OPEN

PRS GLOBAL OPEN

ORIGINAL ARTICLE
Reconstructive

Optimizing the Use of Pedicled versus Random Pattern Local Flaps in the Foot and Ankle

Karen R. Li, BBA*†
Christian X. Lava, MS*†
Seo Yeon Lee, BS†
Julie Suh, BS†
Lauren E. Berger, MD*‡
Christopher E. Attinger, MD*

Background: The aim of this study was to compare the use of pedicled local (PFs) versus random pattern flaps (RpFs) in foot and ankle reconstruction in patients with chronic, nonhealing wounds.
Methods: A single-center, retrospective review of 204 patients with 118 PFs and 86 RpFs was performed. The primary outcome included rates of limb salvage.
Results: PFs were used more often in the hindfoot (44.1% versus 30.2%, $P = 0.045$), lateral and medial surface (39.8% versus 18.6%, $P = 0.001$), and wounds containing exposed bone and hardware (78.8% versus 62.8%, $P = 0.018$). RpFs were used more for forefoot (19.8% versus 10.2%, $P = 0.053$) and plantar defects (58.1% versus 30.3%, $P = 0.000$). RpFs had a higher rate of immediate success (100% versus 95.8%, $P = 0.053$), with no significant differences in rate of long-term limb salvage (77.1% versus 69.8%, $P = 0.237$). PFs had higher rates of ischemia requiring intervention (11.0% versus 3.5%, $P = 0.048$). RpFs had a higher rate of minor amputations (15.12% versus 6.8%, $P = 0.053$) but similar rates of major amputation (15.1% versus 16.1%, $P = 0.848$). There were no significant differences in rates of mortality or ambulatory status.
Conclusions: Both RpFs and PFs remain reliable options to reconstruct defects of the foot and ankle. Optimizing the use of each flap type should consider wound characteristics. RpFs are preferred for dorsal and plantar defects, whereas PFs are protective for minor infections and preferred for deeper wounds despite a higher rate of partial necrosis. *(Plast Reconstr Surg Glob Open 2024; 12:e5921; doi: 10.1097/GOX.0000000000005921; Published online 18 June 2024.)*

INTRODUCTION

Chronic wounds are a major public health challenge, estimated to affect roughly 2% of the US population and causing an economic burden of $25 billion annually.[1–4] Despite the high comorbidity burden of this patient population, limb salvage has been demonstrated to be a feasible option at our institution.[5–10] Local flap coverage remains a versatile reconstructive tool and is indicated when exposed vital structures cannot be primarily closed, and the defect size is appropriate for either local or pedicled flap.

The use of local flaps in foot and ankle reconstruction presents novel surgical challenges due to the unique anatomy of this region due to vascular supply and availability of regional tissues.[11,12] The application of the six angiosomes of the foot and ankle, which was first described by Taylor et al,[13] necessitates a complete understanding of arterial blood supply and bone, muscle, tendon, and tissue components to achieve successful reconstruction. [14,15] With successful revascularization, there are multiple strategies available for local reconstruction.[16–19]

Given the various local flap possibilities, a better understanding of whether pedicled (PFs) versus random pattern flaps (RpFs) perform better for reconstruction of the foot and ankle is warranted. To optimize the use of PFs and RpFs in foot and ankle reconstruction, we sought to conduct a retrospective cohort study to assess the outcomes of these two types of local flaps according to specific locations and characteristics of wound defects in this anatomic region.

*From the *Department of Plastic and Reconstructive Surgery, MedStar Georgetown University Hospital, Washington, D.C.; †Georgetown University School of Medicine, Washington, D.C.; and ‡Plastic and Reconstructive Surgery Division, Rutgers Robert Wood Johnson Medical School, New Brunswick, N.J.*

Received for publication January 29, 2024; accepted May 1, 2024.

DOI: 10.1097/GOX.0000000000005921

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

Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

METHODS

Study Design and Surgical Technique

Following institutional review board approval (MedStar Health Research Institute MGUH 5030), a single-center retrospective study of 204 patients who received local flaps from January 2010 to November 2022 was performed. Patients were included with the following criteria: (1) 18 years of age or more and (2) received a local flap of the foot or ankle. All flaps were performed by the senior author. Current procedural terminology (CPT) codes for "muscle, myocutaneous or fasciocutaneous flap of the lower extremity" (CPT 15738) and "adjacent tissue transfer or rearrangement procedures on the integumentary system" (CPT 14301 and 14302) were included.

Local flaps were defined by the area of tissue coverage adjacent to the location of the defect. RpFs were mobilized as advancement, rotational, or transposition flaps to the area of defect. The blood supply of these RpFs were defined by unnamed arteries and supplied by nonidentifiable perforators located in the tissue. To determine the area used for tissue elevation, a handheld Doppler was used to identify and confirm viable perforators at the flap base (Fig. 1). PFs were harvested as a fasciocutaneous or muscle flaps with a named artery that supplied the blood flow in the flap. In these cases, a source artery was dissected out and visualized by the surgical team, and a handheld Doppler was used to confirm arterial and venous flow through the major pedicle before flap inset (Fig. 2). Subsequent operative approach and anatomic considerations have been previously published by the senior surgeon.[9,10,18,20,21] When indicated, a split-thickness skin graft or Integra was used for secondary coverage of the donor site. The primary outcomes looked at major complications and limb salvage.

Data Collection

Demographics and comorbidities, wound characteristics, postoperative complications, and long-term outcomes were collected from electronic medical records. The Charlson Comorbidity Index scores were calculated to determine comorbidity burdens. Wound characteristics included area, location, and depth, identified by the level of exposed structure. Soft-tissue wounds included skin, subcutaneous tissue, fascia, muscle, and tendon exposure. Immediate outcomes included rates of takeback up to postoperative day 12 and flap success up to postoperative day 7 without vascular compromise or reoperation. Complications included partial necrosis, hematoma, dehiscence, and infection anytime postoperatively and categorized as minor complications receiving nonsurgical treatment, or major complications necessitating reoperation. Rates of ipsilateral and contralateral amputations were further categorized by major amputations including above-the-knee and below-the-knee amputations, or minor amputations, which included all minor foot amputations. Additional long-term outcome measures included total follow-up duration, ambulatory status, and mortality.

Takeaways

Question: What are the outcomes between the use of pedicled flaps (PFs) versus random pattern flaps (RpFs) in foot and ankle reconstruction?

Findings: A retrospective review of 118 PFs versus 86 RpFs showed no significant differences in immediate flap success rate (PF = 95.8% versus RpF = 100%, $P = 0.053$) or limb salvage rates (PF = 77.1% versus RpF = 69.8%, $P = 0.237$). PFs and RpFs differed significantly in their coverage of various wound locations.

