

Keystone Design Perforator Island Flap for Closure of the Anterolateral Thigh Flap Donor Site: a Case Series and Our Experience

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Research Article

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Abstract

Purpose: With the development of microsurgical techniques, the anterolateral thigh (ALT) flap has been widely used in reconstruction of various soft-tissue defects. However, there were few studies focusing on the closure of the ALT flap donor site, especially when the width of the harvested ALT flap was more than 6 cm. The purpose of this study was to share our experience of using Keystone Design Perforator Island Flap (KDPIF) to repair the ALT flap donor site where can't be closed without a skin graft.

Method: A retrospective study was used to analyze 12 patients who underwent the reconstruction of the ALT flap donor site using KDPIF from February 2018 to December 2020. Demographics, flap characteristics, surgical technique, postoperative complications, Vancouver Scar Scale (VSS) score, and Scar Cosmesis Assessment and Rating (SCAR) score were statistically analyzed.

Results: 12 patients (10 males, 2 females) with the mean age 47.5 years (range, 27-66 years) were included in this study. All ALT flap donor sites were closed by the KDPIF. The mean size of the harvested ALT flap (the donor site size) was 8.1 cm × 14.4 cm (range from 8.0 cm × 11.0 cm to 9.0 cm × 21.0 cm), and the mean size of keystone flap was 9.1 cm × 16.4 cm (range from 8.0 cm × 13.0 cm to 12.0 cm × 19.0 cm). At the mean follow-up of 8.3 months (range, 6-12 months), two patients suffered from the skin infection around the flap, which was controlled under the treatment of wound dressing change and oral antibiotics. Wound dehiscence, osteofascial compartment syndrome (OCS), venous return disorder, and skin necrosis were not presented in any patients. All patients were evaluated at the final follow-up with ASS core (mean, 6.7; range, 5-8) and SCAR core (mean, 7.3; range, 6-9).

Conclusion: This study demonstrated that the KDPIF that can be used to close the ALT flap donor site primarily is an effective and alternative treatment for patients with a the width of the donor site more than 6 cm including the advantages of high survival rate, low morbidity, good aesthetics, and simple operation.

Introduction

The anterolateral thigh (ALT) flap has been considered as a reliable flap option for various soft tissue defects because of its concealed position, constant vascular pedicle, large area, and low donor site morbidity [1]. And the application of ALT flap have been described in many previous studies [2-4]. However, there were still few studies on the reconstruction of the ALT flap donor site, especially in the donor site with a large soft tissue defect.

The primary closure of the ALT flap donor site was associated with low morbidity. In most cases, the donor site with a width of <6 cm can be closed directly without skin graft. However, for harvested ALT flap with a width of >6 cm (with adjustment for age and BMI), performing the primary closure of the donor site may cause many complications, such as osteofascial compartment syndrome (OCS), wound dehiscence, and venous return disorder [5, 6]. In clinical work, skin graft was a common method to cover the donor site defects where can't be sutured directly. However, skin graft was associated with many donor site

complications such as additional donor site, skin infections, and necrosis, which may result in patient discomfort and dissatisfaction [6, 7].

Keystone Design Perforator Island Flap (KDPIF) is an islanded perforator flap that relies on V-Y advancement components at the corners to mobilize the middle portion of the flap [8]. Many previous studies have reported that using the KDPIF reconstructs soft tissue defects in extremities with a good outcome [9-11]. However, there were few studies focusing on the closure of the ALT flap donor site, especially when the width of the harvested ALT flap was more than 6 cm. Hence, the purpose of this study was to share our experience of using KDPIF to repair the ALT flap donor site where can't be closed without a skin graft.

Materials And Methods

The current study was conducted with institutional review board approval, and each patient provided written informed consent before the surgery. Of 12 patients who underwent the ALT flap surgery for the initial soft tissue defects in our institution from February 2018 to December 2020. The soft tissue defect of the ALT flap donor site was closed using a KDPIF in all patients. The relative dates of patient's demographics (age and BMI), flap characteristics (ALT flap and keystone flap size), surgical technique, and postoperative complications, were collected from the medical record. Two rating scales of Vancouver Scar Scale (VSS) score, and Scar Cosmesis Assessment and Rating (SCAR) score, were used to evaluate the aesthetics of KDPIF.

