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ORIGINAL ARTICLE
Reconstructive

The Keystone Perforator Island Flap: Review of Utility and Versatile Clinical Applications

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Background: The keystone perforator island flap (KPIF) was described almost a decade ago. However, this flap has only recently been recognized for its advantages in various clinical applications in plastic surgery. A better understanding of the versatility of KPIFs can help promote the widespread adoption of this technique for complex wounds in various anatomical regions.

Methods: A retrospective chart review was conducted of patients undergoing KPIFs from December 2018 to March 2022 at the authors' home institution. The indications, surgical approaches, patient characteristics, and outcomes were extracted for review and analysis.

Results: A total of 12 patients (ages 13–86 years) underwent reconstruction with KPIFs for oncologic and nononcologic defects. By anatomic region, three cases involved the upper back, six involved the lumbosacral region, one involved the perineum, and two involved the midfoot. Half of the patients (n = 6) had failed previous attempts at wound closure. The mean defect size was 13.8×10.0 cm for the upper back lesions, 13.7×4.8 for the lumbosacral defects, and 3.5×2.0 for the metatarsal wounds. Median follow-up time for all patients was 7.5 months (IQR: 4–10.5). On follow-up, there was 100% flap survival.

Conclusion: KPIFs are a simple, safe, and suitable option for reconstructive closure of defects in many anatomical areas, including wounds complicated by previous failed closure attempts, with low complication risk profile. *(Plast Reconstr Surg Glob Open 2024; 12:e5556; doi: 10.1097/GOX.0000000000005556; Published online 6 February 2024.)*

INTRODUCTION

The keystone perforator island flap (KPIF) was first described in 2003 by Behan et al for the closure of cutaneous defects after skin cancer excision, with the benefit of providing a reconstructive approach that could be performed with technical ease while also eliminating donor-site morbidity from skin grafting for postexcisional closure.[1,2] Its traditional design was as a curvilinear trapezoidal flap adjacent at 90 degree angles to an elliptical-shaped excision, with the flap width equal to the width of the defect and its long axis parallel to the long axis of the defect. As such, it has also traditionally been described as representing two opposing V-Y advancement flaps joined together.[1,3,4] The flap is designed longitudinally to the underlying, and the skin is excised down to the fascia, or including fascia, depending on the advancement needed and the type of flap utilized (Fig. 1).[1,3,5] Blunt dissection is emphasized when raising the flaps to preserve the integrity of the underlying perforators and surrounding neurovasculature. Additional benefits to the ease with which KPIFs can be performed include shorter operative times, reliability, and high reproducibility of aesthetic outcomes.[4–8] The versatility of the KPIF has expanded its use beyond cutaneous excisional defects to include breast reconstruction, wound closure of the trunk and extremities, and coverage of traumatic periarticular injuries.[1,4–6,8–10] This is in line with its intended utility, as Behan described its suitability for all areas from head to foot.[1] Despite this, the KPIF often remains underutilized in surgical practice, particularly in complex anatomical regions and closures. In this study, we add to the growing body of literature on the clinical utility of KPIFs and describe the head-to-toe applications

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Received for publication February 27, 2023; accepted October 3, 2023.

Presented at Plastic Surgery: the Meeting 2022, Boston, Massachusetts.

DOI: 10.1097/GOX.0000000000005556

Disclosure statements are at the end of this article, following the correspondence information.

of KPIFs at our institution for both oncologic and nononcologic defects.

METHODS

This study involved a retrospective chart review of patients who underwent reconstructive procedures with KPIFs at a single institution between December 2018 and March 2022. Data that were extracted for analysis included diagnosis and indication for a KPIF, anatomic location of the defect, failed attempts at wound closure, original defect dimensions, KPIF dimensions, intraoperative Doppler use, postoperative follow-up time, and postoperative complications, including flap related complications (eg, flap failure) and other postoperative complications (eg, wound dehiscence). The presence of postoperative complications had been assessed by study physicians at each subsequent follow-up visit. The study protocol conformed to the ethical guidelines of human subjects research, reflected in the approval by the institutional review board of Tufts Medical Center (IRB study number *STUDY00002524*).

