

Free versus Pedicled Perforator Flaps for Lower Extremity Reconstruction: A Multicenter Comparison of Institutional Practices and Outcomes

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Abstract

Background Of all body regions, lower extremity wounds have been and remain the greatest challenge. Perforator free flaps have been accepted as a reasonable option to solve this dilemma but require the complexity of microsurgery. As a consequence, the possibility that pedicled perforator flaps could supplant even perforator free flaps has recently gained intense enthusiasm.

Methods A retrospective investigation was undertaken to compare the validity for the use of perforator flaps of all types at three dissimilar institutions, that is, a university, a regional center, and a community hospital. All flaps performed in the 5-year period, 2011 to 2015, were included to allow at least 1-year follow-up before data analysis. A total of 433 free perforator flaps and 52 pedicled perforator flaps had been performed specifically for the lower extremity.

Results Patient demographics, wound etiology, and comorbidities were similar for all institutions. Free flaps were more commonly needed after trauma and for chronic ulcers. Pedicled flaps were more likely an option after tumor excision. Large defects or those involving the foot were better served by free flaps. Overall success for free perforator flaps was 90.1% and for pedicled perforator flaps was 92.3%, with no significant difference noted ($p = 0.606$) between institutions. Peripheral vascular disease was the only significant comorbidity risk factor for both free and pedicled flap failure.

Conclusion Perforator flaps in general have become a reasonable solution for soft tissue defects of the lower extremity. Following careful consideration of the etiology, dimensions, location, patient comorbidities, and presence of adequate perforators, a pedicled or free perforator flap could potentially be successful. Pedicled perforator flaps, if adequate healthy soft tissues remain adjacent to the defect, forecast a continuance of the evolution in seeking simplicity yet reliability by the best flap possible for soft tissue closure of the lower limb wound.

Keywords

- ▶ perforator flaps
- ▶ pedicled flaps
- ▶ free flaps
- ▶ lower extremity

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Although there may be notable exceptions, the typical role for the reconstructive surgeon in the management of lower extremity wounds is to restore skin integrity.^{1,2} Simpler devices such as subatmospheric pressure systems augmenting secondary intention healing, secondary closure by skin stretching tools, bilaminar dermal regeneration templates, or autogenous skin grafts have often proven to be satisfactory options.³ However, long-standing disease processes such as chronic ulcers, osteomyelitis, or the vasculopath, or acute processes associated with trauma or neoplasms, where fractures, tendons, or prostheses in either scenario are exposed, may more reliably require vascularized tissue as a flap for proper treatment. To achieve this goal, the traditional selection process used available local muscle flaps for the proximal lower limb, and free flaps for the distal leg and foot.⁴ The location of available muscles conveniently divided the lower limb into arbitrary zones (→Fig. 1).

