Pedicled Freestyle Perforator Flap for Reconstruction after Oncosurgical Resection

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Abstract

OBJECTIVES: Evaluation of the surgical technique and feasibility of freestyle pedicled perforator flaps for reconstruction, at different anatomical sites, after oncosurgical resection and identification of the required safety measures to avoid complications.

BACKGROUND: The advancement of flap design coincided with the increased knowledge of skin vascular anatomy. Perforator flaps were first described by Koshima and Soeda. Taylor and Palmer described the angiosome, which is the vascular territory of each vessel and its perforators. Then, Saint-Cyr introduced the perforasome, which is the vascular territory of each perforator. Wei and Mardini improved the use of perforator flaps by describing freestyle free perforator flaps, where any cutaneous flap can be raised if at least one supplying perforator is preserved. They used a handheld Doppler to map the perforators. Finally, the freestyle technique was modified into a pedicled flap technique.

PATIENTS AND METHODS: This study includes the experience acquired at the National Cancer Institute - Cairo University, over the past 5 years (2017-2021), using the freestyle pedicled perforator flaps, based on perforators identified using a handheld Doppler device, to reconstruct various anatomical regions of the body.

RESULTS: The total number of cases was 24 patients and 27 flaps. The ages ranged from 22 to 81 years old. The size of the defects ranged from 2 to 300 cm^2. The head and neck regions were the most common sites of the defects, followed by the trunk, upper and lower extremities. The flaps were used to reconstruct defects after surgical resection of: 17 skin cancers, 6 soft tissue sarcomas, and 1 neck fistula after total laryngectomy. All flaps survived except for 2 complete losses. Other complications encountered were partial loss of 5 flaps and dehiscence of 3 flaps.

CONCLUSION: Freestyle pedicled perforator flaps are a reliable option for the reconstruction of non-composite defects when a sizable perforator is localized and the flap is designed according to the blood flow of the linking vessels. These flaps ensure promising functional and aesthetic results. It is not a time-consuming technique with a low complication rate. Moreover, the feasibility of mapping perforators using a handheld Doppler caused a vast spread of the procedure as a simple technique with favorable results.

Key words: Freestyle; pedicled flaps; perforator; reconstruction.

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INTRODUCTION

The fundamental goal of the reconstruction of any defect is to restore it as closely as possible to the "normal" and minimize the deformity or disability that is being treated while inflicting as little harm as possible at the donor site. If a local flap is available and meets all of the requirements for providing optimum coverage, it will always be preferable to avoid the hazards of microsurgical tissue transfer.[1]

The use of perforator flaps was expanded with the emergence of microsurgery and super-microsurgery, which facilitated micro-neurovascular dissection and anastomoses for small caliber vessels (0.3 – 0.8 mm). Wei and Mardini (2004) [2] presented the freestyle free flaps for the first time.

The freestyle approach includes utilizing a portable Doppler to map skin perforators and harvest perforator flaps by performing retrograde dissection until suitable pedicle length and size are obtained, independent of the source vessel. Finally, this approach was described as a local pedicled flap and has been applied to all anatomical sites. [3]

The use of freestyle flaps should not be perceived as an arrogant disregard for the anatomical landmarks created via the tremendous effort of anatomists, physicians, and surgeons; rather, it should be viewed as a different approach to flaps, even established, well known flaps. The choice of the flap would be based only on the quality and type of tissue that is needed to reconstruct the defect and the satisfactory location accepted by the patient. [1]

The idea of freestyle perforator flaps depends on the understanding of the vascular supply of perforator flaps. Koshima and Soeda (1989) [4] were the first to introduce the concept of perforator flaps. They revealed that muscles and fasciae are not essential to preserve the vascular supply of the flaps, thus granting perforator flaps a higher advantage concerning aesthetic results and donor site morbidity. Eventually, perforator flaps gained wide prevalence for reconstruction, both as free and locally pedicled flaps. Further understanding of the concept of the perforasome, the vascular territory of each perforator, was described by Saint-Cyr and his colleagues, where they published the perforasome theory. [5,6,7]

Freestyle flaps were first described by Wei and Mardini (2004) as "freestyle free flaps".[2] They localized the perforators using Doppler ultrasound. The freestyle approach was modulated as a local flap technique and has been utilized in nearly all the anatomical regions of the body. Regarding the large number of perforators in the body, exceeding 350, it is feasible to harvest a reliable freestyle perforator flap if a sizable perforator is found. [3,8,9,10]

PATIENTS AND METHODS

A prospective study involving 24 patients, presented at the National Cancer Institute at Cairo University between 2017 and 2021. The study included patients who had skin defects following cancer resection, with small to moderate-sized defects, and mild to moderate comorbidities. All defects were reconstructed using pedicled freestyle perforator flaps. Ethical approval was obtained from the local research ethics committee. All patients had an informed written consent that was signed by them, accepting the procedure and participation in the study. Patients' demographics, flap characteristics, complications, and their risk factors were discussed in the present study.