Surgical procedure

The KDPIF was designed to cover the donor site defect that caused by the harvested ALT flap. In operation, the KDPIF width we designed was longer than that of the width of the donor defect, and the width ratio between donor site and keystone flap was adjusted according to the patient's age, BMI and skin tension. If there was a long elliptical defect on the donor site, suturing both ends of the defect can reduce the size of the donor site defect, and then the KDPIF size was designed according to the reduced donor site defect (Fig 1). During the divide process of KDPIF, performing the blunt dissection of the deep fascia can increase the mobilization of the surrounding tissue of the KDPIF (the range of deep fascia dissection was adjusted according to the skin tension), and facilitate the closure of the donor site. The area of the blunt dissection can be increased according to patient's skin tension, and the dissectible area of the deep fascia was illustrated in Figure 2. Careful teasing the circumferential tissues of the KDPIF to preserve the integrity of perforators. After the KDPIF was advanced along the horizontal axis, the skin edge at the widest part of the donor defect was first sutured with the 2-0 nylon. Then the interrupted single layer nylon sutures were performed to close the skin around the flap (Fig 1). Finally, the V-Y advancement of each end of the flap was performed and sutured. Postoperatively, the operated limb was immobilized for 2 weeks to prevent wound dehiscence.

Results

Twelve patients (10 males, 2 females) with the mean age 47.5 years (range, 27-66 years) and mean BMI 24.9 (range, 18.24-31.24) were included in this study. All donor sites can't be closed directly without skin graft according to the evaluation of skin tension conducted by two experienced surgeons and the KDPIFs (type IIA = 8 cases; SMU-modification KDPIF = 4 cases) were designed to close the donor sites. The mean size of the harvested ALT flap (the donor site size) was 8.1 cm × 14.4 cm (range from 8.0 cm × 11.0 cm to 9.0 cm × 21.0 cm), and the mean size of keystone flap was 9.1 cm × 16.4 cm (range from 8.0 cm × 13.0 cm to 12.0 cm × 19.0 cm). At the mean follow-up of 8.3 months (range, 6-12 months), of 12 patients, 2 patients suffered from the skin infection around the flap, which was controlled under the treatment of wound dressing change and oral antibiotics. Wound dehiscence, OCS, venous return disorder, and skin necrosis were not presented in any patients. All patients were evaluated at the final follow-up with ASS core (mean, 6.7; range, 5-8) and SCAR core (mean, 7.3; range, 6-9) (Table 1). And results all the flaps was satisfactory, both clinical reconstruction and aesthetic need can be fulfilled compared with skin graft (Fig 3, 4 and 5).

Case Presentation

A 54-year-old man who was exposed to severe soft tissue defects in his left foot underwent emergency surgery in our hospital 5 hours later after the injury. In the operation, the debridement and Vacuum Sealing Drainage (VSD) were performed to control soft tissue infection. In the second stage of operation, the ALT flap (9.0 cm × 21.0 cm) was used to reconstruct the soft-tissue defects after the infection was controlled, and the donor site was reconstructed using a skin graft. One week after surgery, the patient developed skin necrosis and wound dehiscence in the donor site due to improper activity. After evaluation, the KDPIF was designed to close the donor site defect with a flap size of 12.0 cm × 19.0 cm (Fig 3). No complications such as skin infection, necrosis, and wound dehiscence were observed during telephone follow-up.