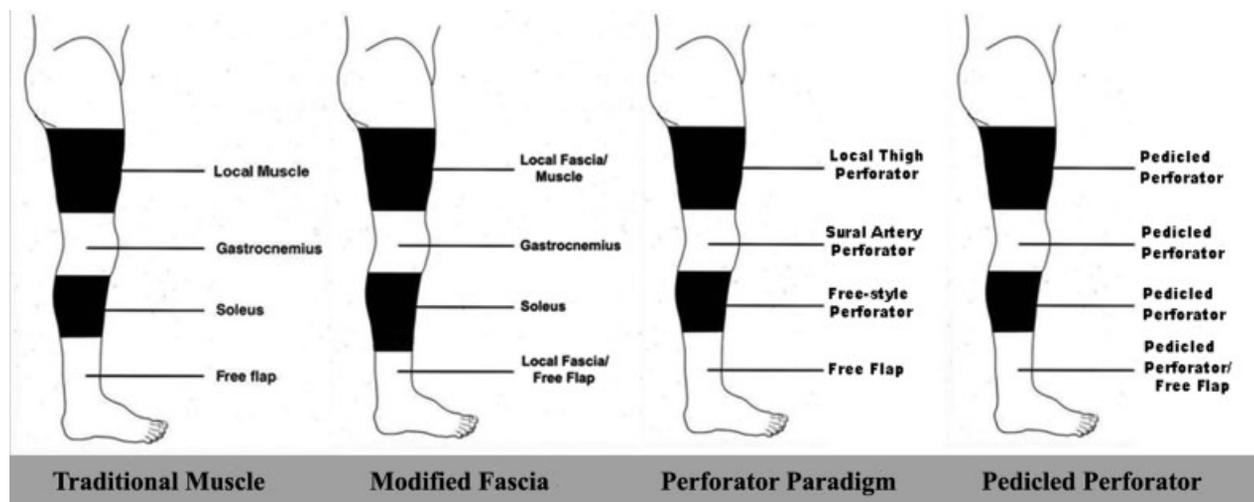
After the reintroduction of fasciocutaneous flaps by Pontén,⁵ the aforementioned muscle flap schema was altered; since many local skin flaps, albeit usually as a peninsular variety, proved to be valuable alternatives. Following the exquisite observations by Nakajima et al,⁶ an even better understanding of the source of skin circulation from basic deep fascial perforator types then helped establish the role of perforator flaps. This resulted in a paradigm shift in flap selection priorities for all zones of the lower extremity as recently summarized in this journal.⁷ Although revolutionary in concept, even that has been dramatically challenged by a new preference whenever possible to seek first a pedicled perforator flap before considering a free perforator flap (→Fig. 1). This presumably has reflected limitations in microsurgical capabilities, or a desire to avoid any complexities by the selection of a more time efficient alternative. Evidence for this conclusion has been corroborated by the

numerous reports of nonmicrosurgical tissue transfers in all the major microsurgical journals.⁸⁻¹⁴ Yet the experienced microsurgeon recognizes that even pedicled perforator flaps must be carefully dissected by still using the most delicate microsurgical techniques.¹⁵

Over the past two decades, perforator free flaps have proven to be as successful as their muscle flap predecessors, but has the more recent transition toward pedicled perforator flaps in the lower extremity also been reasonable?^{12,16} The rapid shift in international practice patterns in this regard has generated few outcome studies designed to answer whether there should be concerns as to the safety and efficacy of pedicled perforator flaps when used instead of free flaps in the lower limb.¹² To provide further insight, a comparison of institutional practice patterns and outcomes using perforator flaps from quite dissimilar settings from diverse parts of the world was reviewed to see if this has been an apropos and reliable evolution.

Materials and Methods

A retrospective chart review of the overall utilization of perforator flaps specifically for the lower extremity was undertaken by three dissimilar institutions, where the leading investigators had a mutual collegiality fostered by their membership in the World Society for Reconstructive Microsurgery. By far the greatest contributor was Asan Medical Center, affiliated with the University of Ulsan in Seoul, Korea. As with any university, there is a constant influx of residents, fellows, and medical students. In this institution, the emphasis has been the treatment of the dysvascular and diabetic patient using supermicrosurgical techniques.^{17,18} Singapore General Hospital is a highly regarded regional center that manages a broad spectrum of lower limb pathology, also using a myriad of



Evolution of Flap Priorities



Fig. 1 Evolution of flap selection priorities according to the zone of the lower limb, from muscle, to fasciocutaneous, and now to pedicled perforator flaps.

residents and fellows. From the other side of the world, Sacred Heart Hospital in the United States is a small community hospital private practice environment where a single physician extender provided the only assistance.

The 5-year period, 2011 to 2015, was arbitrarily chosen as the most recent period that would allow a full-year follow-up through 2016 for complete data analysis. At each institu-

tion, basic demographics were tabulated with also an emphasis on identification of major comorbidities, wound etiology, lower limb region involved, size of the defect requiring coverage, choice of perforator flap, and results and complications including complete flap failure (►Tables 1–6). The size of the defect was defined as minor if < 10 cm,² moderate if 10 to 50 cm,² or major if > 50 cm.²

Table 1 Free versus pedicled flaps: comparison by institution of demographics and defect characteristics