Surgical technique: All patients had an informed consent preoperatively concerning the procedure, participation in the study, and use of their images. Also, all cases signed the permission to publish their photos before the start of the study. A preoperative assessment of perforators was done using a handheld Doppler to identify reliable audible nearby perforators, where their sites were marked preoperatively, and the flap was designed around the most significantly audible one. The flap axis was oriented along the direction of the linking vessels. At this point, low blood pressure would cause difficulty to identify a reliable perforator with a prominent audible signal. To avoid low blood pressures caused by anesthesia induction, it is recommended to localize perforators preoperatively and mark their locations. Flap harvesting starts along one border of the designed flap to surgically identify the perforator. Moreover, incising one side of the flap gives a chance to change the type or design of the flap if an accidental injury affects the perforator. Then, the incision is completed and a retrograde dissection is continued, to achieve adequate pedicle length and size, to avoid tension. The flap is then mobilized either as a V-Y advancement or propeller flap. Some cases require mobilization of the feeding artery from which the perforator arises to compensate for the flap length or axis of rotation. Nearby nerves, especially in the head and neck region, which were not included within the flap tissues, were identified and preserved. The defect site was occasionally narrowed using interrupted sutures to decrease the size of the flap as well as the tension applied to the pedicle. Donor sites were chosen at sites with skin redundancy to allow for primary closure. However, if primary closure was not feasible, then split-thickness grafts were used for the closure of the donor sites. Care was given to avoid any kinks of the feeding vessels after mobilization of the flaps. In some cases, hot fomentations and Xylocaine irrigation were used when an inadequate perfusion of the flap was suspected. Finally, postoperative assessment included an adequate audible perforator signal on the flap to ensure intact mobilized perforators. All cases received close follow-up directly postoperatively and during the early postoperative period to assess for adequate blood supply by detecting any color changes in the flap like pallor, congestion, or ecchymosis. Any cause of flap or pedicle tension (e.g., hematomas) was excluded. After a few days of surgery, if no complications occurred, the patients were discharged for follow-up at the outpatient clinic. Then patients would continue their follow-up according to the schedule planned after resection of their primary tumors.

RESULTS

This study included 24 patients; 17 (71%) were males and 7 (29%) were females. The mean age was 54.7 years (range: 22-81). A total of 27 freestyle flaps were used as three patients each performed two flaps.

The pathologies of the excised tumors were as follows: 17 (71%) had skin cancers, 6 (25%) had soft tissue sarcomas, and 1 (4%) had neck fistula post total laryngectomy.

The head and neck regions were the most common sites of the defects; 16 (66.7%) patients, followed by the trunk; 4 (16.7%) patients, the upper extremity; 2 (8.3%) patients, and the lower extremity; 2 (8.3%) patients. The mean size of the defects was 70.7 cm2 (range: 2-300). The mean length was 8.9 cm (range: 2-20) and the width was 5.8 cm (range: 1-15).

Table 1: Patients' demographics and defect analysis

Patients' demographics and defect analysis	Number	Percentage % (Calculated out of a total of 24 patients)
Number of patients	24	
Sex		
Males	17	71
Females	7	29
Age	The mean age was 54.7 years (range: 22-81)	
Comorbidities and special habits		
Hypertension	4	16.7
Diabetes	4	16.7

Smoking	10	41.7
Timing of reconstruction		
Immediate	21	87.5
Delayed	3	12.5
Cause of the defects (total:24)		
Skin cancer	17	71
Soft tissue sarcoma	6	25
Neck fistula	1	4
Site of the defects (total:24)		
Head and neck	16	66.7
Trunk	4	16.7
Upper extremity	2	8.3
Lower extremity	2	8.3
Size of the defects (total:24) Length	The mean size was 70.7 cm^2 (range: 2-300)	
	The mean length was 8.9 cm (range: 2-20)	
Width	The mean width was 5.8 cm (range: 1-15)	

Table 2: Flap data and complications.

