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Original Article

Donor site outcomes and functional recovery are improved with superficial inferior epigastric artery perforator flap compared to radial forearm flap in oral and maxillofacial reconstruction

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Abstract: Objective: To compare the efficacy of the superficial inferior epigastric artery perforator (SIEA) flap and radial forearm (FA) flap in reconstructing oral and maxillofacial soft tissue defects, with emphasis on donor site complications, functional recovery, aesthetic outcomes, and quality of life. Methods: A retrospective analysis was conducted on 204 patients who underwent SIEA (n = 104) or FA (n = 100) flap reconstruction between 2014 and 2023. Outcomes assessed included flap survival, donor site complications (scarring, sensory abnormalities), functional recovery (mouth opening, speech clarity), and quality of life (based on UW-QOL). Statistical analysis included chi-square tests, t-tests, and logistic regression. Results: Flap survival rates were similar between groups ($P = 0.411$). However, the SIEA group exhibited significantly better donor site outcomes: fewer sensory abnormalities ($P < 0.001$), less severe scarring ($P < 0.001$), and greater aesthetic satisfaction ($P = 0.027$). Functional outcomes also favored the SIEA flap, with improved mouth opening ($P = 0.024$) and speech clarity ($P < 0.001$). However, SIEA reconstruction required longer operative time ($P < 0.001$). Independent risk factors for delayed donor site healing included age ≥ 60 years, BMI ≥ 23 kg/m^2, smoking, diabetes, and extended hospitalization. Conclusion: The SIEA flap offers superior donor site aesthetics, sensory preservation, and functional recovery compared to the FA flap, though it is associated with longer operative time. The FA flap remains a reliable option. Preoperative planning should consider individualized flap selection based on vascular anatomy, comorbidities, and aesthetic goals.

Keywords: Oral and maxillofacial defects, superficial inferior epigastric artery perforator flap, radial forearm flap, donor site morbidity, quality of life, functional recovery

Introduction

The oral and maxillofacial region is crucial for essential physiological functions such as mastication, deglutition, phonation, and facial expression. It also plays a central role in maintaining facial aesthetics [1]. Extensive soft tissue defects in this area - commonly caused by congenital malformations, trauma, or oncologic resections - not only impair function but also lead to significant psychological distress, ultimately reducing patients' quality of life [2, 3].

Oral squamous cell carcinoma, the tenth most prevalent malignancy globally [4], is typically treated through surgical excision combined with adjuvant radiotherapy or chemotherapy [5]. However, tumor resection often results in large soft tissue defects, presenting significant reconstructive challenges. These defects can impair mastication, swallowing, and speech, severely affecting postoperative rehabilitation.

Reconstruction of extensive oral and maxillofacial soft tissue defects following cancer surgery remains a central focus of reconstructive

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surgery. With advances in microsurgical techniques, free flap transplantation has become the standard for soft tissue reconstruction [6]. Among these, the radial forearm free flap (FA) is widely used due to its consistent vascular anatomy, reliable perfusion, and high success rate in head and neck reconstructions [7-9]. However, concerns about donor site morbidity, including sacrifice of the radial artery, skin grafting, and visible scarring, have raised questions about its long-term functional and aesthetic outcomes.

Recently, the concept of “donor site preservation” has gained importance in reconstructive microsurgery. The focus has shifted from flap survival to minimizing donor site morbidity [10]. This has spurred interest in perforator-based flaps, which reduce donor site complications. First described by Koshima et al. in 1989 [12], the superficial inferior epigastric artery perforator (SIEA) flap was initially used for floor-of-mouth and inguinal reconstructions. Anatomic studies have since expanded the understanding of abdominal perforator flaps, including the deep inferior epigastric perforator (DIEP), superficial inferior epigastric perforator, and superficial circumflex iliac artery perforator flaps [13, 14].

Compared to the DIEP flap, which requires dissection of the rectus abdominis muscle, the SIEA flap offers several advantages: reduced surgical trauma due to preservation of muscular and major vascular structures, concealed donor site scars, and better aesthetic results [15, 16]. However, its broader clinical application is limited by anatomical variability and a relatively short vascular pedicle.

Debate continues regarding the comparative effectiveness of the SIEA and FA flaps in oral and maxillofacial reconstruction. Key concerns include donor site morbidity, functional recovery, and aesthetic outcomes - areas where comprehensive evidence remains limited.

