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ORIGINAL ARTICLE**Reliability of keystone Perforator Based Flap for Reconstruction of Leg Defects****Ahmed M Aboelnaga^{1*}, Alshaimaa H Subh², Mohamed A AlBadawy³, Amr A Gomaa⁴**¹ Lecturer of Plastic Surgery, Faculty of Medicine, Suez Canal University² M.B.B.Ch. (2011), Faculty Medicine, Tripoli University, Tripoli, LIBYA³ Professor of Plastic Surgery and Burns, Faculty of Medicine, Suez Canal University⁴ Lecturer of Plastic Surgery, Faculty of Medicine, Suez Canal University**Correspondence to:**

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ABSTRACT

Background: In reconstructive surgery, the perforator flap procedure represents a revolutionary technique that allows more complex reconstruction with less invasive dissection. The trapezoidal-shaped keystone island flap has a unique design that involves two linked V-Y island flaps. Linking both concepts allows greater tissue advancement with a more reliable blood supply.

Objectives: the aim of this study is to determine the feasibility and safety of keystone island perforator flaps in managing various lower limb defects.

Patients and Methods: Patients who presented to the plastic surgery department at the Suez Canal University Hospital with leg defects were the subject of a planned cross-sectional study. 15 patients were included in the study; 10 (66.67%) men and 5 (33.33%) women had soft tissue leg defects. preoperative assessment of Patients includes a detailed medical history, Defect site and characteristics were also evaluated.

Results: In our study, the defects lengths had a minimum of 1 cm and a maximum of 5 cm. Moreover, defects widths had a maximum of 7 cm and a minimum of 1 cm. All were situated in the middle third of the leg. Thirteen patients did not show any complications and the 2 remaining showed one or more complications (Congestion, Partial loss, Total loss, Collection, hematoma or Infection). The descriptive statistics of the Scar Q score and its constituents were as follow Body (20.07 ± 3.73), Appearance (41.67 ± 15.56), Symptom scale (42.13 ± 12.68) and Psychosocial (43.73 ± 14.66). The body component of the score had the lowest mean score.

Conclusion: The keystone perforator flap offers a durable coverage, reduces the need for microsurgical procedures, and shortens the length of the operation. It is a simple and safe solution for covering a variety of limb deformities with the least amount of morbidity.

Keywords: Perforator flap- Keystone flap- reconstructive surgery

**INTRODUCTION**

The basic objectives of reconstruction are the preservation of life, limb and the restoration of shape and function⁽¹⁾. the perforator flap procedure involves mobilization of skin and/or subcutaneous fat from a distant or nearby portion of the body in order to restore the deficient part. The arterial supply of the flap comes from a deep vascular system through perforator vessels crossing either through muscle or intermuscular septa^(2,3).

The main advantages of perforator flaps are underlying muscle preservation, less donor site morbidity, decreased operative times, and better aesthetic result by supplying "like with like." The keystone perforator is a single flap based on multiple perforators, with better outcomes for large defects, while avoiding free tissue transfer

reconstruction with shorter operative times, less postoperative pain, less length of hospital stay, and is ideal for patients with multiple comorbidities. Design of the flap and orientation of the skin paddle should be in the same direction as the linking vessels, which are axial in the extremities and perpendicular to the midline in the trunk^(4,5).

In 2003, the keystone island flap concept as the keystone design perforator island flap was first published. Described as a curvilinear shaped trapezoidal design flap, it fits well into body contours. Since that time, it has been used extensively for wound closure in various regions of the body. The ease of use, short operative time, minimal morbidity, reliable healing and avoidance of costly and morbid free-flap reconstruction in our aging population has led to an explosion in the

use of this technique in recent years ^{4,5,6}, the original description of this flap is based on random fasciocutaneous perforators with its viability supported by the nearby subcutaneous vascular network and fascial and muscular perforators. Performing the keystone flap offers similar easy rearrangement of local tissues ⁷.

Therefore, the purpose of this study was to evaluate the safety and practicability of using the keystone island flap based on sizable local perforator to treat diverse lower limb defects.