RESULTS

A total of 12 patients (ages 13–86) underwent reconstructive surgery utilizing KPIFs during the study period. Most patients (n = 10, 83%) were men. By anatomic region, three cases involved KPIFs to the upper back and shoulder region, six involved the lumbosacral and gluteal regions, one case involved the perineum, and two cases involved reconstruction of defects in the fifth metatarsal. The median follow-up time was 7.5 months (IQR: 4–10.5 months). Most (n = 8, 67%) of the KPIFs were performed for nononcologic indications, with the most common being recurrent pilonidal disease. The defects were elliptical or circular in shape and ranged from 2.0 cm × 1.5 cm to 26.0 cm × 11.0 cm in size. About half of all defects had failed previous attempts at wound closure through less invasive methods or alternative local and regional flaps. A standard 1:1 defect to flap width ratio was used in all reconstructions, and the most common type of KPIF utilized was the type IIA flap (Fig. 1). Preoperative markings followed a traditional KPIF design with modification, if needed, based on anatomic location and skin laxity. Intraoperative Doppler was utilized in all cases to ensure the presence of at least one perforator within the marked flap boundaries to ensure a robust blood supply, especially for the larger flaps. There was 100% survival rate of all KPIFs at the end of patient follow-up, with no flap-associated complications. Four of the twelve patients experienced postoperative complications, with three experiencing minor wound dehiscence at the leading aspect of the flap where the maximum tension was located, which required reinforcement with additional sutures, and one patient with a history of keloid formation who developed a symptomatic keloid scar requiring excision.

KPIFs for Reconstruction of the Upper Back

All three of the upper trunk KPIFs were performed for oncologic indications, including defects caused by wide local excision of dermatofibrosarcoma protuberans or squamous cell carcinoma of the mid-upper back and wide excision of melanoma of the right upper back and shoulder area. The dimensions measured 14.5 × 12.0 cm, 13.0 × 8.0 cm, and 14.0 × 10.0 cm for the wide local excision of dermatofibrosarcoma, SCC, and melanoma, respectively. Fig. 2 depicts the preoperative, intraoperative, and postoperative images of KPIF reconstruction for wide excision of a dermatofibrosarcoma lesion.

None of the patients had undergone previous attempts at wound closure, but two of the patients had undergone negative pressure wound therapy before surgery (Table 1). Skin incisions and dissection of each flap was carried down to the deep fascia, followed by gentle undermining of the subfascial plan of the flap as needed (typically about 1–1.5 cm). Intraoperative Doppler was used in all cases, which identified one to three strong biphasic signals from the thoracodorsal or posterior intercostal artery perforators. This was done before skin incision and following undermining of the fasciocutaneous plane. One of the patients had undergone a type III KPIF, for which two to three perforators were identified on opposing ends of the defect; the opposing flaps were designed symmetrically as there was no concern over crossing joint lines or exposure of critical structures. If further advancement was needed, undermining of the contralateral side of the defect could be used to enhance tension-free closure. Closure was carried out in layered fashion. First, interrupted 3-0 Vicryl sutures were used to approximate Scarpa fascia and the deep dermis in the leading aspect of the flap. Scarpa fascia on the lateral sides of the flap was also closed using 3-0 Vicryl interrupted sutures. Apart from the leading aspect, the remaining deep dermis throughout the flap was closed with a running 3-0 Monoderm Stratafix suture. A running subcuticular 4-0 Monoderm Stratafix suture was used for the most superficial layer of the flap. An additional layer of 3-0 nylon horizontal mattress sutures was used in the leading edge of the flap as this was, by definition, the area with a relatively higher tension (point of maximal tension). Postoperative dressings consisted of incisional wound VAC devices, and one to two 15 French drains were used in all cases. The median operative time was 262 minutes, and the median postoperative follow-up time was 7 weeks. Of the three patients, one developed a small (3cm) wound dehiscence of the central upper suture line of the flap noted on postoperative day 21, which was preceded by heavy lifting of

Takeaways

Question: What are the various clinical applications of keystone perforator island flaps (KPIFs)?

