Perforator Flaps in Head and Neck Reconstruction

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ABSTRACT

Free tissue transfer has revolutionized the management of complex head and neck defects. Perforator flaps represent the most recent advance in the development of free flap surgery. These flaps are based on perforating vessels and can be harvested without significant damage to associated muscles, thereby reducing the postoperative morbidity associated with muscle-based flaps. Elevation of perforator flaps requires meticulous technique and can be more challenging than raising muscle-based flaps. Use of a Doppler device enables reliable identification of the perforating vessels and aids in the design of free-style free flaps, where the flaps are designed purely according to the perforator located. The major advantage of free-style free flaps is that an unlimited number of flaps can potentially be designed on much shorter pedicles. The anterolateral thigh flap is the most commonly used perforator flap in head and neck reconstruction. Its use is described in detail, as is use of other less common perforator flaps. This article also describes head and neck reconstruction in a region-specific manner and gives a short-list of suitable flaps based on the location of the defect.

KEYWORDS: Anterolateral thigh flap, head, neck, perforator flaps, scalp

The immediate reconstruction of head and neck defects after surgical resection continues to challenge the reconstructive surgeon, who must achieve a satisfactory functional and aesthetic outcome. Several local flaps, such as the deltopectoral flap and the pectoralis major musculocutaneous flap, were developed for this purpose.¹⁻³ Pedicled flaps are easy to harvest but are limited by their pedicles, often require multiple surgical procedures, and do not always contain the necessary tissue components. The advent of free tissue transfer revolutionized the field of head and neck reconstruction. Since the first report by Seidenberg et al in 1959, free flaps have been used to reconstruct single or composite tissue defects in the head and neck, resulting in superior functional and aesthetic results in one-stage procedures.⁴⁻⁶

Perforator flaps represent the most recent advance in microvascular surgery. A perforator flap is defined as a flap of skin or subcutaneous tissue based on a “perforating vessel.”⁷ Using enhanced microsurgery techniques, surgeons are able to dissect the blood vessels through the muscle tissue and take them along with the overlying skin and subcutaneous tissue without sacrificing the underlying muscle. Muscle can be incised to expose the underlying perforators; the muscle can then be repaired, avoiding the problem of muscle weakness or hernias. As muscle pain is one of the most common complaints of patients after flap surgery, postoperative recovery time is reduced as a consequence of less pain.⁸ Reduced morbidity reduces the length of hospital stay and is therefore more cost-effective. Functional muscle is left at the

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donor site, and the transfer of denervated muscle is avoided, allowing increased predictability in the bulk of the flap.

The variable anatomy and the necessity for intramuscular dissection of perforators has in the past given perforator flaps a reputation of requiring a relatively difficult dissection technique. However, in recent years advances in perforator flaps have provided familiarity with the technique required for safe dissection, and in turn this has popularized the use of this type of flap for a wide variety of indications.^{9–12}

The classification of perforator flaps is complex, and many classifications have been suggested. A simple strategy involves separating perforator flaps into two groups: those that pass directly through muscle to supply skin or subcutaneous tissues, and those that do not¹³ (Fig. 1). In this second group, the perforators may pass directly through subcutaneous fat or through an intermuscular septum. Both types of perforators can be found supplying the same subcutaneous tissue, allowing versatility in the design and orientation of the flap.

Elevation of perforator flaps requires the careful dissection of, often, small vessels through muscle, which can be challenging. A meticulous technique is required to avoid traumatizing, stretching, or kinking the vessels. The perforators themselves are often variable in size and position, making surgery technically more demanding for the surgeon. Doppler ultrasound is useful for locating perforating vessels preoperatively, with a strong correlation between audible volume signal and perforator diameter.^{14,15}

Perforator flaps are particularly attractive in cases where flaps are planned on the basis of the location of a perforating vessel. These so-called free-style perforator flaps are designed at the time the perforator is located either by Doppler ultrasound signal or after an explor-

atory incision.¹⁶ There is thus an unlimited number of potential donor sites, allowing unparalleled versatility in flap design. The perforators may be smaller, with a shorter pedicle.

PERFORATOR FLAPS IN HEAD AND NECK RECONSTRUCTION

The choice of perforator flaps used in head and neck reconstruction depends upon several factors, including the area and volume of the recipient site. Whichever flap is chosen, the donor site should have four main features:

1. A predictable and consistent blood supply.
2. At least one perforator.
3. Sufficient pedicle length.
4. Minimal functional morbidity with improved cosmetic outcome.

