Extensive Facial Reconstruction Using Thickness-controlled Perforator Free Flaps

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Background: Although small and medium facial defects can be reconstructed with local flaps to ensure skin color and texture matching, extensive facial defects require the application of free flaps, including perforator free flaps. We hereby propose a personalized strategy for facial reconstruction to overcome these limitations, based on the use of free flaps accompanied by local flaps and thickness-controlled perforator flap concept, for extensive facial defects.

Methods: A series of consecutive facial reconstructions were performed from 2006 to 2016 in the Plastic and Reconstructive Surgery Department of our institution. Only extensive facial defects greater than $40\,cm^2$ were included in this study.

Results: A total of 323 patients underwent reconstruction using free flaps with or without local flaps, from November 2005 to March 2019. Of these, 79 extensive facial surface reconstruction cases were analyzed retrospectively. The size of the defects, their areas (upper, middle, or lower third of the face), and the method of reconstruction were analyzed. This led to the development of a personalized reconstruction procedure for extensive facial defects. These extensive facial reconstruction cases included 24 defects of the upper third of the face, 43 cases of the middle third, and 12 of the lower third. Four cases addressed the middle and lower thirds simultaneously.

Conclusions: The facial surface reconstruction strategy I suggest in this study is based on the flap selection, thickness-controlled perforator flap elevation, and combination of local and free flaps. We expect this procedure will improve the treatment and resolution of extensive facial defects. *(Plast Reconstr Surg Glob Open 2020;8:e3210; doi: 10.1097/GOX.0000000000003210; Published online 28 October 2020.)*

INTRODUCTION

Facial reconstruction is a specialty of plastic surgery and can be differentiated from head and neck reconstruction in that the latter is predominantly focused on post-cancer ablation-related reconstruction. Head and neck reconstruction in a broad sense includes facial reconstruction, as well as naso-, oro-, and hypopharyngeal reconstructions. [1,2]

The surface of the facial skin originates from the ectoderm, the facial muscles and skeleton develop from the mesoderm, and the inner mucosal lining derives from the endoderm. Facial reconstruction can refer to reconstruction of the skin surface or to all facial components, including the facial muscles and skeleton. Head and neck reconstruction tends to indicate inner mucosal reconstruction. [3]

Controversies regarding strategies for the reconstruction of the facial surface are ongoing. The traditional approach involves the concept of the reconstruction ladder, wherein primary repair, skin grafts, local flaps, distant flaps, and free flaps are considered for use in that order. The traditional principle for facial reconstruction is "like with like," and local flap transposition remains the standard protocol. This technique makes sense in defects that can be resurfaced with local flaps. However, facial defects that exceed the territory that could be reconstructed with local flaps present a unique problem. Usage of the perforator free flap introduces a new perspective on the reconstruction elevator concept, wherein this flap is the first choice in repairing defects because it can overcome obstacles associated with local flaps. The success percentage of microsurgical reconstruction with perforator free flaps currently surpasses 95%. [4,5]

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However, facial reconstruction presents unique obstacles, such as color, texture mismatch, and skin thickness differences. If such limitations could be overcome, surgeons could freely choose among a range treatment strategies, including free flaps, according to certain facial defects and based on facial landmarks, and accounting for skin color, tissue thickness, and esthetic subunit. In this study, we propose an extensive facial reconstruction strategy based on the combination of local and free flaps, thickness-controlled perforator flap elevation and facial esthetic subunit.

MATERIALS AND METHODS

A series of consecutive facial reconstructions were performed in the Plastic and Reconstructive Surgery Department of our institution. All patients underwent reconstruction surgery using free flaps with or without local flaps, from November 2005 to March 2019. Small and medium facial defects reconstructed using small to medium local flaps, such as Limberg flaps, bilobed flaps, or advancement or rotational flaps, were excluded. Cases involving oral, pharyngeal, and hypopharyngeal reconstruction were also excluded. Extensive facial defects greater than $40\,cm^2$ in size were selected for this investigation.

We preoperatively estimated the depth and extent of the defects and then remeasured these values intraoperatively for confirmation. The ideal donor perforator flap in terms of skin thickness was selected, after which we elevated the perforator flap to as similar a thickness as possible.

The strategy was decided before each operation by considering the location and dimension of the defect, defect tissue components, surrounding skin texture, color matching, expected thickness of free or local flaps, and the facial esthetic subunit principle. Areas of extensive facial defects were categorized into the upper, middle, and lower thirds of the face and each reconstruction protocol was analyzed individually. When a free flap was applied, plane of the flap was recorded into 4 categories: sub-dermal plane, sub-superficial fascia plane, supra-deep fascia plane, and sub-deep fascia plane (Figs. 1, 2).