Findings: A retrospective review found 12 patients (ages 13–86 years) who underwent reconstruction with KPIFs for oncologic and nononcologic defects and head-to-toe applications. Flap survival was 100%.

Meaning: KPIFs are a suitable reconstructive option in various head-to-toe applications, especially among patients with failed previous attempts at complex defect closure.

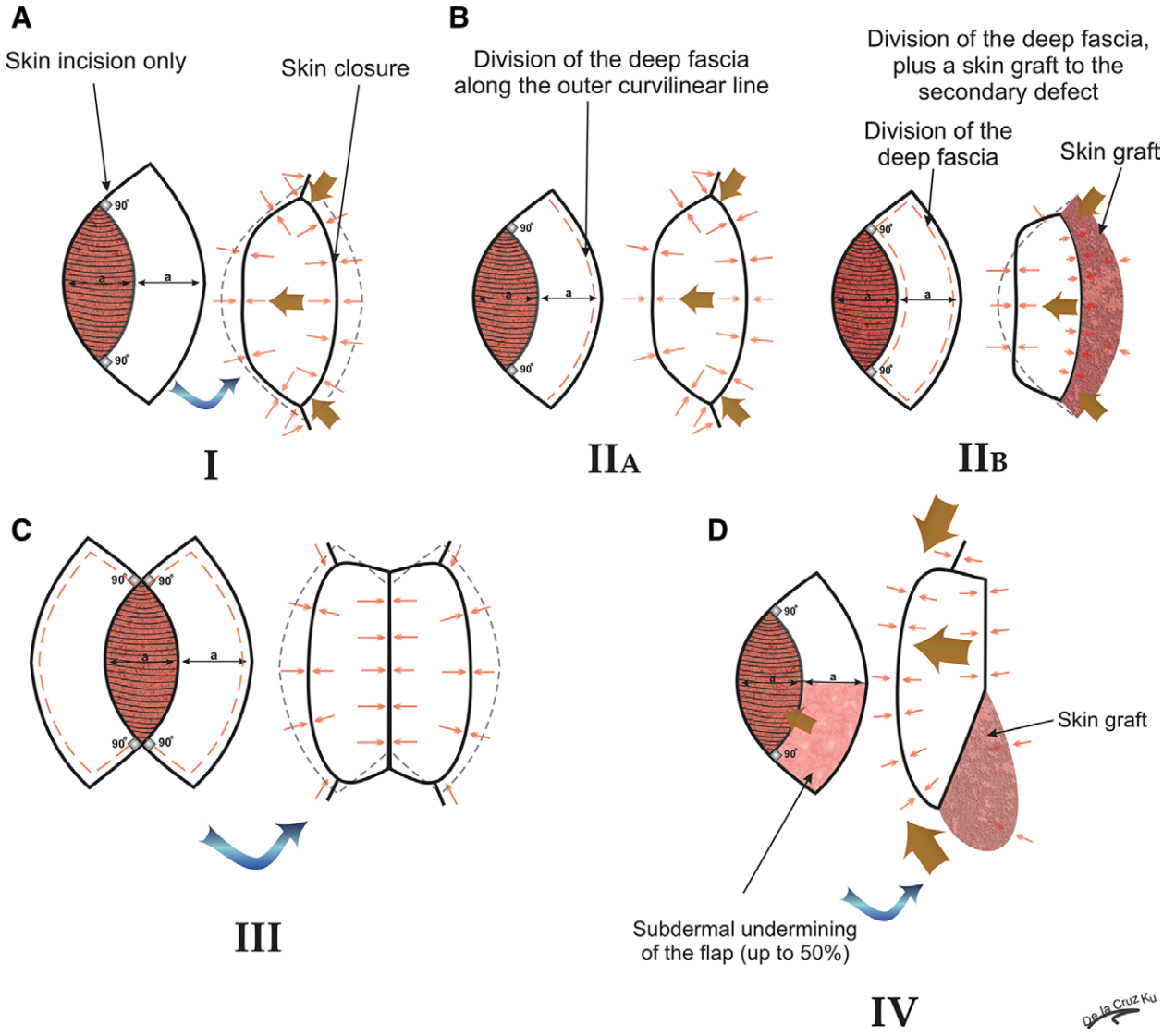

Fig. 1. Illustration depicting the traditional classification of KPIFs, as originally described by Behan.[1] A, Standard flap design as described above (type I), for defects up to 2 cm in width. B, If there is excessive tension, type IIA flap design consists of a standard flap with deep fascia divided at the flap edges, whereas type IIB consists of flap with split thickness skin graft for secondary defect. C, For larger defects (up to 5–10 cm), two opposing keystones can be used (type III). D, A type IV flap has up to 50% of the flap is undermined to facilitate rotation of the flap. Original illustrations by Gabriel De La Cruz Ku.

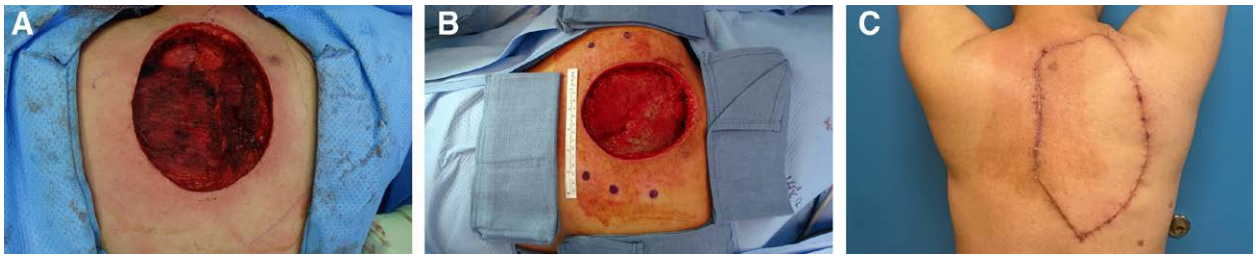

Fig. 2. Reconstruction of a large defect from dermatofibroma resection of the back using KPIF. Intraoperative view of mid-upper back defect after dermatofibrosarcoma resection (A) with Doppler mapping (B) and postoperative results (C) after reconstruction with type IIA KPIF.

15 lbs. over the several days prior. The dehiscence did not recur after reinforcement with additional sutures, which was done in clinic. A second patient with history of keloid formation developed a symptomatic keloid six months after surgery, requiring excision and closure after 11 months postoperatively.