Flap data and complications	**Number**	**Percentage % (Calculated out of a total of 27 flaps)**
Number of flaps	27 (3 patients had 2 flaps)	
Origin of the perforator/s (total:27)		
Facial artery	12	44.4
Supratrochlear artery	4	14.8
Transverse cervical artery	2	7.4
Internal mammary artery	1	3.7
Lateral thoracic artery	1	3.7
Circumflex scapular artery	1	3.7
Suprascapular artery	1	3.7
Posterior intercostal arteries	1	3.7
Profunda brachii artery	1	3.7
Superior and inferior gluteal	2	7.4

arteries Posterior tibial artery	1	3.7
Method of mobilization (total:27) Propeller flap V-Y advancement flap	21 6	77.8 22.2
Donor-site closure (total:27) Primary Split-thickness skin grafts (STSG) STSG for extremities STSG for Trunk STSG for Head & Neck	24 3 3 out of 4 extremities donor-sites - -	88.9 11.1 75 - -
Total Complications (total:27) Major complications Complete loss Partial loss: Marginal tip Superficial partial loss Full-thickness partial loss Minor complications Dehiscence	7 2 5 1 3 1 3	25.9 7.4 18.5 3.7 11.1 3.7 11.1
Flap survival (total:27) Complete loss Survived flaps	2 25	7.4 92.6

Table 3: Analysis of risk factors (related to patients' demographics) for flap complications.

Characteristics (patient related factors)	Major complications (partial or complete loss)	
	Yes	No
Number of patients (total:24 patients, 27 flaps)	7 flaps (25.9%)	20 flaps (74.1%)

Age exceeding 60 (total:10) Age less than 60 (total: 14)	3 (30%) 4 (28.6%)	7 (70%) 10 (71.4%)
Sex Male (total:17) Female (total:7)	 5 (29.4%) 2 (28.6%)	 12 (70.6%) 5 (71.4%)
Diabetes Yes (total:4) No (total:20)	 1 (25%) 6 (30%)	 3 (75%) 14 (70%)
Hypertension Yes (total:4) No (total:20)	1 (25%) 6 (30%)	3 (75%) 14 (70%)
Smoking Yes (total:10) No (total:14)	 1 (10%) 6 (42.9%)	 9 (90%) 8 (57.1%)

Table 4: Analysis of risk factors (related to the flap locally) for flap complications.

Characteristics (Flap related factors)	Major complications (partial or complete loss)	
	Yes	No
Previous radiotherapy Yes (total:3) No (total:24)	 2 (66.7%) 4 (16.7%)	 1 (33.3%) 20 (83.3%)
Location of flap Trunk (total:5) Extremities (total:4) Head & neck (total:18)	 1 (20%) 2 (50%) 4 (22.2%)	 4 (80%) 2 (50%) 14 (77.8%)
Type of flap Advancement V-Y (total:6) Propeller (total:21)	 - 7 (33.3%)	 6 (100%) 14 (66.7%)
Arc of rotation 90˚ (total:12) 180˚ (total:9)	 4 (33.3%) 3 (33.3%)	 8 (66.7%) 6 (66.7%)

Size of flap		
<100 cm2 (total:18)	2 (11.1%)	16 (88.9%)
>100 cm2 (total:9)	5 (55.6%)	4 (44.4%)
Number of perforators Single (total:10)	3 (30%)	7 (70%)
Multiple (total:17)	2 (11.8%)	15 (88.2%)

The most significant predicators of major postoperative complications were previous history of radiotherapy, flap size exceeding 100 cm^2, and flaps located in the extremities. Also, multiple perforator flaps showed a lower complication rate. Similarly, V-Y advancement flaps had a lower complication rate compared to propeller flaps. Flaps raised from the head, neck, and trunk showed a lower complication rate compared to those raised from the extremities. Finally, old age, gender, smoking, and comorbidities were not associated with significant complication rates.

CASE PRESENTATIONS

Case 1: A 43-years-old female, non-smoker with no history of co-morbidities, underwent wide local excision of a left cheek Basal cell carcinoma (BCC). The defect was left without coverage awaiting the final pathological report to assess the surgical margins. The margins were involved, so a wider resection was done, resulting in a defect measuring 5 x 4 cm. A freestyle V-Y advancement nasolabial flap was used for delayed reconstruction based on a facial artery perforator localized using a handheld Doppler. The pedicle was dissected to reach a sufficient length for mobilization.

Figure 1: Anterior view of a defect caused by the resection of a BCC ulcer on the left cheek 2 weeks earlier. The delay of surgical reconstruction was to ensure free surgical margins.

Figure 2: A lateral view of the defect showed the marking of the feeding perforator, mapped by a handheld Doppler, and the flap design.

Figure 3: A defect measuring 5 x 4 cm resulted after a wider resection of the operative bed as the surgical margins of the initial resection were positive.

