Comparison of Anterolateral Thigh Perforator and Peroneal Artery Perforator Flaps in Elderly Patients With Foot Soft Tissue Defects

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Jingjing Hu[1], Fei Wang[1], Jiang Li[1], Liqi Yi[2], Jiguo Yang[2]

[1]Operating Room, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, 318050 Taizhou, Zhejiang, China
[2]Department of Hand and Foot Surgery, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, 318050 Taizhou, Zhejiang, China

AIM: This study aimed to explore the efficacy of anterolateral thigh perforator (ALTP) flap and peroneal artery perforator (PAP) flap transplantation and their influence on levels of pain and wound growth factors in elderly patients with soft tissue defects caused by foot trauma.

METHODS: A total of 98 elderly patients with foot trauma who underwent flap transplantation in the hospital from January 2022 to January 2024 were collected and analyzed retrospectively. Patients were divided into the ALTP group (n = 45, receiving ALTP flap transplantation) and the PAP group (n = 53, receiving PAP flap transplantation). Visual analogue scale (VAS) and American orthopedic foot and ankle society (AOFAS) score were used to assess the pain and functional outcome. Enzyme-linked immunosorbent assay (ELISA) kits were utilized to test the levels of vascular endothelial growth factor (VEGF), basic fibroblast growth factor (bFGF) and hypoxia inducible factor 1 (HIF-1) in wound fluid.

RESULTS: The wound size in the ALTP group was larger than that in the PAP group ($p < 0.001$). Longer operative time, hospitalization time and greater intraoperative blood loss were noted in the ALTP group than in the PAP group ($p < 0.001$). Linear regression analysis showed that the surgical method was the main factor affecting operative time, hospitalization time and intraoperative blood loss ($p < 0.001$). The necrosis rate in the ALTP group (13.33%) was higher than that in the PAP group (3.77%), but the difference was not statistically significant ($p = 0.176$). Compared with the ALTP group, the VAS score of the PAP group was markedly reduced at 3 days and 1 week after surgery, and 1 month after follow-up ($p < 0.001$). 3 days after surgery, the levels of VEGF and bFGF of the PAP group were significantly increased compared with the ALTP group ($p < 0.001$). 1 week after surgery, the levels of bFGF of the PAP group were higher compared with the ALTP group ($p = 0.003$). The total incidence rate of complications in the ALTP group (25/44, 56.82%) was significantly higher than that in the PAP group (7/53, 13.21%) ($p < 0.001$). And multivariate logistic regression analysis showed that ALTP was the independent influencing factors for complications ($p < 0.001$). At 6 months after surgery, there was no significant difference in AOFAS scores between the two groups ($p = 0.078$).

CONCLUSIONS: ALTP and PAP flap transplantation were both suitable for the reconstruction of soft tissue defects caused by foot trauma in elderly patients, with the latter associated with shorter surgical time and hospitalization time, as well as better wound healing, less postoperative pain and fewer complications.

Keywords: anterolateral thigh perforator flap; peroneal artery perforator flap; foot soft tissue defects; pain; wound growth factors

Introduction

The incidence of traffic accidents has increased significantly in recent years. High-energy trauma not only leads to limb injuries but is also accompanied by soft tissue defects. Given the significance of the foot for standing, weight bearing, walking and other functions, repairing foot soft tissues arising from foot trauma is especially critical [1]. Flap transplantation is a common repair modality for soft tissue defects of the foot. Anterolateral thigh perforator (ALTP) flap is a classic choice for flap transplantation. The ALTP flap has the advantages of long vessel tips, thick vascular diameter, and large area [2]. In addition, the aesthetic effect and functional outcome of ALTP flap have also been well recognized [2,3], but performing such transplantation requires superior micro-surgical skills. Patients who receive ALTP flap transplantation are plagued by postoperative complications, such as bulky flap, infections, and hematomas [4,5]. Thus, the safety of elderly patients following flap transplantation is critical.