PATIENTS AND METHODS

Patients who presented to the plastic surgery department at the Suez Canal University Hospital with leg defects were the subject of a planned cross-sectional study. Before carrying out any procedures, the patients signed written informed consent, which was approved by the Suez Canal University Faculty of Medicine's clinical research ethics committee.

Methods

In our study, patients underwent a history-taking process that included gathering information on their demographics, medical history, comorbidities, and surgical indications. Defect type, site and dimensions were also evaluated.

Surgical technique

The defect is shaped to be elliptical, indicating the flap's inner edge, then using a hand held Doppler searching for a sizable perforator with a good signal intensity trying this process in either sides of the defect with priority to the side with good skin laxity and skin condition and trying to locate the perforator into the flap center ,then two lines that are parallel to the inner edge make up the lateral edges. With a 1:1 ratio between the widths of the flap and the defect, the outer edge parallels the inner one. After the skin has been incised, the fibrous subcutaneous septa are delicately divided by blunt dissection in order to preserve as much of the deep veins and nerves as well as the subcutaneous arteries and veins as feasible. On the flap's lateral and exterior borders, the process is the same. After hemostasis, the defect is closed using approximate mattress sutures, each end of which is positioned in alignment with the VY apposition. This is an illustration of a type I keystone flap. To allow for proper flap advancement, the lateral deep fascia margin may be left whole (type I) or separated (type II). If there is excessive tension, the donor site is either largely closed (type IIA) or skin is grafted (type IIB). A continuous running 3/0 absorbable or non-absorbable suture is used to seal the flap borders . flffy dressing is applied leaving a window for flap monitoring

Postoperative Surgical Considerations

it was essential to immobilize the wound site. A graft's vascular bed may be separated by sliding or direct pressure. Splinting, limited motion, bolster dressing used to secure the graft. pinning, or external fixation were only used for patients with associated fractures. Postoperative prophylactic antibiotics and a sterile wound dressing are necessary to avoid infection-related skin transplant loss.

Postoperative flap monitoring strategy used was manual monitoring by follow up of flap skin color, temperature and capillary refill every couple of hours on the first 24 hours. if congestion detected ,sutures or staples was removed to relieve the congestion if congestion was not relieved patient was transferred to the operative theatre for exploration of the wound bed searching for hematoma .medicinal leech used as adjunctive procedure to relieve flap congestion . if the donor site is grafted the first graft dressing was after five days . the patients were discharged to follow up on outpatient basis on a weekly basis using Patient and Observer scar assessment scale (POSAS) Score for assessment of postoperative scar assessment.

STATISTICAL ANALYSIS

Statistical Package for the Social Sciences (SPSS Inc. Chicago) Version 20 was used to analyse the data. To compare various traits, two sample independent group t-tests were run. A Pearson correlation coefficient and the chi-square test were applied. The association between the dependent and independent variables was evaluated using multivariate logistic regression analysis with the forward inclusion and backward deletion approach.

RESULTS

Our participants included 15 Patients, 10 (66.67%) males and 5 (33.33%) females presented with soft tissue leg defects, Soft tissue defects are due to trauma, post skin lesion excision, burn or chronic ulcers or patients presented with traumatic leg defects that are close to audible perforator. **Table 1**

Regarding comorbidities, we reported seven patients were suffering from chronic illnesses. Four of the patients were active smokers. Changes in flap dimensions occurred in only one patient.

Figure 2

In our study, the defects lengths had a minimum of 1 cm and a maximum of 5 cm. Moreover, defects widths had a maximum of 7 cm and a minimum of 1 cm. All were situated in the middle third of the leg. Lengths and widths of the lesions/defects were of statistical significance

against their respective means unlike the areas' means. Operation's duration was never below 1-hour but less than 3 hours. **Table 2**

In our results, nearly half of the patients had their flaps from around the posterior tibial perforator and the rest had their flaps from around the peroneal artery perforator. Maximum flap area was 32 cm² and the maximum length and width of the flap were 4 cm and 8 cm, respectively. **Table 3**