In the past, the radial forearm flap was used in the head and neck for intraoral reconstruction.¹⁷ It was ideal as a donor as no muscle was sacrificed. The flap is supplied with a long, large, consistent and reliable pedicle. It can be raised synchronously during head and neck surgery and can be sensate if required. These factors have all contributed to making this flap popular for soft tissue reconstruction in the head and neck. Unfortunately, there are limitations with the flap¹⁸:

- A major limb vessel is sacrificed.
- Where a large flap is required, the donor site needs to be closed with a full- or split-thickness skin graft, which aesthetically is unsightly.
- Tendon exposure is a potential complication.

As an alternative, where larger flaps are required, some surgeons have opted for the free latissimus dorsi musculocutaneous flap. Here a large flap can be harvested leaving a donor site that can be closed directly. Additional flaps such as the scapular and parascapular flaps may be used on the same pedicle. The main limiting factor in head and neck surgery, however, is the need to reposition the patient for flap harvest after tumor resection, thereby prolonging operative times. This contributes to the unsatisfactory result that can be obtained using this flap.

The rectus abdominis has been used for reconstruction of the tongue where volume and height are restored with the bulk of this flap. It has been the most commonly used flap for total glossectomy. However, this flap may result in abdominal wall complications such as weakness and hernia formation.¹⁹

Perforator flaps fulfill all the criteria of the above three flaps but without donor site morbidity. Perforator flaps used in head and neck reconstruction include (Table 1):

Figure 1 Classification of perforator flaps. MC, musculocutaneous perforator passing through muscle; SC, septocutaneous perforator passing through fat or intermuscular septum; S, skin; F, fat; M, muscle.

Table 1 Perforator Flaps Used in Head and Neck Reconstruction

Perforator Flap	Study and Year	Indications	Advantages	Disadvantages
ALT	Song et al, 1984 ²⁰	Scalp, intraoral, tongue, midface, skull base, neck	Large defects; 3D defects; donor site closed directly; long pedicle; chimeric design; sensate	May be hairy
AMT	Song et al, 1984 ²⁰	Scalp, intraoral, tongue, midface, skull base, neck	Thin and pliable; venous supercharging possible with saphenous vein; provides vascularized fascial grafts	Variable anatomy
DIEP	Koshima and Soeda, 1989 ⁴⁶	Scalp, tongue, midface, skull base	Large defects; bulky flap	May require debulking
TAP	Angrigiani et al, 1995 ¹²	Scalp, midface, skull base, oral cavity	Thin and pliable; long pedicle; for shallow defects; hidden donor site	May require patient repositioning
GAP/sGAP	Koshima et al, 1993 ¹¹ ; Allen and Tucker, 1995 ⁵²	Tongue, cheek	Well-concealed donor site; fatty flap ideal for contour defects	Short pedicle; may require patient repositioning
PAP	Yoshimura et al, 1984 ⁶² ; Yang, 2000 ¹⁰³	Intraoral, mandible, neck contractures, maxilla	Thin pliable flap; donor site closed directly; sensate	Short pedicle; small defects only
Submental	Martin et al, 1993 ⁶⁹	Midface and chin	Excellent color match; concealed scars	Short pedicle; hirsute flap in men
DCIA	Kimata et al, 2001 ⁷⁶ ; Safak et al, 1997 ⁷⁵	Mandible, intraoral	Can be raised as chimeric flap; provides bone	Small skin paddle

ALT, anterior lateral thigh; AMT, anteromedial thigh; DIEP, deep inferior epigastric artery perforator; TAP, thoracodorsal artery perforator; GAP, gluteal artery perforator; sGAP, superior gluteal artery perforator; PAP, peroneal artery perforator; DCIA, deep circumflex iliac artery; 3D, three-dimensional.

- Anterolateral thigh (ALT) perforator flap
- Anteromedial thigh (AMT) perforator flap
- Deep inferior epigastric artery perforator (DIEP) flap
- Gluteal artery perforator (GAP) flap
- Thoracodorsal artery perforator (TAP) flap
- Peroneal artery perforator (PAP) flap
- Submental perforator flap
- Deep circumflex iliac artery (DCIA) perforator flap.