Peroneal artery perforator (PAP) flap transplantation was first proposed by Yoshimura *et al.* [6]. PAP flap is supplied with blood flow from the septocutaneous or musculocuta-

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Correspondence to: Jiguo Yang, Department of Hand and Foot Surgery, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, 318050 Taizhou, Zhejiang, China (e-mail: 215511887@163.com).

neous perforators branching off from the peroneal artery [7]. Some studies have reported the application of PAP flap in the reconstruction of the lower extremity [7,8]. In fact, the opinions on the selection of skin flaps for foot soft tissue reconstruction have been inconsistent. Li *et al*. [5] reported that the lateral supramalleolar flap was more suitable for foot and ankle reconstruction in elderly patients than ALTP, due to the lower surgical time, costs, and incidence of postoperative complications. Another study reported that the ALTP flap has better outcomes in foot and ankle reconstruction compared with the sural neurofasciocutaneous flap, especially suitable for larger and more distally located defects [9]. In addition, a retrospective study showed that the PAP plus fasciocutaneous flap was superior to the posterior tibial artery perforator plus fasciocutaneous flap, because of a lower incidence rate of complications at the donor site [10]. However, the differences in the effectiveness of ALTP and PAP in foot soft tissue reconstruction are still unclear. In addition, considering that most elderly patients suffer from chronic diseases and have poor surgical tolerance, the application of ALTP and PAP in elderly patients needs further investigation. Therefore, this study aims to explore the differences in efficacy between ALTP and PAP flap transplantation, as well as their impacts on the pain levels and wound growth factors in elderly patients with soft tissue defects.

Materials and Methods

Patients

A total of 98 elderly patients with foot trauma who visited Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University between January 2022 and January 2024 were included. The clinical data of patients were collected for retrospective analysis. This study was approved by the ethics committee of Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University (Approval number: K20250313 (EZ)), and all patients signed informed consent forms. The procedures of this study were designed in adherence to the Declaration of Helsinki. The inclusion criteria of this study are as follows: (1) patients aged $\geq$60 years; (2) patients with soft tissue defect caused by foot trauma; (3) patients with fresh wounds or unilateral injury; (4) patients receiving ALTP or PAP flap transplantation; (5) patients with complete clinical data. Patients who can be classified in the following categories were excluded: (1) combined severe impairment in heart, liver, kidney and lung function; (2) combined serious infections; (3) spinal fracture; (4) immune system disorders; and (5) lost to follow-up. Patients were divided into the ALTP group (n = 45, receiving ALTP flap transplantation) and the PAP group (n = 53, receiving PAP flap transplantation) according to the flap transplantation approaches.

Flap Transplantation

The defect areas were carefully inspected and debrided. For patients with fractures, the appropriate fixation methods were performed after evaluation; if only bones or tendons were exposed, external fixation was performed after surgery using casts or splints. Before surgery, the vascular status of the involved area and the perforators of the flap were confirmed using Doppler flowmeter.

ALTP flap transplantation (Fig. 1): The area and shape of the skin flap in the donor site were determined and marked based on the defect area. The skin was incised to the deep fascia. The cutaneous branch of the descending branch of the lateral circumflex femoral artery was carefully separated. The edges, distal and proximal ends of the skin flap were cut. Next, the pedicle was cut. The skin flap was transplanted to the defect area. Anastomosis of blood vessels was performed under the microscope. The donor site was sutured with cosmetic thread. Patients were required to be bedridden for a week after surgery.

PAP flap transplantation (Fig. 2): The area and shape of flap in the donor site were marked. The skin was cut to the deep fascia along the posterior edge. The skin flap was carefully lifted to search for the perforating branches of the peroneal artery. According to the position of perforating arteries in the skin, the design of skin flap was adjusted. Next, the skin flap was separated according to the design. The entire skin flap was carefully lifted and rotated 180 °C to cover the defect site. The wound was sutured using a 4-0 silk suture.

Follow-up and Functional Outcome

The patients were followed up for 6 months after discharge, through outpatient consultation and telephone. The complications were recorded during the follow-up. American orthopedic foot and ankle society (AOFAS) score was used to assess the functional outcome of patients at 6-month follow-up. AOFAS score includes three sub-fields: pain, function, and alignment [11]. The total score ranges from 0 to 100, which is proportional to foot function.