Regarding The Patient and Observer Scar Assessment Scale (POSAS) Observer scale and its constituents were as follow: Vascularity (4.67 ± 2.41), Pigmentation (4.33 ± 2.23), Relief/texture (5.2 ± 2.18), Thickness (5.4 ± 2.35), Pliability (5 ± 2.67) Surface, (5.73 ± 2.34) and Overall opinion (5.06 ± 1.92). Mean scores were almost all around 5. It is worth mention that only one case did not show good scores. There were significant relations of the actual means of the components of the score to their respective variables' samples. **Figure 3**

The descriptive statistics of the POSAS Patient scale and its constituents were as follow: Pain(3.33 ± 2.29), Itching(4 ± 2.2) ,Color difference, (3.67 ± 1.99) , Stiffness(3.2 ± 1.93) , Thickness(4.13 ± 1.19), Irregularity(4.87±1.88) and Overall(3.67 ± 2.26) Mean scores were situated around 3 and 4 points. **Figure 4**

The descriptive statistics of the Scar Q score and its constituents were as follow Body (20.07 ± 3.73), Appearance (41.67 ± 15.56), Symptom scale (42.13 ± 12.68) and Psychosocial (43.73 ± 14.66). The body component of the score had the lowest mean score. **Table 4**

As regarding complications that occurred within the study population, there was a statistically significant difference regarding the distribution of complications among the study's population. Thirteen patients did not show any complications and the 2 remaining showed one or more complications (Congestion, Partial loss, Total loss, Collection, hematoma or Infection). **Table 5**

Table 1: Gender distribution among study population

Attribute	n (%)
Male	10 (66.67)
Female	5 (33.33)
Total	15 (100)
Chi-squared test p-value = 0.198	

Table 2: Dimensions of defects/lesions

Variable	Mean ± SD	p-value	Median	Maximum	Minimum
Defect length (cm)	1.7 ± 1.35	<0.001	1.19	5.00	1.00
Defect width (cm)	1.76 ± 1.52	0.001	1.26	7.00	1.00
Defect area (cm ²)	4.65 ± 9.09	0.067	1.51	35.00	1.07
One-sample t-test					

Table 3: Anatomical sources of flaps

Source	N (%)
Peroneal artery perforator	8 (53.33)
Posterior tibial perforator	7 (46.67)
Total	15 (100)
Chi-squared test p-value = 0.796	

Table 4: Scar Q score constituents

Variable	Mean ± SD	p-value	Median	Maximum	Minimum
Body	20.07 ± 3.73	<0.001	19.00	25.00	15.00
Appearance	41.67 ± 15.56	<0.001	37.00	80.00	27.00
Symptom scale	42.13 ± 12.68	<0.001	40.00	70.00	28.00
Psychosocial	43.73 ± 14.66	<0.001	38.00	77.00	31.00

Table 5: Complications distribution among study population

Complication	Yes (n (%))	No (n (%))
None	13 (86.67)	2 (13.33)
Congestion	2 (13.33)	13 (86.67)
Partial loss	1 (6.67)	14 (93.33)
Total loss	1 (6.67)	14 (93.33)
Collection (haematoma)	2 (13.33)	13 (86.67)
Infection	1 (6.67)	14 (93.33)
Fisher's exact test's p-value = <0.001		

Figure 1 showing classification of keystone island perforator flap. Adopted from ¹