Figure 4: A freestyle flap was raised based on a perforator arising from the facial artery. Skeletonization was avoided to prevent kinking of the pedicle.

Figure 5: The flap was viable directly after surgery with no postoperative complications.

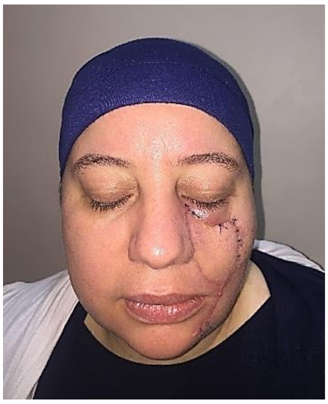

Figure 6: Two weeks later, anterior view of the flap showed the matching flap color and thickness for reconstructing the cheek

Figure 7: Two weeks later, side view of the flap. The flap thickness was optimal for reconstructing the cheek contour.

Figure 8: After one month, side view of the flap showed complete healing.

Figure 9: Anterior view of the flap, one month later.

Case 2: A 44-years-old male, known smoker with no history of co-morbidities, presented with Dermatofibrosarcoma of his left shoulder. After wide local excision of the lesion, a defect measuring 15 x 13 cm resulted. A freestyle para-scapular flap based on the circumflex scapular artery was used for immediate reconstruction. The flap was rotated 90 degrees. Finally, the flap was viable postoperatively.

Figure 10: A lesion arised in the skin and subcutaneous tissues of the left shoulder. A

previous open biopsy revealed Dermatofibrosarcoma protuberans.

Figure 11: The design of the flap and marking of the defect size after adding the proper surgical margin (4 cm) all around the lesion.

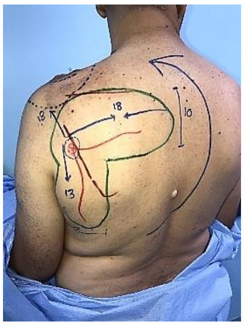

Figure 12: A bilobed flap was designed around the perforators, located by a handheld Doppler, arising from the transverse cutaneous and descending cutaneous branches of the circumflex scapular artery, which is a branch of the subscapular artery that arises from the 3rd part of the axillary artery. The transverse part of the flap measured 18 x 10 cm and the longitudinal part of the flap measured 13 x 8 cm.

Figure 13: The patient was placed in a lateral position where the lesion was excised, resulting in a defect measuring 15 x 13 cm.

Figure 14: A freestyle flap was raised based on perforators arising from the transverse cutaneous and descending cutaneous branches of the circumflex scapular artery.

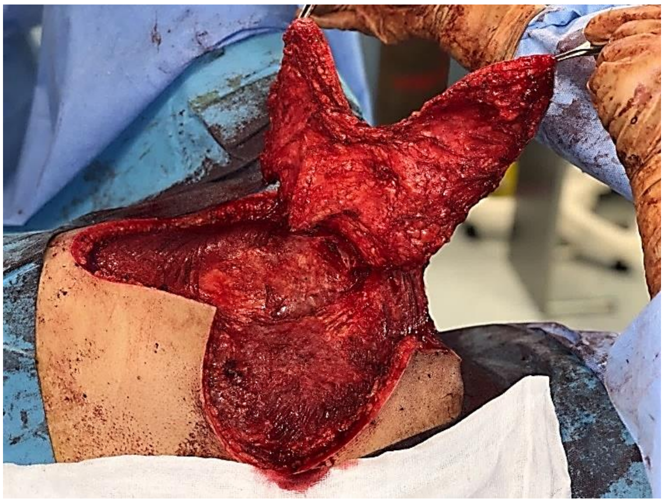

Figure 15: A bilobed flap was raised and rotated 90 degrees where the transverse part of the flap covered the defect and its donor site was closed by the longitudinal part of the flap. Finally, the defect resulting from the longitudinal part was primarily closed.

Figure 16: Directly after surgery, the flap survived completely, and the patient had an uneventful recovery.

Figure 17: Posterior view of the flap after two weeks, a few points of dehiscence occurred along the suture line.

Figure 18: Lateral view of the flap, two weeks postoperatively.

Figure 19: Anterior view of the flap, two weeks postoperatively.

Figure 20: Two months later, complete healing has occurred.

Case 3: A 22-years-old male patient complained of recurrent nasal Chondrosarcoma. Preoperative planning included a superiorly based nasolabial freestyle flap for reconstruction of the inner nasal and nasopharyngeal lining. After resection, the inner nasal defect measured 7 x 4 cm. The flap was rotated 180 degrees to reconstruct the inner nasal lining. The patient was kept under follow-up to ensure the viability of the freestyle pedicled perforator flap using a fibro-optic assessment.