RESULTS

A series of 323 consecutive facial reconstructions was performed from November 2005 to March 2019. Among the 323 facial reconstructions, 79 extensive reconstructions were analyzed retrospectively (Table 1). Causes of the defects included 44 malignant and 2 benign tumors, 13 vascular malformations, 10 traumatic defects, 6 infection-related defects, 3 Parry–Romberg syndromes, 1 burn, 1 radiation consequence, 1 Marjolin's ulcer, and 1 congenital disease. Defect areas ranged from $40\,cm^2$ to $275\,cm^2$ (average = $89.5\,cm^2$). The average vertical dimension was 12.8 cm (range, 8–25 cm), and the average transverse dimension was 7.1 cm (range, 4–13 cm). Patients were 54.3 years of age on average; 48 were men, and 31 were women. The follow-up period ranged from 3 to 104 months (average, 25 months). In all, 24 cases involved defects of the upper third, 43 of the middle third, and 12 of the lower third of the face. Four cases involved the middle and lower thirds simultaneously. Reconstruction timings were immediate reconstruction in 25 patients and delayed reconstruction in 54 patients. Free flaps, local flaps, and tissue expanders were used in the reconstruction procedures. Free flap with or without local flap was used in 61 patients, and local flap was used in 18 patients. Only 1 case used a tissue expander and free flap simultaneously. The free flaps included 31 anterolateral perforator free flaps, 20 radial forearm free flaps, 6 fibular osteocutaneous free flaps, 3 superficial circumflex iliac perforator free flaps, and 1 medial sural perforator free flap. These were used alone and in combination with extensive local flaps such as the cheek advancement flap or forehead flaps. The local flaps were used to overcome limitations associated with free flap use in facial reconstruction and included cheek advancement flaps, forehead flaps, and Bernad-Wester modified lip local flaps. The recipient vessels used in the free flap procedure were 27 superficial temporal vessels, 26 facial vessels, 6 superior thyroid vessels, 1 deep temporal vessel, and 1 occipital vessel.

In all free flap cases, thickness-controlled perforator free flaps were used. Thickness control of perforator flaps was performed by modifying the flap elevation plane, such as the subdermal, sub-superficial fascia, supra-deep fascial, or sub-deep fascial plane. In total, 12 subdermal planes, 20 sub-superficial fascia planes, 7 supra-deep fascial planes, and 28 sub-deep fascial planes were used (Table 2). In 6 patients, subdermal and sub-superficial fascia planes were used simultaneously. In terms of defect location, thin perforator flap was preferred for the upper face and thick perforator flap was often used for the lower face.
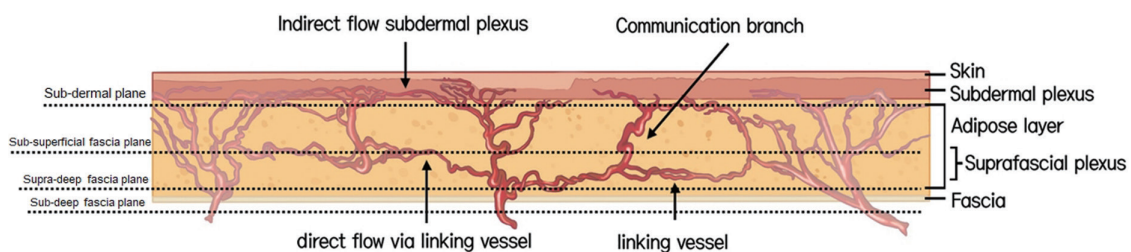