This retrospective study systematically evaluates the clinical outcomes of SIEA and FA flaps in oral and maxillofacial soft tissue reconstruction, focusing on donor site function, aesthetic satisfaction, recipient site recovery, and complication rates. Additionally, the University of Washington Quality of Life (UW-QOL) questionnaire is incorporated to provide a comprehensive assessment of postoperative quality of life, with the goal of informing evidence-based, personalized flap selection strategies.

Materials and methods

Case selection

A retrospective review was conducted on 204 patients undergoing oral and maxillofacial soft tissue reconstruction between January 2014 and December 2023. Based on an electronic medical record search, 104 patients received SIEA treatment, while 100 patients received FA treatment. The study protocol was approved by The Second Hospital & Clinical Medical School and the Lanzhou University Institutional Ethics Committee.

Inclusion and exclusion criteria

Inclusion: (1) Age ≥ 18 years; (2) Oral or maxillofacial soft tissue defects; (3) Required oral and maxillofacial soft tissue reconstruction; (4) No severe systemic diseases (e.g., heart failure, end-stage renal disease) prior to surgery; (5) Complete clinical records and follow-up data.

Exclusion: (1) Oral or maxillofacial tumors with stage > T2 or distant metastasis; (2) Follow-up duration < 3 months; (3) Severe systemic diseases (e.g., end-stage renal failure, heart failure); (4) Unresolved infections or thrombosis complications; (5) Significant mental disorders or patients unable to cooperate with treatment and follow-up.

Surgical methods

All patients underwent standard preoperative evaluations, including computed tomography (CT), magnetic resonance imaging (MRI), and Doppler ultrasound, to assess lesion extent and donor-site vasculature. Surgical contraindications were ruled out. Donor site selection - either the radial artery in the right forearm or the superficial inferior epigastric artery in the lower abdomen - was determined based on individual patient characteristics. Vascular pathways and flap boundaries were marked preoperatively.

Radial forearm flap (FA Group): Under general anesthesia, patients were placed in the supine position. The radial artery and cephalic vein were exposed. The flap was designed along the pre-marked forearm boundaries and incised. Dissection was carried out to isolate the radial artery pedicle and cephalic vein. After harvesting, the flap was transferred to the recipient site, and microvascular anastomosis was performed under a surgical microscope. The donor site was reconstructed using a split-thickness skin graft and secured with pressure dressings postoperatively.

Superficial inferior epigastric artery flap (SIEA Group): Patients were positioned supine, and the lower abdominal flap boundaries and superficial vascular anatomy were confirmed preoperatively. The incision was made parallel to the inguinal ligament. The superficial inferior epigastric artery and its accompanying vein were dissected, preserving adjacent perforators. After flap elevation, it was transplanted to the recipient site, and microvascular anastomosis was performed under a microscope. Donor sites were directly closed with layered suturing, eliminating the need for grafting.

Postoperative management: Both groups received standardized postoperative care, including anti-infective prophylaxis, anticoagulation, and fluid expansion therapy. Flap perfusion was closely monitored, and any signs of vascular compromise were promptly addressed. Wound sites were kept sterile, and sutures and drainage tubes were removed gradually based on recovery progress.

Data collection

Demographic, clinical, and surgical data were extracted from the electronic medical records of all patients included in the study. The collected data included the patient's age at the time of surgery, gender, body mass index (BMI, calculated as weight in kg divided by height in m^2), smoking and alcohol history, presence of diabetes or hypertension, flap size for reconstruction (in cm^2), total operative time (from incision to closure, in minutes), length of hospitalization (in days), location of the oral or maxillofacial tumor (e.g., tongue, palate, oropharynx), tumor staging according to the TNM classification (T1, T2, T3, T4), and tumor size or lesion area (in cm^2). This detailed data collection allowed for the assessment of factors influencing patient outcomes and accurate postoperative analysis.

Functional assessments

UW-QOL questionnaire [18]: Postoperative quality of life was evaluated at 6 months using the University of Washington Quality of Life (UW-QOL) questionnaire, which assesses 12 domains, including pain, appearance, activity, swallowing, and speech. Each domain is scored from 1 to 5, with higher scores indicating better function.

Vancouver scar scale (VSS) [19]: Donor site scarring was evaluated at 3 months postoperatively using the VSS, which assesses four factors: pigmentation, height, pliability, and vascularity. The total score ranges from 0 to 13, with higher scores indicating more severe scarring.