Table 1. Patient and KPIF Characteristics

Patient	Age (y)	Sex	Location	Previous Attempts at Wound Closure	Wound Dimensions	KPIF Type	Indication	Complication	Follow-up Time (wk)
1	69	M	Right upper back/ shoulder	No	14×10	IIA	Melanoma	3 cm wound dehiscence at the central upper suture line of the flap documented on POD21, after strenuous lifting over several days	7
2	15	M	Natal cleft	Yes—failed primary closure	16×6	IIA	Recurrent pilonidal disease	3 cm wound dehiscence at the distal most aspect of the surgical scar, closest to the perianal area.	15
3	40	M	Mid-upper back	No	14.5×12	IIA	Dermatofibrosarcoma protuberans	Formation of symptomatic keloid after 6 months postoperatively requiring excision	7
4	13	F	Fifth metatarsal	No	2×1.5	I	Chronic osteomyelitis	None	12
5	24	M	Lumbosacral region	Yes—failed paraspinal muscle flap closure	15×3	IIA	Lumbosacral spine trauma complicated by hardware infection	None	8
6	16	M	Natal cleft	No	15×5.5	IIA	Recurrent pilonidal disease	None	8
7	61	M	Fifth metatarsal	Yes—failed primary closure	5×2.5	I	Chronic osteomyelitis	6 cm wound dehiscence on leading edge of the flap requiring delayed primary closure	9
8	21	M	Natal cleft	Yes—failed closure by secondary intention	12×5	IIA	Recurrent pilonidal disease	None	2
9	23	M	Natal cleft	Yes—failed Karydakis flap	9×4	IIA	Recurrent pilonidal disease	None	3
10	17	M	Natal cleft	Yes—failed primary closure	15×5	IIA	Recurrent pilonidal disease	None	5
11	86	M	Mid-upper back	No	13×8	III	Squamous cell carcinoma	None	2
12	56	F	Vulva	No	26×11*	IV	Squamous cell carcinoma	None	15