Surgical Indicators and Necrosis Rate

The clinical data about the operation were collected, including wound size, debridement time, operative time, intraoperative blood loss, and hospitalization time. Wound size was measured by the manual planimetry method. Briefly, the wound size was marked on a transparency film, and then the area was calculated. Complete necrosis was defined as flap necrosis >60%, whereas partial necrosis was flap necrosis $\leq$60% [12]. Necrosis rate was calculated using the following formula:

$$\text{Necrosis rate}\ (\%) = (\ \text{Complete necrosis} + \text{Partial necrosis}\ )/\text{Total case}\ \times 100.$$

Assessment of Pain

Visual analogue scale (VAS) was adopted to assess the pain before surgery, 3 days and 1 week after surgery, and at

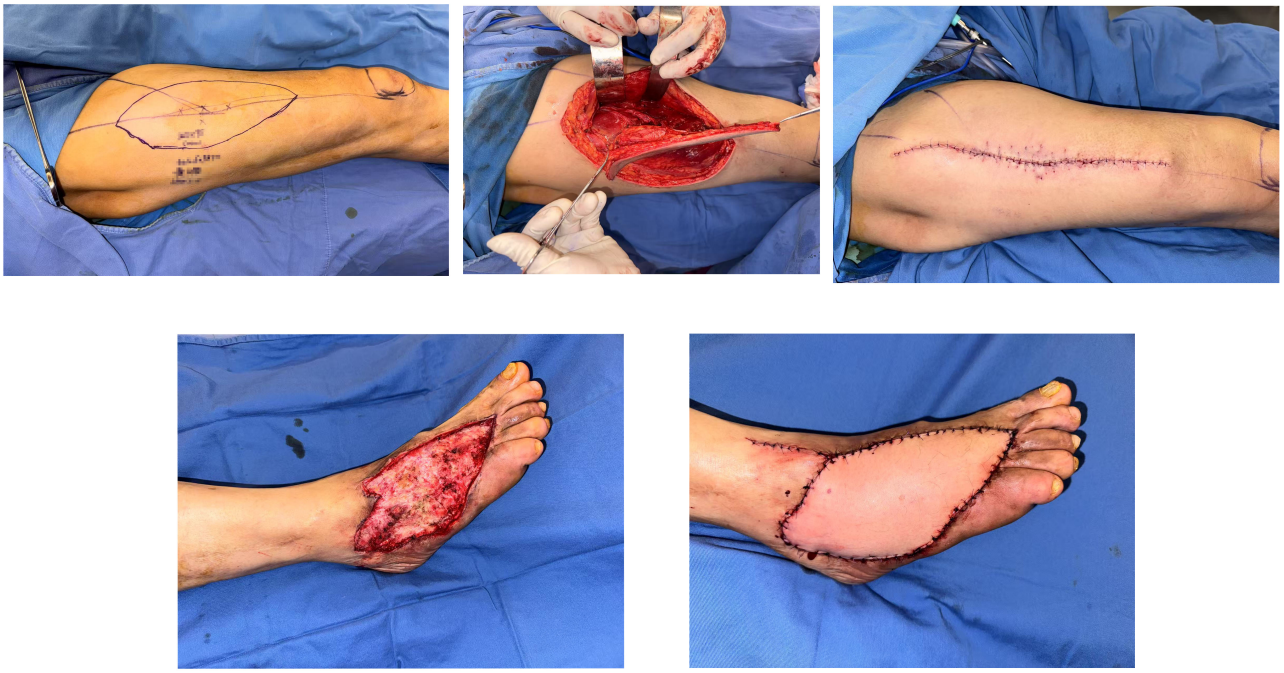

Fig. 1. Surgical procedure of anterolateral thigh perforator (ALTP) flap transplantation.

