CC).

In group II (Cross leg flap), thirteen patients (12 male and 1 females), their age ranged from 6 to 60 years (30.38±18.25). Defect size ranged from 7X11 to 10X15Cm. All patients did not need any blood transfusion intraoperative or postoperative.

In group III (Medial/lateral septocutaenous perforator flap), nine patients (6 male and 3 females), their age ranged from 4 to 40 years (23.11±12.05). Defect size ranged from 4X5 to 8X14Cm. All patients did not need any blood transfusion intraoperative or postoperative.

Operative procedures:

All patients were admitted to emergency unit. Stabilization and exclusion of other life endanger comorbid emergencies.

Patients were examined by orthopedic, vascular and plastic surgeons as multidisciplinary team. Fracture fixation as planned by orthopedic surgeons; most cases have external fixator done. Ensure good distal perfusion to all cases by vascular surgeon and debridement done at this stage plus fasciotomy if needed. After 48 hours another debridement and dressing and at this time planning for covering done.

The choice of covering method depend on many factors; size of the defect, the defect level, associated skin degloving injury, availability of nearby perforator detected by Doppler, and intact major vascular bundles. The patient general condition (associated medical condition of the patient, smoker or nonsmoker). The availability of microvasculr free flap perquisites; two teams, operating microscope, and long operative procedure requirement (OR time, anaethesia). All these factors affected the covering methods.

Routine work up, laboratory investigation, needed X-rays, colored Doppler, CT angiography if needed, and blood cross matching for all cases.

Technique:

Group I (free LD flap):

Tow team worked simultaneously, one team started preparing for the recipient vessel away from trauma zone one artery, and two veins prepared; one vena commitant and one subcutaneous vein. The other team started LD muscle elevation and preparation. Once recipient vessel with good arterial flow was detected, the LD muscle flap was

separated and microvascular anastomosis was started under microscope; veins were anastomosed first then the artery. The muscle flap was in sited and tucked to the surrounding defect edge. Soft drain under the flap was routine in all cases. Postoperative flaps monitoring and IV heparin infusion 25 thousand units per 24 hours for 5 days. After 2 weeks all cases with viable flaps underwent split thickness skin graft 2ry procedures.

Group II (crossed leg flap):

In this group the flap size and dimensions was planned on the medial posterior tibial septal perforator about 1-2cm from the medial border of the tibia in its middle third. Flaps are raised as fasciocutaneous flaps involving not only posterolateral but also anterior compartmental tissue if needed. Flaps were in-sited covering most of the defect (about 75% of the defect) at time of surgery, the position was fixed with external fixator that was applied with orthopedic surgeons, and the donor site was covered with STSG harvested from the contralateral thigh. Tie over applied over graft in all case. After 3 to 4 weeks flaps separation done, enough skin was taken to cover the remaining defect.

Group III (medial/lateral septocutaneous perforator):

In this group, all patients are without history of degloving injury of the leg skin, a hand-held Doppler examination of the area were done to detect perforator/perforators with good signal near the defect, proposed flap was designed over the leg skin keeping in mind arc of rotation, pivot points from the defect in flap measurements.

Under loupe magnification through an exploratory incision, dissection done in the subfascial plan, the pre-detected perforators were explored and also other perforators were dissected. The largest nearer perforator was selected and the flap was readjusted over the selected perforator. Perforators were dissected from the surrounding deep fascia all around for few centimeters. The perforator flaps can be trans-positioned from 90 degree up to 180 degree as propeller flap. Traction, twisting, or kinking of the pedicle should be avoided. Soft drains are kept under the flap for 48 hours.

The donor site was covered by split thickness skin graft harvested from the contralateral thigh then tie over dressing was applied in all cases. Below knee POP slab applied to stabilize the foot and leg.

Postoperative flaps were monitored continuously, good hydration, leg elevations and antibiotics. Site and the flap covering the defect 3 month postoperative.

Statistical analysis:

Data were analyzed by Statistical Package of Social Science (SPSS), software version 22.0 (SPSS Inc., 2013). Continuous data were expressed as Mean ± SD, while the nominal data were presented by the frequency and percentage.

The one-way analysis of variance (ANOVA): Is used to determine whether there are any significant differences between the means of three independent groups. Least significance difference (LSD): It is one of the post hoc tests. It is used for multiple comparisons between groups. It was calculated at different probability values. *p*-value <0.05 considered significant.

RESULTS

There was no significant deference in patients' age among the three operated groups ($p>0.05$). The time relapsed from injury to surgery was significantly shorter in group I (8.91±4.55 days) than those of group II (20.46±10.88, $p<0.01$) and group III (19.22±11.72, $p<0.05$), but no significant deference could be detected between group II and group III ($p>0.05$). The operation time (hours) was significantly longer ($p<0.001$) in group I (6.55± 1.40) than those of group II (2.46±0.35) and group III (2.06±0.25), however, no significant deference could be detected between group II and group III ($p>0.05$).