Fig. 1. Illustration showing the plane of flap elevation. When free flap elevation was performed, 4 categories of plane were used: sub-dermal plane, sub-superficial fascia plane, supra-deep fascia plane, and sub-deep fascia plane.
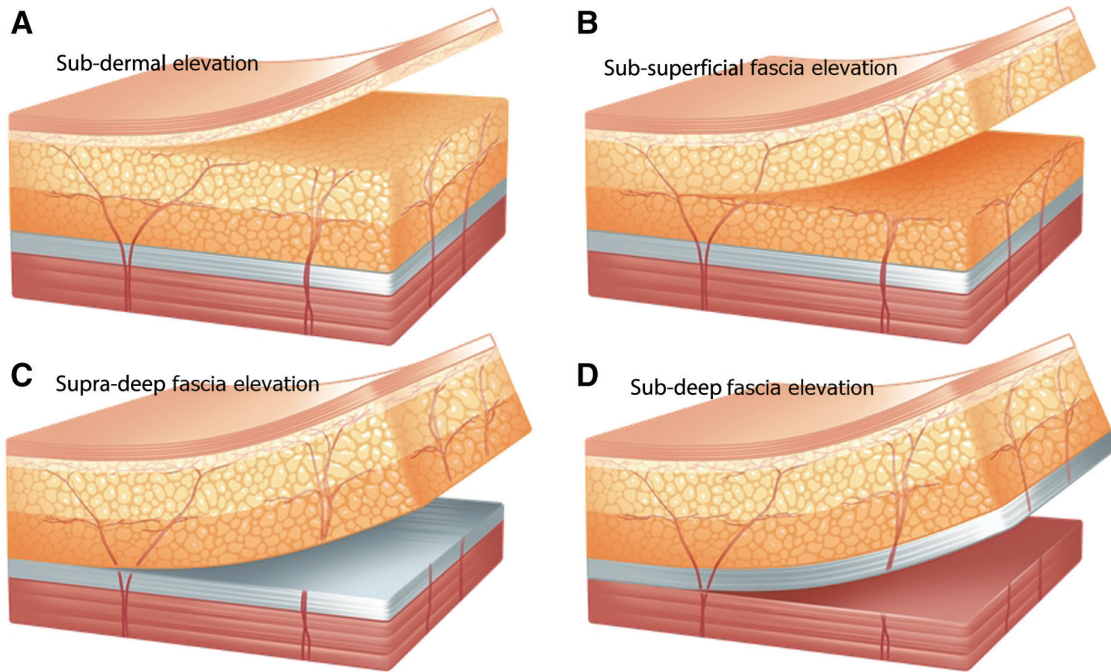
Fig. 2. Schematic illustrations showing the thickness control of flap. Sub-dermal plane (A), sub-superficial fascia plane (B), supra-deep fascia plane (C), and sub-deep fascia plane (D).

Of potential local flaps, cheek advancement flaps, forehead flaps, tongue flaps, and Bernard–Webster modified lip local flaps were used with the free flaps. Defects on the upper and lower eyelids were reconstructed using full-thickness skin grafts. Full defects of red dry vermilions on the lips were reconstructed using tongue flaps.

The thicknesses of the perforator free flaps ranged from 3 to 10 mm (average, 5.1 mm), while the average vertical dimension was 12.8 cm (range, 8–25 cm). The average transverse dimension was 7.1 cm (range, 4–13 cm). The pedicles were 10.3 cm long on average (range, 5–15 cm) and depended on the type of flap; radial forearm free

flaps averaged 11.8 cm, anterolateral perforator free flaps 10.7 cm, fibular osteocutaneous free flaps 8 cm, medial sural perforator free flaps 8 cm, and superficial circumflex iliac perforator free flaps 5 cm.

Complications occurred in 21 of the 79 patients (Table 3). Wound dehiscence occurred in 10 patients. Six complications were treated with simple repair, 2 with local flap, and 1 with FTSG. Partial flap loss occurred in 4 patients; 3 patients received free flaps, and 1 received a forehead flap. Two patients underwent FTSG to resolve partial flap loss. Hematoma occurred in 2 patients, and exploration was performed in one of these to confirm bleeding focus. Infection occurred in 4 patients, and debridement was performed in 2 patients. Scar contracture occurred in one patient, and contracture release was performed.

A total of 60 secondary procedures were performed (Table 4). Sixteen pedicle divisions of the forehead flap were performed. In total, 6 of 8 debulking procedures were performed in free flap patients, 4 with ALT flaps, and 2 with SCIP flaps. All 5 skin grafts were full-thickness; 2 patients also received split-thickness skin grafts. Five debridements were performed due to partial flap necrosis or infection. A tissue expander was used in 2 free flap patients. One patient underwent reconstruction of the frontal bone with a titanium plate accompanied by an ALT flap, but wound dehiscence occurred and was resolved using a tissue expander. One patient underwent a cranioplasty for temporal bone reconstruction in the lateral forehead area. Wound dehiscence developed after use of a radial forearm flap and was resolved with a tissue expander. In one flap revision, the patient received an ALT free flap, followed by flap congestion on the day of

Table 1. Patient Demographics

	Total	Free Flap	Local Flap
No. patients	79	61	18
Age	54.3	53.9	53.3
Sex (male:female)	48: 31	38: 23	10: 8
Defect size (cm²)	89.5	91.9	81.5
	(40–275)	(40–275)	(45–110)
Location of defect			
Upper	24	24	0
Middle	43	25	18
Lower	12	12	0
Cause of defect			
Malignant tumor	44	36	8
Benign tumor	2	2	0
Vascular malformation	10	5	5
Traumatic defect	10	9	1
Infection-related defect	6	5	1
Parry–Romberg syndrome	3	2	1
Burn	1	1	0
Marjolin's ulcer	1	1	0
Radiation therapy	1	0	1
Congenital disease	1	0	1
Timing of reconstruction			
Immediate	25	24	1
Delay	54	37	17