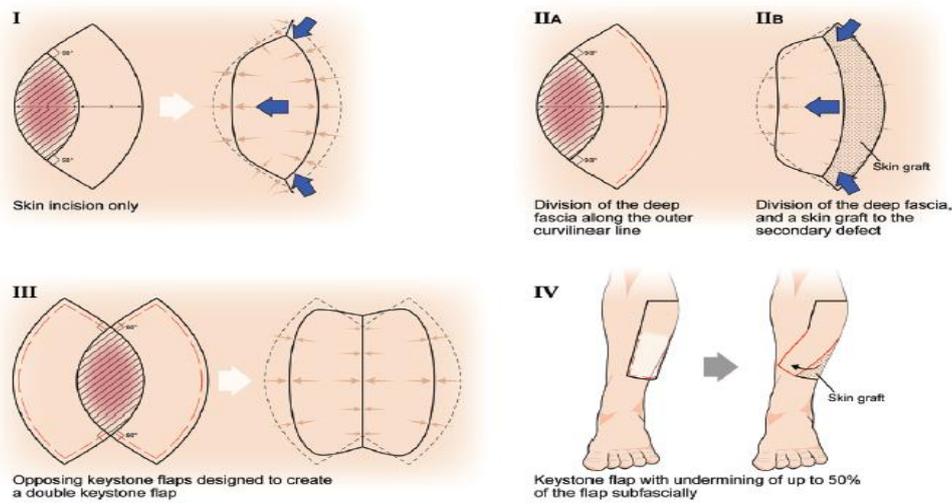


Figure 2: Comorbidities distribution among study population

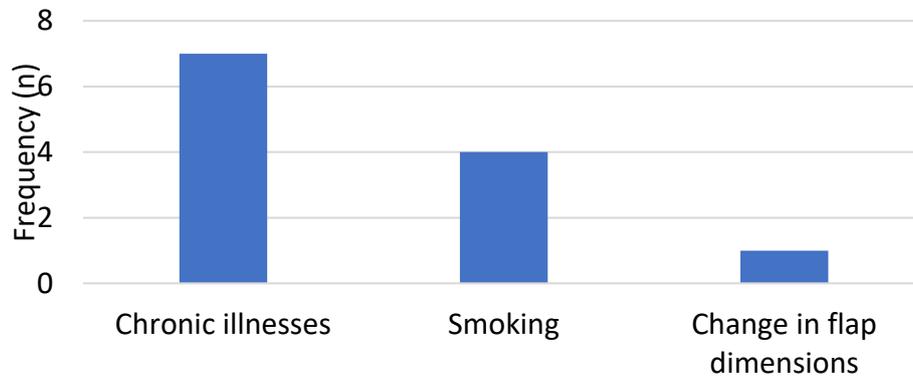