Regarding flap size (Cm^2), free latissmus dorsi flap (group I) had a significant wider size (164.73 ±88.59) when compared with the size of cross leg flap (group II) (107.00±22.24, $p<0.05$) and medial septocutaenous perforator flap (group III) (50.78 ±26.21, $p<0.001$), moreover, group II had a significant wider size than that of group III ($p<0.05$). The wound healing time (weeks) was significantly rapid in group III (2.00±1.69) when compared to that of group I (4.32±0.96) and group II (4.88± 1.66) ($p<0.001$), but no significant difference could be detected between group I and group II concerning healing time ($p>0.05$).

The period of hospital stay (days) and follow-up period (months) were significantly shorter in group III (3.33±2.69 day, 10.77±5.85 month) when compared to that of group I (22.90±5.59, 16.64± 7.53) and group II (31.00±8.19, 15.62±4.15), however, no significant difference could be detected

between group I and group II regarding the period of hospital stay or follow-up period ($p>0.05$).

Secondary procedure in group I had done in all cases (100%) (10 patients operated by split thickness skin graft and Cross leg flap for one patient). In group II all patients obligatory had a flap separation after 3 weeks, moreover, one case needed further defatting and other had Debridement, reinsertion of flap. In group III: Only one case (9.09%) needed split thickness skin graft.

Donor site morbidity in group I (45.45% of cases); 3 cases got seroma, one needed debridement then reinsertion and one case got ugly scar. In group II: Only one case got ugly scar (7.5%). However, group III had no donor site morbidity (0%).

Complications or failure in group I occurred in 7 cases (63.63%): Marginal flap necrosis in 2 cases, Collection under the flap in 4 cases and Hematoma under the flap in 1 case. In group II: 4 cases (30.76%) were complicated by Partial flap dehiscence (3 cases) and Bulky flap (one case). In group III: 2 cases (22.22%) were complicated by Partial distal flap necrosis in one patient and sinus pouring seropurrulent in another patient who was treated by dressing and antibiotics.

Table (1): Statistical analysis of age (years), flap size (Cm^2), postoperative DASH score, cosmetic evaluation score and follow-up period (month) between the three operated groups (free latissmus dorsi flap, cross leg flap and medial/lateral septocutaenous perforator flap).

Parameters \ Groups	Free latissmus dorsi flap (group I)	Cross leg flap (group II)	Medial/lateral septocutaenous perforator flap (group III)
Age (year):		30.38±18.25	23.11±12.05
Mean ± SD	29.91±12.89	0.813**a**	0.399**a**, 0.275**b**
Time from injury to surgery/days:			
Mean ± SD	8.91±4.55	20.46±10.88	19.22±11.72
p-value		0.006**a**	0.022**a**, 0.766**b**
Operation time/hrs:			
Mean ± SD	6.55±1.40	2.46±0.35	2.06±0.25
p-value		<0.001**a**	<0.001**a**, 0.286**b**
Flap size (cm^2):			
Mean ± SD	164.73±88.59	107.00±22.24	50.78 ±26.21
p-value		0.015**a**	<0.001**a**, 0.025**b**
Healing time/weeks:			
Mean ± SD	4.32±0.96	4.88±1.66	2.00±1.69
p-value		0.264	<0.001**a**, <0.001**b**
Hospital stay/days:			
Mean ± SD	22.90±5.59	31.00±8.19	3.33±2.69
p-value		0.67**a**	<0.001**a**, <0.001**b**
Follow-up:			
Mean ± SD	16.64±7.53	15.62±4.15	10.77±5.85
p-value		0.676**a**	0.035**a**, 0.05**b**
Cosmetic evaluation:			
Mean ± SD	6.56±0.67	5.56±0.65	6.71±0.31
p-value		<0.001**a**	0.582**a**, <0.001**b**
Patient satisfaction:			
Mean ± SD	5.69±0.49	6.65±0.36	5.99±0.76
p-value		0.66**a**	0.007**a**, 0.002**b**

a = Versus group A. **b** = Versus group B.

Fig. (1): Pre operative soft tissue defect of lower leg and exposed fixation plate (A), Elevated LD flap (B) and after flap insetting in the soft tissue defect of lower leg (C).

Fig. (2): After Split thickness Theirsh graft on the LD flap (A &B), after healing of STTG (C&D).

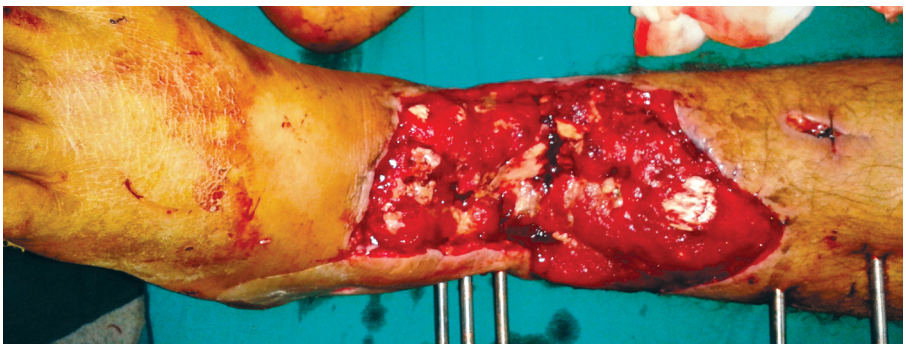

Fig. (3): A preoperative soft tissue defect of lower leg.