Muscle strength: Abdominal and upper limb muscle strength were assessed using the Lovett scale [20], where grade 0 indicates complete paralysis and grade 5 denotes normal strength.

Mouth opening: Maximal mouth opening was classified according to Lemmon's classification [21]: Normal: $\geq$ 4.5 cm. Grade I: 3.0-4.5 cm. Grade II: 1.7-3.0 cm. Grade III: < 1.7 cm.

Speech clarity: Speech intelligibility was assessed using Hofstetter's scoring system [22], with scores ranging from 0 to 100. A score of 100 represents perfectly intelligible speech.

Outcome definitions

Flap necrosis [23]: Defined as partial or complete tissue loss due to compromised vascular supply. Diagnosis was based on clinical indicators (e.g., discoloration, temperature changes), Doppler ultrasound findings, or confirmation via surgical exploration.

Delayed healing [17]: Defined as failure to achieve complete wound closure by postoperative day 21, characterized by persistent exudate, infection, or wound dehiscence.

Outcome measures

Primary outcomes: Flap survival rate and causes of necrosis. Functional recovery at the recipient site (speech clarity, swallowing ability,

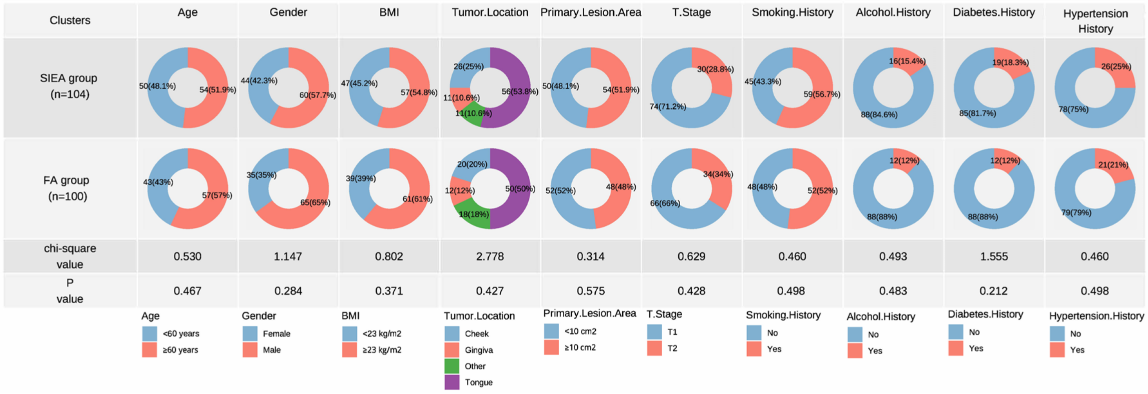

Figure 1. Comparison of baseline characteristics between SIEA and FA groups. Note: Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA), Body Mass Index (BMI).

and mouth opening). Donor site complications, including delayed healing and infection.

Secondary outcomes: Operative data, including flap harvest time, total surgical duration, and length of hospitalization. Donor site aesthetic outcomes, including VSS score and patient-reported satisfaction. Overall postoperative quality of life, assessed by the UW-QOL.

Statistical analysis

Data were analyzed using SPSS 26.0 and R 4.3.3. Categorical variables were compared using chi-square tests, with results expressed as percentages. Continuous variables were assessed for normality using the Kolmogorov-Smirnov test. If the data were normally distributed, parametric tests (t-test) were applied, with results presented as means ± standard deviations. For non-normally distributed data, non-parametric tests (Mann-Whitney U) were used, with results expressed as medians with interquartile ranges (P50 [P25, P75]). Logistic regression analysis was performed to identify independent risk factors for delayed healing. ROC curves were used to determine optimal predictive thresholds. Figures were generated using ggplot2. Statistical significance was set at $P < 0.05$.

Results

Comparison of baseline characteristics

No significant differences were observed between the SIEA and FA groups in terms of age ($P = 0.467$), gender ($P = 0.284$), BMI ($P = 0.371$), tumor location ($P = 0.427$), primary lesion area ($P = 0.575$), T stage ($P = 0.428$), smoking history ($P = 0.498$), alcohol consumption history ($P = 0.483$), diabetes ($P = 0.212$), or hypertension ($P = 0.498$). These results indicate that the baseline characteristics were well-balanced and comparable between the two groups (**Figure 1**).

Comparison of surgical data

There were no significant differences in flap harvest time ($P = 0.190$) or length of hospital stay ($P = 0.254$) between the groups. However, the SIEA group demonstrated significantly longer operative times and larger flap areas (both $P < 0.001$) compared to the FA group, suggesting notable differences in surgical data (**Table 1**).