Figure 3: POSAS Observer score constituents distribution among study population

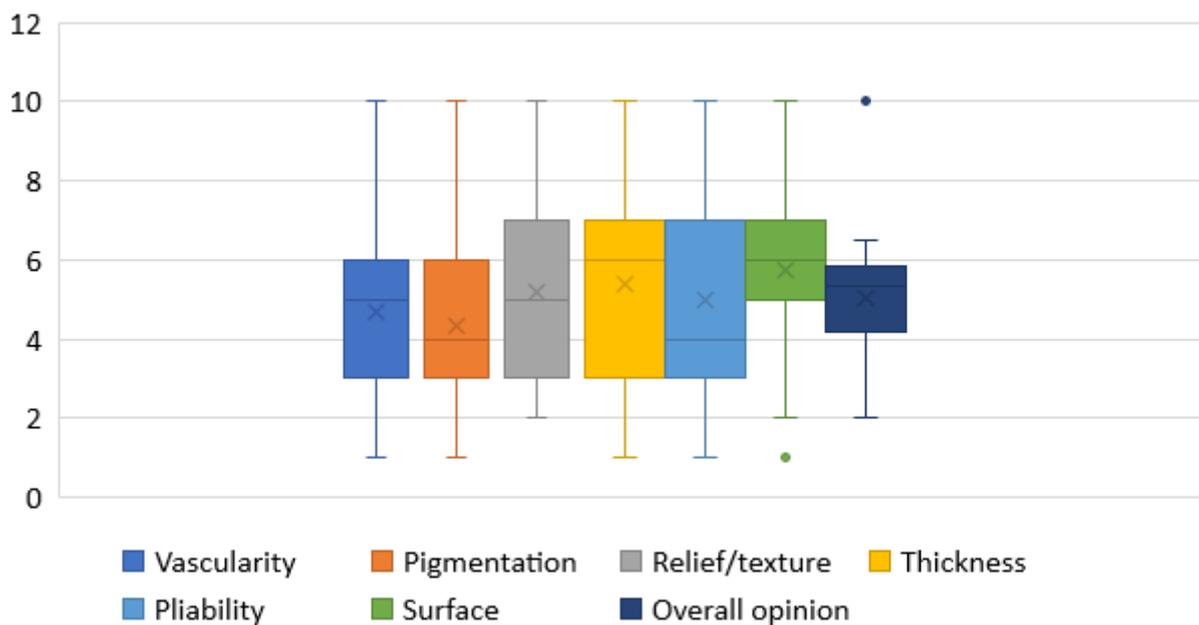


