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Free-style local perforator flaps: concept and classification system

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KEYWORDS
Free-style;
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Classification

Summary *Background:* Defect reconstruction according to the free-style concept applied to perforator flaps allows flap harvesting in any anatomical region where an audible Doppler signal of a perforator is detected. We report the results of a study in which local perforator flaps were selected for reconstruction in different anatomical areas and were harvested using the free-style concept.
Methods: During a 2-year period, defect coverage was carried out in 21 patients ($n = 21$) in the following anatomical areas: cervical ($n = 3$), sternal/parasternal ($n = 4$), axillary ($n = 2$), tibial ($n = 5$), trochanteric ($n = 2$) and sacral/gluteal ($n = 5$). The mean age of patients (15 male and six female) was 57.8 years. Flap selection was based solely on preoperative Doppler mapping in areas adjacent to soft-tissue defects. The mean follow-up period was 1 year.
Results: All flaps survived, demonstrating postoperatively acceptable aesthetic results with good patient satisfaction. The donor sites were closed primarily in 17 patients; four patients required skin grafting. Two patients required surgical revision due to flap-margin dehiscence. There was no loss of function at donor sites. Increased flap mobility could be achieved through extended perforator dissection. One perforator-based flaps offered the widest arc of rotation serving as propeller flaps. If more than one perforator vessel was preserved, flap mobility was limited, but still allowed sufficient flap movement either as a rotation or advancement flap or as a combination of both. A classification is proposed according to the number of perforator vessels preserved and to the type of flap movement.
Conclusions: The concept of free-style local perforator flaps represents a safe, versatile and reliable surgical procedure. It not only offers a greater freedom in flap selection but also provides good aesthetic results. The classification proposed might aid in the decision-making process involved in order to achieve adequate results with this procedure.

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The use of perforator flaps today represents a safe and reliable procedure in reconstructive plastic surgery. The major reason for selecting this type of flap as compared to conventional musculocutaneous flaps is the reduction of morbidity at the donor site with the preservation of nerves and muscles.[1,2] Normally, the procedure of perforator-flap planning follows the guidelines of angiosome mapping introduced by Taylor and Palmer.[3–5] The concept of free-style perforator-flap surgery offers greater freedom in choosing a donor-site area because flap selection is based on the quality and volume of soft tissue required at the recipient site.[6] Flap design and harvest are carried out according to previous Doppler mapping.[7]

The purpose of our study was to evaluate the reconstruction of defects in different anatomical areas with local perforator flaps using the free-style concept. Moreover, an effort has been made to classify the different types of free-style local perforator flaps according to the number of perforator vessels preserved and to the type of flap movement carried out.

Patients and methods

Between September 2004 and October 2006, a total of 21 patients ($n = 21$) underwent surgery secondary to trauma, tumour or pressure-sore-induced soft-tissue defects that were located at various anatomical sites: sternal and parasternal ($n = 4$), cervical ($n = 3$), axillary ($n = 2$), tibial ($n = 5$), trochanteric ($n = 2$) and sacral/gluteal ($n = 5$). The study comprised 15 male and six female patients, with a mean age of 57.8 years (range: 41–72 years). Detailed patient information is presented in Table 1. A total of 21 local perforator flaps within an area adjacent to the defect were harvested using the free-style technique. Doppler investigation of perforator vessels was carried out using a portable acoustic Doppler ultrasound device (Medasonics, Newark, NJ, USA) connected to a 5-MHz vascular probe (VP5). Doppler mapping was performed after the administration of anaesthesia and before marking the flap dimensions. All flaps were dissected in the suprafascial plane until the vicinity of the marked perforator was reached. At this point, flap elevation was continued subfascially to facilitate the localisation and dissection of the perforators.