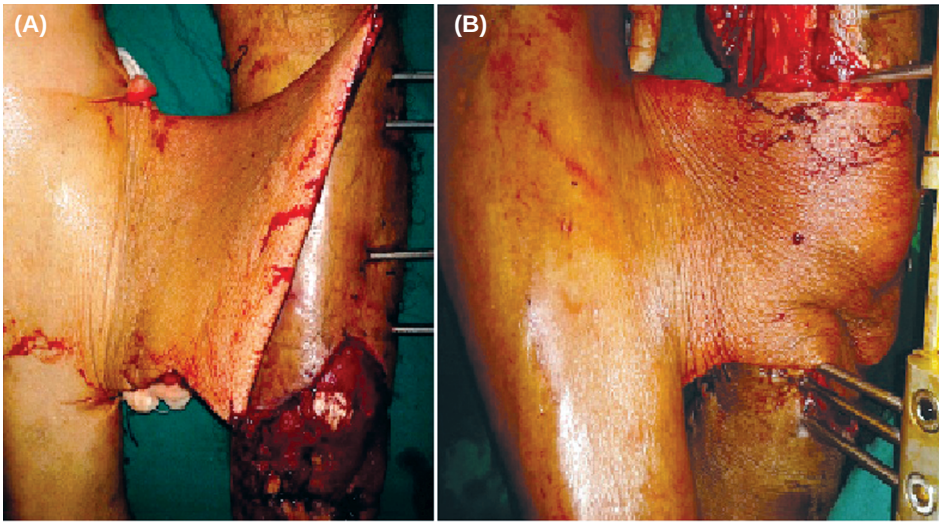

Fig. (4): Elevation of the cross leg flap (A), and In-setting of the cross leg flap (B).

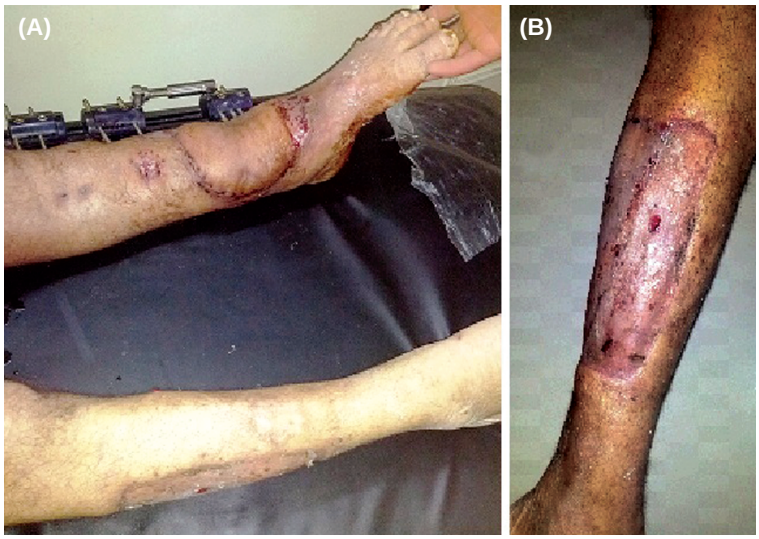

Fig. (5): After separation of the cross leg flap recipient site (A) and donor site (B).

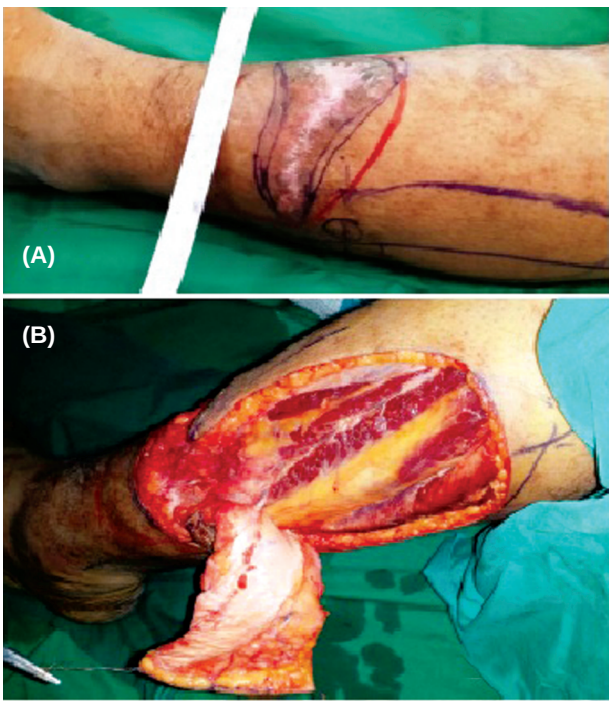

Fig. (6): Peroneal septal perforator preoperative drawing (A), peroneal septal perforator elevation (B&C).