Discussion

ALT flap has been widely used to reconstruct various complex soft-tissue defects due to its advantages of considerable harvesting area, long vascular pedicle, concealed donor site, and large vessel diameter [1, 3]. There were numerous studies focusing on the application of the ALT flap in reconstruction of soft tissue defects [3]. However, many complications of the ALT flap donor site still needed further research and resolution. Patients with a width of donor site defect more than 6 cm who underwent the primary closure may suffer from wound dehiscence and skin necrosis [6]. Skin graft was a common method to solve the donor site defect, but this method was associated with a secondary donor site and low aesthetic [12]. In the present study, we used the KDPIF to reconstruct the ALT flap donor site defect with a width of more than 6 cm in 12 patients. The efficiency of KDPIF was assessed by the aesthetics and complications in the donor site.

As an emerging reconstructive technique, KDPIF was first introduced by Behan in 2003 [8]. There were four types of KDPIF that were described in the previous study with Type I (a standard flap design with

direct closure of defects), Type IIA (type I combined with the additional division of the deep fascia), Type IIB (a skin graft is required to cover the secondary defect), Type III (double keystone flaps like a butterfly wing), and Type IV (rotational reconstruction) [8]. Furthermore, another modified keystone flap mentioned by Moncrieff et al. was named SMU (Sydney Melanoma Unit) - modification KDPIF [13]. A skin bridge along the greater arc of the KDPIF was maintained in patients with the SMU-modification KDPIF, which allows additional vascularity, preserves subdermal lymphatics, and promotes wound healing [13, 14]. In this study, 12 patients received the treatment of KDPIF (type IIA = 8 cases; SMU-modification KDPIF = 4 cases) for the ALT flap donor site defects (the mean width was 8.1 cm; range from 7 to 10 cm).

During the operation of KDPIF, the soft tissue defect in the donor site can be transferred from an area without surrounding tissue laxity to an area with sufficient laxity, and this method follows the principle of recruitment of laxity [9]. The skin tension can be redistributed from the donor site to both ends of KDPIF via the V-Y advancement [15]. Furthermore, The V-Y advancement flap from the corner of the KDPIF to the center provides an additional laxity for the horizontal axis movement of KDPIF into the donor site defect [8]. In this way, the donor site defect can be covered with local skin (replace like-with-like) without the need for harvesting free flap and vascular anastomosis, which not only reduces the incidence of vascular crisis, but also avoids the difference of skin color caused by free flap or skin graft. In the flap size designing, the original design of KDPIF was based on the 1:1 ratio between the width of the KDPIF and the elliptical defect [8]. However, due to there were many strong skeletal muscles and insufficient laxity in the thigh, this ratio was modestly increased (with adjustment for age and BMI) to ensure a lower skin tension. Furthermore, the deep fascia in the flap margin was divided to increase the flap movement to close the ALT flap donor site in all patients. In our follow-up, no one case presented the wound dehiscence, which indicated that the KDPIF was associated with satisfactory work to bear the skin tension. Hence, we recommended that the blunt dissection of deep fascia around the flap should be created when patients with the donor site defect were repaired using the KDPIF, so as to increase the movement of the KDPIF and disperse the skin tension, which can better prevent the risk of wound dehiscence caused by excessive skin tension in the thigh. Furthermore, the dissociation of deep fascia should be performed according to the patient's age, BMI, and intraoperative skin tension assessment. For patients with low skin tension, the conventional dissociation (the deep fascia around the KDPIF) can be divided; for patients with high skin tension, the dissociation area should be gradually increased to prevent the high skin tension in the sutured area (Fig 2).

Additionally, the KDPIF was also associated with an extremely high survival rate, which was related to the fact that the flap was based on a multi-perforator-based advancement [16]. There were multiple hot spots of the perforator in thigh skin, which provides a reliable blood circulation for KDPIF even when the large keystone flap was designed. Furthermore, during the blunt dissection of the deep fascia around the flap, the central position of the flap (where the center of the flap was located near the hot spots of the perforator) was not divided, and the vascular pedicle was not dissected and anastomosed, so as to ensure the integrity of perforators and contribute to a high survival rate of the flap [7, 16-18]. In addition, by the blunt dissociation of the peripheral deep fascia, an unequal distribution of skin tension around the flap can be created with a considerable tension in the periphery of the flap and less skin tension in the

central area [7]. The blood circulation was preserved in the area of low skin tension (the central area of the flap) where the vascular pedicle was not dissected, which may contribute to the reliable blood circulation of KDPIF. In this study, none of the patients developed wound dehiscence or vascular based flap necrosis.