	Seoul		Singapore	
	Free flap (n = 323)	Pedicled flap (n = 21)	Free flap (n = 76)	Pedicled flap (n = 16)
Demographics				
Age	50 (18.1)	52.3 (22.4)	48 (16.1)	59 (16.1)
Males	216 (66.9)	9 (42.9)	53 (69.7)	11 (68.8)
Females	107 (33.1)	12 (57.1)	23 (30.3)	5 (31.3)
Etiology				
Trauma	81 (25.1)	0	30 (39.5)	3 (18.8)
Cancer/tumor	75 (23.2)	14 (66.7)	9 (11.8)	5 (31.3)
Chronic ulcer	105 (32.5)	3 (14.3)	4 (5.3)	0
Infection	6 (1.9)	1 (4.8)	31 (40.8)	8 (50)
Others	56 (17.3)	3 (14.3)	2 (2.6)	0
Size ^a				
Minor	0	0	5 (6.6)	2 (12.5)
Moderate	65 (20.1)	9 (42.9)	23 (30.3)	6 (37.5)
Major	255 (78.9)	11 (52.4)	48 (63.2)	8 (50)
Not specified	3 (0.9)	1 (4.8)	0	0
Zone				
Thigh	13 (4.0)	14 (66.7)	3 (3.9)	1 (6.3)
Leg (upper 1/3)	37 (11.5)	2 (9.5)	8 (10.5)	2 (12.5)
Leg (mid 1/3)	32 (9.9)	1 (4.8)	8 (10.5)	0
Leg (lower 1/3)	42 (13)	1 (4.8)	14 (18.4)	7 (43.8)
Foot	199 (61.6)	3 (14.3)	43 (56.6)	6 (37.5)
	United States		Total	
	Free flap (n = 34)	Pedicled flap (n = 15)	Free flap (n = 433)	Pedicled flap (n = 52)
Demographics				
Age	51 (13.7)	55 (15.3)	50.6 (17.4)	54.3 (19.2)
Males	27 (79.4)	9 (60)	296 (68.3)	29 (55.8)
Females	7 (20.6)	6 (40)	137 (31.7)	23 (44.2)
Etiology				
Trauma	18 (52.9)	4 (26.7)	129 (29.8)	7 (13.5)
Cancer/tumor	1 (2.9)	5 (33.3)	85 (19.6)	24 (46.2)
Chronic ulcer	6 (17.6)	4 (26.7)	115 (26.6)	7 (13.5)
Infection	3 (8.8)	1 (6.7)	40 (9.2)	10 (19.2)
Others	6 (17.6)	1 (6.7)	64 (14.8)	4 (7.7)
Size ^a				
Minor	2 (5.9)	4 (26.7)	7 (1.6)	6 (11.5)

(Continued)

Table 1 (Continued)

	United States		Total	
	Free flap (n = 34)	Pedicled flap (n = 15)	Free flap (n = 433)	Pedicled flap (n = 52)
Moderate	21 (61.8)	6 (40)	109 (25.2)	21(40.4)
Major	11 (32.4)	5 (33.3)	314 (72.5)	24 (46.2)
Not specified	0	0	3 (0.7)	1 (1.9)
Zone				
Thigh	0	2 (13.3)	16 (3.7)	17 (32.7)
Leg (upper 1/3)	4 (11.8)	2 (13.3)	49 (11.3)	6 (11.5)
Leg (mid 1/3)	5 (14.7)	1 (6.7)	45 (10.4)	2 (3.8)
Leg (lower 1/3)	6 (17.6)	3 (20)	62 (14.3)	11 (21.2)
Foot	17 (50)	12 (80)	34 (7.9)	19 (36.5)

Age calculated as "Mean (Standard Deviation)."

All other tabulations listed as n = number (percentage).