Table 2. Plane of Flap Elevation

Plane of Flap Elevation	Patient Number	Upper Face	Middle Face	Lower Face
Sub-dermal plane	12	6	4	2
Sub-superficial fascia plane	20	10	4	6
Supra-deep fascia plane	7	3	3	1
Sub-deep fascia plane	28	8	15	5

Table 3. Complications

	Total	Free Flap	Local Flap
Major complication			
Total flap necrosis	0	0	0
Partial flap loss	4	3	1
Minor complication			
Wound dehiscence	10	8	2
Infection	4	2	2
Hematoma	2	2	0
Scar contracture	1	1	0

Table 4. Secondary Procedures

	Total	Free Flap	Local Flap
Flap division	16	0	16
Debulking	8	6	2
Dehiscence repair	6	5	1
Skin graft	5	5	0
Scar revision	5	2	3
Local flap	5	5	1
Fat graft	3	3	0
Debridement	5	2	3
Tissue expander	2	2	0
Contracture release	2	2	0
Hematoma exploration	1	1	0
Flap revision	1	1	0

surgery and vein re-anastomosis. This patient suffered no further issues.

Case 1

A 46-year-old man presented with a cavernous hemangioma, 10 cm × 8 cm, across the left forehead and the upper eyelid. After removal of the cavernous hemangioma, a subdermal anterolateral thigh flap was elevated, and anastomoses were performed on the superficial temporal artery and vein in an end-to-end fashion. The thickness of the flap was adjusted to about 3 mm to match the thickness of the defect (Fig. 3).

Case 2

A 38-year-old woman presented with a capillary malformation involving the left forehead, the left eye area, the left cheek, and the upper left lip. The range of capillary malformation was about 20 cm × 10 cm, and a superficial circumflex iliac artery perforator free flap and *full thickness skin graft were performed on the upper lip*. Superficial temporal vessels were selected as recipient vessels (Fig. 4).

Case 3

A 90-year-old man presented with recurring BCC in the nasal area. After removal of the cancer, the defect size was about 20 cm × 15 cm, and defect ranges included the bilateral medial orbital rim, maxillary sinus wall, ethmoid sinus, and lower part of frontal sinus. Titanium mesh insertion and anterolateral thigh free flap were performed immediately, and superficial temporal vessels were used as recipient vessels. Forehead flaps were utilized to reconstruct the nose, and anterolateral thigh flap debulking, full thickness skin grafts, and a cheek advancement flap were performed in a subsequent procedure (Fig. 5).

Case 4

A 68-year-old man was diagnosed with an arteriovenous malformation that had invaded across the lower lip, chin, left cheek, and left lower eyelid. An anterolateral thigh free flap was used to reconstruct the lower lip and jaw area, and the facial artery and vein were used as recipient
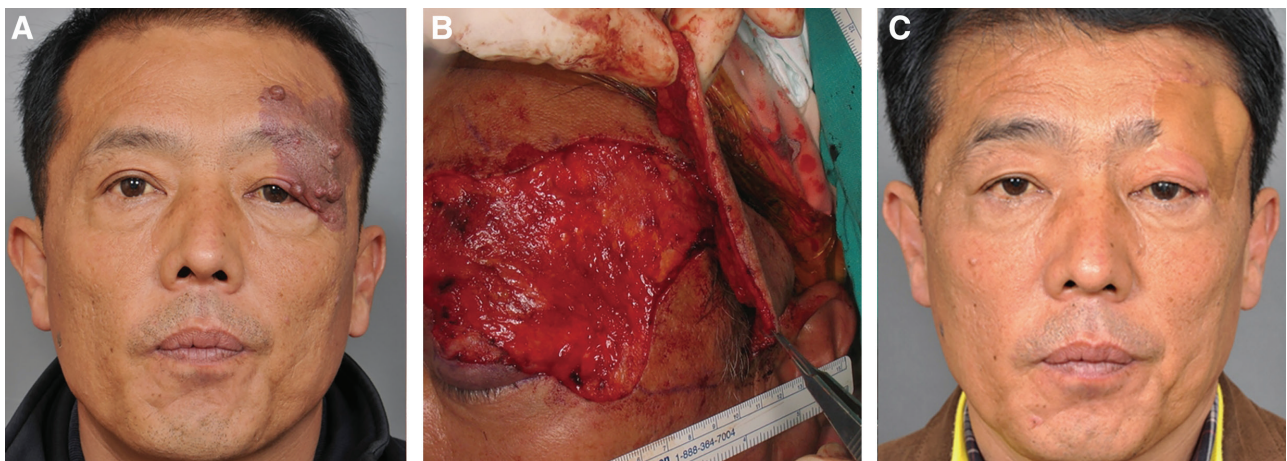