Figure4: POSAS score constituents distribution among study population

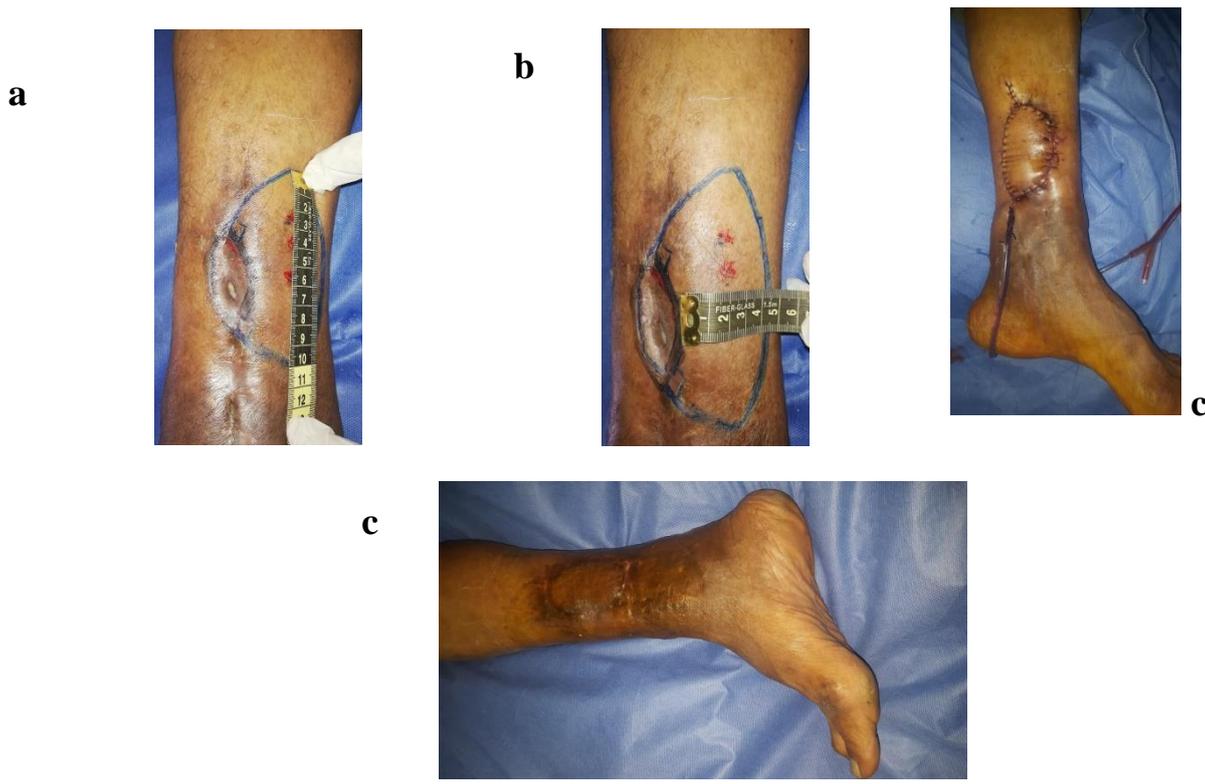
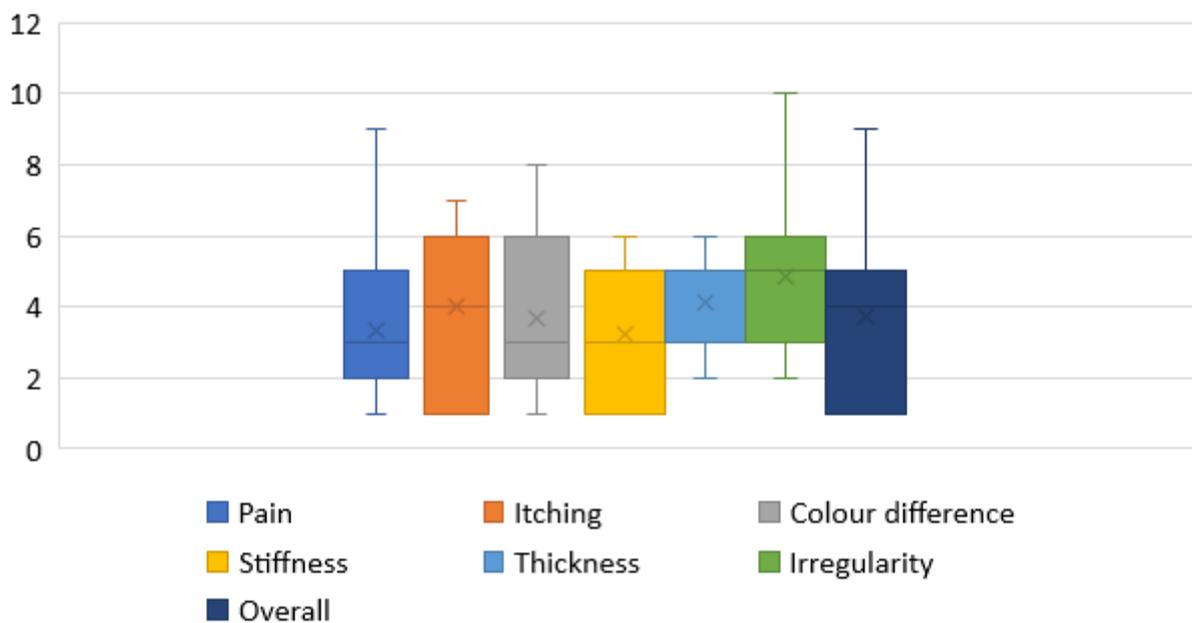