Surgical technique

After evaluating the defect, an appropriate area adjacent to the injury site is selected. Doppler investigation and mapping within the area of interest are carried out, followed by marking of the flap design. The decision of the number of perforator vessels to be preserved during

Table 1 Patient profile and characteristics

Patient Flap	Age/Sex/type	Diagnosis/Location/Source vessel	Flap shape (size in cm), No. of perforator vessel/type of flap movement	Complication	Follow-up (months)
1	58/m/I	pressure sore, distal lower extremity, PTA	elliptical (7 × 22), 1, propeller flap	0	8
2	52/m/I	pressure sore, distal lower extremity, PTA	elliptical (9 × 32), 1, propeller flap	dehiscence flap margin	9
3	65/f/I	trauma, distal upper extremity, RA	elliptical (6 × 14), 1, propeller flap	0	9
4	57/f/I	trauma, distal upper extremity, RA	elliptical (4 × 12), 1, propeller flap	0	12
5	61/m/I	trauma, cervical, TCA	triangular (10 × 23), 1, propeller flap	0	6
6	63/m/I	pressure sore, trochanteric, SGA	V-rectangular (12 × 22), 1, propeller flap	0	12
7	61/f/II	pressure sore, trochanteric, SGA	V-rectangular (16 × 30), 3, rot., advm. flap	0	14
8	66/m/II	pressure sore, sacral, SGA	elliptical (18 × 27), 3, rot., advm. flap	0	10
9	72/m/II	pressure sore, sacra, SGA	rectangular (17 × 30), 4, rot., advm. flap	0	12
10	68/m/II	pressure sore, sacral, SGA	triangluar (13 × 18), 3, advm. flap	0	14
11	71/m/III	pressure sore, sacral, SGA	peninsular (12 × 19), 3, rot., advm. flap.	0	5
12	52/m/II	trauma, para-, sternal, IMA	triangluar (12 × 21), 2, advm. flap	0	14
13	41/m/II	trauma, para-, sternal, IMA	elliptical (11 × 23), 3, advm. flap	0	12
14	54/f/II	trauma, para-, sternal, IMA	triangluar (13 × 20), 2, advm. flap	0	13
15	61/f/II	trauma, para-, sternal, IMA	triangluar (12 × 19), 3, advm. flap	dehiscence flap margin	10
16	49/f/II	trauma, axillary, TDA	elliptical (14 × 27), 2, advm. flap	0	9
17	41/m/II	tumor, axillary, TDA	elliptical (13 × 24), 2, advm. flap	0	12
18	58/m/II	trauma, cervical, TCA	triangluar (10 × 20), 2, advm. flap	0	9
19	61/m/II	trauma, cervical, TCA	triangluar (9 × 17), 2, advm. flap	0	6
20	52/m/II	trauma, cervical, TCA	elliptical (10 × 18), 2, advm. flap	0	10
21	62/m/III	pressure sore, sacral, SGA	peninsular (19 × 25), 5, rot., advm. flap	0	3

Index: female (f), male (m), posterior tibial artery (PTA), radial artery (RA), thoracodorsal artery (TDA), internal mammary artery (IMA), superior gluteal artery (SGA), transverse cervical artery (TCA); rotation (rot.), advancement (advm.).

dissection depends on the intended flap size, flap-movement pattern and Doppler signal quality. If the planning considers the inclusion of only one perforator vessel into the flap, we recommend marking of at least two other vessels in case of vascular damage or detection of inadequate vessel size or length during dissection.

The first incision is performed most distally from the marked perforator vessels, followed by sharp dissection above the muscle fascia together with meticulous haemostasis. Once located, the perforator vessels are carefully dissected and liberated from the surrounding tissue. The vascularity of the flap is constantly monitored. After the dissection is completed, flap mobility is evaluated through careful elevation and movement towards the tissue defect. Usually, a moderate flap rotation or advancement along the perforator axis is sufficient once the perforators have been dissected. Major stretching or twisting of the perforator vessels which serve as vascular pedicle should be avoided. If flap mobilisation is not sufficient to achieve a tension-free defect closure, the dissection of the perforator is continued until adequate pedicle length is achieved. Tracing the perforator vessel to its original source vessel is not necessary once sufficient flap mobility is obtained. In flaps with more than one perforator vessel, it is usually necessary to perform intramuscular dissection of the vessels to achieve an adequate degree of flap rotation.