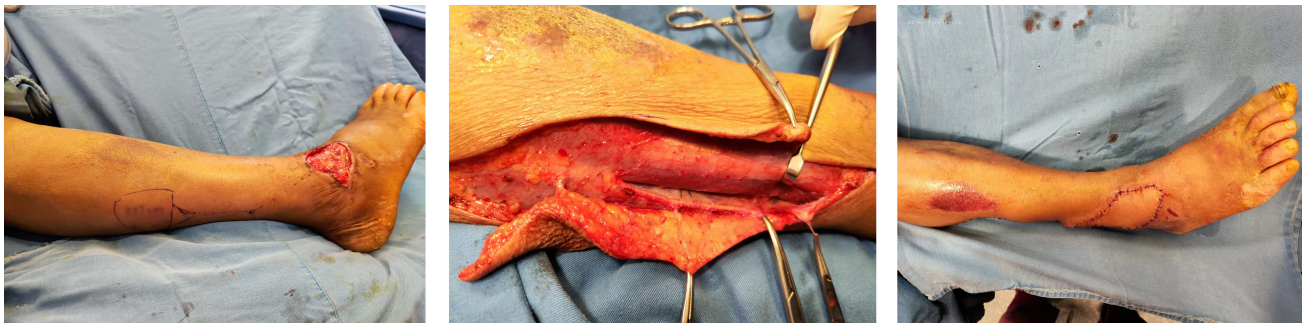

Fig. 2. Surgical procedure of peroneal artery perforator (PAP) flap transplantation.

1-month follow-up. The VAS score ranges from 0 to 10 points, with a higher score indicating more severe pain.

A patient-controlled intravenous analgesia (PCIA) pump was applied to relieve pain. Dexmedetomidine (H20203335, Sinopharm, Langfang, China) and sulfentanil (H20054171, Humanwell Pharmaceutical Co., Ltd., Yichang, China) were used. The locking time was set at 15 min, and the analgesics were infused at a rate of 2 mL/h. When the patient experiences pain, the dose of the drug can be increased by pressing the button of PCIA. A single loading dose was 2 mL. The total number of PCIA compressions was recorded.

Detection of Wound Growth Factors

Wound fluid was collected using sterile gauze applied at the wound site. The fluid was collected in a centrifuge tube prior to centrifugation (4 °C, 3000 rpm/min, 10 min). The upper liquid layer was collected and stored at –20 °C. The level of growth factors was tested using enzyme-linked immunosorbent assay (ELISA) kits, including vascular endothelial growth factor (VEGF; SP10198, Saipei Biotechnology Co., Ltd., Wuhan, China), basic fibroblast growth factor (bFGF; SP10182, Saipei Biotechnology Co., Ltd., Wuhan, China) and hypoxia inducible factor 1 (HIF-1; SP10393, Saipei Biotechnology Co., Ltd., Wuhan, China). The detection of growth factors was conducted before surgery, 3 days and 1 week after surgery. In addition, total protein concentration of the samples was detected using bicinchoninic acid assay (BCA) protein assay kit (PC0020, Solarbio, Beijing, China). The level of VEGF, bFGF, and HIF-1 was normalized to the total protein in wound fluid.

Statistical Analysis

The clinical data were analyzed using SPSS software (version 20, IBM, Armonk, NY, USA). The Shapiro–Wilk test

Table 1. General information about patients.

General information	ALTP group (n = 45)	PAP group (n = 53)	t/χ^2	p
Age, year	73.47 ± 4.64	72.06 ± 5.21	1.403	0.164
Gender, n (%)			0.053	0.819
Female	18 (40.00%)	20 (37.74%)		
Male	27 (60.00%)	33 (62.26%)		
Body mass index, kg/m^2	22.02 ± 2.77	22.75 ± 3.33	1.167	0.246
Cause of trauma, n (%)			1.866	0.393
Traffic accident injury	25 (55.56%)	34 (64.15%)		
High-explosive injury	14 (31.11%)	16 (30.19%)		
Crush injury	6 (13.33%)	3 (5.66%)		
Drinking, n (%)	25 (55.56%)	31 (58.49%)	0.086	0.770
Smoking, n (%)	20 (44.44%)	31 (58.49%)	1.924	0.165
Diabetes, n (%)	27 (60.00%)	31 (58.49%)	0.023	0.880
Hypertension, n (%)	20 (44.44%)	25 (47.17%)	0.073	0.787
Injured foot, n (%)			1.608	0.205
Right	27 (60.00%)	25 (47.17%)		
Left	18 (40.00%)	28 (52.83%)		

Note: ALTP, anterolateral thigh perforator; PAP, peroneal artery perforator.

Table 2. Comparison of surgical indicators and necrosis rate between the two groups.