With the continuous development of microsurgical techniques, aesthetics has become an important goal for patients and surgeons. It is our experience that patients are more receptive to linear scars compared to sheet scars (Fig 4). Furthermore, the local flap advancement in the reconstruction of soft-tissue defects can readily achieve an ideal reconstructive goal (replace like-with-like) and avoid large areas of pigmentation and skin color differences, which may be caused by skin graft [19]. In the present study, we performed VSS score and SCAR score for 12 patients with ASS core (mean, 6.7; range, 5-8) and SCAR core (mean, 7.3; range, 6-9), and all patients were satisfied with the appearance of the donor site. Furthermore, the skin morbidity in the donor area may significantly impact the aesthetics of the donor area and the patient's rehabilitation. In our observation, patients who underwent the skin graft to repair the ALT flap donor site more likely to present the morbidity in initial or secondary donor site. However, the primary closure of the ALT flap donor site that was managed using KDPIF was associated with lower donor site morbidity and higher aesthetics compared with a skin graft. In this present study, there were just two cases exposed to the modest skin infection and controlled by the treatment of wound dressing change and oral antibiotics.

Another great advantage of the KDPIF is that it is easy to operate. The procedure does not require superb microsurgical techniques and microsurgical equipment. And it is easily performed in a variety of levels of medical institutions. As long as the surgeon strictly grasps the operative indications and the design scheme of the flap, and carefully separates the deep fascia around the flap during the operation, a high success rate of the operation can be achieved. In addition, the donor defect of the ALT flap was usually elliptical, which was in line with the design principles of KDPIF. In conclusion, this study demonstrated that using the KDPIF to close the ALT flap donor site primarily is an effective and alternative treatment including the advantages of high survival rate, low morbidity, good aesthetics and simple operation.

Conclusion

With the development of microsurgical techniques, the ALT flap has been widely used to reconstruct various soft tissue defects. However, the donor site morbidity remains a challenge for surgeons, especially when the width of harvested ALT flap was greater than 6 cm. In this study, primary closure of the ALT donor site was completed using the KDPIF, which method not only reduces the donor site morbidity but also increases the aesthetics compared to conventional treatment (skin graft). Hence, this study provides an experience of effective and alternative treatment for repairing the donor site defects caused by the ALT flap.

Abbreviations

ALT flap: Anterolateral thigh flap

KDPIF: Keystone Design Perforator Island Flap

OCS: Osteofascial compartment syndrome

VSS score: Vancouver Scar Scale score

SCAR score: Scar Cosmesis Assessment and Rating score

VSD: Vacuum Sealing Drainage

BMI: Body mass index

SMU: Sydney Melanoma Unit

Declarations

Acknowledgments

Not applicable

Authors' Contributions

FYC and YSL were the patient's first-visit doctors, followed up the patient and contributed to manuscript drafting; KL reviewed the literatures and were responsible for the revision of the manuscript for important intellectual content; JJ and AY were the patient's surgeons, performed the surgery and were responsible for final approval of the version of the article to be published. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

All procedures performed in this study were carried out in accordance with the Declaration of Helsinki. This study was approved by the Ethics Committee of The First Affiliated Hospital of Xinjiang Medical

University. Written informed consents were obtained from the patients for their data to be recorded in our study.

Consent for publication

Written informed consents were obtained from the patients for publication of this study and any accompanying images. A copy of the written consents is available for review by the Editor of this journal.

Competing interests

The authors declare that they have no competing interests.