Fig. 3. A 46-year-old man who received a subdermal anterolateral thigh flap (Case 1). Photographs were taken preoperatively (A) and 1 year postoperatively (C). B, Note that the thickness of the flap was about 3 mm and was matched to the defect.
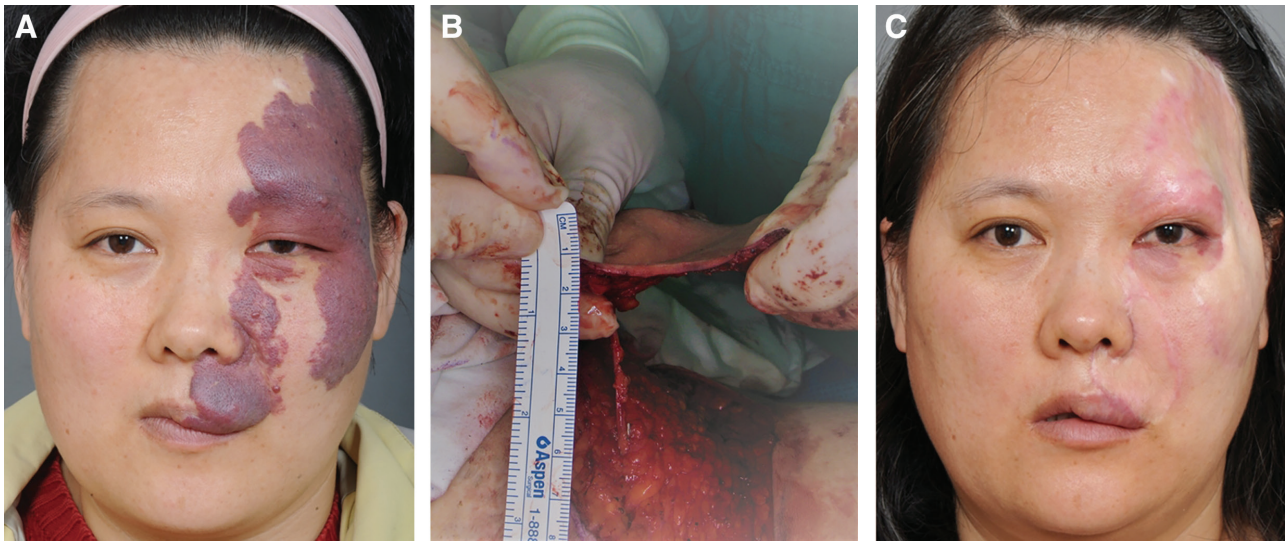
Fig. 4. A 38-year-old woman presented with a capillary malformation in several areas of the face (Case 2). Preoperative (A) and postoperative (B) images were shown. The dimension of capillary malformation was about 20 cm × 10 cm, and the patient received a superficial circumflex iliac artery perforator (SCIP) free flap elevated using subdermal plane.
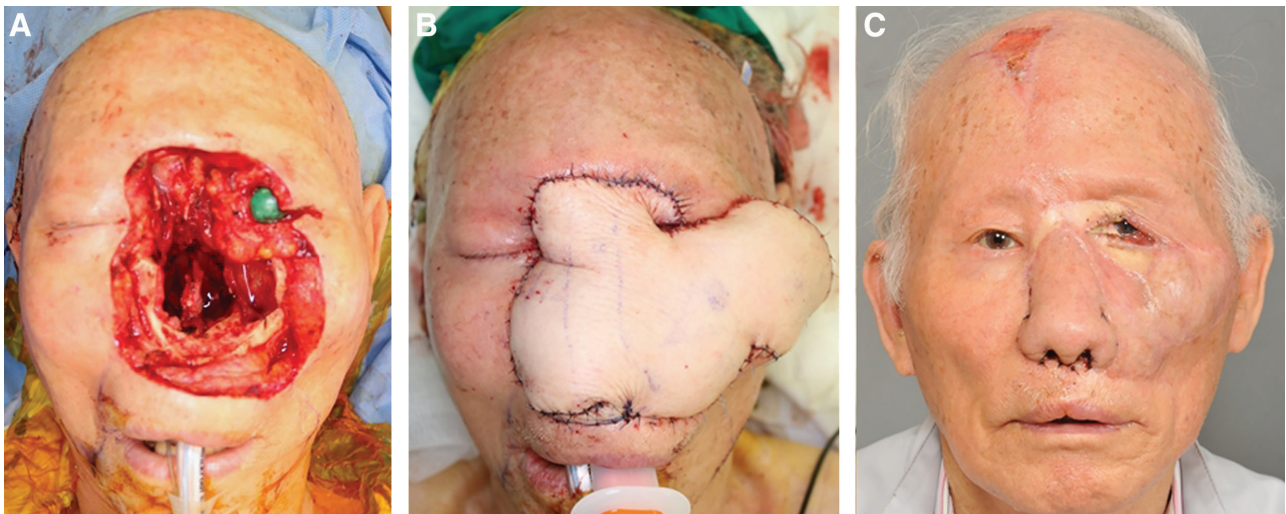