Meaning: Although both PFs and RpFs achieve high success rates, the preferred use of flap type should consider location and wound characteristics.

Statistical Analysis

Descriptive statistics were calculated for all patient data. Shapiro–Wilk testing of normality was performed to assess the distribution of continuous variables. Normally distributed continuous variables were reported as means and SDs and nonnormally distributed variables were reported using median and interquartile range. Categorical variables were reported as frequencies and percentages. Comparative analyses were performed between cohorts of PF and RpF with the χ^2 test used for categorical variables and t test used for continuous variables. The multiple logistic regression model included significant covariates between the two cohorts to account for potential confounders. Subanalyses were performed in four groups to compare outcomes between PFs and RpFs: (1) forefoot and midfoot wounds, (2) hindfoot and ankle wounds, (3) soft-tissue wounds, and (4) wounds involving exposed bone or hardware. Statistical analyses were conducted using Stata Software (Stata Corp LLC, College Station, Tex.), and a P value of less than 0.05 was considered statistically significant. Results are reported per the Strengthening the Reporting of Observational Studies in Epidemiology checklist for cohort studies.[22]

RESULTS

Patient Demographics and Perioperative Characteristics

A total of 204 patients with local flaps performed of the foot and ankle area were included for analysis, further grouped by 118 (57.8%) PFs and 86 (42.2%) RpFs. All RpFs were fasciocutaneous, whereas among the PFs, 72 (61.0%) were composed of muscle and 46 (39.0%) were fasciocutaneous. Overall, 141 (69.1%) patients were male, median age of 61 years, median body mass index of 30.1 kg/m^2, and median Charlson Comorbidity Index score of 5. Those in the RpF group had higher rates of a history of myocardial infarction (15.1% versus 5.1%, $P = 0.015$), history of neuropathy (81.4% versus 67.0%, $P = 0.022$), current use of chronic steroids (7.0% versus 0.9%, $P = 0.043$), history of ipsilateral amputation (40.7% versus 23.7%, $P = 0.010$), and history of vascular bypass (17.9% versus 7.7%, $P = 0.028$). There were no significant differences between groups for remaining comorbidities (Table 1).

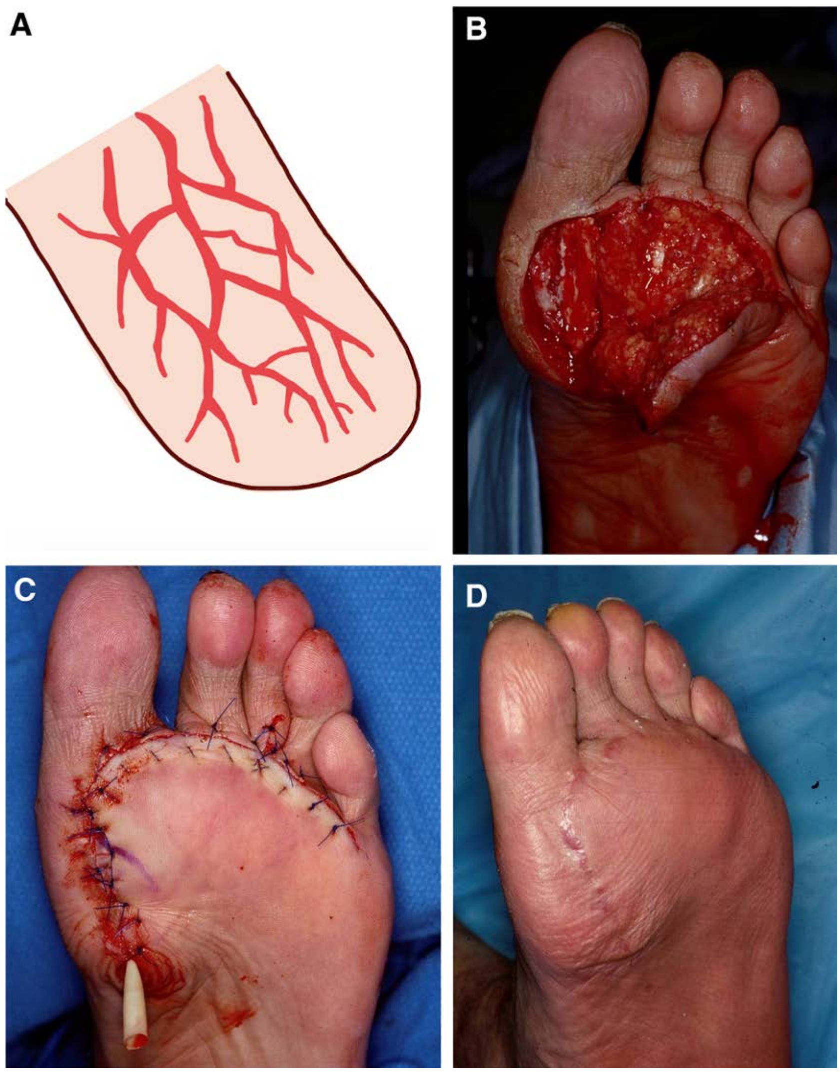

Fig. 1. RpF. A, A diagram of a random pattern vascular supply, (B) a photograph of a plantar defect to exposed tendon, (C) a photograph of a rotational flap medially to cover the defect with biased sutures on closure to reduce tension, and (D) a photograph of the final result.

Wound characteristics are outlined in Table 2. PFs covered a smaller median area (32 versus 48 cm^2, P = 0.0002). PFs were used more often in the hindfoot (44.1% versus 30%, P = 0.045), lateral and medial foot and ankle (39.8% versus 18.6%, P = 0.001), and the posterior heel (10.2%, 1.2%, P = 0.009). RpFs were used more often in the forefoot (19.8% versus 10.2%, P = 0.053) and plantar defects (58.1% versus 30.3%, P = 0.000). RpFs were used more often for soft-tissue defects (37.2% versus 22.0%), and PFs were used in wounds with exposed bone and hardware (78.0% versus 62.8%, P = 0.018). RpFs received supplementary skin graft coverage at the donor site at a significantly higher rate than PFs (24.4% versus 11.9%, P = 0.019).

Outcomes by Pedicled versus Random Pattern Flap Type

The outcomes of patients by PF versus RpF are summarized in Table 3. Immediate flap success was 95.8% for PFs and 100% for RpFs (P = 0.053). Rate of takeback was 4.2% (n = 5) for PFs versus 1.2% (n = 1) for RpFs (P = 0.404).

