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KEYSTONE ISLAND FLAP FOR RECONSTRUCTION OF ANTERIOR LOWER LIMB DEFECTS: AN INSTITUTIONAL EXPERIENCE

Plastic Surgery

Dr Shanoo Agarwal* 3rd year resident, Department of Plastic Surgery, S. M. S. Medical College, Jaipur, Rajasthan, India *Corresponding Author

Prof. Dr Pradeep Goil Professor and Unit Head , Department of Plastic Surgery, S. M. S. Medical College, Jaipur, Rajasthan, India

Dr. Tanmay Jain Consultant, Department of General Surgery, S.M.S Medical College, Jaipur, Rajasthan

ABSTRACT

Lower leg skin and soft-tissue defects reconstruction remains a challenge because this area has less soft tissues and limited tissue mobility. Here, we present a retrospective review of our experience with lower leg reconstruction using the keystone flap in patients with post traumatic defects. We describe the utility of Keystone flaps for reconstruction of lower limb defects located anteriorly. The medical records of 12 patients who underwent reconstruction with a KDPIF to cover a lower leg defect between February 2019 and October 2019 were reviewed. Clinical and operative data were collected. All 12 KDPIFs fully survived.The defect size varied from 3 × 2 cm2 to 6× 4cm2. The flap size varied from 5 × 3 to 15 × 8 cm2. The mean operative time was 80minutes (range = 28-100 minutes). No postoperative complications occurred. Thus, the KDPIF is a good reconstruction modality with few complications and provides an alternative to free flaps for lower leg defect reconstruction

KEYWORDS

Lower leg defects, anterior leg defects ,keystone flaps, trauma, post traumatic defects

The coverage of defects in lower leg regions is challenging for reconstructive surgeons because the lower leg area has relatively less soft tissue than other lower-leg areas, commonly resulting in defects with bone exposure.1 Many reconstructive options (skin grafts, locoregional flaps, and free flaps) exist for the repair of defects in the lower extremities. Each technique has its advantages and disadvantages. Skin grafts are easily and readily performed but cannot be done when underlying bed is contaminated or when vital structures (eg, major vessels and bony structures) are exposed. Additionally, they are prone to shearing and formation of unstable scars which subsequently requires another operation .Free flaps are a good reconstructive modality for lower-extremity defects and have been widely utilized . 2-4 However, the use of free flaps is limited because of lack of skilled microsurgeons , postoperative monitoring and long duration of time which is not feasible in the scenario of developing countries.1,5 Various locoregional flaps are also available and can be used as an alternative to free-tissue transfer in the coverage of lower-extremity defects but have limitations in the arc of rotation (mobility),have more donor-site morbidities, and may cause functional deficits .1Recently, pedicled perforator flaps (PPFs) have revolutionized lower-limb reconstruction because they are free from constraints in the width-to-length ratio, provide flexibility in design, and offer a comparable, like-with-like tissue type for reconstruction.6 This is generally performed using island and propeller flaps, which require cumbersome perforator dissection techniques which may result in extended operative times and represent a steep curve for upcoming surgeons.8. Keystone flaps have a curvilinear-shaped trapezoidal design, which is essentially 2 end-to-side V-Y flaps.9They are traditionally classified into 4 types: type I (skin incision only), type II (A, division of the deep fascia along-the outer curvilinear line; B, division of the deep fascia and skin graft to the secondary defect), type III (opposing keystone flaps designed to create a double-keystone flap), and type IV (keystone flap with undermining of up to 50% of-the flap subfascially).9 Keystone flaps are used in lower- limb reconstruction and are mainly performed after skin and soft-tissue tumor resection in the thigh, calf, and sole.9-11Here, we present our case series using keystone flaps for the reconstruction of lower leg post traumatic defects . The main purposes of the present retrospective study are to demonstrate the utility of keystone flaps in the reconstruction of lower leg defects and to evaluate outcomes.