*Other flaps were used in conjunction to achieve closure of large bilateral defect.

KPIFs for Reconstruction of the Lumbosacral and Intergluteal Region

Six pediatric surgery patients (ages 16–24) underwent defect reconstruction with KPIFs of the lower trunk, specifically the lumbosacral or intergluteal region. All cases consisted of nononcologic indications for undergoing reconstructive surgery, with five patients having a history of recurrent pilonidal disease and one patient with spinal trauma requiring hardware fixation that was complicated by recurrent wound infection. All six patients had defects that had failed previous attempts to achieve wound closure, including prior attempts with paraspinal muscle or Karydakis flaps (Table 1). The average defect size was 14.0×5.0 cm. After declaring the KPIF margins, type IIA dissection of the flaps was carried down to the presacral or gluteus maximus fascia using electrocautery (Fig. 3). For the cases with recurrent pilonidal disease, it was imperative that special care was taken to excise the entirety of the diseased tissue and to tailor the extent of the incisions, particularly in the caudal direction when too close to the anal margin, while still achieving closure of the resultant dead space (Fig. 4).

Deepithelialization of the flap was not needed to further fill in the dead space, though this is an option that can be considered. Intraoperative Doppler was used before incision and during surgery to identify one to three strong biphasic signals from lumbar artery or superior gluteal artery perforators. The leading flap edge and Scarpa fascia were inset using 3-0 Vicryl or Monocryl sutures, with special attention given to obliterating dead space, as mentioned previously. The deep dermal and subcuticular layers were closed with running absorbable barbed sutures. For wounds that were very close to the anal margin, the lowermost aspect of the wound was approximated with a running 4-0 plain gut suture, as attempts for suture removal would cause extreme discomfort for the patient. The median operative time was 196 minutes, and the median follow-up time was 7 weeks. Toward the end of the follow-up period,

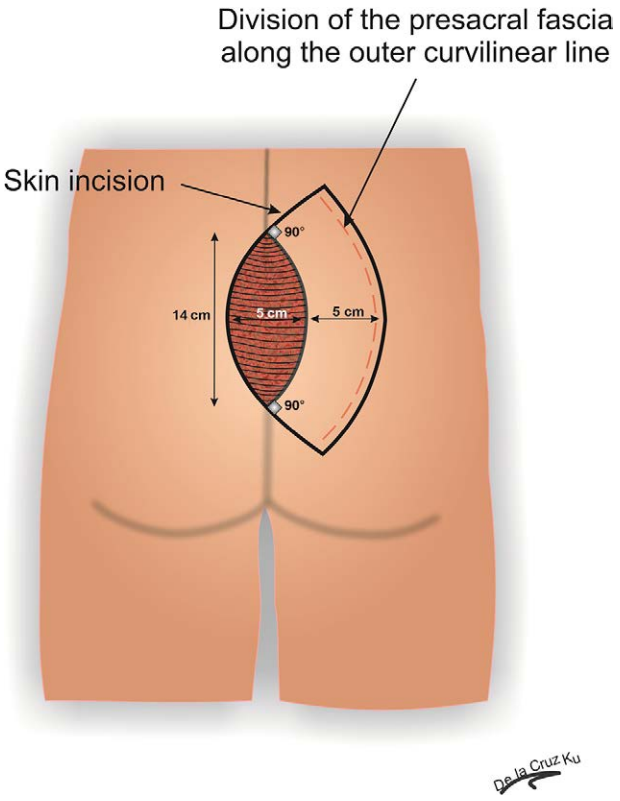

Fig. 3. Illustration of the utility of type IIA KPIF for defect closure after recurrent pilonidal disease. Original illustration by Gabriel De La Cruz Ku.

one of the cases experienced a minor (3 cm) wound dehiscence at the distal most aspect of the surgical scar, closest to the perianal area, which required excisional debridement and suture closure. The remaining patients did not experience any postoperative complications.