After achieving tension-free flap insertion into the defect, suction drains are placed at donor and recipient sites, followed by two-layer flap suturing. Light dressings are applied, thus avoiding pressure on the flap.

Results

All flaps survived postoperatively with good vascular and acceptable aesthetic outcome with regards to tissue texture and colour match at the recipient site. The donor site was closed primarily in 17 patients, and skin grafting was performed in four patients with minimal donor-site morbidity and without loss of function in any of the cases. None of the patients experienced major complications due to flap congestion, necrosis or infection (Figures 1–3). Two patients required surgical revision due to flap-margin dehiscence. Doppler mapping performed in the gluteal region was not always precise: the phenomenon of skipping vessels and/or a low precision of vessel location was observed.

Increased flap mobility was achieved through extended perforator dissection either into the fascia or, if necessary, up to the original source vessel. Hospital stay ranged from 13 to 18 days. The surgical time required to complete the procedure varied from 2.5 to 4 h depending on each individual case. In all the cases, surgery was performed by the same team of surgeons. The follow-up duration was 12 months. All patients were pleased with the surgical result achieved when interrogated during their follow-up visits after surgery. The outcome and aesthetic result were rated by an experienced plastic surgeon who had not participated in any surgery.

Local perforator flaps could include one or more perforator vessels. Flaps which included only one perforator offered best movement patterns with an arc of rotation of