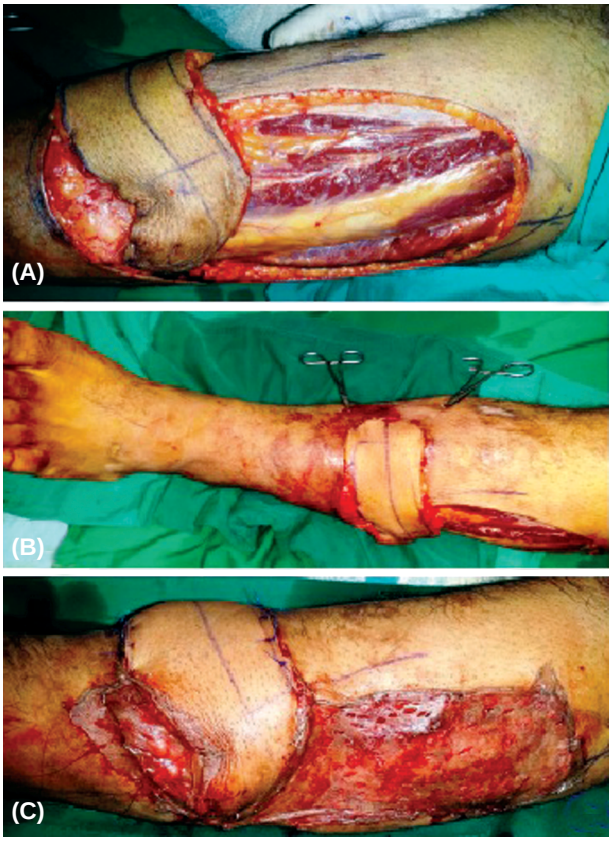

Fig. (7): Peroneal septal perforator in-setting (A&B) and Peroneal septal perforator flap skin grafting (C).

Fig. (8): Peroneal septal perforator flap after healing (A&B).

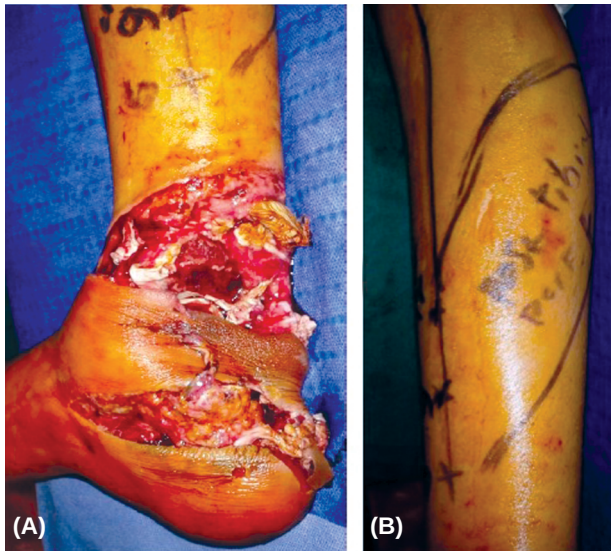

Fig. (9): Medial septal perforator preoperative defect (A) and Medial septal perforator flap drawing (B).

Fig. (10): Medial septal perforator flap elevation.

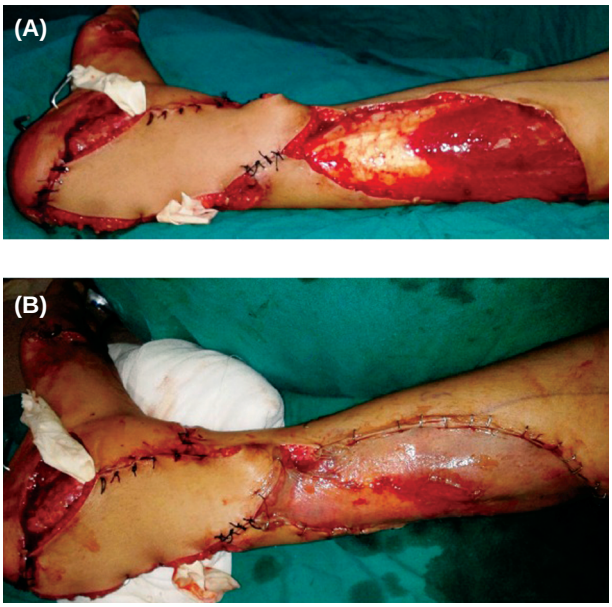

Fig. (11): Medial septal perforator flap in-setting (A) and medial septal perforator flap in-setting with skin graft (B).

Fig. (12): Medial septal perforator 3 weeks postoperative.

DISCUSSION

Lower one third of the leg is common to be injured. At this level most of soft tissue covering become insufficient even with moderate trauma the bone and deeper structures become exposed. The surrounding tissues are deficient enough to cover large defects; smaller to moderate size defect could be covered by using surrounding tissue flaps that depend on medial or lateral perforator. Perforator flap could be done supposed that no degloving skin injury.