Fig. 5. A 90-year-old man with recurring BCC around the nose (Case 3). For example, the extensive face surface reconstruction could be done based on the combination of the free flap and local flap. Extensive facial defects include the skull base exposure. In the 1st stage, titanium mesh insertion and anterolateral thigh free flap were performed. At the 2nd stage, a forehead flap was selected to reconstruct the nose; flap debulking, full thickness skin grafts, and cheek advancement flap were performed in the delayed stage.

vessels. A split thickness skin graft was performed on the left cheek and around the left eyelid. Six months after the anterolateral thigh flap, flap debulking, and cheek advancement flap were performed (Fig. 6).

DISCUSSION

Controversies surrounding facial reconstruction strategies remain ongoing, including whether to use a local flap or a free flap for the procedures. Local flaps have many advantages, such as color and skin texture match, ease of surgery, and correspondence to the ideal that surgery should reconstruct defects using like materials. However, when a defect is greater than the area that a local flap can cover, a local flap necessitates tissue expansion.[6,7] Although a tissue-expanded flap can also be considered a local flap, the associated procedure is laborious and tedious for both the doctor and the patient. In addition, tissue expansion has many limitations, including restricted expansion and relatively high complication rates of 10% to 80%.[8] Free flaps confer certain advantages over conventional local flaps, including the possibility of elevating a flap with extensive dimensions, and the potential to utilize multiple tissue components, such as the skin, fat, and muscle. However, because free flaps are harvested from distant areas of the body, differences in terms of skin color and texture are major disadvantages, particularly for reconstruction of the facial surface.

The thickness and bulk of the flap are important considerations, and a thorough understanding of the vascular
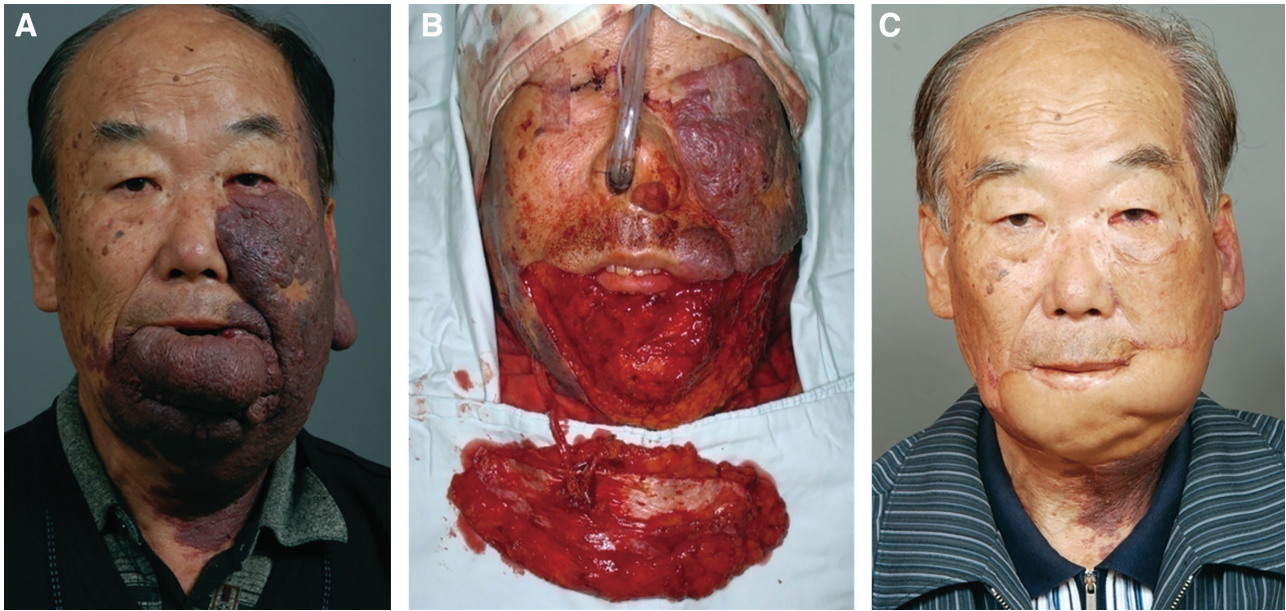
Fig. 6. A 68-year-old man who received an anteriolateral thigh flap (Case 4). Photographs were taken preoperatively (A), perioperatively (B), and 2-year postoperatively (C). A split thickness skin graft was performed on the left cheek and around the left eyelid. Six months after placement of anterolateral thigh flap, flap debulking and cheek advancement flap were performed.