PFs trended higher rates of partial necrosis (11.0% versus 4.7%, P = 0.128), whereas RpFs trended higher rates of dehiscence (33.7% versus 25.4%, P = 0.197) and infection (43.0% versus 31.3%, P = 0.087). RpFs saw a significantly higher rate of minor infections (25.6% versus 13.6%, P = 0.044). PFs had a significantly higher rate of ischemic complications (11.0% versus 3.5%, P = 0.048), which remained independently predictive on multivariate logistic regression (odds ratio: 5.075, 95% confidence interval: 1.20–21.53) in Table 4. The limb salvage rate trended higher for PFs (77.1% versus 69.8%, P = 0.237).

Subanalyses by wound location were performed. For midfoot and forefoot wounds (Table 5), 100% of RpFs achieved immediate flap success compared with 93.3% of PFs (P =

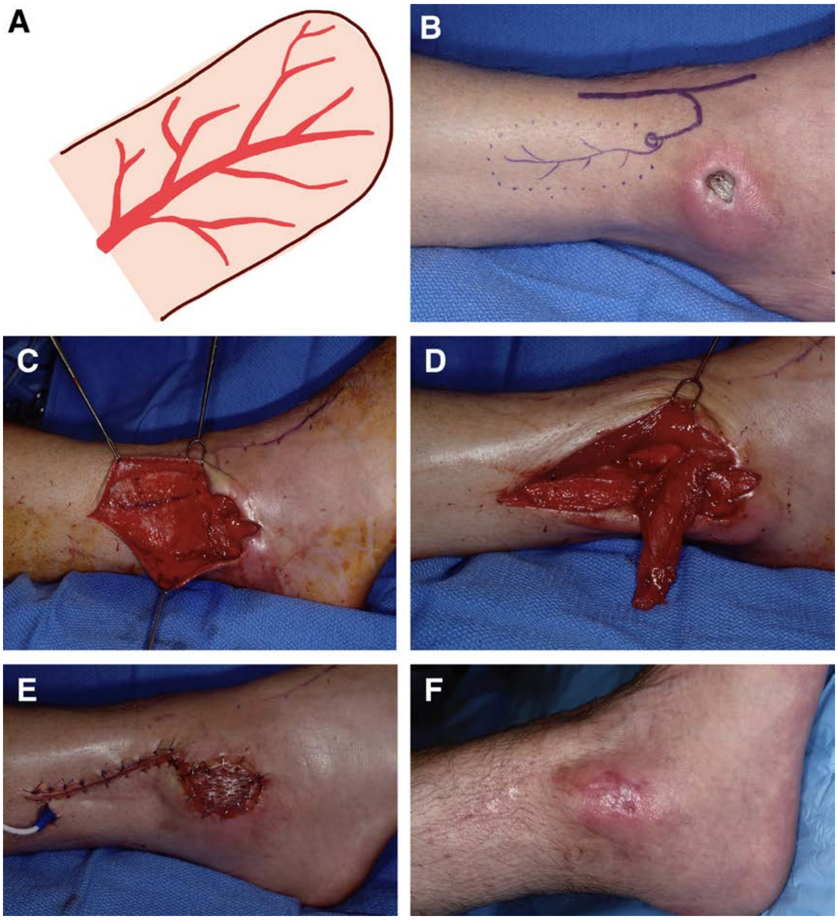

Fig. 2. PF. A, A diagram of an axial vascular supply, (B) a photograph of a lateral ankle defect with pedicled artery planning, (C) a photograph of a flap dissection for lateral supramalleolar flap, (D) a photograph of an elevated fasciocutaneous flap, (E) a photograph of a primary closure and use of skin graft over defect, and (F) a photograph of the final result.

0.085). RpFs trended lower rates of takeback (0.0% versus 6.7%, $P = 0.085$), and ischemic major complications (4.7% versus 13.3%, $P = 0.267$). Rates of limb salvage were similar between RpFs and PFs (RpF = 67.4% versus PF = 66.7%, $P = 0.755$). In the hindfoot and ankle (Table 6), RpFs had significantly higher rates of dehiscence (34.9% versus 17.8%, $P = 0.038$) and trended higher major infectious complications (23.3% versus 11.0%, $P = 0.088$). Rates of limb salvage were higher for PFs (83.6% versus 69.8%, $P = 0.081$).

Subanalyses by wound depth were also performed. There were no significant differences in outcomes found between PFs and RpFs for soft-tissue wounds (Table 7). For wounds with exposed bone and hardware (Table 8), there were also no significant differences in outcomes found between PFs and RpFs. The rate of postoperative ipsilateral minor amputations was significantly higher for RpFs (20.4% versus 7.6%, $P = 0.024$). The limb salvage rate trended higher for the PF group (75.0% versus 61.1%, $P = 0.077$).

DISCUSSION

Several reconstruction options exist for wounds in the foot and ankle region based on the defect location, complexity, and size.[12,15] In our study, we found that both PFs and RpFs are able to achieve similar rates of immediate flap success and long-term limb salvage rates. However, the utility and indication of wound coverage and common postoperative complications differ for pedicled and random pattern local flaps and require a high reoperation rate for further surgical refinement.

Utilization of RpFs

Local RpFs provide a reliable and efficient option for coverage of plantar and dorsal defects of the foot.[23] As first described by McGregor et al,[24] RpFs rely on a vascular pattern of perforators that supply the subdermal plexus.[25] Further studies showed that local vascular anatomy can support fasciocutaneous island flaps with no defined axial input.[25–27] During elevation, preservation of the subdermal plexus is essential for the viability of these flaps.[17,28] A handheld Doppler should be used to confirm perforators and minimize the risk of necrosis. The ratio of the flap base can extend upwards toward 1.5:1 and 3:1 for larger defects, as long as blood supply is confirmed to the extended area.[8,19,29,30] At our institution, the highest ratio achieved was 3.5:1.