Most of the patients in this study were males with mean age 27 years in all groups; the most common cause of the trauma was road traffic accidents. Most of the defects were at the distal one third of legs. The defect size in this study was ranged from 6x13cm to 14x30cm in group I, 7x11cm to 10x15cm in group II, and 4x5cm to 8x14cm in group III.

In this study flap size (Cm^2) the free latissmus dorsi flap (group I) had a significant wider size (164.73±88.59) when compared with the size of cross leg flap (group II) (107.00±22.24, $p<0.05$) and medial septocutaenous perforator flap (group III) (50.78 ±26.21, $p<0.001$), moreover, group II had a significant wider size than that of group III ($p<0.05$).

In spite of the different available options, free tissue transfer remains as one of important options for coverage of lower third leg defects. As free tissue transfer have advantages as it can cover large defect, it can be used in acute trauma by choosing recipient vessels away from the zone of injury, there is no additional scarring in the surrounding area, as what happen when local flaps are used, it has a higher success rate (could be as high as 98%) if planned well and finally according to the need of the defect the flap to be chosen, muscle flaps for cavities filling and skin flaps when surface defects are to be covered or there is a need for secondary procedures like bone grafting **[1]**.

Regarding the mean time (in days) between trauma and definitive coverage in this study was 9 days in group I, 20 days in group II, and 19 days in group III.

The challenge for the reconstructive surgeon is to match the original tissue properties if joint function and esthetic form are to be preserved. Free tissue transfer has been the traditional reconstructive modality in this region; however, microsurgical skill, specialized equipment, and resources required for these complex operations are not commonly available outside of tertiary care centers. Furthermore, tissue properties of some free flaps may not be ideal matches to the thin, supple fasciocutaneous tissue of the ankle region. Muscle flaps are associated with a loss of function, albeit often imperceptibly, as well as with inadequate reach in the distal lower extremity **[20,21]**.

Reconstruction with local fasciocutaneous flaps is an ideal option because it provides the closest

match to lost tissue in terms of skin color, durability, volume, and pliability. Local random pattern flaps are unreliable because of limited flap dimensions, a wide pedicle base restricting flap mobility, and relatively poor tissue laxity. There is an upward of 25% flap necrosis in single-stage distal lower extremity reconstruction utilizing the most robust random pattern flaps **[22].** It is well known that the free flap procedure needs a higher technical level of surgical expertise and more complex surgery **[23,24].**

Compared with a free flap, using a perforator-based propeller flap requires a simpler operation and shorter operating times, and can be performed without the staff expertise and complex logistical setup **[24].**

The use of a fibula osteoseptocutaneous flap provides good evidence of how peroneal artery perforator-based propeller flaps are a better option for skin harvesting of a larger area **[25].**

Furthermore, perforator-based propeller flaps offer versatility in terms of providing different shapes and sizes, and they can be easily retrieved from other parts of the body for covering small defects in the lower leg **[13,26]**.

Most importantly, this procedure ensures blood supply by avoiding the major blood vessels. In particular, its greater rotation versatility allows an easier distal lower leg soft tissue reconstruction. Detailed examination of the perforator-based propeller flap technique has shown it to be a highly reliable and the preferred surgical option for treating soft tissue defects of the lower leg **[27,28].**

It also provides a good cosmetic postoperative appearance. The traditional fasciocutaneous flap always has a skin bridge at the pedicle. Keeping the skin bridge at the base of a peninsular flap may in fact kink the pedicle, which might compromise the vascular supply of the flap. This makes flap rotation difficult and calls for the need to harvest a bigger flap **[29,30].**

The propeller flap always needs a skeleton of pedicle vessels, so that it can rotate freely from 0 to 180. Flap rotation will work successfully as long as the pedicle does not become tight after the flap rotation. Alternative local flaps are also used, such as the distally-based sural flap or the distally-based peroneus brevis flap **[31,32].**

Wounds that can to be covered by a peroneal perforator-based pedicle propeller flap can also be covered by both the distally based sural flap and the distally-based peroneus brevis flap; and these two flaps are easier to undertake surgically than the propeller flap at the pedicles of the flaps **[31,32,33].**

However, these two types of flaps produce 'dog ears' at the pedicle after flap rotation. It is evident that the bulky 'dog ears' of the traditional fasciocutaneous flap is visually unappealing and if the aesthetics of the leg are poor, then the operation would need to be performed again, especially if the ankle is distorted and wearing footwear is not possible. In this case, cosmetic surgery may also be necessary. Furthermore, application of the distally-based sural flap would damage the nerve, which then leads to sensation dysfunction **[34,35].**

In contrast, the peroneal perforator-based pedicle propeller flap does not damage the nerve **[26].**

In terms of post-operative complications, such as venous congestion, haematocele, infection, and skin grafting necrosis at the donor-site, the rates of these are similar for the distally-based sural flap, the distally-based peroneus brevis flap and the peroneal perforator-based pedicle propeller flap **[26,33,36-38].**