^aSize: minor < 10 cm²; moderate = 10–50 cm²; major > 50 cm.²

All categorical variables were listed by numbers observed and percentages. Age was the only continuous variable and was expressed as a mean and standard deviation. Flap outcome was divided into overall success, that is, the flap met

the reconstructive goal, or complete flap failure where this objective was not met even if there was partial flap survival. All analyses were conducted with IBM SPSS Software. Differences between variables among all institutions were

Table 2 Free versus pedicled flaps: comorbidities by institution

	Seoul		Singapore		p-Value
	Free flap n (%)	Pedicled flap n (%)	Free flap n (%)	Pedicled flap n (%)	
IHD	34 (10.5)	0	5 (6.6)	3 (18.8)	
DM	119 (36.8)	5 (23.8)	24 (31.6)	8 (50)	
PVD	88 (27.2)	2 (9.5)	7 (9.2)	1 (6.3)	
Renal	35 (10.8)	1 (4.8)	7 (9.2)	1 (6.3)	
Smoker	67 (20.7)	1 (4.8)	14 (18.4)	2 (12.5)	
Radiation	17 (5.3)	3 (14.3)	0	0	
Degloving	9 (2.8)	0	9 (11.8)	0	
Obesity	0	0	3 (3.9)	1 (6.3)	
Others	16 (5)	2 (9.5)	6 (7.9)	0	
	United States		Total		p-Value
	Free flap n (%)	Pedicled flap n (%)	Free flap n (%)	Pedicled flap n (%)	
IHD	6 (17.6)	3 (20)	45 (10.4)	6 (11.5)	0.799
DM	9 (26.5)	3 (20)	152 (35.1)	16 (30.8)	0.535
PVD	7 (20.6)	2 (13.3)	102 (23.6)	5 (9.6)	0.022
Renal	2 (5.9)	1 (6.7)	44 (10.2)	3 (5.8)	0.312
Smoker	6 (17.6)	3 (20)	87 (20.1)	7 (13.5)	0.253
Radiation	0	0	17 (3.9)	5 (9.6)	0.0625
Degloving	2 (5.9)	0	20 (4.6)	0	–
Obesity	4 (11.8)	3 (20)	7 (1.6)	4 (7.7)	–
Others	17 (50)	12 (80)	34 (7.9)	19 (36.5)	–

Abbreviations: DM, diabetes mellitus; IHD, ischemic heart disease; N (%), number flaps (percentage with that morbidity) (multiple morbidities were frequent); PVD, peripheral vascular disease.

Table 3 Flap selections by institution

	Seoul	Singapore	United States
Free flaps, <i>n</i> (%)			
SCIP	183 (56.7)	22 (28.9)	0
ALT	91 (28.2)	46 (60.5)	21 (61.8)
TDAP	3 (0.9)	4 (5.3)	1 (2.9)
Medial sural	0	2 (2.6)	12 (35.3)
Others	46 (14.2)	2 (2.6)	0
Total	323	76	34
Pedicled flaps, <i>n</i> (%)			
Peninsular	0	8 (50)	1 (6.7)
Island	0	1 (6.3)	2 (13.3)
Propeller	20 (95.2)	7 (43.8)	2 (13.3)
Others	1 (4.8)	0	10 (66.7)
Total	21	16	15

Abbreviations: ALT, anterolateral thigh; *N* (%), number of flaps (percentage of total by that institution); SCIP, superficial circumflex iliac artery perforator; TDAP, thoracodorsal artery perforator.

considered significant ($p < 0.05$) using chi-square test and independent *t*-tests. A logistic regression model was then used to estimate the odds ratio between what proved to be significant risk factors and flap failure, with $p < 0.05$ deemed as significant.

Results

An evaluation of population demographics showed no significant difference in age or gender between the three involved centers (►Table 1). By far the most lower extremity perforator free flaps were performed at the largest institution in Seoul, whereas pedicled perforator flaps were approximately equally spread out between all three participants (►Fig. 2). Overall, there was a total of 433 perforator free flaps and 52 pedicled perforator flaps utilized. Of these,

74.6% of free flaps, and 51.9% of pedicled flaps were selected for the distal leg and foot, where the absolute numbers demonstrated a continued dependence on primarily free perforator flaps that existed at all hospitals. This coincided with the fact that diabetes mellitus, peripheral vascular disease, and traumatic injuries were the dominant comorbidities (►Table 2), where as a consequence adequate healthy local tissues that could safely routinely allow a pedicled perforator flap did not exist. Also, moderate or large sized wounds obviously still required a free flap (►Table 1).