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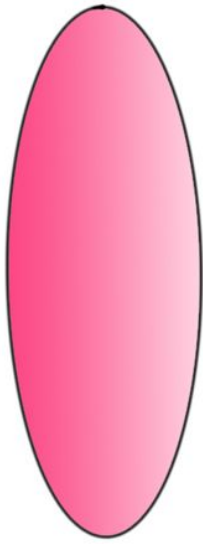
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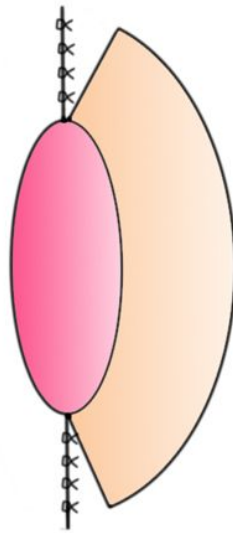
Tables

Table 1. Patients' demographic data							
Patient No.	Age/Sex	BMI	ALT flap size (m ²)	Keystone flap size (m ²)	Complications	VSS score	SCAR score
1	54, M	21.45	9 × 21	12 × 19	none	7	6
2	47, M	25.16	8 × 14	9 × 15	none	6	7
3	63, F	29.31	7 × 15	9 × 17	none	7	7
4	35, M	23.74	8 × 12	8 × 15	none	7	8
5	41, M	19.62	7 × 12	8 × 15	none	7	8
6	38, M	24.73	8 × 13	9 × 15	none	6	6
7	27, M	31.24	8 × 11	8 × 13	none	6	7
8	49, M	26.45	7 × 15	8 × 18	none	7	8
9	55, F	18.24	8 × 14	9 × 16	Skin infection	8	8
10	51, M	27.52	9 × 19	10 × 21	none	5	6
11	66, M	23.93	10 × 15	11 × 18	Skin infection	8	9
12	44, M	27.42	8 × 12	8 × 15	none	7	8
<p>Note: Complications include wound dehiscence, osteofascial compartment syndrome (OCS), venous return disorder, skin infection and necrosis.</p> <p>Abbreviations: BMI, body mass index; ALT flap, The anterolateral thigh flap; VSS, Vancouver Scar Scale score; SCAR, Scar Cosmesis Assessment and Rating score</p>							

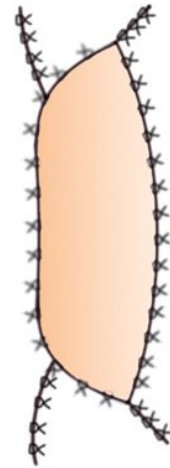
Figures



a



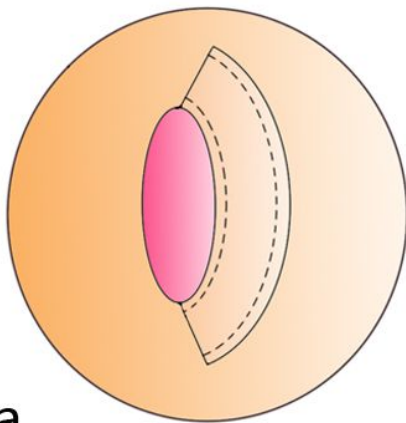
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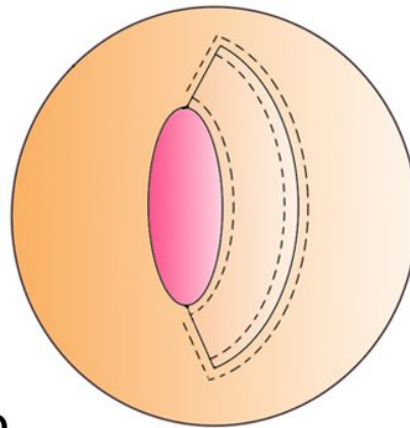
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Figure 1

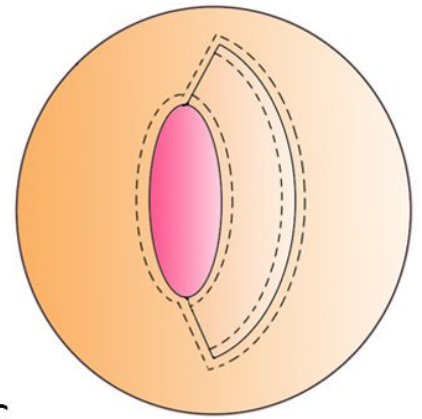
The Design of Keystone Design Perforator Island Flap (KDPIF) reconstruct anterolateral thigh (ALT) flap donor site defect. a. suturing both ends of the donor site reduce the size of defect; b. KDPIF was designed according to the defect size; c. advance and suture the KDPIF.