There are a number of disadvantages associated with using perforator-based propeller flaps. Unfortunately, venous congestion cannot be totally avoided during the propeller flap operation because the walls of the perforator vessels are more delicate compared with the perforator arterial wall and it is difficult to control venous wall damage after the 180 rotation of the pedicle **[39].**

Venous congestion can give rise to necrosis at the distal flap. After rotation of the flap, if the pedicle is pulled tightly it will lead to venous congestion. If the pedicle is not bared, the deep fascia around the pedicle will compress the vessels in the pedicle when the flap is rotated **[40].**

Venous congestion is one of the most difficult problems to deal with and constitutes one of the main reasons for flap necrosis **[37,38].**

A precise preoperative plan can reduce the rate of venous congestion **[41,42].**

The performance of the flap relies on: (i) the flap length; (ii) the pedicle size; and (iii) the rotation angle **[13].**

Since Taylor **[43]** introduced the concept of angiosomes, various techniques of perforator based local flaps in the leg have been developed **[44,45].**

Perforators from the three main arteries in the lower leg and found that those of the PTA were distributed evenly compared to the other two arteries. PTA perforators are found to be the largest of the lower leg and easier to dissect compared to the PAP. They are predominantly septocutaneous, arising from within the intermuscular septum between soleus and flexor hallucis longus **[14,46]**.

Ozdemir et al. **[46]** also performed comprehensive cadaver studies to conclude that distal lower leg is suitable for PTAPF elevation because PTA perforators are larger and concentrated in the lower leg and ankle region which they categorized zone I and II. Moreover, Jakubietz et al. **[47]** recently described that the PTA perforator was most favorable as source vessel due to its constant subfascial directionality, which is almost always about 90~100 degrees. The PTA perforators are connected in an axial network and this enables the surgeon to raise large flaps reported up to 19x13cm. **[49]**.

Cross-leg flaps have problem because of difficulties in immobilization and position fixation of the extremities from the time of initial coverage to detachment. The use of external fixator for immobilization facilitates many of these problems and helps the use of cross-leg flaps in patients in whom free flaps may not be optimal **[9,50]**.

Hafeez et al. **[51]** conducted their study on 24 patients with defects over the lower half of the leg. They covered these defects using a posterior tibial artery perforator island flap harvested from the medial aspect of the leg. The major etiology of soft-tissue defect was road traffic accident, which corresponds to our study.

For a long period of time cross-leg flaps were the only reconstructive option for the difficult areas of the distal leg and foot, with high success rates and minimal morbidity in expert hands. Cross leg flaps, however, are highly technique dependent, which explains the variable success rates described in the literature **[18,52]**. These flaps were described as being handicapped by the inherent problems of positioning and immobilization **[53]**, because of their short, thick and inextensible pedicles, awkward postures and bulky external fixation devices are invariably needed **[54,55]**.

In comparison to one-stage reconstruction using free flaps, cross-leg flaps require at least two surgical stages. Moreover, they do not augment the blood supply of the recipient defect. However, despite the widespread use of microsurgery in management of lower leg injuries, still the cross leg flaps have their role. However they have the disadvantage of prolonged immobilization and incidence of partial or total flap loss. Several modifications were published to overcome this incidence of failure by delaying the division of the flap or incorporating fascial extension in the flap **[55,56]**.

In conclusion:

flap coverage for lower one third leg defect is difficult question to answer, a lot of flaps could be used each method has its pros and cons, perforator flap is easy and versatile with learning curve it can be used for small to moderate size defects, cross leg flap remain as easy and versatile flap and can be used as backup plan for other methods, free LD flap provide large flap size used for large defects.

Conflict of interests: The authors declare no Conflict of interests.

REFERENCES

1- Bajantri B., Bharathi R.R. and Sabapathyindian S.R: Wound coverage considerations for defects of the lower third of the leg. J. Plast. Surg., 45 (2): 283-290, 2012.

2- Pu L.L.: Medial hemisoleus muscle flap: A reliable flap for soft tissue reconstruction of the middle-third tibial wound. Int. Surg., 91: 194-200, 2006.

3- Pu L.L.: Soft-tissue reconstruction of an open tibial wound in the distal third of the leg: A new treatment algorithm. Ann. Plast. Surg., 58: 78-83, 2007.

4- Georgescu A.V. and Ivan O.: Emergency free flaps. Microsurgery, 23: 206-16, 2003.

5- Levin L.S.: Foot and ankle soft-tissue deficiencies: Who needs a flap? Am. J. Orthop. (Belle Mead NJ), 35: 11-9, 2006.

6- Rad A.N., Singh N.K. and Rosson G.D.: Peroneal artery perforator-based propeller flap reconstruction of the lateral distal lower extremity after tumor extirpation: Case report and literature review. Microsurgery, 28: 663-670, 2008.

7- Baden J.M., Warr R.P. and Khan U.: Immediate free tissue transfer for coverage of Achilles tendon injury or reconstruction. Foot Ankle Surg., 16: 164-169, 2010.

8- Smit J.M., Darcy C.M., Audolfsson T., Hartman E.H. and Acosta R.: Multilayer reconstructions for defects overlying the Achilles tendon with the lateral-arm flap: Long-term follow-up of 16 cases. Microsurgery, 32: 438-444, 2012.