	ALTP group (n = 45)	PAP group (n = 53)	t/χ^2	p
Wound size, cm^2	95.98 ± 15.42	62.88 ± 10.91	15.278	<0.001
Preoperative debridement times, h	1.92 ± 0.49	1.70 ± 0.66	1.845	0.068
Operative time, min	209.53 ± 25.46	134.17 ± 23.15	15.339	<0.001
Intraoperative blood loss, mL	119.62 ± 19.05	70.13 ± 15.30	14.260	<0.001
Hospitalization time, day	25.44 ± 3.09	14.81 ± 2.31	19.454	<0.001
Partial necrosis, n (%)	5 (11.11%)	2 (3.77%)	1.024	0.312
Complete necrosis$^{\&}$, n (%)	1 (2.22%)	0 (0)	/	0.459
Necrosis rate, n (%)	6 (13.33%)	2 (3.77%)	1.829	0.176

Note: $^{\&}$Fisher's exact test.

was used for assessing the normality of data distribution. Continuous data with normal distribution are presented as mean ± standard deviation (SD). Independent-sample t test was adopted to compare the differences between the two groups, while a paired t test was adopted to compare variables at preoperative and postoperative time points. Data with skewed distribution is expressed as median (quartile). The inter-group comparisons were conducted using Mann–Whitney U test, whereas the paired Wilcoxon Signed-Rank test was applied for analyzing intra-group differences. Categorical data are expressed as counts and percentages. Chi-square test (if 1 < theoretical number < 5) or Fisher's exact test (if theoretical number <1) was employed for comparison between two groups. Multiple stepwise linear regression analyses were used to explore the factors influencing operative time, hospitalization time and intraoperative blood loss. The impact of surgical methods and wound area on the complications was explored using logistic regression analysis. Differences with $p < 0.05$ were considered statistically significant.

Results

General Information of Patients

In the ALTP group, there were 18 female cases and 27 male cases, with an average age of 73.47 ± 4.64 years. In the PAP group, 20 cases were female, and 33 cases were male, with an average age of 72.06 ± 5.21 years. There were no significant differences in general information between the two groups ($p > 0.05$) (Table 1).

Comparison of Surgical Indicators and Necrosis Rate Between Two Groups

The wound size in ALTP group was larger than that in PAP group ($p < 0.001$). Patients in the ALTP group spent a longer time in operation and hospitalization and experienced greater intraoperative blood loss compared with those in the PAP group ($p < 0.001$) (Table 2). Next, linear regression was conducted to determine whether these differences were caused by surgical methods or wound size. The results showed that the surgical method was the main factor affecting operative time, hospitalization time and intraoperative blood loss ($p < 0.001$) (Table 3).

Table 3. Linear regression analysis.

	Univariate analysis					Multivariate analysis				
	B	SE	β	t	p	B	SE	β	t	p
Operative time										
Surgical method										
PAP					Reference					Reference
ALTP	75.364	4.913	0.843	15.340	<0.001	68.842	7.860	0.770	8.759	<0.001
Wound size	1.483	0.157	0.695	9.459	<0.001	0.199	0.188	0.093	1.062	0.291
Intraoperative blood loss										
Surgical method										
PAP					Reference					Reference
ALTP	49.490	3.471	0.824	14.259	<0.001	43.593	5.531	0.726	7.881	<0.001
Wound size	0.993	0.106	0.693	9.410	<0.001	0.180	0.132	0.126	1.365	0.175
Hospitalization time										
Surgical method										
PAP					Reference					Reference
ALTP	10.633	0.546	0.893	19.464	<0.001	9.812	0.872	0.824	11.247	<0.001
Wound size	0.208	0.020	0.732	10.526	<0.001	0.025	0.021	0.088	1.205	0.231

Table 4. Comparison of pain between the two groups.

VAS score	ALTP group (n = 44)	PAP group (n = 53)	Z	p
Before surgery	9 (8, 9)	9 (8, 9)	0.139	0.890
3 days after surgery	7 (6, 8)*	6 (5, 7)*	4.149	<0.001
1 week after surgery	4 (3, 5)*	3 (2, 4)*	4.050	<0.001
1-month follow-up	1 (1, 2)*	1 (1, 2)*	3.326	<0.001
Total number of PCIA compression	10.55 ± 3.34	8.91 ± 3.71	2.267	0.026

Note: * $p < 0.05$ compared with before surgery. PCIA, patient-controlled intravenous analgesia; VAS, visual analogue scale.