Table 1. Patient Demographics and Comorbidities

Variable	Total	Pedicled	Random Pattern	*P*
n (%)	204	118 (57.8)	86 (42.2)	
Patient demographics				
Age, median (IQR)				
Sex				0.892
Male	141 (69.1)	82 (69.5)	59 (68.6)	
Female	63 (30.9)	36 (30.5)	27 (31.4)	
Race				0.510
Black or African American	85 (41.7)	46 (39.0)	39 (45.4)	
White	101 (49.5)	62 (52.5)	39 (45.4)	
Hispanic	1 (0.5)	0 (0.0)	1 (1.2)	
Other/unknown	17 (8.3)	10 (8.5)	7 (8.1)	
BMI (kg/m^2), median (IQR)	30.8 (9.6)	29.8 (9.9)	31.9 (8.7)	0.260
Hospital LOS (d), median (IQR)	14 (13)	14 (13)	14 (11)	0.300
Comorbidities				
Smoking				0.493
Never smoker	124 (60.8)	68 (57.6)	56 (65.1)	
Former	56 (27.5)	34 (28.8)	22 (25.6)	
Current	24 (11.8)	16 (13.6)	8 (9.3)	
CCI, median (IQR)	5 (3.3)	5 (4)	6 (3)	0.355
Diabetes mellitus	149 (73.0)	82 (69.5)	67 (77.9)	0.181
Peripheral artery disease	104 (51.0)	56 (47.5)	48 (55.8)	0.238
ESRD	29 (14.2)	17 (14.4)	12 (14.0)	0.927
Hx neuropathy	149 (73.0)	79 (67.0)	70 (81.4)	**0.022**
Hx VTE	44 (21.6)	25 (21.2)	19 (22.1)	0.876
Hx of MI	19 (9.3)	6 (5.1)	13 (15.1)	**0.015**
CVA/TIA	22 (10.8)	13 (11.0)	9 (10.5)	0.900
Current chronic steroid use	7 (3.4)	1 (0.9)	6 (7.0)	**0.043**
Limb history				
Prior ipsilateral amputation	63 (30.9)	28 (23.7)	35 (40.7)	**0.010**
Prior contralateral amputation	40 (19.6)	21 (17.8)	19 (22.1)	0.445
Hx of vascular bypass	24 (11.9)	9 (7.7)	15 (17.9)	**0.028**

BMI, body mass index; CCI, Charlson Comorbidity Index; CVA, cerebrovascular accident; ESRD, end-stage renal disease; Hx, history; IQR, interquartile range; LOS, length of stay; MI, myocardial infarction; TIA, transient ischemic stroke; VTE, venous thromboembolism.
Values in bold signify significant *P* values ($P < 0.05$).

Table 2. Perioperative Characteristics

Variable	Total	Pedicled	Random Pattern	*P*
n (%)	204	118 (57.8)	86 (42.2)	
Wound characteristics				
Wound area (cm^2), median (IQR)	40 (30)	32 (30)	48 (28.5)	**0.000**
Wound location				
Forefoot	29 (14.2)	12 (10.2)	17 (19.8)	0.053
Midfoot	59 (28.9)	33 (28.0)	26 (30.2)	0.724
Hindfoot	78 (38.2)	52 (44.1)	26 (30.2)	**0.045**
Ankle	38 (18.6)	21 (17.8)	17 (19.8)	0.721
Wound surface				
Plantar foot	74 (36.3)	24 (30.3)	50 (58.1)	**0.000**
Dorsal foot	15 (7.4)	8 (6.8)	7 (8.1)	0.713
Medial foot/ankle	36 (17.7)	25 (21.2)	11 (12.8)	0.120
Lateral foot/ankle	63 (30.9)	47 (39.8)	16 (18.6)	**0.001**
Posterior heel	13 (6.4)	12 (10.2)	1 (1.2)	**0.009**
Multiple surfaces	3 (1.5)	2 (1.7)	1 (1.2)	1.000
Wound level				**0.018**
Soft tissue	58 (28.4)	26 (22.0)	32 (37.2)	
Bone and hardware	146 (71.6)	92 (78.0)	54 (62.8)	
Intraoperative characteristics				
Donor site skin graft*	35 (17.2)	14 (11.9)	21 (24.4)	**0.019**

Values in boldface signify significant *P* value ($P<0.05$).
Soft tissue: subcutaneous tissue, muscle, fascia, tendon.
Bone and Hardware: exposed bone and hardware.
*Skin graft: either Integra or a split-thickness skin graft on date of surgery.
IQR, interquartile range.

Table 3. Postoperative Outcomes

Variables	Total	Pedicled	Random Pattern	*P*
n (%)	204	118 (57.8)	86 (42.2)	
Postoperative outcomes				
Immediate flap success	199 (97.6)	113 (95.8)	86 (100)	0.053
Takeback	6 (2.9)	5 (4.2)	1 (1.2)	0.404
Flap salvage	4 (66.7)	3 (60.0)	1 (100.0)	1.000
Postoperative complications				
All complications				
Partial necrosis	17 (8.3)	13 (11.0)	4 (4.7)	0.128
Hematoma	5 (2.5)	4 (3.4)	1 (1.2)	0.400
Dehiscence	59 (28.9)	30 (25.4)	29 (33.7)	0.197
Infection	74 (36.3)	37 (31.3)	37 (43.0)	0.087
Minor complications	69 (33.8)	35 (29.7)	34 (39.5)	0.141
Partial necrosis	8 (3.9)	5 (4.2)	3 (3.5)	1.000
Hematoma	5 (2.5)	4 (3.4)	1 (1.2)	0.400
Dehiscence	39 (19.1)	21 (17.8)	18 (20.9)	0.593
Infection	38 (18.6)	16 (13.6)	22 (25.6)	**0.044**
Major complications	85 (41.7)	46 (39.0)	39 (45.4)	0.362
Infection	47 (23.0)	26 (22.0)	21 (24.4)	0.690
Ischemia	16 (7.8)	13 (11.0)	3 (3.5)	**0.048**
Dehiscence	22 (10.8)	11 (9.3)	11 (12.8)	0.496
Postoperative ipsilateral amputation	53 (26.0)	27 (22.9)	26 (31.2)	0.237
Minor amputation	21 (10.3)	8 (6.8)	13 (15.1)	0.053
Major amputation	32 (15.7)	19 (16.1)	13 (15.1)	0.848
Amputation reason				
Nonhealing wound	18 (8.8)	9 (7.6)	9 (10.5)	0.480
Infection	24 (11.8)	13 (11.0)	11 (12.8)	0.698
Ischemia	6 (2.9)	4 (3.4)	2 (2.3)	0.657
Dehiscence	3 (5.7)	1 (3.7)	2 (7.7)	0.574
Other	2 (3.8)	0 (0.0)	2 (7.7)	
Postoperative contralateral amputation	23 (11.5)	15 (12.8)	8 (9.6)	0.654
Limb salvage rate	151 (74.0)	91 (77.1)	60 (69.8)	0.237
Long-term outcomes				
Follow-up duration (d), median (IQR)	500 (1151)	371 (1019)	780 (1232)	0.112
Ambulatory status				0.307
Yes, independently	69 (34.5)	35 (30.2)	34 (40.5)	
Yes, with assistance	74 (37.0)	45 (38.8)	29 (34.5)	
Mortality	51 (25.1)	25 (21.4)	26 (30.2)	0.150

Values in boldface signify significant *P* value ($P<0.05$).
IQR, interquartile range.