9- Schaverien M.V., Hamilton S.A., Fairburn N., Rao P. and Quaba A.A.: Lower limb reconstruction using the islanded posterior tibial artery perforator flap. Plast. Reconstr. Surg., 125: 1735-1743, 2010.

10- Blondeel P.N., Van Landuyt K., Monstrey S.J., Hamdi M., Matton G.E., Allen R.J., Dupin C., Feller A.M., Koshima I., Kostakoglu N. and Wei F.C.: The "Gent" consensus on perforator flap terminology: Preliminary definitions. Plast. Reconstr. Surg., 112: 1378-1382, 2003.

11- Kansal S., Goil P., Agarwal V., Agarwal S., Mishra S., Agarwal D. and Singh P.: Reverse pedicle-based greater saphenous neuro-venofasciocutaneous flap for reconstruction of lower leg and foot, Eur. J. Orthop. Surg. Traumatol., 24: 67-72, 2014.

12- Georgescu A.V., Capota I., Matei I., Ardelean F., Avram A., Ignatiadis I. and Olariu O.: The place of local/regional perforator flaps in complex traumas of the forearm. J. Hand Microsurg., 1: 25-31, 2009.

13- Pignatti M., Ogawa R., Hallock G.G., Mateev M., Georgescu A.V., Balakrishnan G., Ono S., Cubison T.C., D'Arpa S., Koshima I. and Hyakusoku H.: The "Tokyo" consensus on propeller flaps. Plast. Reconstr. Surg., 127: 716-722, 2011.

14- Gir P., Cheng A., Oni G., Mojallal A. and Saint-Cyr M.: Pedicled-perforator (propeller) flaps in lower extremity defects: A systematic review. J. Reconstr. Microsurg., 28: 595-601, 2012.

15- Nelson J.A., Fischer J.P., Brazio P.S., Kovach S.J., Rosson G.D. and Rad A.N.: A review of propeller flaps for distal lower extremity soft tissue reconstruction: Is flap loss too high? Microsurgery, 33: 578-586, 2013.

16- Ahmad I., Akhtar S., Rashidi E. and Khurram M.F.: Hemisoleus muscle flap in the reconstruction of exposed bones in the lower limb. J. Wound Care, 22: 635, 638-40, 642, 2013.

17- Georgescu A.V., Irina C. and Ileana M.: “Cross-leg tibial posterior perforator flap”, Microsurgery, 27 (5): 379-383, 2007.

18- Agarwal P. and Raza H.K.T.: “Cross-leg flap: Its role in limb salvage”, Indian Journal of Orthopaedics, 42 (4): 439-443, 2008.

19- Calhoun J.H., Gogan W.J., Beraja V., Howard R.J. and Oliphant J.R.: Dynamic axial fixation for immobilization of cross-leg flaps in chronic osteomyelitis. Ann. Plast. Surg., 23: 354-356, 1989.

20- Quaba O. and Quaba A.: Pedicled perforator flaps for the lower limb. Semin Plast. Surg., 20: 103-111, 2006.

21- Kamath B.J., Joshua T.V. and Pramod S.: Perforator based flap coverage from the anterior and lateral compartment of the leg for medium sized traumatic pretibial soft tissue defects-A simple solution for a complex problem. J. Plast. Reconstr. Aesthet. Surg., 59: 515-520, 2006.

22- Almeida M.F., da Costa P.R. and Okawa R.Y.: Reverse-flow island sural flap. Plast. Reconstr. Surg., 109: 583-591, 2002.

23- Pinsolle V., Reau A.F., Pelissier P., et al.: Soft tissue reconstruction of the distal lower leg and foot: Are free flaps the only choice? Review of 215 cases. J. Plast. Reconstr. Aesthet. Surg., 59: 912-917, 2006.

24- Jakubietz R.G., Jakubietz D.F., Gruenert J.G., et al.: Reconstruction of soft tissue defects of the Achilles tendon with rotation flaps, pedicled propeller flaps and free perforator flaps. Microsurgery, 30: 608-613, 2010.

25- John J.R., Tripathy S., Sharma R.K., et al.: Peroneal artery perforator-based flaps for reconstruction of middle and lower third post-traumatic defects of the leg. ANZ J. Surg., 85: 869-872, 2015.

26- Lu T.C., Lin C.H., Lin C.H., et al.: Versatility of the pedicled peroneal artery perforator flaps for soft-tissue coverage of the lower leg and foot defects. J. Plast. Reconstr. Aesthet. Surg., 64: 386-393, 2011.

27- Pignatti M., D'Arpa S. and Cubison T.C.S.: Novel fasciocutaneous flaps for the reconstruction of complicated lower extremity wounds. Techniques in Orthopedics, 24: 88-95, 2009.

28- Chang S.M., Tao Y.L. and Zhang Y.Q.: The distally perforator-pedicled propeller flap. Plast. Reconstr. Surg., 128: 575e-577e, 2011.