Fig 5: A 53-year-old male patient presented with osteomyelitis with a septic focus. Patient was hypertensive. Keystone flap was implanted.

(a, b) pre operation keystone island flap mark out on peroneal perforators by audible Doppler ultrasound, (c) Intra-op Direct closure with strategic simple sutures with radivac, (d) three-months post-operatively during our follow up without bulky and no skin color change.

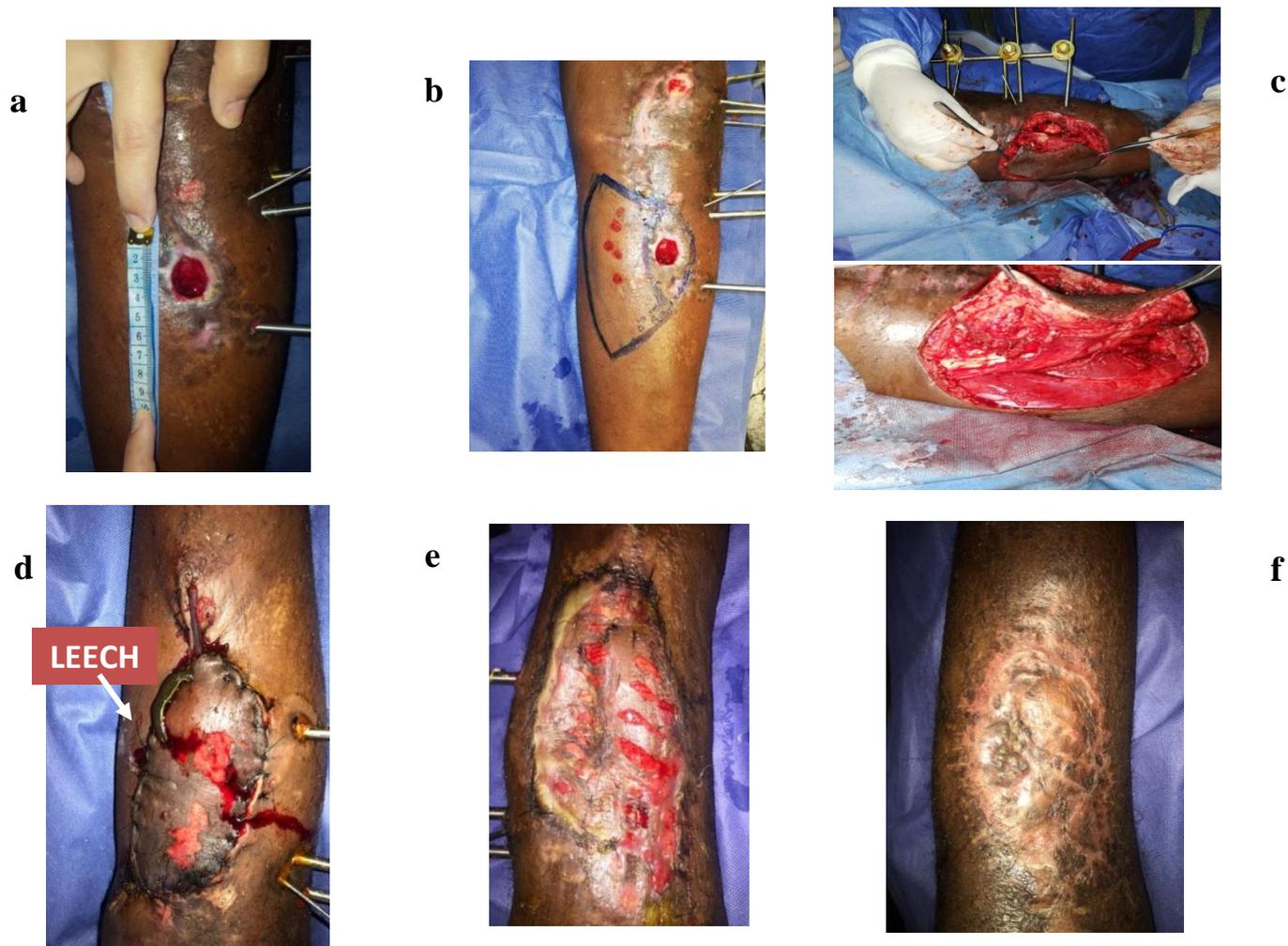


Fig 6: A 27-year-old male patient who undergone a road-traffic accident, and had external fixation. He had exposed bone and raw area. Six-hours post-operatively, the keystone flap appeared cyanosed. Medical leeches were applied, but there was loss of a small area from upper of the flap. Split-thickness skin graft was done later-on.

(a, b) Pre-operative keystone island flap mark out 3×2 cm² in diameter on peroneal perforators by audible Doppler ultrasound, (c) Intra-op dividing fascia V-Y flaps at angle to each other directed into defect to closed completely with preservation of superficial peroneal nerve, (d) Six-hours post-operative appearance started congestion was treated with Leech, (e) 1st month post-operatively partially loss and treated by split thickness skin graft, (f) 3-months post-operatively.

DISCUSSION

This study was designed as a cross sectional study on patients with leg defects. We aimed in this study to determine the feasibility and safety of keystone island flap in managing various limb defects.

Our participants included 15 Patients, 10 males and 5 females their ages ranged from 17 to 54 years with mean ages of 36.4 years presented with soft tissue leg defects, Soft tissue defects are due to trauma, post skin lesion excision, burn or chronic ulcers or patients presented with traumatic leg defects that are close to audible perforator. Comparing to our study, Rao and Janna, 2015, twenty patients had been included in their study. Ages of the patients were ranging from 18 to 65 y with an average of 38.75 y; similarly to our study

gender distribution was of no statistically significance in study¹.