Comparison of vascular pedicle length, arterial diameter, and venous diameter

Significant differences were observed between the SIEA and FA groups across all vascular measurements (all $P < 0.001$). The SIEA group had longer vascular pedicles and larger arterial and venous diameters than the FA group (all $P < 0.001$) (**Table 2**).

Comparison of flap survival and necrosis etiology

Flap survival rates were similar in the SIEA (96.15%) and FA (95.00%) groups ($P = 0.411$). In the FA group, flap necrosis occurred in five cases due to infection ($n = 1$), inadequate arterial supply ($n = 2$), thrombosis ($n = 1$), and

Table 1. Comparison of surgical general data between SIEA and FA groups

Variable	Total	FA Group (n = 100)	SIEA Group (n = 104)	Statistic Value	*P*-value
Flap Preparation Time (min)	40.25±3.96	39.88±3.62	40.61±4.26	-1.314	0.190
Hospitalization Duration (days)	17.00 [16.00, 18.00]	17.11±2.19	17.00 [16.00, 18.00]	1.129	0.254
Operative Time (min)	523.50 [455.50, 616.00]	486.09±88.87	590.65±171.24	-5.504	< 0.001
Flap Area (cm^2)	51.24 [40.37, 59.25]	40.01±5.26	59.54±4.87	-27.477	< 0.001

Note: Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA).

Table 2. Comparison of vascular pedicle length, arterial diameter, and venous diameter between SIEA and FA groups

Variable	Total	FA Group (n = 100)	SIEA Group (n = 104)	Statistic Value	*P*-value
Vascular Pedicle Length (cm)	9.13 [5.84, 10.44]	5.82±0.34	10.47±0.65	64.075	< 0.001
Arterial Diameter (mm)	1.78 [1.54, 1.99]	1.52 [1.44, 1.63]	1.99 [1.86, 2.11]	11.841	< 0.001
Venous Diameter (mm)	2.48 [2.00, 3.18]	2.00 [1.99, 2.01]	3.19±0.30	-12.337	< 0.001

Note: Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA).

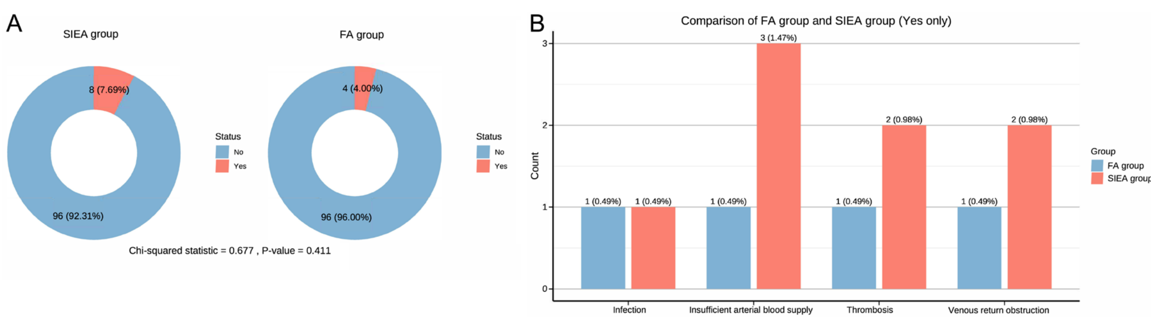

Figure 2. Comparison of flap survival rate and causes of necrosis between SIEA and FA groups. A. Comparison of the skin flap survival rate in the two groups; B. Display of causes of flap death in both groups. Note: Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA).

venous crisis (n = 1). The SIEA group had four necrosis cases caused by infection (n = 1), insufficient arterial supply (n = 1), thrombosis (n = 1), and venous crisis (n = 1). No significant difference in the distribution of necrosis etiologies was found between the groups (P > 0.05) (**Figure 2**).

Comparison of mouth opening and speech clarity

The SIEA group exhibited a significantly better distribution of mouth opening grades (P = 0.024), with higher proportions of "normal" and "Grade I" outcomes. Additionally, speech clarity scores were significantly higher in the SIEA group (81.0 vs. 77.7, P < 0.001), indicating improved postoperative functional outcomes (**Table 3**).