Materials and Methods :

Between February 2019 and October 2019, 12 patients (10 men and 2 women), with an average age of 32 years (range = 26-38 years), underwent Keystone flaps reconstruction to cover skin and soft-tissue defects in lower leg regions. We retrospectively reviewed the defect location, defect size, type of keystone flap, flap size, flap elevation time, total operative time, flap survival, complications, and follow-up duration for each patient. We obtained written informed consent from all patients.

Surgical Techniques:

After proper assessment of the wound, patients were taken on serial debridement and regular dressings for at least 1 week .Thus, the wound was optimised by reducing edema, controlling infections, and promoting perfusion around the wounds and healthy granulation tissue formation in the wound bed. We then performed the final coverage of the defect using a Keystone flap.The operation was performed with the patients in the supine position and under spinal anesthesia. After complete debridement, the final defect size was measured and planned according to defect size . When designing the flap in accordance with the defect size, several points were considered. First, the flap-to-defect ratios were larger than the 1:1 ratio used in the original design.Second, the flap for defects less than 4 cm was marked based on approximate location of adjacent perforators . The marking of flap for defects more than 4 cm was done according to the adjacent perforators based on anterior tibial, posterior tibial or peroneal artery depending on defect location . These perforators were marked by using hand held Doppler probe.After skin incisions were made, flap elevation was performed distally to proximally with division of the deep fascia (subfascially) until the flap could be inset into the defect without restriction or tension during advancement. Great care was taken during the dissection to minimise the undermining and avoid compromising the perforator vascular supply. After insetting the flap, the donor site was closed primarily or with graft. Silastic or closed suction drains were placed under the flap and in the donor site.

RESULTS:

Patient characteristics and clinical data are presented inTable 1. All defects resulted from trauma. The defect locations included the upper pretibial area in 8 cases and lower pretibial region in 4 cases. The defect size varied from 3 × 2 to 10 × 6cm2. All defects were covered using keystone flaps , with type IIA in 10 cases, and type IIBin 2case.The flap size varied from 6x4 to 20x10 cm2. The mean flap elevation time was 12minutes (range = 10-14minutes).The mean operative time was 60 minutes (range = 28-110 minutes). All flaps fully survived, and there were no postoperative complications, such as arterial insufficiency , venous congestion, flap failure, or wound infection. After-an average follow-up period of 10.6 months (range = 10-12months), all patients reported that they were satisfied with their final functional and aesthetic outcomes.

Case Presentations :

Case 1 (Figure 1)A 25year-old boy was admitted to our hospital for a right pretibial skin and soft tissue defect caused by a traffic accident. We performed serial debridement, Dressings and intravenous

antibiotic treatment for 1 week to achieve wound preparation and negative wound culture. The size of the final post debridement defect in the upper pretibial area was 4 x 2 cm2. We performed reconstruction using IIB keystone flap(10 × 6cm2) .The donor site was closed primarily after tension-free insetting of the flap. The flap harvest time was 10 minutes, and the total operative time was 70 minutes. There were no postoperative complications, and the flap completely survived. The patient did not remarkably complain of postoperative pain at the operative site, and he was satisfied with the final outcome at the 11-month follow-up.Case 2 (Figure 2)A 32year-old woman was admitted to our hospital for left pretibial skin and soft-tissue defect caused by trauma. The size of the final post debridement defect in the upper pretibial area was 10×5cm2. We performed reconstruction using typeIIA keystone flap (20x10cm2) based on the perforators of the Anterior tibial artery . Primary closure of the donor site was achieved after tension-free insetting of the flap. The flap harvest time was 19 minutes, and the total operative time-was 100minutes. There were no postoperative complications, and the flap completely survived. The patient did not remarkably complain of postoperative pain at the operative site, and she was satisfied with the final outcome at the10-month follow-up.

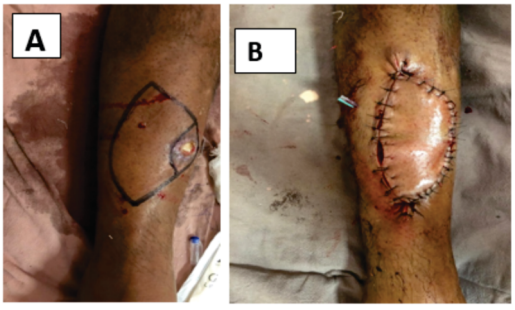

Figure 1. Clinical photographs (case1): (A) Final postdebridement defect (4x 2 cm2) in the right upper pretibial area (B) Primary closure of donor site of type IIA keystone flap.