a



b



c

Figure 2

Blunt dissection of deep fascia around the flap. a. the conventional dissociation of the peripheral deep fascia; b. expending the area of conventional dissociation; c. adding the dissociation of the deep fascia around the donor site defect.

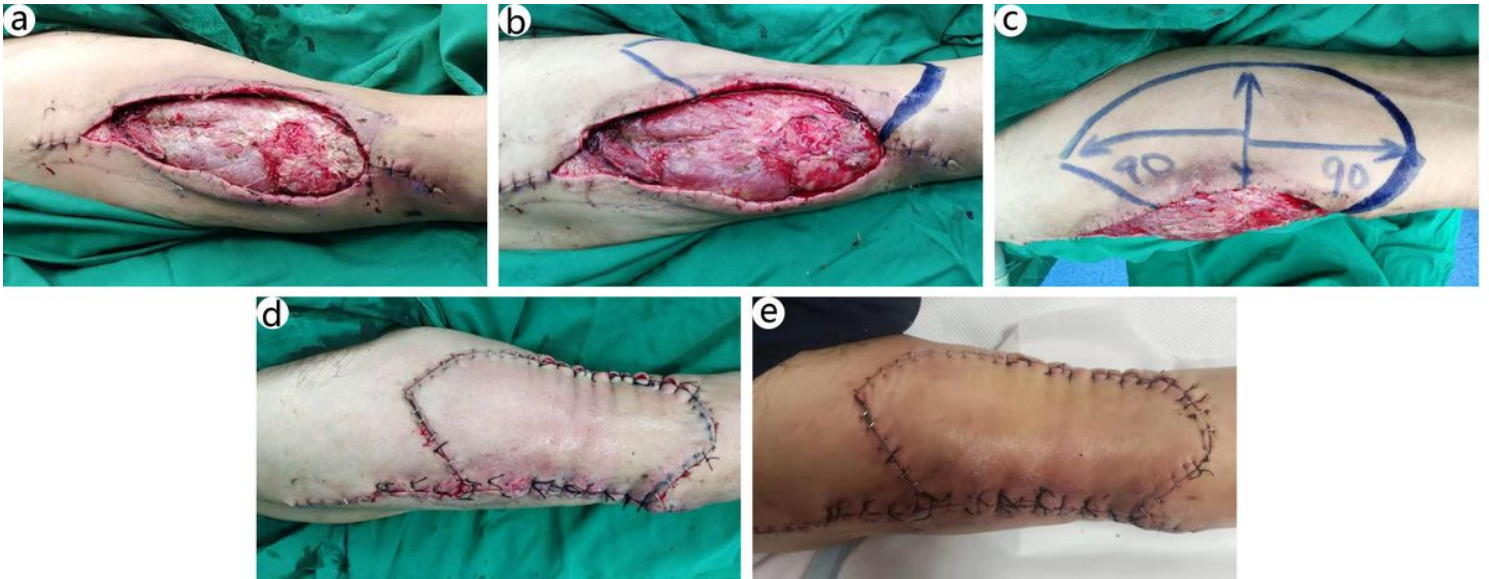


Figure 3

The design and advance of Keystone Design Perforator Island Flap (KDPIF). a. The anterolateral thigh (ALT) flap donor site defect; b-c. designing the KDPIF; d-e. advancing and suturing the KDPIF and postoperative appearance.