Table 4. Multivariate Logistic Regression for Major Ischemic Complications

	OR (95% CI)	*P*
Major ischemic complications		
Flap type (PF vs RpF)	5.07 (1.2–21.53)	**0.028**
Hx neuropathy	1.05 (0.29–3.78)	0.937
Hx MI	0.52 (0.05–5.02)	0.568
Chronic steroid use	5.21(0.46–59.37)	0.183
Hx vascular bypass	3.93 (0.97–15.96)	0.056
Hx ipsilateral amputation	1.39 (0.41–4.68)	0.597

Values in boldface signify significant *P* value ($P<0.05$).
CI, confidence interval; Hx, history; MI, myocardial infarction; OR, odds ratio.

Also important to RpFs is their vascular architecture, which is organized to distribute perfusion more evenly across the flap. In our study, RpFs had an overall higher immediate success rate, suggesting that the minimally disturbed subdermal plexus can achieve adequate perfusion for flap viability in the immediate postoperative time period. The dorsal and plantar surfaces of the foot are supplied the dorsalis pedis and posterior tibial, respectively, which make coverage of these surfaces ideal for RpFs. Additionally, the use of RpFs in our study provided median coverage for defects up to 150% greater in size than PFs, most likely because they are not limited by pedicle length and can be utilized for larger defects within the same angiosomes located on the dorsal and plantar surfaces of the foot. However, RpFs are dependent on their distal perforators, which limit their mobility to cover beyond their transposed area. Additionally, we found that RpFs required a significantly higher rate of supplementary skin graft coverage at the donor site. From our experience, pedicled muscle flaps (PmFs) are smaller in size and do not need additional coverage, whereas the transposed RpF creates a donor defect that is too large for safe secondary closure. Integra is an alternative option in the interim between local flap placement and split-thickness skin graft coverage.

Table 5. Outcomes by Location: Forefoot & Midfoot

Variables	Total	Pedicled	Random Pattern	P
n (%)	88	45 (51.1)	43 (48.9)	
Postoperative outcomes				
Immediate flap success	85 (96.6)	42 (93.3)	43 (100.0)	0.085
Takeback	3 (3.4)	3 (6.7)	0 (0.0)	0.085
Postoperative complications				
All complications				
Partial necrosis	5 (5.7)	3 (6.7)	2 (4.7)	1.000
Hematoma	2 (2.3)	2 (4.4)	0 (0.0)	0.495
Dehiscence	31 (35.2)	17 (37.8)	14 (32.6)	0.608
Infection	33 (37.5)	16 (35.6)	17 (39.5)	0.700
Minor complications	34 (38.6)	16 (35.6)	18 (41.9)	0.544
Partial necrosis	2 (2.3)	1 (2.2)	1 (2.3)	1.000
Hematoma	2 (2.3)	2 (4.4)	0 (0.0)	0.495
Dehiscence	24 (27.3)	13 (28.9)	11 (25.6)	0.813
Infection	20 (22.7)	8 (17.8)	12 (27.9)	0.313
Major complications	40 (45.5)	22 (48.9)	18 (41.9)	0.508
Infection	22 (25.0)	12 (26.7)	10 (23.3)	0.712
Ischemia	8 (4.7)	6 (13.3)	2 (4.7)	0.267
Dehiscence	10 (11.4)	6 (13.3)	4 (9.3)	0.739
Postoperative ipsilateral amputation	28 (31.8)	15 (33.3)	13 (30.2)	0.938
Minor amputation	11 (12.5)	4 (8.9)	7 (16.3)	0.347
Major amputation	17 (19.3)	11 (24.4)	6 (14.0)	0.213
Amputation reason				
Nonhealing wound	8 (9.1)	4 (8.9)	4 (9.3)	1.000
Infection	12 (13.6)	7 (15.6)	5 (11.6)	0.758
Ischemia	5 (5.7)	3 (6.7)	2 (4.7)	1.000
Dehiscence	2 (2.3)	1 (2.2)	1 (2.3)	1.000
Limb salvage rate	59 (67.1)	30 (66.7)	29 (67.4)	0.755
Long-term outcomes				
Mortality	27 (31.0)	11 (25.0)	16 (37.2)	0.218

Values in boldface signify significant *P* value ($P<0.05$).

This is in contrast to the medial and lateral surfaces of the foot, which are composed of conjoint angiosomes at the glabrous junction. Adjacent angiosomes are linked by choke vessels that dilate to true open vessels between perforator angiosomes.[31] As seen in our study, PFs are better utilized in these locations because they are mobile and can rely on the dominant pedicle instead of the subdermal plexus. However, the risk of partial necrosis is higher for PFs, supported by our outcomes between PFs versus RpFs.

A key advantage of local RpFs in cases of plantar defects allows for locoregional replacement of similar histological tissue, which was supported by our significantly greater use of RpFs for plantar wounds.[23,28] Our study saw RpFs also had higher rates of dehiscence. Considering that they were most often used for plantar defects, the dehiscence was likely secondary due to excessive tension on closure, insufficient distal perforators, or poor adherence to offloading protocols postoperatively. The risk of dehiscence in cases of plantar wounds or larger defects should be protected with the use biased stitches on closure, which are angled stitches to decrease distal flap tension during flap inset.

Utilization of PFs

Local PFs offer a diverse range of reconstructive options in the foot ankle, primarily for the heel and ankle areas. PmFs are based on an type 2 blood supply, fed by a dominant pedicle from an axial source artery with distal minor pedicles.[32] This allows the PmF to be rotated on its dominant pedicle in any direction without relying on distal minor pedicles to survive, creating a range of mobility for flap inset. However, the ligation of minor pedicles during dissection also risks distal portions of the flap of becoming ischemic, as seen by the higher rates of partial necrosis and significantly higher rates of major ischemic complications in our study. To minimize the risks of flap necrosis, a handheld Doppler should be used intraoperatively to confirm arterial blood flow to the visualized pedicle before and after flap inset. For those patients with a high clinical suspicion of poor lower extremity vascularity, a preoperative angiogram is warranted to ensure that a viable pedicle can be used.