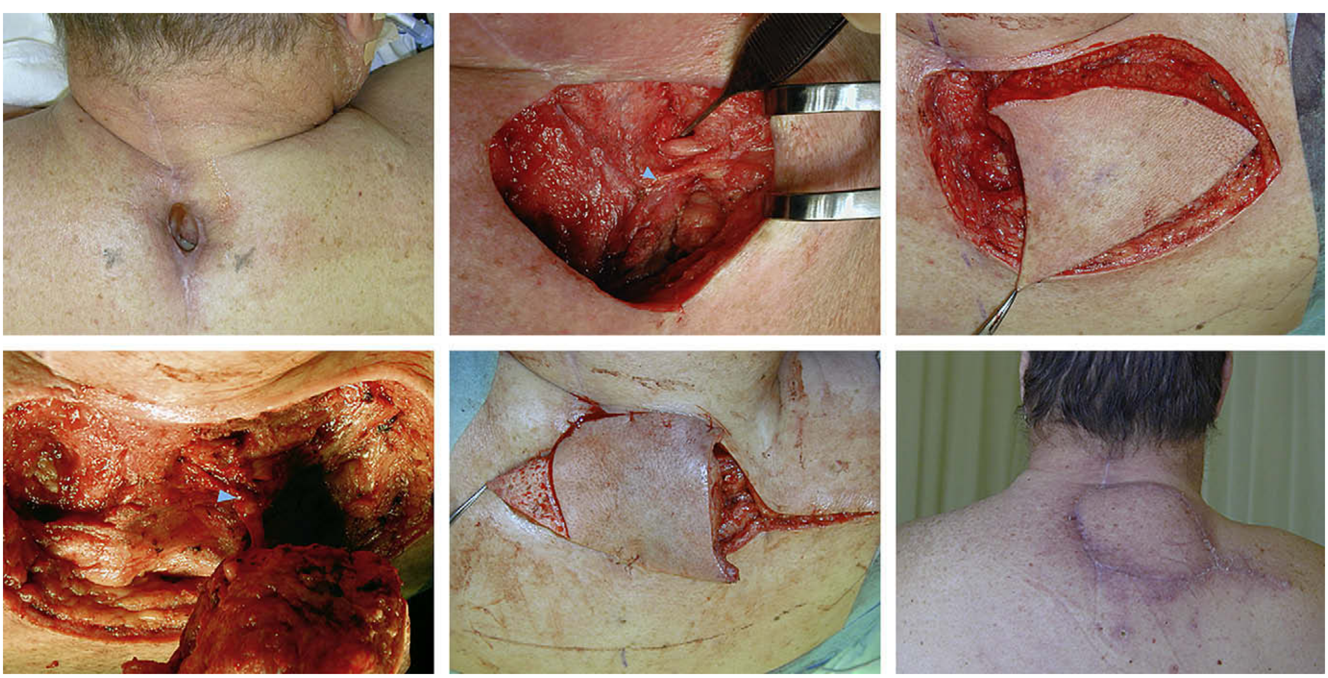

Figure 1 Case 1 (no. 5 in Table 1) Soft-tissue defect secondary to spinal-hardware exposure and infection after a neurosurgical spine procedure of the back in a 61-year-old male patient. After wound debridement, flap harvest based on the transversal cervical artery with inclusion of one perforator vessel was performed. Propeller-like flap movement was carried out with deepithelisation of the tip of the flap in order to occlude dead space in the recipient site (single free-style local perforator flap; type I). The postoperative recovery was uneventful. (Top; left to right) Tissue defect prior to surgery; defect after debridement (arrow indicating perforator) and local perforator flap dissected. (Bottom; left to right) Elevated flap showing one perforator vessel (arrow); after 180° propeller-like flap movement into the tissue defect (notice deepithelized tip) and postoperative result after 6 months.

Figure 2 Case 2 (no. 17 in Table 1) Soft-tissue defect after tumour removal (soft-tissue sarcoma) in the axillary region in a 41-year-old male patient. After achieving tumour-free wound margins with good wound debridement, flap elevation was based on the thoracodorsal and thoracolateral artery, including two perforator vessels. Flap movement was performed as an advancement transposition (multi-free-style local perforator flap; type II). The donor site was closed primarily with uneventful healing postoperatively. Top left: tissue defect after tumour removal showing flap marking. Top right: dissection of flap margins. Bottom left: raised flap showing two perforator vessels. Bottom right: postoperative result after 6 months.

up to 180° (clockwise and counterclockwise). The rotation did not impair the flap's vascular viability. Flaps that included more than one perforator were carried out either as rotation or as advancement flaps or as a combination of both. In two cases, a random-pattern flap with the design of a peninsula with the inclusion of one or more perforator vessels was performed (Figure 4).

Based on the results of this study, a classification of local perforator flaps using the free-style concept is proposed (Table 2).

Discussion

In reconstructive plastic surgery, perforator flaps have received much attention, and, to date, numerous flap types have been described in the literature.[8,9] Although originally intended for unexpected events occurring during flap harvest or in cases with anatomical variations, the technique of free-style perforator flap surgery was already performed more than 30 years ago.[11—14] In 2003, the concept of free-style perforator flap surgery as a routine procedure was introduced by Wei and Mardini, reporting a greater freedom in flap planning since flap harvest could be carried out in any anatomical area where a Doppler signal of a sizable perforator vessel could be detected.[10] Recently, Morris et al. reported successful closure of soft-tissue defects of the lower extremity through local perforator flaps harvested according to the free-style concept.[15] The authors recommended this technique especially for smaller soft-tissue defects located in areas of the upper and lower extremities.

We performed free-style local perforator flap surgery in different anatomical areas of the body with a flap harvest adjacent to the soft-tissue defect. Flap selection was based solely on the detection of an audible Doppler signal. Flap movement was carried out as a rotation manoeuvre, as an advancement procedure or as a combination of both. Yildirim et al. presented a study on free-style local-perforator-based V—Y-advancement flaps at various anatomical areas, concluding that the free-style concept represents a safe, reliable and versatile technique offering good aesthetic and functional results.[16]

In free-style flap surgery, the preoperative Doppler investigation is mandatory because it provides useful information about the quality and topography of the perforator vessels.[17,18] However, when performed in the gluteal region, we observed that Doppler sonography with a hand-held Doppler unit was not always accurate. We relate this to the voluminous tissue layers in this specific anatomical area since underlying structures have been described to influence the Doppler signal.[19,20] A similar experience has been reported by Muneuchi et al. who related the insufficient Doppler investigation at the donor