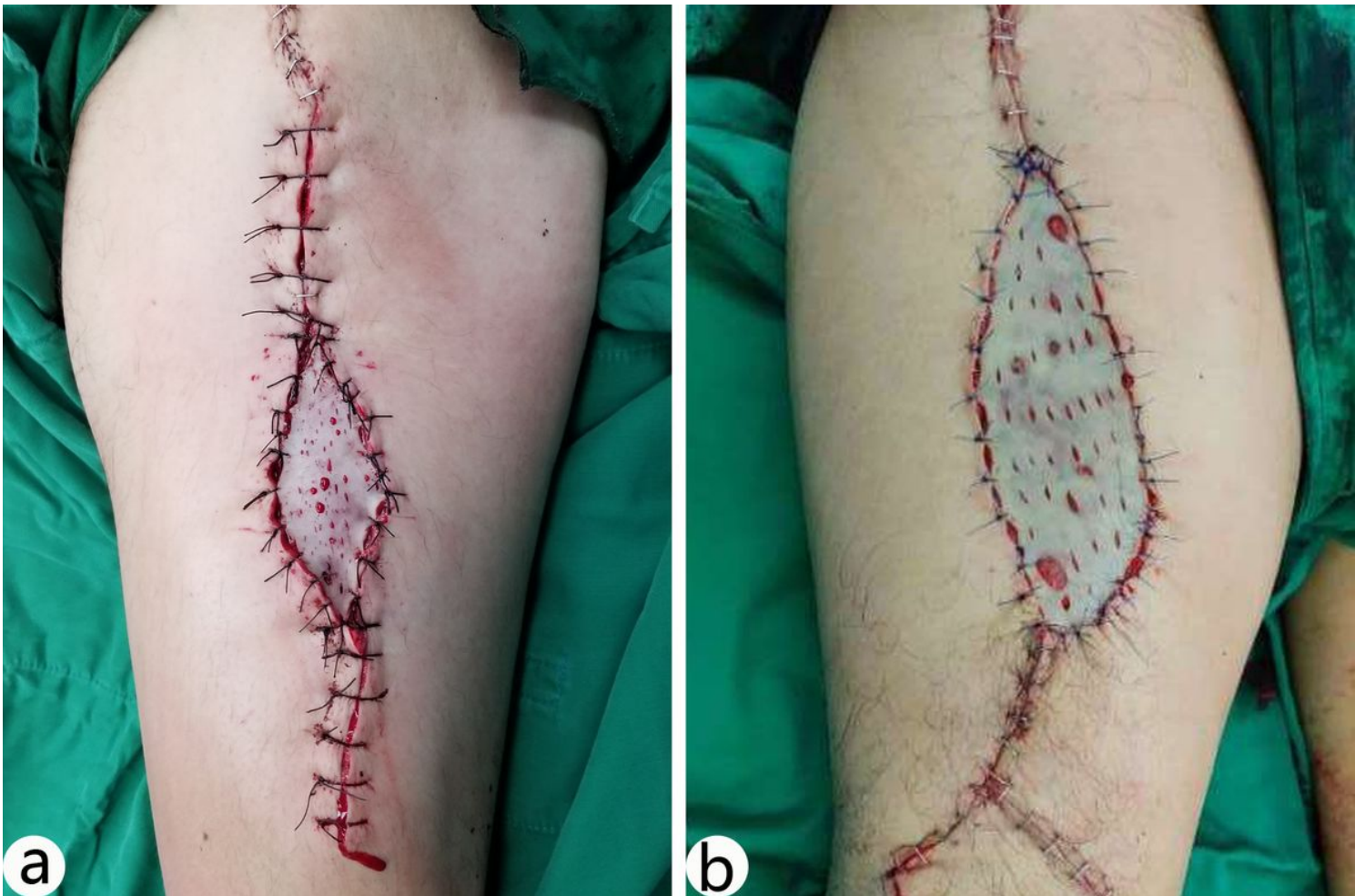


Figure 4

Skin graft reconstruct the ALT flap donor site. a-b. sheet scars caused by the skin graft.