KPIFs for Perineal Reconstruction

Our study involved a 56-year-old woman with large invasive squamous cell carcinoma of the vulva that was treated with vulvectomy complicated by wound dehiscence. The patient required pelvic exenteration, bilateral ureteral stenting, and a sigmoid diverting ostomy; plastic surgery was consulted for perineal reconstruction. In its entirety, the perineal defect was measured to be 26.0 × 11.0 cm. After intraoperative discussion, it was determined that reconstruction would take place using a vertical rectus abdominis musculocutaneous (VRAM) flap for the superior and central aspect of the defect, with two thigh flaps (a left-sided Singapore flap and a right-sided KPIF) that were advanced medially to reconstruct the remainder of the defect. The keystone flap dimensions were marked as 20.0 × 5.0 cm, and an intraoperative Doppler was used to identify at least three perforators stemming from the internal pudendal artery along the medial aspect of the right thigh. Once the circumferential cuts around the flap were done, careful dissection was performed lateral to medial until the three perforators were preserved. Approximately 50% of the flap around the perforators was dissected off of the underlying muscle (type IV flap) to allow for optimal advancement from lateral to medial. Next, the VRAM flap was advanced intra-abdominally out of the pelvic outlet to avoid kinking of the deep inferior epigastric pedicle. The skin paddle of the VRAM was then placed centrally into the perineal defect. Finally, a posteriorly based Singapore flap was performed on the left thigh to assist in partial defect and tension-free closure. The final inset of both thigh-based flaps was performed with deep dermal layer closure using 3-0 Vicryl interrupted sutures. Given the anticipated edema that would surround the defect in the acute postoperative period, tight skin closure with suture was avoided, and skin closure was instead achieved using titanium stapling to allow swelling to occur without compromise of the subdermal plexus. Two #15 drains were also placed underneath the flap and secured to the side with 3-0 nylon sutures. The total operative time was 398 minutes, which included the time for total pelvic exenteration and the previously mentioned procedures. The follow-up time of this patient was 15 weeks. Although the patient experienced

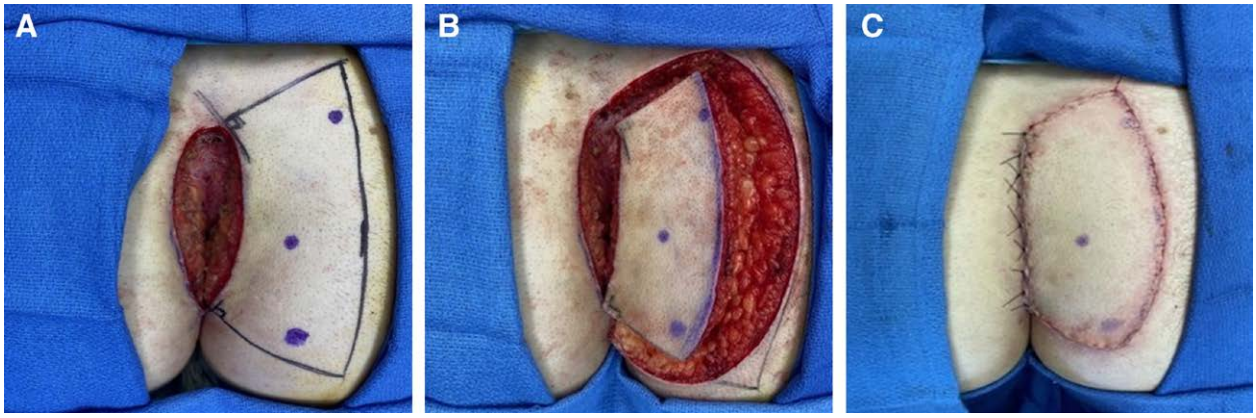

Fig. 4. Gluteal cleft defect reconstruction using KPIF. Intraoperative design with marked perforators (A) and type IIA undermining (B) of KPIF to close dead space in defect after resection of recurrent pilonidal disease. Immediate postoperative outcome reveals flap with tailored extensions to fill in defects of the natal cleft (C).