Figure 21: Marking the forehead bicoronal incision and the part of the facial bones to be resected.

Figure 22: The defect resulted after resection of the superior part of the nasal bones.

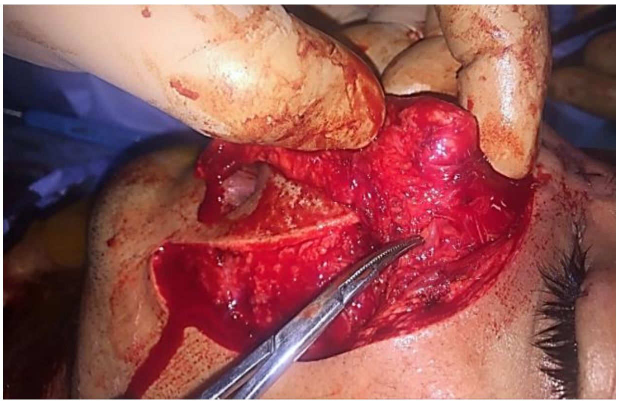

Figure 23: A superiorly based freestyle perforator flap was raised based on perforators arising from the facial artery.

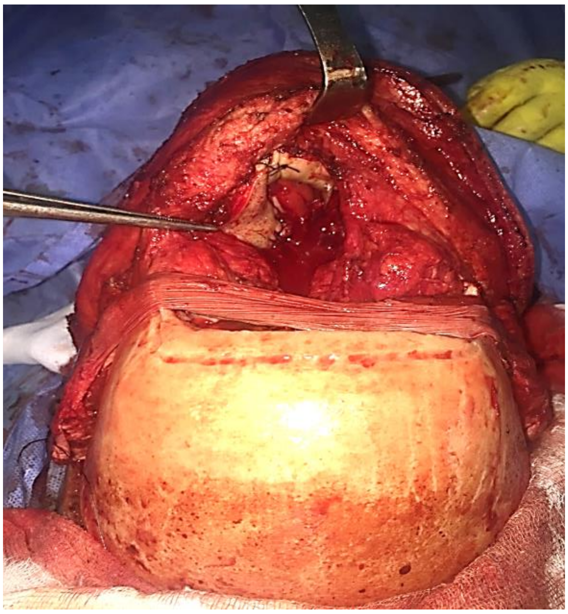

Figure 24: The flap was viable immediately after surgery. It was used to reconstruct the inner nasal lining and the left superolateral nasopharyngeal wall. A fibro-optic assessment was used to ensure the viability of the flap until complete healing occurred.

Case 4: A 45-years-old male patient complained of recurrent dermatofibrosarcoma of the upper aspect of the right thigh and inguinoscrotal region. After resection, a defect measuring 20 x 10 cm resulted. A pedicled freestyle flap was designed based on the perforators arising from the descending branch of the lateral femoral circumflex artery arising from the profunda femoris artery. The flap was rotated 90 degrees to close the defect.

Figure 25: Recurrent dermatofibrosarcoma occupied the upper aspect of the right thigh and inguinoscrotal region.

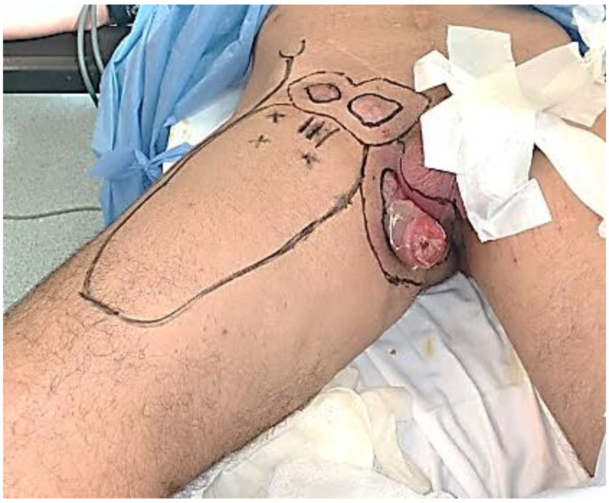

Figure 26: The flap was designed based on perforators arising form the descending branch of the lateral femoral circumflex artery arising from the profunda femoris artery.

Figure 27: A defect resulted measuring 20 x 10 cm.

Figure 28: A pedicled freestyle flap was raised.

Figure 29: The flap was rotated 90 degrees to close the defect.

Figure 30: Directly postoperatively.