Comparison of subjective evaluation of donor site function

There was no significant difference in the incidence of muscle weakness between the SIEA (9.6%) and FA (15%) groups (P = 0.338). However, the SIEA group showed a significantly lower rate of sensory abnormalities (21.2% vs. 44.0%, P < 0.001) and greater aesthetic satisfaction at the donor site (79.8% vs. 65.0%, P = 0.027), demonstrating superior donor site preservation (**Table 4**).

Comparison of donor site scar evaluation

The SIEA group achieved significantly better (VSS scores across all domains - pigmentation, height, vascularity, pliability, and total score - compared to the FA group (all P < 0.001), sug-

Table 3. Comparison of mouth opening and speech clarity between SIEA and FA groups

Group	Mouth Opening				Speech Clarity Score
	Normal	I	II	III	
FA Group (n = 100)	22	40	27	11	77.66±4.55
SIEA Group (n = 104)	36	47	17	4	81.00 [77.00, 84.00]
Z Value	9.407				3.920
P-value	0.024				< 0.001

Note: Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA).

Table 4. Postoperative subjective comparison of donor site functionality between SIEA and FA groups

Clusters	Muscle weakness	Sensory abnormality	Donor site appearance
FA Group (n = 100)	15 (15.00%)	44 (44.00%)	35 (35.00%)
SIEA Group (n = 104)	10 (9.60%)	22 (21.20%)	21 (20.20%)
Statistic Value	0.919	11.137	4.894
P-value	0.338	< 0.001	0.027

Note: Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA).

gesting milder scar formation and better resemblance to normal tissue (**Table 5**).

Comparison of postoperative UW-QOL outcomes

No significant differences were found in any domain of the University of Washington Quality of Life (UW-QOL) questionnaire between the two groups, including pain (P = 0.058), appearance (P = 0.522), swallowing (P = 0.850), and anxiety (P = 0.147), indicating comparable postoperative quality of life (**Table 6**).

Univariate analysis of risk factors for delayed donor site healing

Age ≥ 60 years (P = 0.025), BMI ≥ 23 kg/m^2 (P < 0.001), smoking history (P = 0.011), diabetes (P < 0.001), and prolonged hospitalization (≥ 17.5 days, P < 0.001) were significantly associated with delayed donor site healing. No significant associations were observed with surgical approach, gender, tumor location, lesion area, T stage, alcohol history, hypertension, or flap size (P > 0.05) (**Table 7**).

Multivariate analysis of risk factors for delayed donor site healing

Following variable assignment (**Table 8**), multivariate logistic regression identified the following independent risk factors for delayed healing: age ≥ 60 years (OR = 0.391, 95% CI: 0.169-0.864), BMI ≥ 23 kg/m^2 (OR = 0.309, 95% CI: 0.122-0.729), smoking history (OR = 0.425, 95% CI: 0.183-0.948), diabetes (OR = 0.190, 95% CI: 0.067-0.505), and prolonged hospitalization ≥ 17.5 days (OR = 0.104, 95% CI: 0.044-0.231) (**Table 9**).

Discussion

The reconstruction of oral and maxillofacial soft tissue defects presents a significant clinical challenge due to the region's complex anatomy and vital functional roles. With the advancement of microsurgical techniques, free flap transplantation has become the standard approach for soft tissue reconstruction. Among these, the FA is widely used due to its well-defined anatomical structure and reliable vascular supply. However, its limitations, including the sacrifice of the radial artery, prominent donor site scarring requiring skin grafting, and associated functional and aesthetic impairments, have become increasingly evident [24]. A systematic review and meta-analysis revealed that soft tissue flaps experience a postoperative volume reduction of up to 37%, significantly higher than the 14% observed in osseous flaps, highlighting the adverse effect of soft tissue atrophy on functional recovery [24].

In contrast, the SIEA flap has gained attention due to its concealed donor site and minimal postoperative scarring. However, its clinical adoption has been limited by anatomical variability and a relatively short pedicle. Studies emphasize that vascular anastomosis techniques are critical to the success of free flaps, especially for SIEA flaps, where anatomical variability and shorter pedicle length complicate vessel selection and anastomosis [25]. This study systematically compares the clinical outcomes of SIEA and FA flaps in oral and maxillofacial reconstruction, providing valuable evidence to guide clinical decision-making.