The most common free flap donor site was the superficial circumflex iliac artery perforator flap (►Table 3), because of unrestrained size, thinness, and unrivalled donor site morbidity.¹⁸ However, none were used in the community hospital since unlike Seoul, no supermicrosurgery capabilities were available. All three institutions frequently used the anterolateral thigh free flap as also an ideal soft tissue flap.¹⁹ All types of pedicled perforator flaps were used at all locations.

Overall complication rates where there was complete flap failure occurred in 9.9% of free flaps and 7.7% of pedicled flaps (►Table 4), which was not a statistically significant difference ($p = 0.606$), and found also to be a similar rate for all institutions (►Fig. 2). These findings differed only slightly if just the foot and distal third of the leg were considered, as 11.1% of free flaps and an identical 11.1% of pedicled flaps had flap failure. Comorbidities that should raise caution when using perforator free flaps as there would be a significant increase in the risk of failure included trauma or diabetes mellitus, and its cousins cardiac and peripheral vascular disease (►Table 5). Only peripheral vascular disease proved to be a significant risk factor when a pedicled perforator flap was chosen (►Table 6).

Discussion

Perforator flaps have become mainstream,²⁰ as these can provide the skin color and consistency similar to the defect, readily can be elevated for secondary procedures, are easily monitored using clinical exam alone, dissection in a

Table 4 Free versus pedicle flaps: overall outcome by institution

	Seoul		Singapore		<i>p</i> -Value
	Free flap <i>n</i> (%)	Pedicled flap <i>n</i> (%)	Free flap <i>n</i> (%)	Pedicled flap <i>n</i> (%)	
Overall survival	287 (88.9)	19 (90.5)	73 (96)	14 (87.5)	
Complete flap failure	36 (11.1)	2 (9.5)	3 (3.9)	2 (12.5)	
	United States		Total		<i>p</i> -Value
	Free flap <i>n</i> (%)	Pedicled flap <i>n</i> (%)	Free flap <i>n</i> (%)	Pedicled flap <i>n</i> (%)	
Overall survival	30 (88.2)	15 (100)	390 (90.1)	48 (92.3)	
Complete flap failure	4 (11.8)	0	43 (9.9)	4 (7.7)	0.606

Abbreviation: *N* (%), number type flap (percentage that type).

Table 5 Univariate analysis of risk factors for free flaps

	Overall Success	Complete Failure	p-Value	OR	95% CI
Comorbidity					
IHD	34 (75.6)	11 (24.4)	0.001	3.60	1.67–7.77
DM	129 (84.9)	23 (15.1)	0.009	2.33	1.23–4.39
PVD	78 (76.5)	24 (23.5)	<0.001	5.05	2.64–9.69
Renal	31 (70.5)	13 (29.5)	<0.001	5.02	2.38–10.59
Smoker	75 (86.2)	12 (13.8)	0.650	–	–
Radiation	16 (94.1)	1 (5.9)	0.586	–	–
Degloving	18 (90.0)	2 (10.0)	0.845	–	–
Obesity	7 (100)	0	0.431	–	–
Etiology					
Trauma	123 (95.3)	6 (4.7)	0.021	0.35	0.145–0.856
Cancer	80 (94.1)	5 (5.9)	0.164	–	–
Chronic ulcer	89 (77.4)	26 (22.6)	< 0.001	5.17	2.69–9.96
Infection	39 (97.5)	1 (2.5)	0.099	–	–
Size^a					
Minor	7 (100)	0	–	–	–
Moderate	99 (90.8)	10 (9.2)	0.760	–	–
Major	281 (89.5)	33 (10.5)	0.513	–	–
Not specified	3 (100)	0	–	–	–
Zone					
Thigh	14 (87.5)	2 (12.5)	0.913	–	–
Leg (upper 1/3)	47 (95.9)	2 (4.1)	0.245	–	–
Leg (middle 1/3)	42 (93.3)	3 (6.7)	0.439	–	–
Leg (lower 1/3)	58 (93.5)	4 (6.5)	0.322	–	–
Foot	229 (87.7)	32 (12.3)	0.046	2.05	1.00–4.18

Abbreviations: CI, confidence interval; DM, diabetes mellitus; IHD, ischemic heart disease; OR, odds ratio; PVD, peripheral vascular disease.