Fig. 5. KPIF in foot reconstruction. Defect overlying the fifth metatarsal due to left foot contracture and ulcerations complicated by osteomyelitis before (A) and after (B) KPIF reconstruction.

postoperative complications (necrosis) pertaining to the colostomy, no complications associated with the KPIF were reported.

KPIFs for Foot Defects

Two patients in the study underwent KPIFs of the foot, specifically for soft tissue defects overlying the fifth metatarsal caused by chronic osteomyelitis from two very different etiologies. One case was a 13-year-old girl who was born with a lipomyelomeningocele tethering the spinal cord, leading to eventual left foot contracture and ulcerations that were complicated by osteomyelitis (Fig. 5). This patient had not had previous attempts at wound closure, though she underwent negative pressure wound therapy for four weeks before surgical repair of a full thickness 2.0×1.5 cm defect with exposed bone. The total follow-up time was 12 weeks, and there was no occurrence of postoperative complications.

The second patient was a 61-year-old man with chronic diabetes mellitus complicated by Charcot foot deformity and osteomyelitis, who had multiple failed attempts at primary closure. The dimensions of this patient's wound were 5.0×2.0 cm, the total operative time during the reconstructive surgery was 117 minutes, and the total follow-up time was 9 weeks. The patient experienced a minor wound dehiscence (6 mm) requiring delayed primary wound closure. As in previously mentioned cases, intraoperative Doppler was used, and a strong signal from the dorsal metatarsal perforating artery was located and marked. Due to the small size of the defects, these cases involved reconstruction with type I KPIFs and no undermining of the leading edges was needed (Fig. 6).

DISCUSSION

This study highlights the clinical utility of KPIFs across different anatomic regions, defect sizes, and pathologic conditions. Of the 12 patients undergoing wound closure with KPIFs during the study period, three patients had upper trunk defects, six had defects of the lumbosacral region due to trauma or recurrent pilonidal disease, one patient required perineal reconstruction due to invasive culver squamous cell carcinoma, and two patients had nonhealing midfoot defects at the level of the fifth metatarsal, with exposed bone. Although the KPIF was originally designed as a reconstructive approach to cutaneous defects due to skin cancer, 67% (n = 8) of the patients in this study successfully underwent KPIFs for nononcologic indications. Patients across different demographic groups were included in this study, including seven (58%) pediatric patients, which further highlights the versatility of the KPIFs for various surgical diseases.

Even for the cases involving large, complex wound closure, perforator vessels and other relevant structures (such as the cutaneous nerves) could be easily identified during dissection and preserved. Conservative undermining in the subfascial plane is an important technical consideration that aids in maximizing flap survival. Undermining the superficial layers on the contralateral side of the wound can provide additional laxity to achieve tension-free closure without necessitating additional KPIF undermining that threatens the integrity of the perforators.

Intraoperative Doppler identification of perforator vessels is an extra step we use that allows relatively more aggressive undermining of the KPIF to the level of the perforator, which increases flap advancement without compromising its vascular supply. This corresponds to the 100% flap survival of KPIFs and the absence of arterial insufficiency, venous congestion, or sensory loss among patients highlighted in this study.