29- Zhang F.H., Chang S.M., Lin S.Q., et al.: Modified distally based sural neuro-veno-fasciocutaneous flap: Anatomical study and clinical applications. Microsurgery, 25: 543-550, 2005.

30- Chai Y., Zeng B., Zhang F., et al.: Experience with the distally based sural neurofasciocutaneous flap supplied by the terminal perforator of peroneal vessels for ankle and foot reconstruction. Ann. Plast. Surg., 59: 526-531, 2007.

36- Ono S., Sebastin S.J, Yazaki N., et al.: Clinical applications of perforator-based propeller flaps in upper limb soft tissue reconstruction. J. Hand Surg. Am., 36: 853-863, 2011.

37- Innocenti M., Menichini G., Baldrighi C., et al.: Are there risk factors for complications of perforator-based propeller flaps for lower-extremity reconstruction? Clin. Orthop. Relat. Res., 472: 2276-2286, 2014.

38- de Blacam C., Colakoglu S., Ogunleye A.A., et al.: Risk factors associated with complications in lower-extremity reconstruction with the distally based sural flap: A systematic review and pooled analysis. J. Plast. Reconstr. Aesthet. Surg., 67: 607-616, 2014.

39- Wong C.H., Cui F., Tan B.K., et al.: Nonlinear finite element simulations to elucidate the determinants of perforator patency in pro-peller flaps. Ann. Plast. Surg., 59: 672-678, 2007.

40- Selvaggi G., Anicic S. and Formaggia L.: Mathematical explanation of the buckling of the vessels after twisting of the micro-anastomosis. Microsurgery, 26: 524-528, 2006.

41- Teo T.C.: The propeller flap concept. Clin. Plast. Surg., 37: 615-626, 2010.

42- Higueras Suñé M.C., López Ojeda A., Narvaéz García J.A., et al.: Use of angioscanning in the surgical planning of perforator flaps in the lower extremities. J. Plast. Reconstr. Aesthet. Surg., 64: 1207-1213, 2011.

43- Taylor G.I.: The angiosomes of the body and their supply to perforator flaps. Clin. Plast. Surg., 30: 331-42, 2003.

44- Venkataramakrishnan V., Mohan D. and Villafane O.: Perforator based V-Y advancement flaps in the leg. Br. J. Plast. Surg., 51: 431-5, 1998.

45- Lees V. and Townsend P.L.: Use of a pedicled fascial flap based on septocutaneous perforators of the posterior tibial artery for repair of distal lower limb defects. Br. J. Plast. Surg., 45: 141-145, 1992.

46- Whetzel T.P., Barnard M.A. and Stokes R.B.: Arterial fasciocutaneous vascular territories of the lower leg. Plast. Reconstr. Surg., 100: 1172-83, 1997.

47- Ozdemir R., Kocer U., Sahin B., Oruc M., Kilinc H. and Tekdemir I.: Examination of the skin perforators of the

posterior tibial artery on the leg and the ankle region and their clinical use. Plast. Reconstr. Surg., 117: 1619-1630, 2006.

48- Jakubietz R.G., Schmidt K., Zahn R.K., Waschke J., Zeplin P.H., Meffert R.H., et al.: Subfascial directionality of perforators of the distal lower extremity: An anatomic study regarding selection of perforators for 180-degree propeller flaps. Ann. Plast. Surg., 69: 307-311, 2012.

49- Heymans O., Verhelle N. and Peters S.: The medial adiposofascial flap of the leg: Anatomical basis and clinical applications. Plast. Reconstr. Surg., 115: 793-801, 2005.

50- Velazco A., Fleming L.L. and Nahai F.: Soft-tissue reconstruction of the leg associated with the use of the Hoffmann external fixator. J. Trauma, 23: 1052-7, 1983.

51- Hafeez K., Siddiqui A., Haroon-ur-Rashid C.S.I. and Cheema T.A.: The posterior tibial island flap for coverage in complex injuries of the lower extremity. Microsurgery, 32: 539-545, 2012.

52- Morris A.M. and Buchan A.C.: The place of the cross leg flap in reconstructive surgery of the lower leg and foot: A review of 165 cases. Br. J. Plast. Surg., 31: 138, 1978.

53- Dawson R.L.: Complications of the cross-leg flap operation. Proc. R. Soc. Med., 65: 626, 1972.

54- Arnander C., Eriksson G., Korlof B. and Nylen B.: Transfixation in cross-leg procedures using Hoffman's instruments: Report of forty-two cases. Scand. J. Plast. Reconstr. Surg., 9: 68, 1975.

55- Khaled S. Farag Z.M., Ali A., and Abdel Rohman Y.M.: Staged Division of Cross-Leg Flap to Enhance Flap Viability by Increasing its Contact with the Reconstructed Bed Egypt, J. Plast. Reconstr. Surg., 34 (1): 49-54, 2010.

56- Georgescu A.V., Matei I., Ardelean F. and Capota I.: Microsurgical nonmicrovascular flaps in forearm and hand reconstruction. Microsurgery, 27: 384-394, 2007.