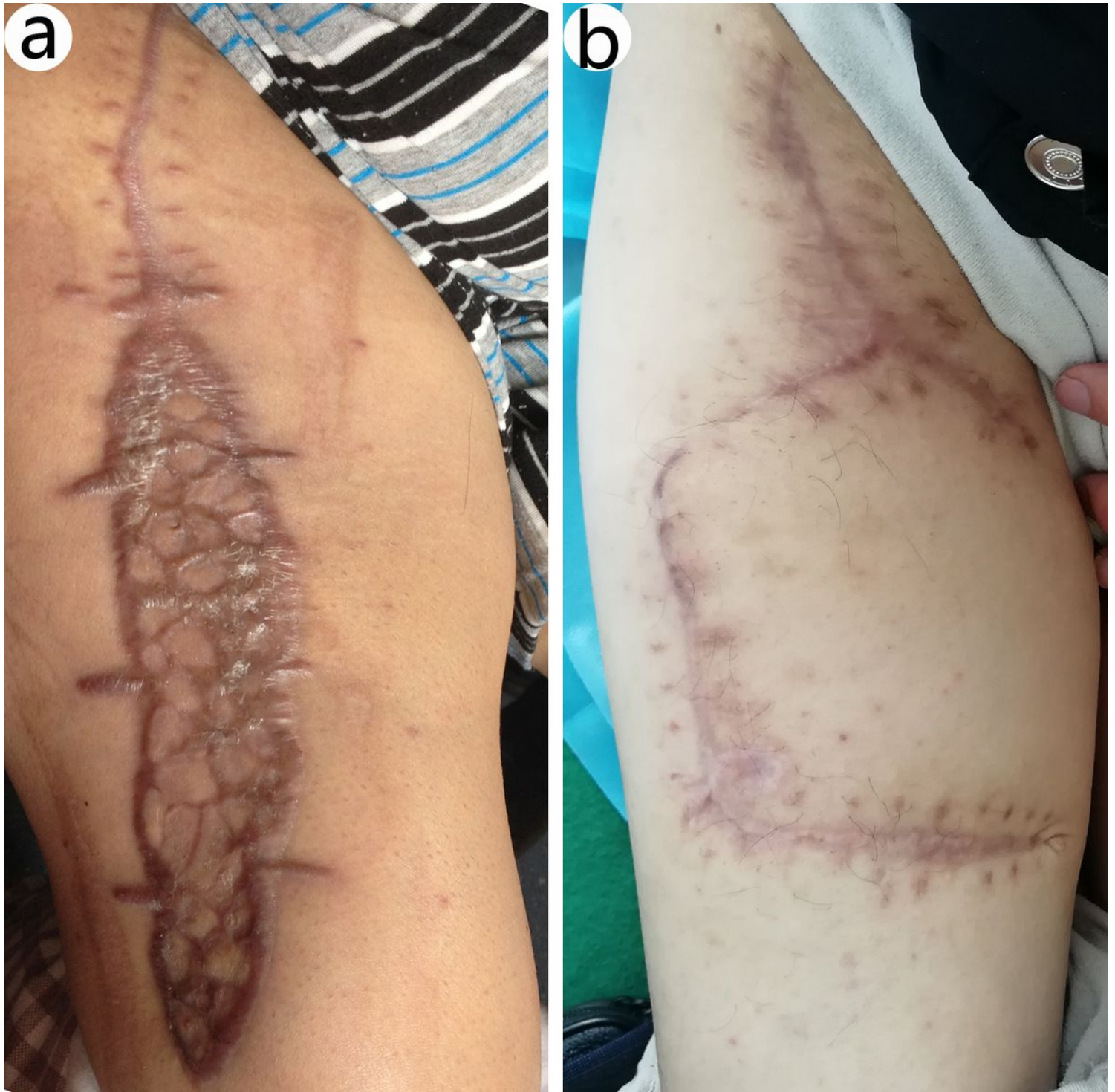


Figure 5

Aesthetic comparison between skin graft and KDPIF for reconstructing the ALT flap donor site after operation. a. skin graft was associated with sheet scar; b. KDPIF was associated with the linear scar.