All values listed as number for that characteristic = *N*(percentage).

^aSize: minor < 10 cm²; moderate = 10–50 cm²; major > 50 cm².

superficial plane is expedient, and have a plethora of potential donor sites depending only on the presence of an adequate perforator.¹ The availability of perforator free flaps has witnessed a paradigm shift away from muscle or fasciocutaneous flaps for closure of soft tissue defects of the lower extremity wounds due to these numerous advantages.⁷ Yet the evolution in the flap selection process for the notorious lower extremity continues as many now consider pedicled perforator flaps to be the better initial selection, since this avoids the vagaries and frustrations theoretically more common with microsurgery. Whether this has been indeed a safe and effective transition in general has been proven in the affirmative from this review of the practice patterns and outcomes from three quite dissimilar institutions, as the risk of using a pedicled or free tissue transfer when chosen under the right circumstances was no different (► **Table 4**). However, caution must still be observed as these surgeons have a similar level of expertise and experience with perforator

flaps themselves, having long overcome the learning curve before their use could be predictable.²¹

In spite of the fact that the risks of free or pedicled perforator flaps were found to be the same, the selection of a free flap still had a high priority, especially in Seoul where their capabilities with supermicrosurgery are well respected for the treatment of their patients who have a high incidence of diabetes and peripheral vascular disease for whom pedicled flaps in this subgroup may be less reliable.¹⁷ As a corollary, the superficial circumflex iliac artery perforator flap was their predominant soft tissue flap not only because donor site sequela is unparalleled, but is ideal again within their context of the application of supermicrosurgery.¹⁸ For more conventional microsurgery as practiced in the United States, the anterolateral thigh flap remains the flap of choice especially for moderate or major sized wounds.¹⁹ The types of pedicled perforator flaps ran the entire gamut of peninsular, propeller, or

Table 6 Univariate analysis of risk factors for pedicled flaps

	Overall success	Complete failure	p-Value	OR	95% CI
Comorbidity					
IHD	5 (83.3)	1 (16.7)	0.380		–
DM	15 (93.7)	1 (6.3)	0.795	–	–
PVD	3 (60.0)	2 (40.0)	0.020	15.00	1.53–146.94
Renal	3 (100)	0	–	–	–
Smoker	6 (100)	0	–	–	–
Radiation	3 (100)	0	–	–	–
Degloving	0	0	–	–	–
Obesity	4 (100)	0	–	–	–
Etiology					
Trauma	7 (100)	0	–	–	–
Cancer	23 (95.8)	1 (4.2)	0.377	–	–
Chronic ulcer	6 (85.7)	1 (14.3)	0.482	–	–
Infection	8 (80.0)	2 (20.0)	0.104	–	–
Size^a					
Minor	6 (100)	0	–	–	–
Moderate	19 (90.5)	2 (9.5)	0.683	–	–
Major	22 (91.7)	2 (8.3)	0.872	–	–
Not specified	1 (100)	0	–	–	–
Zone					
Thigh	16 (94.1)	1 (5.9)	0.565	–	–
Leg (upper 1/3)	6 (100)	0	–	–	–
Leg (middle 1/3)	2 (100)	0	–	–	–
Leg (lower 1/3)	9 (81.8)	2 (18.2)	0.141	–	–
Foot	15 (93.7)	1 (6.3)	0.795	–	–

All values listed as number for that characteristic = N (percentage).

Abbreviations: CI, confidence interval; DM, diabetes mellitus; IHD, ischemic heart disease; OR, odds ratio; PVD, peripheral vascular disease.