anatomy of each flap is essential. Because the perforator free flap technique has recently evolved, there are now several perforator free flaps available. Microsurgeons are increasingly turning to these new flaps[8–10]; however, while the popularity of freestyle perforator-based free flaps has increased, so has the requirement to personalize the thickness of each perforator flap. Despite aggressive defatting procedures, the degree of flap defatting is limited so as to reduce the likelihood of marginal flap necrosis. As such, the proper perforator flaps for ideal facial surface reconstruction must be considered in terms of skin thickness. The range of thickness variation among patients precludes the outline of a specific set of principles on this; however, overall tendencies can be suggested.

The possible drawbacks of thickness-controlled elevation of the perforator free flaps would be like this. If the perforator runs axially in deeper subcutaneous plane, this elevation might risk the survival of the flap. However, according to my experiences, the sub superficial fascial elevation or supra deep fascial elevation do not risk the survival of the flap. Sometimes, I experienced marginal necrosis when the subdermal elevation was done. In this situation, I recommend to include the additional perforators inside the perforator flap. Some surgeons have tried to do the microdissection around the perforators.[11] The branches of the perforators in the superficial fat layer could be dissected despite some added risk of the flap survival. A safer way to get the thinner perforator flaps is to preserve the 1 or 2 m subcutaneous cuff around the perforator itself. I mostly prefer the latter. But, if the bulk should be avoided, I do microdissect the perforators.

Some surgeons might wonder thinning might cause the complications after the radiation therapy. According to my experiences until now, the thickness-controlled perforator flap do not cause the problems after the radiation. I believe that the excellent blood supply of the perforator free flaps would prevent the complications related to the radiation therapy regardless of the thickness of the perforator flaps.

The functional benefits include the many parts of the deep or superficial fascia could be preserved, which would be better for the function of the legs. The obstacles of the thickness-controlled elevation of the perforator flaps would include the possibility of the marginal necrosis when the sub-dermal elevation was done.

Although multiple head and neck reconstruction strategies have been proposed, few articles detail extensive facial reconstruction. We hereby propose a guideline protocol for extensive facial reconstruction that requires free flaps, as follows:

1. If necessary, free and local flaps should be combined to maximize the advantages of each flap type. In our series of extensive facial defects, the free perforator flap was the primary option when the dimension of the facial defect surpassed local flap parameters. Free flaps were combined with local flaps to enhance facial esthetics and animation function, in a individual manner according to each case.

2. Respect the facial esthetic subunit principle.[12,13] Exceptions do occur and vary by case, but generally speaking, the facial esthetic subunit principle should be adhered to in facial reconstruction to the fullest extent possible. However, if flap color and texture can be matched to the surrounding tissue and healthy surrounding tissue is not excised, this obstacle could be addressed in a subsequent procedure with meticulous intraoperative tissue approximation and scar revision.

3. Carefully assess the thickness and bulkiness of the free flap. If the thickness or the bulk does not match the

recipient defect, thickness-controlled perforator flaps or intraoperative thinning procedures should be used to modify the flap elevation plane.[14] Because of the range of individual variation that exists, the application of this concept must be determined individually for each patient.

4. Staged operations are viable options. While one-stage reconstruction is ideal, in terms of facial esthetics, staged operations can yield an improved result, as facial esthetics sometimes require multiple operations. We did not hesitate to split the operational procedure into stages if the vascular circulations of the flaps would be compromised. The first priority is complete wound healing and reconstruction with healthy tissue. If this is not possible, successful facial esthetic revisional surgery that can be maintained over the long-term is the secondary goal. Because facial appearance and function are extremely important, it has been our experience that patients with more extensive facial defects agree to staged operations.