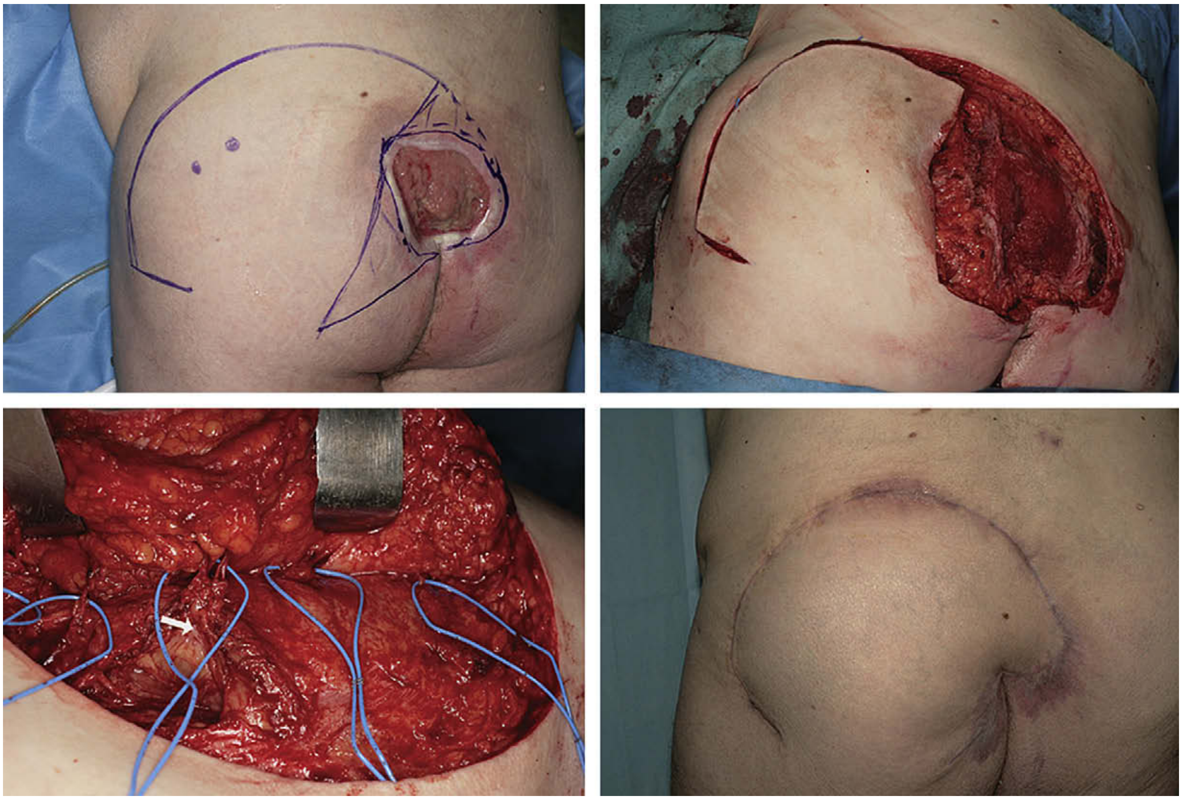

Figure 3 Case 3 (no. 21 in Table 1) Soft-tissue defect caused by pressure sore in the sacral area in a 62-year-old patient. Defect closure was achieved with a rotation-advancement flap of the gluteal area, including five perforator vessels (peninsular free-style local perforator flap; type III). Postoperative recovery was uneventful. Pressure sore and flap design showing marked Doppler signals (top left); tissue defect after debridement (top right); peninsular flap of gluteal area showing five perforator vessels preserved (bottom left). Note the intramuscular dissection of a large central perforator in order to achieve adequate flap mobilisation (arrow bottom left); postoperative result after 3 months (bottom right).

site of a rhomboid perforator flap in an infant to thin vessel structures and an immature vascular system.[21] Careful attention and special care are recommended when approaching preoperatively marked perforators in the lower back and gluteal regions. The decision regarding the number of perforators to be included into the flap is based on the individual defect size and location, as well as on the Doppler mapping of perforator vessels. In case of large flap dimensions or weak Doppler signalling, we generally recommend the preservation of more than one perforator vessel.