A retrospective analysis of 204 patients yielded several key findings. First, the SIEA flap dem-

Table 5. Comparison of donor site scar scale scores between SIEA and FA groups

Variable	Total	FA Group (n = 100)	SIEA Group (n = 104)	Statistic Value	*P*-value
Color	2.00 [1.00, 2.00]	2.00 [2.00, 3.00]	1.00 [0.00, 1.00]	10.778	< 0.001
Thickness	2.00 [1.00, 3.00]	3.00 [2.00, 3.00]	1.00 [0.75, 1.00]	11.009	< 0.001
Vascular Distribution	2.00 [1.00, 2.00]	2.00 [2.00, 2.00]	1.00 [1.00, 2.00]	7.445	< 0.001
Pliability	2.00 [1.00, 2.00]	2.00 [2.00, 3.00]	1.00 [1.00, 1.00]	9.795	< 0.001
Total Score	6.00 [4.00, 9.00]	9.00 [8.75, 10.00]	4.00 [3.00, 5.00]	12.326	< 0.001

Note: Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA).

Table 6. Comparison of postoperative UW-QOL scores between SIEA and FA groups

Variable	Total	FA Group (n = 100)	SIEA Group (n = 104)	Statistic Value	*P*-value
Pain	4.00 [4.00, 5.00]	5.00 [4.00, 5.00]	4.00 [4.00, 5.00]	1.689	0.058
Appearance	4.00 [3.00, 4.00]	4.00 [3.00, 4.00]	4.00 [3.00, 4.00]	0.533	0.522
Vitality	4.00 [3.00, 4.00]	4.00 [3.00, 4.00]	4.00 [3.00, 4.00]	0.352	0.691
Recreation	4.00 [4.00, 5.00]	4.00 [4.00, 5.00]	4.00 [4.00, 5.00]	0.332	0.690
Swallowing	3.00 [2.00, 3.00]	2.50 [2.00, 3.00]	3.00 [2.00, 3.00]	-0.170	0.850
Chewing	2.00 [2.00, 3.00]	2.00 [2.00, 3.00]	2.00 [2.00, 2.00]	0.925	0.252
Speech	3.00 [3.00, 4.00]	3.00 [3.00, 4.00]	3.00 [3.00, 4.00]	-0.397	0.653
Shoulder	3.00 [3.00, 4.00]	3.00 [3.00, 4.00]	3.00 [3.00, 4.00]	0.703	0.413
Taste	3.00 [3.00, 3.00]	3.00 [3.00, 3.00]	3.00 [3.00, 3.00]	1.020	0.151
Saliva	3.00 [2.00, 3.00]	3.00 [2.00, 3.00]	3.00 [2.00, 3.00]	-1.216	0.171
Mood	4.00 [3.00, 4.00]	4.00 [3.00, 4.00]	4.00 [3.00, 4.00]	-0.203	0.824
Anxiety	3.00 [3.00, 4.00]	3.00 [3.00, 4.00]	3.00 [3.00, 4.00]	1.287	0.147

Note: Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA), University of Washington Quality of Life (UW-QOL).

onstrated superior outcomes in donor site aesthetics and functional preservation. The incidence of sensory abnormalities was significantly lower in the SIEA group, and scar assessments more closely resembled normal tissue, leading to higher patient satisfaction regarding donor site appearance. Second, the SIEA flap showed notable advantages in functional recovery at the recipient site, with significantly more patients achieving normal or Grade I mouth opening and better speech clarity scores. However, UW-QOL assessments revealed no significant difference in overall quality of life between the two groups. Finally, multivariate analysis identified age ≥ 60 years, BMI ≥ 23 kg/m^2, smoking history, diabetes, and hospitalization ≥ 17.5 days as independent risk factors for delayed donor site healing.

The superior donor site outcomes of the SIEA flap are attributed to its anatomical features. The SIEA flap's vascular pedicle originates from the superficial inferior epigastric artery and avoids muscle layer dissection, enabling direct closure of the donor site with minimal nerve damage and scar formation. In contrast, the FA flap involves harvesting skin, subcutaneous tissue, and superficial nerves, often requiring skin grafting, which increases the risk of nerve injury and prominent scarring, reducing patient satisfaction. These findings align with previous studies reporting higher donor site complication rates with FA flaps, particularly in sensory disturbances and visible scarring [26, 27]. Moreover, Tidke et al. [28] noted that fibular flaps provide superior outcomes compared to FA flaps in preserving donor site integrity. However, the technical complexity of SIEA flaps, particularly their variable vascular anatomy and shorter pedicles, presents challenges for less experienced microsurgeons. To overcome these limitations, standardized dissection protocols, preoperative vascular imaging (e.g., 3D-CT angiography and Doppler ultrasound), and targeted microsurgical training are essential.