In the ALTP group, 1 case developed complete necrosis after surgery and 5 cases developed partial necrosis. PAP group has 2 cases of partial necrosis. The necrosis rate in the ALTP group (13.33%) was higher than that in the PAP group (3.77%), but the difference was not statistically significant ($p = 0.176$) (Table 2). Partial necrosis of the skin flap was restored by postoperative care. One patient in the ALTP group with complete necrosis required debridement and skin grafting surgery; therefore, this case was not included in the subsequent analysis.

Comparison of Pain Between the Two Groups

There was no significant difference in VAS score between the ALTP and PAP groups before surgery ($p = 0.890$). In the two groups, the VAS scores after surgery were decreased compared to before surgery ($p < 0.05$), and progressively decreased with time. Compared with the ALTP group, the VAS score of the PAP group was markedly reduced at 3 days and 1 week after surgery, and 1 month after follow-up ($p < 0.001$). After surgery, the total number of PCIA compressions in the PAP group was lower than that in the ALTP group ($p = 0.026$) (Table 4).

Comparison of Wound Growth Factors Between the Two Groups

In the two groups, the levels of VEGF, bFGF and HIF-1 were significantly higher at 3 days after surgery than before surgery ($p < 0.05$). No significant differences in the levels of VEGF, bFGF and HIF-1 were observed before surgery between the two groups ($p > 0.05$). At 3 days after surgery, the levels of VEGF and bFGF of the PAP group were significantly increased compared with those of the ALTP group ($p < 0.001$). At 1 week after surgery, the levels of bFGF of the PAP group were significantly increased compared with the ALTP group ($p = 0.003$) (Table 5).

Comparison of Complications and Functional Outcomes

The total incidence of complications in the ALTP group (25/44, 56.82%) were significantly higher than those in the PAP group (7/53, 13.21%) ($p < 0.001$). In the ALTP group, 13 patients had a bulky flap after surgery, and all of them underwent second revision surgery. At 6 months after surgery, there was no significant difference in AOFAS scores between the two groups ($p = 0.078$) (Table 6).

In order to eliminate the influence of wound size on complications, logistic regression analysis was used to explore

Table 5. Comparison of wound growth factors between the two groups.

Growth factors	ALTP group (n = 44)	PAP group (n = 53)	t	p
VEGF, ng/L				
Before surgery	389.57 ± 47.85	370.12 ± 54.89	1.840	0.069
3 days after surgery	542.58 ± 124.58*	689.73 ± 165.79*	4.857	<0.001
1 week after surgery	495.36 ± 97.25*	533.35 ± 113.14*	1.753	0.083
bFGF, ng/L				
Before surgery	119.22 ± 22.84	123.35 ± 31.89	0.719	0.474
3 days after surgery	268.77 ± 43.99*	339.26 ± 52.71*	7.060	<0.001
1 week after surgery	201.89 ± 35.26*	227.19 ± 45.58*	3.009	0.003
HIF-1, ng/L				
Before surgery	80.11 ± 19.33	75.36 ± 17.20	1.280	0.204
3 days after surgery	119.36 ± 33.28*	125.11 ± 35.50*	0.817	0.416
1 week after surgery	92.35 ± 29.87*	84.59 ± 24.63*	1.403	0.164

Note: * $p < 0.05$ compared with before surgery. bFGF, basic fibroblast growth factor; HIF-1, hypoxia inducible factor 1; VEGF, vascular endothelial growth factor.

Table 6. Comparison of complications and functional outcomes between the two groups.

	ALTP group (n = 44)	PAP group (n = 53)	t/χ^2	p
Complications				
Pressure ulcer	6 (13.64%)	2 (3.77%)	1.924	0.165
Infection	4 (9.09%)	1 (1.89%)	1.291	0.256
Venous thrombosis of the lower limbs	2 (4.54%)	1 (1.89%)	0.027	0.870
Bulky flap	13 (29.54%)	3 (5.66%)	9.957	0.002
Total	25 (56.82%)	7 (13.21%)	20.683	<0.001
Functional outcomes				
AOFAS score	81.55 ± 6.52	83.85 ± 6.16	1.783	0.078

Note: AOFAS, American orthopedic foot and ankle society.

the factors that affect complications. The univariate analysis showed that wound size (p = 0.010) and ALTP (p < 0.001) were the influencing factors of complications. But multivariate analysis showed that ALTP was the independent influencing factor for complications (p < 0.001) (Table 7).