5. Skin color and texture matching are essential in facial surface reconstruction and vary widely among individuals. The anterolateral thigh perforator free flap can sometimes enable satisfactory esthetic outcomes in skin color and texture. However, in many cases, such flaps require additional procedures, such as laser abrasion or full-thickness skin graft. If skin color and texture do not match the surrounding tissue, a full-thickness skin graft should be considered. In our experience, inguinal skin is somewhat darker than facial skin. Our preference includes the preauricular, postauricular, and supraclavicular area in Asian patients. Although the supraclavicular skin glistens a bit more or is brighter than the facial skin in white patients, it can be a good source of extensive full-thickness skin graft harvest. For eyelid reconstruction, pre- or postauricular skin is preferable. In some instances, a full-thickness skin graft from the forehead is a good option for a small defect. The importance of skin color and texture characteristics when performing perforator flaps should not be underestimated, as this could lead to poor outcomes, from an esthetic point of view.[15–17]

There are limitations to this study. This study is based on a retrospective review. In addition, now that the extensive facial defects should be different on an individual basis, the standardization of the defects would be limited. Finally, this investigation was done on East Asian patients, who would have different skin characteristics from those of the Western patients.

CONCLUSIONS

The facial surface reconstruction protocol suggested herein accounts for many issues, such as flap selection, thickness control of the selected flap, and application of the facial esthetic subunit principle. We expect this report to improve treatment of extensive facial defects encountered in the future.

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PATIENT CONSENT

Patients provided written consent for the use of their images.

REFERENCES

1. Kanthak FF. Reconstruction of the face following treatment of cancer. *J Med Assoc Ga.* 1957;46:369–377.
2. Orticochea M. The use of the intact side of the face for reconstruction of the injured opposite side. *Br J Plast Surg.* 1970;23:235–241.
3. Blocker TG Jr. Principles of reconstruction of defects about the face. *Tex State J Med.* 1947;42:526–531.
4. Choi DH, Goh T, Cho JY, et al. Thin superficial circumflex iliac artery perforator flap and supermicrosurgery technique for face reconstruction. *J Craniofac Surg.* 2014;25:2130–2133.
5. Park YM, Lee WJ, Yun IS, et al. Free flap reconstruction after robot-assisted neck dissection via a modified face-lift or retroauricular approach. *Ann Surg Oncol.* 2013;20:891–898.
6. Pallua N. "Reconstruction of the face and neck scar contractures using staged transfer of expanded "super-thin flaps". *Burns.* 2008;34:739; author reply 740–739; author reply 741.
7. Zan T, Li H, Du Z, et al. Reconstruction of the face and neck with different types of pre-expanded anterior chest flaps: a comprehensive strategy for multiple techniques. *J Plast Reconstr Aesthet Surg.* 2013;66:1074–1081.
8. Choi JW, Nam SY, Choi SH, et al. Applications of medial sural perforator free flap for head and neck reconstructions. *J Reconstr Microsurg.* 2013;29:437–442.
9. Goh TL, Park SW, Cho JY, et al. The search for the ideal thin skin flap: superficial circumflex iliac artery perforator flap—a review of 210 cases. *Plast Reconstr Surg.* 2015;135:592–601.
10. Hong JP, Choi JW, Chang H, et al. Reconstruction of the face after resection of arteriovenous malformations using anterolateral thigh perforator flap. *J Craniofac Surg.* 2005;16:851–855.
11. Taş S. Microdissected prefabricated flap: an evolution in flap prefabrication. *Arch Plast Surg.* 2016;43:599–603.
12. Thompson S, Menick FJ. Aesthetic facial reconstruction: blending human perception and the facial subunit theory. *Plast Surg Nurs.* 1994;14:211–216, 224.
13. Reddy R, Mobley SR. The apical triangle: an overlooked aesthetic facial subunit. *Dermatol Surg.* 2011;37:1343–1347.
14. Rossi M, Milia A, Carmisciano M, et al. Advancement perforator cheek flap for aesthetic one-stage reconstruction of postoncological extended split-thickness defects of the nasal sidewall. *Sci World J..* 2013;2013:169208.
15. Chang CC, Wong CH, Wei FC. Free-style free flap. *Injury.* 2008;39 (suppl 3):S57–S61.
16. Wallace CG, Kao HK, Jeng SF, et al. Free-style flaps: a further step forward for perforator flap surgery. *Plast Reconstr Surg.* 2009;124(6 suppl):e419–e426.
17. Borsuk DE, Christensen J, Dorafshar AH, et al. Aesthetic microvascular periorbital subunit reconstruction: beyond primary repair. *Plast Reconstr Surg.* 2013;131:337–347.