Certainly, the inferences that can be drawn from this descriptive study are impacted by the limitations inherent to retrospective case series, including a small sample size, lack of control group, uncontrolled study setting, and lack of strict patient selection criteria. Nevertheless, the findings of this study are in line with previous case reviews of KPIFs that support the increased utilization of KPIFs in clinical practice. Although complications may

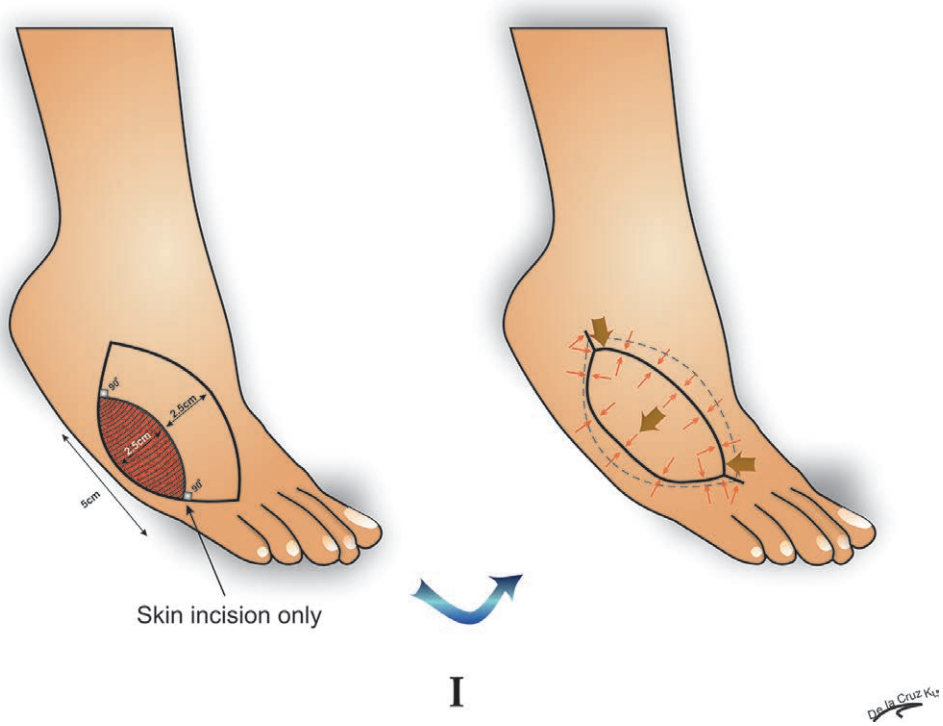

Fig. 6. Type I KPIF performed for closure of a chronic wound of the fifth metatarsal as a result of chronic osteomyelitis and Charcot foot deformity. Original illustration by Gabriel De La Cruz Ku.

still occur among patients undergoing KPIFs, previous literature has shown that the majority can be treated conservatively or with minor intervention.[2,6,11] In this study, four patients experienced postoperative complications (three with minor wound dehiscence and one with symptomatic keloid formation) that fully resolved with minimal suture reinforcement or simple excision, respectively. These patients otherwise enjoyed early mobilization and relatively pain free recovery, highlighting the benefit of KPIFs in eliminating the need for specialized postoperative monitoring.[5,12] Additionally, the shortened operative times and ease in execution of the KPIF makes it possible for these flaps to be performed in tandem with other procedures on the same day, as seen in the study participant undergoing pelvic exenteration, bilateral ureteral stenting, and a sigmoid diverting ostomy for which perineal reconstruction was performed with concurrent KPIF, VRAM, and Singapore flaps.

The ability to perform in-tandem procedures allows patients to avoid extended traveling and undergoing additional anesthesia for delayed procedures to achieve wound closure. Taken together, KPIFs seem to be a reliable, safe, and versatile approach to correcting soft-tissue defects across different clinical conditions while eliminating secondary defects, with the benefit of locoregional tissue rearrangement.

CONCLUSIONS

The KPIF offers an excellent reconstructive approach that may be modified to suit different anatomic regions and surgical indications. Moreover, KPIFs have reliable survival and a favorable postoperative safety profile, with the majority of complications amenable to minimal or conservative interventions. This supports the expansion of KPIF use in various clinical applications in plastic and reconstructive surgery.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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