Discussion

Elderly patients often suffer from some chronic diseases and poor tolerance for surgery, which brings challenges to the soft tissue reconstruction of the lower limbs [13]. At present, various skin flaps have been developed for the repair of soft tissue defects, such as perforated flap, free flap, pedicled flap, and myocutaneous skin flap [14–16]. Many flap options are available, each having its own indications and defects [17]. ALTP skin flap is widely used in clinical practice. The blood supply of ALTP flap was mostly from the perforator vessel from the descending branch of the lateral femoral circumflex artery [18]. The ALTP flap has the advantages of a concealed donor site, large flap area, constant vascular pedicle, thick diameter, and no impact on limb function, which is a commonly used flap for soft tissue repair [19]. However, ALTP flap transplantation requires proficient microsurgical techniques. The peroneal artery descends along the medial edge of the fibula and sends out perforating arteries along the way to supply the skin. These perforating blood vessels pass through the gap between the peroneus longus/brevis and the soleus muscle [7]. The clinical application of PAP flap in repairing soft tissue defects of the lower limbs has been reported [7]. PAP flap has the advantages of minimal donor site damage, flexible flap shape design, and easy acquisition [20,21]. In this study, we compared the effects of these two types of skin flaps in soft tissue defects caused by foot trauma. Compared with the ALTP group, the PAP group experienced shorter surgical time and hospitalization time, and significantly reduced intraoperative blood loss. This is because PAP flap transplantation does not require microvascular anastomosis, reducing surgical time and blood loss. This reduces the surgical risk for elderly patients and is beneficial for the postoperative recovery. The patients included in this study were all elderly patients suffering from some chronic diseases, including diabetes and hypertension. The blood glucose and pressure of the patients were controlled within the normal range before the surgery, and these indicators were strictly controlled during the wound recovery period. The flap necrosis rate in the ALTP group (13.33%) was higher than that in the PAP group (3.77%), but the difference was

Table 7. Logistic regression analysis for determining factors that affect complications.

	Univariate analysis					Multivariate analysis				
	β	SE	Wald	OR (95% CI)	p	β	SE	Wald	OR (95% CI)	p
Wound size	0.029	0.011	6.618	1.029 (1.007–1.052)	0.010	–0.027	0.019	2.160	0.973 (0.938–1.009)	0.142
ALTP	2.157	0.507	18.090	8.647 (3.200–23.364)	<0.001	3.076	0.830	13.747	21.662 (4.262–110.101)	<0.001

Note: CI, confidence interval; OR, odds ratio.

not statistically significant. The reason may be related to the microvascular anastomosis. Patients in the ALTP group have larger wounds than those in the PAP group. The large wound may augment tissue tension and blood flow supply, enhancing surgical difficulty. It is also more prone to the occurrence of edema or infection, leading to flap necrosis [22]. In addition, ALTP flap transplantation requires microvascular anastomosis. Improper selection of anastomotic vessels or prolonged anastomosis time can affect the survival of the flap [23]. For instance, one case in the ALTP group developed complete necrosis, mainly due to irreversible venous thrombosis. The patient underwent complete debridement and skin grafting surgery afterwards to close the wound. Patients with partial flap necrosis gradually improve after a conservative dressing change.

The total incidence of complications in the ALTP group was significantly higher than that in the PAP group. In the ALTP group, 13 patients had a bulky flap after surgery and underwent a second revision surgery. Meanwhile, the incidence of pressure ulcers and infections in the ALTP group was higher than that in the PAP group. This may be due to the fact that patients in the ALTP group required longer periods of bed rest. Previous research has reported short- and long-term complications of ALTP flap transplantation, including flap necrosis, venous thrombosis, and secondary revision surgery. It has been reported that 3% of the skin flaps were completely necrotic, and 10% of patients underwent a second revision surgery to thin the bulky skin flap [4], which differs from our results. The possible reason is that the patients included in this study suffered from not only foot injuries, but also injuries to hands, scalp, and abdomen.