Another advantage of the PF is the option to use muscle, whereas RpFs only provide fasciocutaneous coverage.[33] PFs were used more often when there was exposed bone or hardware. In our subanalysis of only wounds with bone or hardware involvement, the rate of minor amputations was significantly lower for PFs, supporting the utility of PFs for more complex wounds. Our results also showed that the most common reason for postoperative ipsilateral amputation was due to infection. Muscle flaps

Table 6. Outcomes by Location: Hindfoot and Ankle

Variables	Total	Pedicled	Random Pattern	P
n (%)	116	73 (62.9)	43 (37.1)	
Postoperative outcomes				
Immediate flap success	114 (98.3)	71 (97.3)	43 (100.0)	0.529
Takeback	3 (2.6)	2 (2.7)	1 (2.3)	1.000
Postoperative complications				
All complications				
Partial necrosis	12 (10.3)	10 (13.7)	2 (4.7)	0.122
Hematoma	3 (2.6)	2 (2.7)	1 (2.3)	1.000
Dehiscence	28 (24.1)	13 (17.8)	15 (34.9)	**0.038**
Infection	41 (35.3)	21 (28.8)	20 (46.5)	0.053
Minor complications	35 (30.2)	19 (26.0)	16 (37.2)	0.205
Partial necrosis	6 (5.2)	4 (5.5)	2 (4.7)	0.846
Hematoma	3 (2.6)	2 (2.7)	1 (2.3)	1.000
Dehiscence	15 (12.9)	8 (11.0)	7 (16.3)	0.409
Infection	18 (15.5)	8 (11.0)	10 (23.3)	0.077
Major complications	45 (38.8)	24 (32.9)	21 (48.8)	0.088
Infection	25 (21.6)	14 (19.2)	11 (25.6)	0.418
Ischemia	8 (6.9)	7 (9.6)	1 (2.3)	0.255
Dehiscence	12 (10.3)	5 (6.9)	7 (16.3)	0.124
Postoperative ipsilateral amputation	25 (21.6)	12 (16.4)	13 (30.2)	0.081
Minor amputation	10 (8.6)	4 (5.5)	6 (14.0)	0.176
Major amputation	15 (12.9)	8 (11.0)	7 (16.3)	0.409
Amputation reason				
Nonhealing wound	10 (8.6)	5 (6.9)	5 (11.6)	0.376
Infection	12 (10.3)	6 (8.2)	6 (14.0)	0.327
Ischemia	1 (0.9)	1 (1.4)	0 (0.0)	1.000
Dehiscence	1 (0.9)	0 (0.0)	1 (2.3)	0.371
Limb salvage rate	91 (78.5)	61 (83.6)	30 (69.8)	0.081
Long-term outcomes				
Mortality	24 (20.7)	14 (19.2)	10 (23.3)	0.601

Values in boldface signify significant *P* value ($P<0.05$).

are considered to be a more reliably perfused option for deeper wounds with extensive soft-tissue loss or for defects involving exposed bone, tendon, or joints at the base.[9,16,18,21,33–35] Similarly, they are preferred in cases of osteomyelitis or when patients are at a higher risk of infection.[20,33] In cases of infection, they can deliver a higher volume of antibiotics and immunological components to the wound site due to their higher perfusion rate, promoting faster healing.[36,37] This was supported by our study with a significantly lower rate of minor infections for PFs. If patients have a history of osteomyelitis, are at higher risk of infection, or have complex wounds with deeper exposed structures, we suggest the use of PFs over RpFs whenever available, to achieve better long-term outcomes and higher rates of limb salvage.[38–43]

Optimizing the Use of RpF versus PF

As the six angiosomes of the foot and ankle fundamentally guide the principles of reconstruction, we also evaluate use of RpFs versus PFs by location to guide surgical decision-making in flap planning.[14,25,44] We provide a guide for commonly used PFs and RpFs in different locations of the foot and ankle. (**See figure, Supplemental Digital Content 1**, which shows pedicled and random pattern local flaps by location. **http://links.lww.com/PRSGO/D310**.) First, RpFs are preferred in flat areas, including the dorsal and plantar surfaces of the foot, forefoot, and midfoot regions where the subdermal plexus can be preserved easily. The perfusion of an RpF may be uncertain if it is elevated to include an angiosome territory beyond its existing margins. For this reason, PFs are preferred at the junctions of neighboring angiosomes, as evidenced in our study by their use on the medial and lateral sides of the foot and ankle. Furthermore, the mobility of PFs allows them to cover neighboring angiosome territories, as long as the dominant pedicle is patent. For example, the medial plantar artery can be used as a fasciocutaneous flap or with the abductor hallucis brevis for coverage of the medial side of the foot and ankle, medial, or plantar heel. The versatility of the lateral plantar artery pedicle supplies several muscle flaps including the abductor digiti minimi, flexor digiti minimi, and flexor digitorum brevis, which can be used for various plantar heel, lateral midfoot, and ankle defects.[18]

The calcaneal branches of the posterior tibial artery and peroneal artery, the two major arteries of the heel, run closely along the medial heel in the distal tarsal tunnel or just distal to the lateral plantar heel. They are limited by their pedicle length and may risk higher rates of necrosis if advanced too far forward into the distal midfoot and forefoot, but are versatile within the hindfoot

Table 7. Outcomes by Wound Depth: Soft Tissue

Variables	Total	Pedicled	Random Pattern	P
n (%)	58	26 (44.8)	32 (55.2)	
Postoperative outcomes				
Immediate flap success	57 (98.3)	25 (96.2)	32 (100.0)	0.448
Takeback	2 (3.5)	2 (7.7)	0 (0.0)	0.197
Postoperative complications				
All complications				
Partial necrosis	5 (8.6)	3 (11.5)	2 (6.3)	0.475
Hematoma	2 (3.5)	1 (3.9)	1 (3.1)	1.000
Dehiscence	23 (39.7)	10 (38.5)	13 (40.6)	0.867
Infection	21 (36.2)	8 (30.8)	13 (40.6)	0.437
Minor complications	25 (43.1)	10 (38.5)	15 (46.9)	0.520
Partial necrosis	3 (5.2)	1 (3.9)	2 (6.3)	1.000
Hematoma	1 (1.7)	0 (0.0)	1 (3.1)	1.000
Dehiscence	13 (22.4)	6 (23.1)	7 (21.9)	0.913
Infection	18 (31.0)	6 (23.1)	12 (37.5)	0.238
Major complications	19 (32.8)	9 (34.6)	10 (31.3)	0.786
Infection	8 (13.8)	4 (15.4)	4 (12.5)	1.000
Ischemia	3 (5.2)	2 (7.7)	1 (3.1)	0.582
Dehiscence	10 (17.2)	4 (15.4)	6 (18.8)	1.000
Postoperative ipsilateral amputation	9 (15.5)	4 (15.4)	5 (15.6)	0.980
Minor amputation	3 (5.2)	1 (3.9)	2 (6.3)	0.681
Major amputation	6 (10.3)	3 (11.5)	3 (9.4)	0.788
Amputation reason				
Nonhealing wound	3 (5.2)	1 (3.9)	2 (6.3)	1.000
Infection	3 (5.2)	1 (3.9)	2 (6.3)	1.000
Ischemia	2 (3.5)	2 (7.7)	0 (0.0)	0.197
Dehiscence	1 (1.7)	0 (0.0)	1 (3.1)	1.000
Limb salvage rate	49 (84.5)	22 (84.6)	27 (84.4)	1.000
Long-term outcomes				
Mortality	16 (27.6)	6 (23.1)	10 (31.3)	0.489

Values in boldface signify significant *P* value ($P<0.05$).

region. Generally, smaller defects in the plantar heel can be covered using a flexor digitorum brevis, medial plantar artery, abductor hallucis brevis, or abductor digiti minimi. A flap from the calcaneal branch of the peroneal artery can also be elevated from the lateral malleolus and placed on the posterior heel.