Case 5: A 42-years-old male patient presented with an upper lip Squamous cell carcinoma (SCC) invading the upper alveolar margin. Resection of the lesion included the anterior part of the alveolar margin, the anterior part of the hard palate, and the middle 1/3 of the upper lip. Bilateral freestyle nasolabial flaps were used for inner and outer reconstruction of the upper lip. Both flaps were completely viable postoperatively.

Figure 31: Preoperative marking of the area to be resected and the bilateral nasolabial flaps planned for reconstruction.

Figure 32: The defect resulted after resection of SCC of the upper lip, invading the upper alveolar margin.

Figure 33: The resected specimen involved the middle 1/3 of the upper lip, the anterior part of the alveolar margin, together with the anterior part of the hard palate.

Figure 34: Bilateral nasolabial freestyle flaps were used for reconstruction. The left side was used to cover the outer skin defect of the lip.

Figure 35: The right flap was rotated to reconstruct the inner mucosal defect of the lip.

Figure 36: Directly postoperatively.

Figure 37: One month later.

DISCUSSION

The term "Freestyle" is derived from the freedom one has in designing the flap, without abiding by certain measurements performed with other types of flaps. The proper understanding of the limits of the vascular supply of each perforator grants liberty to outline the flap similar to the shape of the defect.

According to this study, there was a wide range of indications for using pedicled freestyle flaps for the repair of soft tissue defects. One of the most significant benefits of freestyle flaps is the ability to select them from any anatomical site in the body. This study included defects located in the head and neck, trunk, and extremities. Freestyle flaps were also shown to be popular in the head and neck area.

As revealed in this study, many benefits were offered by using pedicled perforator freestyle flaps for the reconstruction of soft tissue defects compared to other reconstructive techniques. These benefits included; less donor site morbidity, favorable aesthetic results, simple, and less time-consuming technique that could be used for major and specialized reconstructions. Minimal donor site morbidity was achieved in most of the cases included in this study. All cases had primary closure of the donor site, with sparing of underlying muscles, nerves, and major vessels, except for 3 cases that needed split-thickness skin grafts (STSG). This was achieved due to the freedom of choosing the site and shape of the flap at the nearest area to the defect, where skin laxity allows for primary closure.

Favorable aesthetic results were achieved using pedicled perforator freestyle flaps for the reconstruction of skin and soft tissue defects, at various anatomical regions, due to their unique features. These flaps were ideal for the head and neck region. According to this study, good cosmetic results were achieved in 16 cases with head and neck defects.

Freestyle flaps are often thin, pliable, and easily moldable, resulting in favorable aesthetic results. This is crucial in the anatomical regions where greater aesthetic care is required, such as the head and neck area.

According to this study, a good contour was achieved during the insetting of the flaps. The plane of dissection was a suprafascial plane (above deep fascia) for all flaps included in this study. This allowed the flap to be more pliable and flexible, which helped the insetting of the flaps and resulted in matching contours.

A simple and less time-consuming surgical technique can be achieved with pedicled freestyle flaps. Using a handheld Doppler, perforator localization was achievable for all flaps included in this study. Freestyle flaps provide more flexibility in flap design since the flap harvest may be performed in any anatomical location where a Doppler signal from a large perforator vessel can be identified.

According to this study, a simple approach could be used for the reconstruction of non-composite defects, using pedicled freestyle flaps without the need for complex microsurgical procedures. Thus, avoiding lengthy procedures and the need for trained centers and personnel. Also, patients with significant comorbidities, which would not make them good candidates for microsurgery, would have a simple reconstructive technique with the least risk possible.

All cases included in this study, except for 3 cases, underwent a one-stage surgery including resection and reconstruction in the same setting. A main advantage of the freestyle perforator flaps is the possibility of performing a one-stage procedure rather than the two-staged procedure usually performed with local flaps.

Major and specialized reconstruction were also achieved, according to this study. For example, a nasolabial freestyle pedicled perforator flap was used in this study as a buried flap for reconstruction of the inner nasal lining and nasopharyngeal mucosa after craniofacial resection involving the base of the skull. According to our knowledge, this was the first case reported to use pedicled freestyle flaps for nasopharyngeal reconstruction. Also, it was used as bilateral nasolabial flaps for reconstruction of the outer and inner layers of the upper lip, after resection of a tumor invading the upper alveolar margin and lip. While most of the perforator flaps are mainly used for small to moderate-sized defects, large defects up to 300 cm^2 were successfully reconstructed in this study. A bilobed parascapular freestyle perforator flap was used to cover a large shoulder defect measuring 15 x 13 cm. Also, bilateral V-Y advancement flaps based on the superior and inferior gluteal artery perforators were used to cover a large gluteal defect measuring 20 x 15 cm. Also, large defects were closed using multiple freestyle flaps to provide enough tissue for closure without tension. We had three patients who needed two flaps each.