Regarding recipient site outcomes, the SIEA flap's advantages may be attributed to its relatively larger arterial and venous calibers, which

Table 7. Univariate analysis of risk factors for delayed donor site healing

Variable	Total (n = 204)	Delayed Healing Group (n = 55)	Non-Delayed Healing Group (n = 149)	Statistic Value	*P*-value
Surgical Approach					
FA Group	100 (49.02%)	25 (45.45%)	75 (50.34%)	0.383	0.536
SIEA Group	104 (50.98%)	30 (54.55%)	74 (49.66%)		
Age					
≥ 60 years	111 (54.41%)	37 (67.27%)	74 (49.66%)	5.021	0.025
< 60 years	93 (45.59%)	18 (32.73%)	75 (50.34%)		
Gender					
Male	125 (61.27%)	29 (52.73%)	96 (64.43%)	2.318	0.128
Female	79 (38.73%)	26 (47.27%)	53 (35.57%)		
BMI					
≥ 23 kg/m^2	118 (57.84%)	45 (81.82%)	73 (48.99%)	17.750	< 0.001
< 23 kg/m^2	86 (42.16%)	10 (18.18%)	76 (51.01%)		
Tumor Location					
Tongue	106 (51.96%)	27 (49.09%)	79 (53.02%)	0.660	0.883
Gingiva	23 (11.27%)	7 (12.73%)	16 (10.74%)		
Buccal Mucosa	46 (22.55%)	14 (25.45%)	32 (21.48%)		
Other	29 (14.22%)	7 (12.73%)	22 (14.77%)		
Primary Lesion Area					
≥ 10 cm^2	102 (50.00%)	30 (54.55%)	72 (48.32%)	0.622	0.430
< 10 cm^2	102 (50.00%)	25 (45.45%)	77 (51.68%)		
T Stage					
T1	140 (68.63%)	37 (67.27%)	103 (69.13%)	0.064	0.800
T2	64 (31.37%)	18 (32.73%)	46 (30.87%)		
Smoking History					
Yes	111 (54.41%)	38 (69.09%)	73 (48.99%)	6.541	0.011
No	93 (45.59%)	17 (30.91%)	76 (51.01%)		
Alcohol History					
Yes	28 (13.73%)	8 (14.55%)	20 (13.42%)	0.043	0.836
No	176 (86.27%)	47 (85.45%)	129 (86.58%)		
Diabetes History					
Yes	31 (15.20%)	19 (34.55%)	12 (8.05%)	21.877	< 0.001
No	173 (84.80%)	36 (65.45%)	137 (91.95%)		
Hypertension					
Yes	47 (11.52%)	13 (11.82%)	34 (11.41%)	0.015	0.902
No	157 (38.48%)	42 (38.18%)	115 (38.59%)		
Flap Preparation Time (min)	40.25±3.96	40.67±4.12	40.09±3.91	-0.925	0.356
Hospitalization Duration (days)	17.00 [16.00, 18.00]	19.00 [17.50, 19.50]	16.00 [15.00, 17.25]	7.013	< 0.001
Operative Time (min)	523.50 [455.50, 616.00]	558.00 [451.00, 629.50]	516.00 [461.00, 607.00]	1.093	0.274
Flap Area (cm^2)	51.24 [40.37, 59.25]	52.55 [41.02, 61.11]	49.95 [40.19, 59.00]	0.734	0.463

Note: Body Mass Index (BMI), Superficial Circumflex Iliac Artery Perforator Flap (SIEA), Radial Forearm Flap (FA).

Table 8. Variable assignment for multivariate analysis

Variable	Variable Type	Assignment
Age	(X)	≥ 60 years = 1, < 60 years = 2
BMI	(X)	≥ 23 kg/m^2 = 1, < 23 kg/m^2 = 2
Smoking History	(X)	Yes = 1, No = 2
Diabetes History	(X)	Yes = 1, No = 2
Hospitalization Duration	(X)	≥ 17.5 days = 1, < 17.5 days = 2
Delayed Healing	(Y)	Yes = 1, No = 2

Note: Body Mass Index (BMI).