Although local flaps are versatile, they may not always resolve the clinical problem at hand. If the local flap cannot sufficiently cover the defect, a free flap should be considered. In these cases, free flaps are used when the defect size is too large or blood flow may be compromised due to location.

Limitations

The findings of this study are inherently limited by the retrospective nature of data collection, whereby any missing data within the electronic medical record may have affected reported frequencies. Cases span an 11-year time period, in which advancements in technology, surgeon skill, and postoperative management have evolved and may contribute to outcomes. This study's retrospective and observational design limits the ability to establish a causal relationship between surgical approach and clinical outcomes. Additionally, the corresponding author performed all local flaps, whose expertise in foot and ankle reconstruction may compromise the generalizability of our favorable findings.

CONCLUSIONS

The use of PFs versus RpFs for foot and ankle reconstruction should be optimized depending on wound location and clinical indication. RpFs should be used for dorsal or plantar defects in the forefoot and midfoot regions when there is a patent source artery and the transposition of the flap can be maintained within the angiosome. PFs are best used for the medial and lateral foot and hindfoot, and in cases with infection or complex defects with exposed bone and hardware.

Christopher E. Attinger, MD
Department of Plastic and Reconstructive Surgery
Medstar
Georgetown University Hospital
3800 Reservoir Road, NW
Washington, DC 20007
E-mail: cattinger@gmail.com

DISCLOSURE

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

Table 8. Outcomes by Wound Depth: Bone and Hardware Involvement

Variables	Total	Pedicled	Random Pattern	*P*
n (%)	146	92 (63.0)	54 (37.0)	
Postoperative outcomes				
Immediate flap success	142 (97.3)	88 (95.7)	54 (100.0)	0.297
Takeback	4 (2.7)	3 (3.3)	1 (1.9)	1.000
Postoperative complications				
All complications				
Partial necrosis	12 (8.2)	10 (10.9)	2 (3.7)	0.211
Hematoma	3 (2.1)	3 (3.3)	0 (0.0)	0.296
Dehiscence	36 (24.7)	20 (21.7)	16 (29.6)	0.286
Infection	53 (36.3)	29 (31.5)	24 (44.4)	0.117
Minor complications	44 (30.1)	25 (27.2)	19 (35.2)	0.308
Partial necrosis	5 (3.4)	4 (4.4)	1 (1.9)	0.652
Hematoma	4 (2.7)	4 (4.4)	0 (0.0)	0.297
Dehiscence	26 (17.8)	15 (16.3)	11 (20.4)	0.535
Infection	20 (13.7)	10 (10.9)	10 (18.5)	0.194
Major complications	66 (45.2)	37 (40.2)	29 (53.7)	0.114
Infection	39 (26.7)	22 (23.9)	17 (31.5)	0.318
Ischemia	13 (8.9)	11 (12.0)	2 (3.7)	0.133
Dehiscence	12 (8.2)	7 (7.6)	5 (9.3)	0.726
Postoperative ipsilateral amputation	44 (30.1)	23 (25.0)	21 (38.9)	0.077
Minor amputation	18 (12.3)	7 (7.6)	11 (20.4)	**0.024**
Major amputation	26 (17.8)	16 (17.4)	10 (18.5)	0.864
Amputation reason				
Nonhealing wound	15 (10.3)	8 (8.7)	7 (13.0)	0.412
Infection	21 (14.4)	12 (13.0)	9 (16.7)	0.547
Ischemia	4 (2.7)	2 (2.2)	2 (3.7)	0.627
Dehiscence	2 (1.4)	1 (1.1)	1 (1.9)	1.000
Limb salvage rate	102 (6.9)	69 (75.0)	33 (61.1)	0.077
Long-term outcomes				
Mortality	35 (24.2)	19 (20.9)	16 (29.6)	0.234

Values in boldface signify significant *P* value ($P<0.05$).