In our study, we had 15 flaps, risk factors were present in 4 flaps m of which only one had total loss which treated by major intervention. While In Bhat, 2013 who had of the successful 53 flaps, risk factors were present in 31 flaps, of which five had some complication. One patient was the only to had complication that needed a major intervention⁸.

We observed in our study that 7 cases had chronic illness (46%) (diabetes mellitus and hypertension), smoking was in 4 cases (26%) and flap dimensions change was in 2 cases (13%), while Rao and Janna, 2015 observed in their study that fourteen cases in their series had distinct risk factors like smoking (30%), diabetes (25%) and radiation therapy (15%).¹.

In our results, nearly half of the patients had their flaps from around the posterior tibial perforator and the rest had their flaps from around the peroneal artery perforator. Maximum flap area was 32 cm² and the maximum length and width of the flap were 4 cm and 8 cm, respectively. Comparing to this finding in our study, Yoon et al., 2017 who made size of the final post debridement defect in the upper pretibial area from 48 cm² and this is a large size compared to our study, they performed reconstruction using anterior tibial artery perforators. The donor site was closed using a split-thickness skin graft after tension-free in setting of the flap. In comparison to Yoon et al., 2017, we had small size defects post debridement, and our flaps covered all defects size and wounds of adjacent flaps closed by primary simple sutures⁹.

In our study, we observed that defects lengths had a minimum of 1 cm and a maximum of 5 cm. Moreover, defects widths had a maximum of 7 cm and a minimum of 1 cm. All were situated in the middle third of the leg. We found that keystone accomplished wound closure and with primary simple sutures without tension and bulky.

In comparison to our study, Measurements performed by Donovan et al., 2018 who performed the release of the posterior fascia along the greater arc of the keystone provided the largest drop in tension. In contrast to our study they found no biomechanical benefit of the keystone flap and were unable to close “enclosable wounds,” and found the keystone to be able to facilitate closure of wounds that could not be closed primarily¹⁰. Our results support the benefit of the keystone in accomplishing wound closure.

In our observations, we found that two patients had temporary Congestion treated with leeches, Partial loss treated with leeches and Split-thickness skin graft, Total loss treated with Split-thickness skin graft, hematoma treated with evacuation and medical treatment or Infection. Similarly, Rao and Janna, 2015, found in their study that there was one instance of partial flap necrosis (6%) and one total flap loss (6%). Both of these cases were salvaged with a split skin graft. Two patients (1.1%) developed cellulitis that required admission for intravenous antibiotics, and one patient (.6%) developed a deep-vein thrombosis. In comparison to Rao and Janna, 2015, our study we had not cellulitis and deep vein thrombosis and we used leeches in treating temporary congestion, but Rao and Janna did not use leeches¹.

In our observation, we found the POSAS Observer scale and its constituents were almost all around 5 and the POSAS Patient scale and its constituents were around 3 and 4 points. It is worth mention that only one case did not show good scores. There were significant relations of the actual means of the components of the score to their respective variables' samples. Similar results in Dobbs et al., 2018, who showed that statistically, the keystone flap is aesthetically and functionally preferable, with the observer component of the POSAS demonstrating a significantly lower score in the keystone group¹¹.

In our study, we observed the association between source of flap and final fate; we found the two of the peroneal artery flaps showed failure as a final fate. The rest of the peroneal artery flaps and the posterior tibial flaps showed final success and thus we concluded that peroneal perforators are a week compared to posterior tibial perforators. As Fate after follow-up, there was a failure of 2 flaps one was lost completely and the other was partially lost.

CONCLUSION

Keystone flap provides a sensitive cover, reduces the need for microsurgical procedures, and shortens the length of the operation. It is a simple and safe solution for covering a variety of limb abnormalities with the least amount of morbidity. A common technique for treating big soft-tissue lesions in the trunk and extremities is the keystone island flap. Large volumes of soft tissue can now be transferred for reconstruction using keystone flaps, which also reduce donor site morbidity, avoid technically demanding microsurgical free flap reconstruction, produce superior aesthetic results, require less postoperative observation, reduce patient-reported pain, and shorten hospital stays.

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