Table 9. Multivariate analysis of risk factors for delayed donor site healing

Variable	Estimate	Std Error	*P* Value	OR	Lower	Upper
Age	-0.939	0.415	0.024	0.391	0.169	0.864
BMI	-1.174	0.452	0.009	0.309	0.122	0.729
Smoking History	-0.855	0.417	0.040	0.425	0.183	0.948
Diabetes History	-1.661	0.510	0.001	0.190	0.067	0.505
Hospitalization Duration	-2.259	0.423	0.000	0.104	0.044	0.231

Note: Body Mass Index (BMI).

ensure adequate blood supply and promote graft survival and integration. Additionally, the SIEA flap's tissue thickness closely approximates that of native oral and maxillofacial soft tissue, contributing to superior functional and aesthetic results. In contrast, the FA flap's thinner tissue may limit its capacity for full functional restoration, despite its technical simplicity. These findings align with previous studies highlighting the limitations of FA flaps in achieving optimal functional recovery [26, 29]. Song et al. [30] similarly reported that peroneal artery perforator flaps offer better outcomes than FA flaps in terms of patient satisfaction and functional rehabilitation.

Despite its advantages, the clinical application of the SIEA flap is limited by vascular variability and a short pedicle length. Preoperative imaging, such as Doppler ultrasound or CTA, is crucial to assess vascular suitability and improve surgical outcomes. Meanwhile, the FA flap continues to be associated with significant donor site morbidity, including sensory loss and conspicuous scarring [27]. Previous studies by Cariati [31] and Zheng [32] emphasized the importance of precise preoperative assessment and refined intraoperative techniques in ensuring successful vascular anastomosis. Additionally, postoperative complications such as vascular crises and flap necrosis remain concerns for SIEA flaps, especially in patients with diabetes or localized infections, which significantly increase the risk of surgical failure [23]. Addressing these risks will require enhanced microsurgical training, improved postoperative care protocols, and integration of advanced technologies like 3D imaging navigation to streamline surgical procedures.

This study identified several risk factors for delayed donor site healing, including age ≥ 60 years, diabetes, and BMI ≥ 23 kg/m^2. These factors are interlinked through shared pathophysiologic mechanisms that impair wound healing. Aging is associated with reduced cellular regeneration, diminished collagen synthesis, compromised angiogenesis, and weakened immune responses, often compounded by comorbidities like hypertension and diabetes [33]. Diabetes impairs wound healing through hyperglycemia-induced microvascular damage, accumulation of advanced glycation end products, and diminished fibroblast and keratinocyte function, which disrupt collagen remodeling and immune defenses [23, 34]. Obesity contributes through increased adipose tissue deposition, chronic inflammation (elevated TNF-α and IL-6 levels), and heightened mechanical tension at the wound site, all of which prolong the inflammatory phase and reduce capillary density [17, 35].

Smoking is another independent risk factor, primarily through nicotine-induced vasoconstriction and carbon monoxide-mediated tissue hypoxia, which together decrease tissue perfusion, inhibit fibroblast activity, and delay collagen synthesis and wound closure [27, 36]. Smoking also impairs vascular endothelial function, further hindering healing. Preoperative smoking cessation has been shown to improve wound healing outcomes, highlighting the importance of incorporating cessation programs into perioperative care.

Prolonged hospitalization (≥ 17.5 days) was both a predictor and consequence of delayed healing. Persistent inflammation, infection, and impaired tissue repair extend hospital stays, while prolonged hospitalization increases the risk of complications such as decreased mobility, malnutrition, and nosocomial infections, creating a vicious cycle [37, 38]. Comprehensive postoperative management - including infection control, tailored nutritional support, and psychological counseling - is essential to facilitate wound healing and minimize hospital stays [39].

This study is subject to certain limitations inherent in its single-center retrospective design, such as selection bias and limited generalizability. The relatively short follow-up period restricts the assessment of long-term functional and aesthetic outcomes. Furthermore, incomplete preoperative imaging data in some cases may have influenced flap selection and confounded results. Future multicenter, prospective studies with larger sample sizes and extended follow-up are needed to validate these findings. Additionally, emerging technologies such as 3D bioprinting and tissue engineering offer promising avenues for individualized reconstructive strategies [40].

In conclusion, this study demonstrated that the SIEA flap provides superior outcomes in terms of donor site preservation and recipient site functional recovery, particularly in aesthetic and functional dimensions. However, the FA flap remains a viable and widely applicable option due to its procedural simplicity and established clinical utility. Preoperative flap selection should be personalized, considering individual anatomic characteristics, comorbidities, and desired outcomes to optimize surgical planning and reconstruction success.

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Disclosure of conflict of interest

None.

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