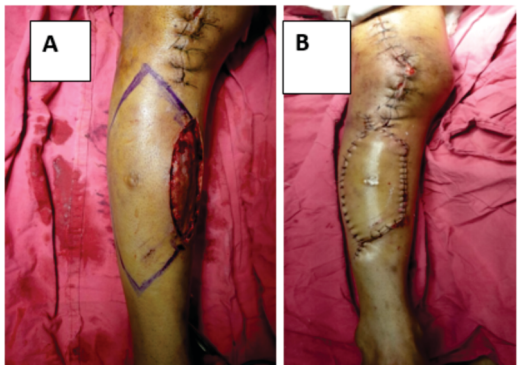

Figure 2. Clinical photographs (case 2) (A) Final postdebridement defect (10 × 5 cm2) in the left upper pretibial area (mediallydominant). (B) Elevation of an type IIA keystone-designed perforator island flap (20 × 10 cm2) .Tension-free closure and primary closure of the donor site.

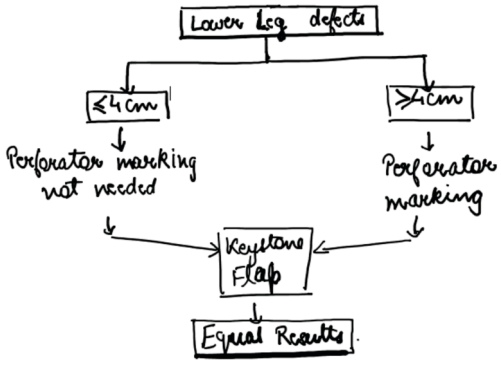

Figure 3

TABLE 1

Cases	Age(year)/ Sex	Defect size	Type of KDPIF	Flap size	Donor site closure	Flap elevation time	Total operative time	Flap survival	Complication
1	25/M	3x2	IIA	6x4	Primary	20	80	Fully	None
2	28/M	6x4	IIA	12x8	Primary	30	100	Fully	None
3	34/M	8x6	IIB	15x8	SSG	25	110	Fully	None
4	26/M	4x2	IIA	8x4	Primary	15	85	Fully	None
5	24/M	6x3	IIA	12x6	Primary	22	94	Fully	None
6	26/M	5x3	IIA	10x6	Primary	28	96	Fully	None
7	22/M	4x2	IIA	8x4	Primary	20	70	Fully	None
8	26/M	5x2	IIA	12x6	Primary	27	78	Fully	None
9	30/M	6x3	IIA	12x8	Primary	24	86	Fully	None
10	24/M	8x4	IIB	15x10	Primary	30	90	Fully	None
11	32/F	10x6	IIB	20x10	SSG	20	110	Fully	None
12	28/F	6x3	IIA	12x6	Primary	22	98	Fully	None

DISCUSSION:

The reconstruction of lower leg defects has always been troublesome and challenging. The anterior leg region is nearly bone to skin, with less underlying tissues than the posterior area of the lower extremities (the calf) .1 These characteristics can render the coverage of even a small defect in this area difficult.1Many alternatives have been used for coverage like locoreginal fasciocutaneous and muscle flaps, free flaps and pedicels perforator flaps, each with its risks and benefits. Locoregional fasciocutaneous flap provide a pliable and nonbulky coverage but have disadvantages of donor site morbidity and limited length to width ratio. Local muscle flaps (including gastrocnemius, soleus) provide good vascularity but are usually associated with functional deficits, leading to increased donor-site morbidities and contour deformities.1 Free flaps have been considered the gold standard for reconstruction of anterior leg defects with advantages of coverage of moderate to large sized defects but with the limitations of required expertise, dedicated postoperative monitoring , bulky appearance and staged debulking procedures afterwards1.Recently, the use of pedicled perforator flaps have provided an alternative conventional loco regional flaps in the reconstruction of small to moderate sized lower extremity defects with less donor site morbidity and less constraints of length to width ratio.Moreover, these are less bulky and are a good match in terms of color and texture, 6 However, perforator dissection technique is usually required which is quite cumbersome and the venous supercharging technique is frequently used.6,7 As noted earlier, perforator dissection is not universally practiced by all reconstructive surgeons and needs a longer time; thus, simpler perforator flap techniques (eg, keystone flaps) which do not require microsurgical perforator dissection, have been devised. 7The Keystone flap is a multiperforator advancement flap, which has a curvilinear trapezoidal shape representing the keystone in Roman arches.9 This flap has been described as a combination of 2 opposing V-Y flaps: the initial V-Y-advancement at the corners of the keystone flap along the longitudinal axis toward the center and parallel to the defect provides residual laxity within the flap, allowing for translation or advancement of the keystone horizontally into the defect.9 It does not require intramuscular pedicle dissection. Several studies have reported on the use of Keystone flap to cover full-thickness defects in a variety of anatomical locations ,including the face, neck, trunk, and extremities.9 However, most of these studies involved reconstructions after tumor resections or included heterogeneous causes of defects. Furthermore, in previous studies of lower-extremityreconstruction with KDPIFs, defects were generally located-in the calf and sole.9-11 In the present study, all defects were-located in anterior leg areas,

which have less-sufficient surrounding tissue than other areas of the lower extremity.In addition, all defects homogeneously resulted from traumatic causes.A previous study reported that traumatic defects are relatively contraindicative to keystone flap reconstruction, and care should be taken when reconstructing lower-extremity-defects with keystone flap .Traumatic defects differ from oncological defects in that the surrounding tissues are under the injury zone, and there is wound infection usually. As such, wound healing complications occur at a high rate in the reconstruction of traumatic defects. Thus, wound preparation and stabilization before flap coverage is indispensable to the reconstruction of traumatic lower-extremity defects and should include serial surgical debridement, regular dressings , and intravenous antibiotic treatment. We routinely performed these managements for-at least 1 week and covered the defects only after wound preparation and optimisation was sufficiently achieved. Therefore, in the present study, all the flaps fully survived, without wound healing complications or surgical site infections.The use of keystone flap has distinct advantages, including design simplicity and a robust vascular supply, short operative time, minimal donor site morbidity, reliable healing, fast recovery, and favorable cosmetic outcome. We noticed in our series that there is no need of perforator marking preoperatively and visualisation intraoperatively in cases of small defects of less than 4 cm.In cases of moderate to large defects, perforator marking and visualisation is needed.Thus, the KDPIF is a particularly suitable reconstructive modality for patients with post traumatic lower leg small to moderate sized defects.As aforementioned, KDPIFs are traditionally classified into 4 types.9 Small- to moderate-sized defects in the postero lateral regions of the lower extremity can be covered with a type I or type IIA KDPIF, with donor sites closed primarily. However, KDPIF reconstruction for larger anterior leg defects often requires a skin graft for covering the-donor site and more movement of the flap because of the aforementioned inherent characteristics of this area (less underlying tissue and limited tissue mobility). Thus, a typeIIB or type IV KDPIF is useful for larger-sized anterior leg defect coverage. The Ω-variant KDPIF involves a tension reducing modification and is useful in anterior leg defect coverage requiring reduced tension in the center of the original defect, without the sacrifice of normal tissue, allowing greater advancement of the flap. In the present study, we used a type IIA KDPIF in 10 cases involving relatively smaller -sized defects . For moderate -sized defects, type IIB KDPIF in 2 cases.This is summarised in flow chart (FIG 3).Although we successfully covered anterior leg defects with keystone flaps, the present study has some limitations like small number of cases and younger patients which need to be acknowledged in further studies. Inspite of all these limitations, its simplicity and safety should be considered and keystone flap should have a place in armamentarium of reconstructive surgeons.

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