In contrast to free perforator flaps, local perforator flaps offer a limited range of flap movement depending on tissue elasticity and perforator vessel length. The latter can be increased through perforator dissection into the fascia and/or the muscle. In our series, flaps which included only one perforator offered the best range of flap mobility, allowing rotational flap movements of up to 180° (propeller-like flap movements: clockwise and counterclockwise) without the development of any congestion or thrombosis. When performing such propeller-like flap movements, it is important to obtain sufficient vessel length since the perforator vessel of such flaps represents the central axis of rotation.[22–24] Experimental studies revealed that longer pedicles are less sensitive to twisting forces since the length of a vessel (l) is inversely proportion to the critical angle of twisting (Δ_T): [$l \propto 1/\Delta_T$].[25–29] Flaps with more than one perforator vessel allowed partly rotational or advancement manoeuvres, or a combination of both, depending on the number of vessels preserved. However, regardless of the type of flap movement carried out, any stretching of the perforator vessels should be avoided to minimise the risk of vascular complication (e.g., blood-flow turbulences, endothelium alteration and platelet aggregation).[30] Therefore, although it would be possible to perform 180° rotations in a propeller-like fashion while including more than one perforator, the success of these flaps would depend heavily on the distance between each perforator and on their length. We believe that in these cases where a 180° propeller-like rotation is needed, it is safer to base the axis of rotation on only one perforator.

Our study comprises flaps that include only one perforator, more than one perforator vessel and random-pattern skin flaps with several perforator vessels. The random-pattern skin flaps are similar to previously described local perforator flaps.[21,31,32] All flap types of this study offer different manoeuvres of transposition. Thus, we propose a classification of free-style local perforator flaps taking into account the number of perforator vessels preserved, the flap design and the type of flap movement performed.