^aSize: minor < 10 cm²; moderate = 10–50 cm²; major > 50 cm².

advancement flaps, the latter including keystone flaps²² which in themselves are gaining interest. The medial sural artery island local perforator flap was the first choice for knee coverage only in the United States, a reflection of prejudice in its choice by the long-standing research interests of the most senior author.²³

In spite of our enthusiasm for perforator flaps, we recognize that sometimes traditional muscle flaps may be a superior option, and they should not be forgotten.^{24,25} Obviously, if a dynamic flap is required, this can only be fulfilled by a muscle. Avulsion or degloving wounds, or ischemic regions may no longer have local perforators remaining to permit a pedicled perforator flap. Three-dimensional wounds may better be filled or wrapped around by a more flexible muscle flap. If a perforator flap based on a musculocutaneous perforator has failed, the involved muscle may still be adequate to serve as a secondary option.²⁶

The influx of perforator flaps as Lachica² has proselytized has changed the need for a flap selection process according to the historical zones of the lower extremity (– Fig. 1). Rather, wound dimensions and type of tissue loss and intended function preservation are more pertinent as to whether a free or pedicled perforator flap is preferable. For example, the weight bearing zones of the foot or patella must be treated differently than the rest of the lower limb where more simply only coverage is needed. Smaller wounds may be better treated by pedicled perforator flaps, but if larger will still require free flaps. Hopefully, interpretation of our data will verify that if reasonably chosen, pedicled perforator flaps will be as reliable as free perforator flaps, yet just as important is the fact there will always be a role for both. Proper preoperative flap selection will be essential to minimize risk, and always requires a cogent understanding of the limitations due to the etiology creating the defect, its

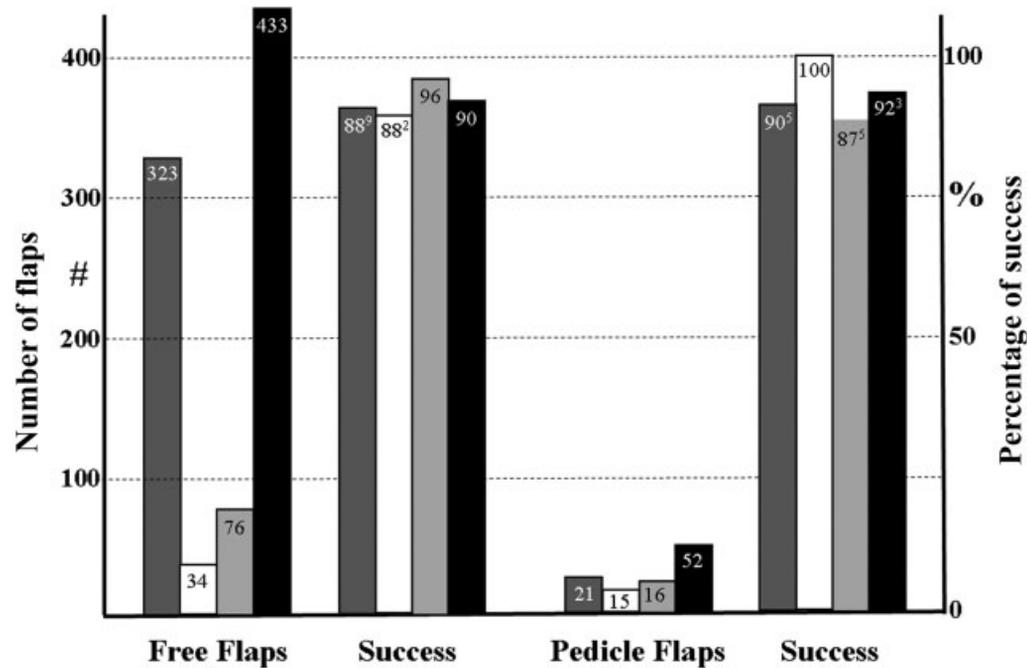


Fig. 2 Comparison of Seoul (dark gray), United States (white), Singapore (light gray), and overall total (black) number of free and pedicled perforator flaps, and their success percentages where “#” refers to number of flaps, “%” refers to percent successful. Superscript numbers are the first decimal place, for example, 88⁹ = 88.9 percent.

dimensions, and the patient’s comorbidities, no matter what flap is selected.

Note

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