Flap-related complications encountered in this study were divided into; major complications that affected flap survival and minor complications in the form of wound infection, which led to wound dehiscence. In spite of being a minor complication, dehiscence was added to complicated cases to explain all possible forms of complications that occurred. However, total flap survival was encountered in 92.6% of our cases.

The major flap complication (flap-related) rate in this study was 25.9%. Five cases showed partial loss of the flaps (18.5%) including: 1 flap showed a marginal tip loss (3.7%) that was left to heal by secondary intention, 3 flaps revealed superficial partial necrosis (11.1%) that was healed spontaneously, and 1 flap suffered a full-thickness partial loss (3.7%) that required a local flap. Complete loss occurred in 2 cases (7.4%) of this study. The first case was complicated by vascular insufficiency early after surgery; this was probably attributed to a combination of patient factors, such as age and smoking, as well as flap factors, such as a 180-degree arc of rotation and reliance on a single perforator. A similar situation occurred with the second flap, where signs of vascular insufficiency and a lost Doppler signal were evident in the early postoperative hours. Both cases were scheduled for reconstruction with local flaps.

Wound infection and associated wound dehiscence occurred in 11.1% of the cases included in this study. The management of these cases included culture-based antibiotic treatment and repeated dressings. This issue is not directly related to the freestyle perforator flaps approach, but it is worth mentioning for the sake of a clear explanation of all the possible complications. However, the survival of the flaps was not affected, and complete healing occurred in all cases. Failure to find perforators either preoperatively or intraoperatively is a technical problem that is mainly attributed to the inability to localize a sizable audible perforator preoperatively or during exploration. This complication was not encountered with any case in this study. Weak signals were mainly attributed to low blood pressures, pre-existing vascular diseases, or simply “small diameters”. Thus, according to this study, no mapping or marking of perforators was done after the induction of anesthesia to avoid the hypotension associated with it. Accordingly, a preoperative marking of perforators is recommended after ensuring the patient is normotensive. Also, patients with known microvascular diseases were advised to use reconstructive techniques other than perforator flaps in general.

Arterial spasm was not encountered in any of the cases included in this study. Venous congestion occurred in only one case in this study and was completely resolved intraoperatively. After the flap was raised, its color was normal, then right away, after a 90-degree rotation of the flap, diffuse congestion appeared. The flap was returned to its original position, and its pedicle was irrigated with Xylocaine. Twenty minutes later, the flap regained its normal color. The flap color was normal after subsequent mobilization. No further congestion occurred later on during the follow up. Finally, complete healing occurred after one month.

Risk factor analysis in relation to complications encountered in this study included patient-related and flap-related factors. Patient-related factors included age, gender, comorbidities, and history of radiotherapy, while flap-related factors included its location, number of perforators, size, and mode of mobilization. Age exceeding 60 years old and gender were not associated with a remarkable increase in the complication rate. The major complication rate related to patients exceeding the age of 60 years was only one third of this age category (30%). Similar rates were encountered at younger ages (28.6%). While the rate of complications was equal between males and females; 29.4% and 28.6%, respectively. However, there was an increased risk of complications associated with elderly patients suffering from other co-morbidities affecting their vascular system.

Contradicting what was predicted, smoking and comorbidities such as diabetes and hypertension were also not associated with an increased complication rate. In this study, the rate of complications related to diabetes, hypertension, and smoking was not significantly high; 25%, 25%, and 10%, respectively. Similar results were achieved in the study conducted by **Paik and Pyon (2017)**, involving 50 patients who had defects reconstructed with 55 pedicled freestyle flaps. They found no evidence linking comorbidities with an increased complication rate. However, it is well established that comorbidities that affect the peripheral circulation might affect the survival of the flaps.[11]

A previous history of radiotherapy, at the defect and donor sites, was associated with an increased risk of complications; major complications were encountered in 2 cases (66.7%) out of 3 who had a previous history of radiotherapy; those complications were in the form of complete loss of one flap and partial loss of the other one. Moreover, the third case was complicated by a minor complication in the form of wound dehiscence. Previous studies revealed that radiotherapy is widely documented to create changes in skin and its vasculature. Radiation therapy affects the skin in the form of atrophy of the epidermis and hypocellular fibrosis of the dermis. Vascular changes include arterial intimal hyperplasia and adventitial fibrosis, which can lead to thrombosis and vascular occlusions. Fibrosis induced by radiotherapy might cause difficult dissection and perforator damage. Also, the possible kinking of vessels with flap mobilization might induce flap complications.[11,12,13]