In this study, the wound size in the ALTP group was larger than that in the PAP group. The flap area obtained from patients in the ALTP group was larger, which is suitable for flap transplantation of large wounds. In order to eliminate the effects of wound area on operative time, hospitalization time, intraoperative blood loss and complications, linear regression and logistic regression analyses were conducted. These results showed that the wound area was not an independent factor for operative time, hospitalization time, intraoperative blood loss and complications. A difference in the surgical methods used was the plausible reason contributing to the differences in these indicators between the two groups. To determine whether wound size affects the relevant surgical index, only two factors—wound size and surgical methods—were included in the regression analysis. A previous study showed that ALTP flap transplantation is associated with longer operative and hospitalization time than lateral supramalleolar flap transplantation, despite no significant difference in wound area between the two groups [5], suggesting that wound area may not be the primary factor affecting surgery and hospitalization time, offering findings in support of our conclusion in this study.

Reducing postoperative pain contributes to early wound recovery and also improves the patient's quality of life after surgery [24]. In this study, at 3 days and 1 week after surgery, and 1 month of follow-up, the VAS scores of the PAP group were significantly lower than those of the ALTP group, indicating a lower level of postoperative pain in the PAP group than the ALTP group. In addition, there was no significant difference in AOFAS scores between the ALTP group and PAP group at 6 months of follow-up, indicating that patients of the two groups achieved good recovery in ankle function after ALTP and PAP flap transplantation.

VEGF is a potent promoter of angiogenesis. During the wound healing process, VEGF increases vascular permeability, changes in extracellular matrix, stimulates endothelial cell proliferation and angiogenesis [25]. HIF-1 can regulate the expression of growth factors, cytokines, and matrix metalloproteinases related to wound healing, playing a positive role in the process of wound repair [26]. bFGF can significantly promote the proliferation and differentiation of fibroblasts and endothelial cells, promote the formation of new blood vessels, and accelerate wound healing [27]. In the early stages of trauma, these growth factors are secreted in large quantities, promoting the reconstruction of subcutaneous tissue and skin appendages, which helps to restore skin function and structure [28]. In this study, at 3 days after surgery, the levels of VEGF, HIF-1, and bFGF of the wounds were significantly increased; the levels of these factors were decreased at 1 week after surgery. At 3 days after surgery, the levels of VEGF and bFGF in the PAP group were significantly higher than those in the ALTP group; at 1 week after surgery, the level of bFGF in the PAP group was higher than that in the ALTP group. This indicates that PAP flap transplantation outperformed its ALTP counterpart in wound repair and healing.

This study provided a reference and guidance for the selection of flap transplantation, especially in elderly patients with foot trauma. PAP flap transplantation is a more appropriate method for elderly patients with poor surgical tolerance. But for large areas of soft tissue defects, ALTP flap can provide broader coverage. Our study is not without any limitations. First, as a retrospective study, this study

is prone to selection bias. Thus, a prospective study performed with strict inclusion criteria and randomization procedures is needed to validate the current findings. Secondly, the small sample size of this study may lead to biased results. Large-scale cohort studies should be performed to verify these findings. In addition, long-term effects of ALPT and PAP can be investigated subsequently through longitudinal studies. Finally, the specific costs of the ALTP and PAP flap transplantation treatments were not obtained from the patients. In general, ALTP procedure is more costly than PAP; however, some other factors may also affect the cost of surgery, including health insurance and health status of patients. Therefore, economic factors should also be considered in the selection of flap transplantation, especially among elderly patients who are financially constrained. Cost-effectiveness analysis should be performed to assess the economic value of these surgeries in the future.

Conclusions

ALTP and PAP flap transplantation are both suitable for reconstructing soft tissue defects caused by foot trauma in elderly patients. Compared with ALTP flap transplantation, PAP flap transplantation is associated with shorter surgical time and hospitalization time, better wound healing, lower level of postoperative pain, and fewer complications.

Availability of Data and Materials

The data required during the current study are available on request from the corresponding author.

Author Contributions

JY and JH designed the research study and drafted the manuscript. FW and JL performed the research. JH and LY analyzed the data. All authors contributed to important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the ethics committee of Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University (Approval number: K20250313 (EZ)), and all patients signed informed consent forms. The procedures of this study were designed in adherence to the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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