REFERENCES

1. Sen CK. Human wounds and its burden: an updated compendium of estimates *Adv Wound Care (New Rochelle)*. 2019;8:39–48.
2. Martinengo L, Olsson M, Bajpai R, et al. Prevalence of chronic wounds in the general population: systematic review and meta-analysis of observational studies. *Ann Epidemiol*. 2019;29:8–15.
3. Schneider C, Stratman S, Kirsner RS. Lower extremity ulcers. *Med Clin North Am*. 2021;105:663–679.
4. Rice JB, Desai U, Cummings AK, et al. Burden of diabetic foot ulcers for medicare and private insurers. *Diabetes Care*. 2014;37:651–658.
5. Frykberg RG, Banks J. Challenges in the treatment of chronic wounds. *Adv Wound Care (New Rochelle)*. 2015;4:560–582.
6. Kolbenschlag J, Hellmich S, Germann G, et al. Free tissue transfer in patients with severe peripheral arterial disease: functional outcome in reconstruction of chronic lower extremity defects. *J Reconstr Microsurg*. 2013;29:607–614.
7. Black C, Fan KL, Defazio MV, et al. Limb salvage rates and functional outcomes using a longitudinal slit arteriotomy end-to-side anastomosis for limb-threatening defects in a high-risk patient population. *Plast Reconstr Surg*. 2020;145:1302–1312.
8. Clemens MW, Attinger CE. Functional reconstruction of the diabetic foot. *Semin Plast Surg*. 2010;24:43–56.
9. Attinger CE, Ducic I, Cooper P, et al. The role of intrinsic muscle flaps of the foot for bone coverage in foot and ankle defects in diabetic and nondiabetic patients. *Plast Reconstr Surg*. 2002;110:1047–1054; discussion 1055.
10. Ducic I, Attinger CE. Foot and ankle reconstruction: pedicled muscle flaps versus free flaps and the role of diabetes. *Plast Reconstr Surg*. 2011;128:173–180.
11. Prohaska J, Sequeira Campos M, Cook C. Rotation flaps. In: *StatPearls*. Treasure Island, Fla.: StatPearls Publishing; 2023.
12. Hollenbeck ST, Woo S, Komatsu I, et al. Longitudinal outcomes and application of the subunit principle to 165 foot and ankle free tissue transfers. *Plast Reconstr Surg*. 2010;125:924–934.
13. Taylor GI, Doyle M, McCarten G. The Doppler probe for planning flaps: anatomical study and clinical applications. *Br J Plast Surg*. 1990;43:1–16.
14. Attinger CE, Evans KK, Bulan E, et al. Angiosomes of the foot and ankle and clinical implications for limb salvage: reconstruction, incisions, and revascularization. *Plast Reconstr Surg*. 2006;117(7 Suppl):261S–293S.
15. Clark N, Sherman R. Soft-tissue reconstruction of the foot and ankle. *Orthop Clin North Am*. 1993;24:489–503.
16. Frykberg RG, Attinger C, Smeets L, et al. Surgical strategies for prevention of amputation of the diabetic foot. *J Clin Orthop Trauma*. 2021;17:99–105.
17. Patel SR. Local random flaps for the diabetic foot. *Clin Podiatr Med Surg*. 2022;39:321–330.
18. Black CK, Kotha VS, Fan KL, et al. Pedicled and free tissue transfers. *Clin Podiatr Med Surg*. 2019;36:441–455.
19. Jordan DJ, Malahias M, Hindocha S, et al. Flap decisions and options in soft tissue coverage of the lower limb. *Open Orthop J*. 2014;8:423–432.
20. Attinger CE, Ducic I, Zelen C. The use of local muscle flaps in foot and ankle reconstruction. *Clin Podiatr Med Surg*. 2000;17:681–711.
21. Deldar R, Merle C, Attinger CE, et al. Soft tissue coverage of lower extremity defects: Pearls and pitfalls in the chronic wound population. *Plast Aesthet Res*. 2022;9:13.

22. Vandenbroucke JP, von Elm E, Altman DG, et al; STROBE Initiative. Strengthening the reporting of observational studies in epidemiology (STROBE): explanation and elaboration. *Int J Surg*. 2014;12:1500–1524.
23. Caravaggi CM, Sganzaroli AB, Bona F, et al. Square, random fasciocutaneous plantar flaps for treating noninfected diabetic plantar ulcers: a patient series. *J Foot Ankle Surg*. 2016;55:1100–1105.
24. McGregor IA, Morgan G. Axial and random pattern flaps. *Br J Plast Surg*. 1973;26:202–213.
25. Behan FC. The fasciocutaneous island flap: an extension of the angiotome concept. *Aust N Z J Surg*. 1992;62:874–886.
26. Gómez OJ, Barón OI, Peñarredonda ML. Keystone flap: overcoming paradigms. *Plast Reconstr Surg Glob Open*. 2019;7:e2126.
27. Saint-Cyr M, Wong C, Schaverien M, et al. The perforasome theory: vascular anatomy and clinical implications. *Plast Reconstr Surg*. 2009;124:1529–1544.
28. Low OW, Sebastin SJ, Cheah AEJ. A review of pedicled perforator flaps for reconstruction of the soft tissue defects of the leg and foot. *Indian J Plast Surg*. 2019;52:26–36.
29. Evans GRD, Christie BM, Bentz ML. Local random pattern flaps. In Evans G, ed., *Operative Plastic Surgery*, 2nd ed. New York, N.Y.: Oxford Academic; 2019.
30. Liu Y, Cai P, Cheng L, et al. Local random pattern flap coverage for implant exposure following open reduction internal fixation via extensile lateral approach to the calcaneus. *BMC Musculoskelet Disord*. 2021;22:567.
31. Taylor G, Chubb DP, Ashton MW. True and "choke" anastomoses between perforator angiosomes: part I. anatomical location. *Plast Reconstr Surg*. 2013;132:1447–1456.
32. Mehta A, Goldman JJ. Axial flaps. In: *StatPearls*. Treasure Island, Fla.: StatPearls Publishing; 2023.
33. Klebuc M, Menn Z. Muscle flaps and their role in limb salvage. *Methodist Debakey Cardiovasc J*. 2013;9:95–99.
34. Craig GC. Intrinsic muscle flaps for coverage of small defects in the foot. *Clin Podiatr Med Surg*. 2020;37:789–802.
35. Price A, Contractor U, White R, et al. The use of vascularised muscle flaps for treatment or prevention of wound complications following arterial surgery in the groin. *Int Wound J*. 2020;17:1669–1677.
36. Gosain A, Chang N, Mathes S, et al. A study of the relationship between blood flow and bacterial inoculation in musculocutaneous and fasciocutaneous flaps. *Plast Reconstr Surg*. 1990;86:1152–1162; discussion 1163.
37. Koepple C, Kallenberger AK, Pollmann L, et al. Comparison of fasciocutaneous and muscle-based free flaps for soft tissue reconstruction of the upper extremity. *Plast Reconstr Surg Glob Open*. 2019;7:e2543.
38. Anthony JP, Mathes SJ, Alpert BS. The muscle flap in the treatment of chronic lower extremity osteomyelitis: results in patients over 5 years after treatment. *Plast Reconstr Surg*. 1991;88:311–318.
39. Fitzgerald RH, Jr, Ruttle PE, Arnold PG, et al. Local muscle flaps in the treatment of chronic osteomyelitis. *J Bone Joint Surg Am*. 1985;67:175–185.
40. Patzakis MJ, Abdollahi K, Sherman R, et al. Treatment of chronic osteomyelitis with muscle flaps. *Orthop Clin North Am*. 1993;24:505–509.
41. Gonzalez MH, Weinzweig N. Muscle flaps in the treatment of osteomyelitis of the lower extremity. *J Trauma*. 2005;58:1019–1023.
42. Chang N, Mathes SJ. Comparison of the effect of bacterial inoculation in musculocutaneous and random-pattern flaps. *Plast Reconstr Surg*. 1982;70:1–10.
43. Calderon W, Chang N, Mathes SJ. Comparison of the effect of bacterial inoculation in musculocutaneous and fasciocutaneous flaps. *Plast Reconstr Surg*. 1986;77:785–794.
44. Neville RF, Attinger CE, Bulan EJ, et al. Revascularization of a specific angiosome for limb salvage: does the target artery matter? *Ann Vasc Surg*. 2009;23:367–373.