Regarding the locations of the defects, an increased incidence of complications was noticed with the flaps raised from the extremities (50%) compared to those raised from the trunk (20%), head and neck regions (22.2%). Moreover, 75% of donor sites in the extremities needed split-thickness skin grafts (STSG) for closure, while none were needed for trunk, head and neck donor sites. Previous studies[10,11] also noticed a remarkable increase in the complication rate of pedicled freestyle flaps raised in the extremities compared with the trunk. The decreased complication rate of the flaps raised from the trunk was attributed to the increased number of perforators in this region, in addition to the wide perforasome territories. Furthermore, the skin of the upper and lower limbs tends to be more fixed with less redundancy, which leads to an increased need for skin grafts for donor site closure. Consequently, this added more donor site morbidity and an aesthetically unpleasing appearance. In addition, flaps raised from areas with thin subcutaneous tissue and adherent skin would have short pedicles (e.g., extremities, proximity to joints). This would necessitate further dissection and skeletonization of the pedicle to increase its length and avoid tension on the pedicle. Areas with more subcutaneous tissue (e.g., abdomen and trunk) tend to have longer perforators. Thus, less dissection is needed to obtain an adequate length of the pedicle to avoid tension created by the flap mobilization.

The increased number of perforators included within the flap decreased the incidence of complications. According to this study, one third of the flaps based on a single perforator showed a higher rate of major complications (30%). On the other hand, flaps based on multiple perforators showed a complication rate of only 11.8%. Preserving more perforators would increase the blood flow to the flap while limiting its mobility. This might be considered as a safety measure to avoid complications. Thus, whenever feasible, multiple perforators should be preserved. Preoperative planning should include mapping of all the reliable signals in the designed area. Then, intraoperatively, all these perforators should be preserved until it is necessary to cut them down for mobilization.

Concerning the size of the flaps, according to this study, the complication rate was higher with larger flaps. Flaps measuring less than 100 cm^2 showed a complication rate of 11.1%, while those measuring more than 100 cm^2 showed a complication rate of 55.6%. According to our experience, the safe of flaps differ from one anatomical region to another due to the different sizes of perforasomes. According to previous studies,[3,14] it is still uncertain if there should be a size constraint on the perforator-based flaps. As a result, concerns about the relationship between the perforator size and the amount of tissue that can be harvested without complications are still unresolved, and there are no specific limits concerning the flap size that can be proposed. However, the true constraint on the size of the flap is the amount of tissue raised while allowing for primary closure of the donor site rather than vascularity considerations.

Regarding mobilization and the arc of rotation, according to this study, V-Y advancement flaps were associated with better results compared to those encountered with propeller flaps. Six V-Y advancement flaps were raised with no major complications encountered, like partial or complete loss. While 7 propeller flaps were associated with major complications, including both partial and complete loss, forming 33.3% of all flaps raised in a propeller manner. However, the arcs of rotation, whether 90 or 180 degrees, were associated with similar rates of complications. Thus, we recommend starting with simpler choices like V-Y advancement and pedicled perforator flaps with minimal angles of rotation. Finally, flap mobilization with 180 degrees of rotation should only be done if the surgical situation is demanding.

Finally, to obtain the best results, it is advisable to properly design the flaps according to their vascular territories. Proper mapping of nearby reliable perforators, using the handheld Doppler signal, around the defects is recommended. As with all possible techniques of reconstruction, the benefits should be weighed against the possible risk factors of losing the flap, whether completely or partially. Freestyle perforator pedicled flaps are reliable choices for reconstruction, particularly for the elderly, who are known to have multiple comorbidities that favor simple procedures. It is recommended for this age group as it is a simple technique, short procedure, with little morbidity occurring from surgery, and complete reconstruction can be achieved in a single surgery. The same should be considered for patients with other co-morbidities. Proper planning might be needed for those with a history of radiotherapy or defects in the distal extremities. For these situations, the possibility of keeping multiple perforators with a minimal angle of rotation for the pedicle is advisable to enhance the flap vascularity.

CONCLUSION

Freestyle pedicled perforator flaps are reliable flaps for non-composite reconstruction, even for large defects, when a sizable perforator is retrieved and the flap is designed according to the blood flow of the linking vessels. It is not a time-consuming technique with a low incidence of complications in experienced hands. Moreover, the feasibility of mapping perforators using a handheld Doppler caused a vast spread of the procedure as a simple technique with favorable results.

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