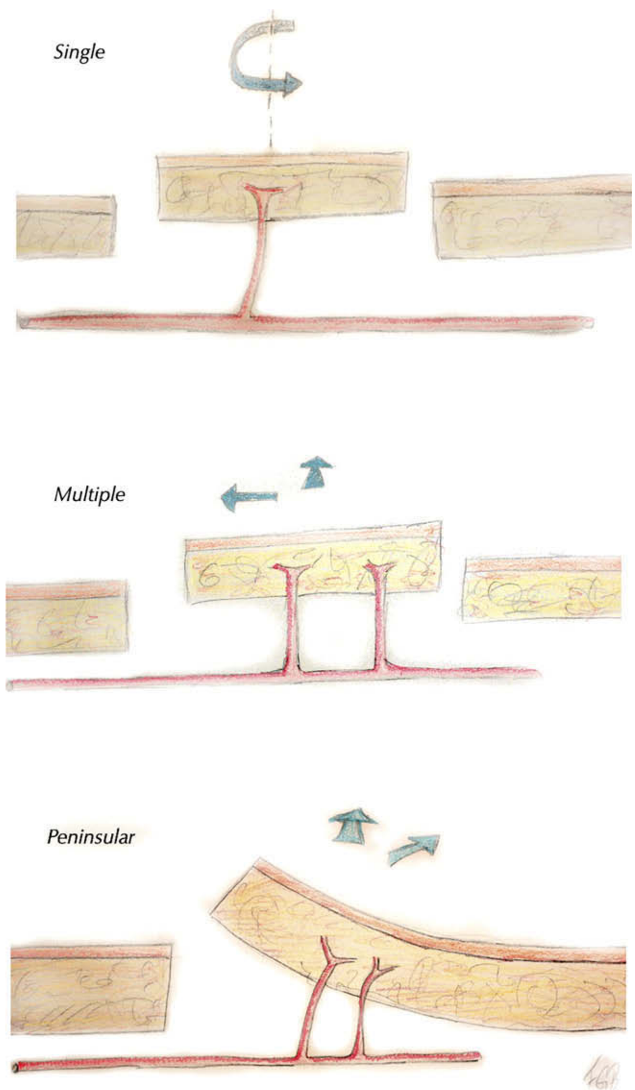

Figure 4 Classification of free-style local perforator flaps (FSLPF). Type I, flap based only on one perforator, allowing propeller-like movement (single-FSLPF) (top); type II, free-style local perforator flap with inclusion of at least two perforator vessels (multi-FSLPF) (centre) and type III, peninsular flap with preservation of one or more perforator vessels (peninsular-FSLPF) (bottom).

We suggest differentiating among the following three types of free-style local perforator flaps: perforator flaps including one perforator vessel allowing any type of flap movement, including propeller-like flap rotations (type I); perforator flaps including more than one perforator vessel offering a limited arc of rotation, an advancement movement or a combination of both (type II) and conventional fasciocutaneous flaps or random-pattern skin flaps in which a skin bridge is maintained and where one or more perforator vessels are included into the flap allowing tissue transposition as an advancement procedure (type III). Type III offers a dual blood supply. In contrast to flap types I and II which represent island flap designs, flap type III represents a peninsular flap design. Taking these major characteristics into account, we named flap type I as a single-free-style local perforator flap (single-FSLPF), flap type II as a multi-free-style local perforator flap (multi-FSLPF) and flap type III as a peninsular-free-style local perforator flap (Peninsular-FSLPF). 'Single' refers to the flaps based on only one perforator, 'multi' to the possibility of including several perforator vessels into the flap and 'peninsular' to the particular flap design in which a skin bridge is maintained.

We may acknowledge that the proposed classification seems to be inconsistent with the original idea of the free-style concept: unlimited flap harvesting in almost any anatomical area. However, this classification refers to local perforator flaps, meaning flaps adjacent to an original soft-tissue defect. We believe that with regards to the confusion experienced in perforator flap classification and nomenclature,[33–36] this classification of local perforator flaps might contribute to a better understanding of this concept and facilitate its surgical application. Although we understand the effort undertaken by previous nomenclature systems[33–36] in order to avoid ambiguity and confusion when describing perforator flaps, it has been our experience that factors, such as the source vessel; the type of perforator: musculocutaneous (MCp), septocutaneous (SCp) or direct cutaneous (DCp); whether or not it is a perforator flap or a perforator-based flap and whether the flap is skin only, faciocutaneous or musculocutaneous, do not strongly influence the indication and outcome of local perforator flap surgery. The classification presented herein attempts to simplify the nomenclature of local perforator flaps and therefore stresses the application of the free-style concept to local perforator flap harvesting. It

Table 2 Classification and characteristics of free-style local perforator flaps

TYPE I	TYPE II	TYPE III
SINGLE-FSLPF	MULT-FSLPF	PENINSULAR-FSLPF
- 1 perforator vessel - maximum range of movement advancement, rotational (propeller-like movement) - versatility of flap design - island flap	- $>$1 perforator vessel - good range of movement advancement, partly rotational - versatility of flap design - island flap	- $\geq$1 perforator vessels - limited range of movement advancement, limited rotational - limited flap design - peninsular flap (random pattern)

Index: FSLPF (free-style local perforator flap).

addresses what we believe are the key factors in the decision-making process of local perforator flap design and execution and is in accordance with Taylor's suggestions on keeping the nomenclature of perforator flaps as simple as possible.[37]

The concept of free-style local perforator flap surgery represents a safe, versatile and reliable treatment option in the management of soft-tissue defects. The free-style technique applied to local perforator flaps not only offers a greater freedom in flap selection but also provides good aesthetic results. The classification proposed might aid in the decision-making process involved in performing local perforator flap surgery using the free-style concept.

Disclosure

None of the authors has any financial interest in any medical devices, drugs or products mentioned in this article.

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