THE ANTEROLATERAL THIGH FLAP

The ALT flap, first described by Song et al in 1984,²⁰ has become the flap of choice for soft tissue reconstruction of the head and neck. Song et al described a septocutaneous flap based on the descending branch of the lateral circumflex artery.²⁰ It was later determined that the flap was supplied only by musculocutaneous perforators in the majority of cases and that septocutaneous supply only occurred in a small percentage of cases.^{21–24}

Use of this flap for the reconstruction of head and neck defects was first described more than a decade ago.^{25–27} Further reports have outlined the utility of this flap in head and neck reconstruction as it can be adapted to cover most defects of the face, neck, or intraoral regions.^{24,28–31} The flap can be thinned for

pure intraoral defects. It also has good pliability and can be folded for the reconstruction of both the inner and outer lining of through-and-through defects. The vascular pattern also allows use of a more versatile design with double skin paddles based on multiple perforators. In addition, the flap can be used in combination with vastus lateralis muscle as a myocutaneous flap or combined with adjacent flaps according to the chimeric flap principle to reconstruct large or complex three-dimensional defects. The ALT flap can be harvested with fascia lata to provide a vascularized fascial sling when the facial nerve has been damaged or removed.³²

Flap Anatomy

The ALT flap is supplied by the descending branch of the lateral circumflex femoral artery (LCFA), which is the largest branch of the profunda femoris system (Fig. 2). The pedicle lies in the groove between the rectus femoris and vastus lateralis muscles along with the motor nerve to the vastus lateralis. The anterior branch of the lateral cutaneous nerve of the thigh can be included to create a sensory flap. The pedicle length ranges between 8 cm and 16 cm with a vessel diameter larger than 2 mm. The pedicle supplies perforating branches to the surrounding rectus femoris and vastus lateralis muscles and septocutaneous vessels to the ALT

Figure 2 Anatomy of the ALT flap. LCFA, lateral circumflex femoral artery; A, ascending branch; T, transverse branch; D, descending branch.

skin. In some instances, the predominant vascular supply to the flap may originate from the transverse branch of the LCFA or even directly from the profunda femoris system.

Flap Dissection

With the patient in a supine position, a line is drawn from the anterosuperior iliac spine to the superolateral border of the patella, indicating the muscular septum between rectus femoris and vastus lateralis muscles. Cutaneous perforators are mapped using a Doppler probe centered over the midpoint of this line.^{22,24,33} The majority of skin perforators are located within a circle of 3-cm radius centered at this midpoint. Xu et al located at least one perforator in the inferolateral quadrant of this circle in 80% of cases.²¹ The flap is centered over the location of these vessels, and its long axis is designed parallel to that of the thigh (Fig. 3A).

Dissection usually begins at the medial border of the flap over the rectus femoris muscle (Fig. 3B). An incision is made through the deep fascia, and the flap is raised laterally toward the intermuscular septum located between rectus femoris and vastus lateralis. At this stage, the descending branch of the LCFA is identified in the groove between the rectus femoris and vastus lateralis. A septocutaneous vessel may be identified that facilitates further dissection. However, in the largest series to date, septocutaneous vessels were encountered in only 12.9%

of cases.²⁴ Therefore, in the majority of cases flap harvest requires a careful dissection of a suitable intramuscular perforator. The course of the perforator can easily be traced by dividing the muscle over the perforator and ligating or cauterizing the small branches to the muscle. The perforator is traced back to the main descending branch of the LCFA, which is divided according to pedicle length requirements (Fig. 3C–H).

In the majority of cases, the flap is harvested as a fasciocutaneous flap. When a thin pliable flap is required for intraoral defects, a cutaneous flap may be raised using a suprafascial dissection (Fig. 4A). Once a suitable skin perforator is identified, the flap is raised suprafascially, and a small cuff of fascia is maintained around the perforator (Fig. 4B). The cutaneous flap can be further thinned to 5 mm, but excessive thinning should be avoided to prevent marginal necrosis. Indications for thin ALT flaps include reconstruction for hemi-tongue, buccal mucosa, palate and pharyngeal wall, and scalp.

When soft tissue bulk is required for the reconstruction, the flap may be raised as a musculocutaneous flap. The skin and muscle components can be raised on different branches of the same vascular pedicle as a bipaddled composite flap (Fig. 5). In the majority of cases, an intramuscular dissection of the perforator is not required. However, it is prudent to determine the course of the perforator to the source vessel by de-roofing the muscle fibers over the chosen perforator as the perforator may have a variable and tortuous intramuscular course. This maneuver avoids inadvertent injury to the perforator during incision of the muscle and also establishes that the perforator supplies the skin paddle of the musculocutaneous flap. Determining the course of the perforator to the source vessel is important because in 10% of cases, the perforator may arise from the transverse branch of the lateral circumflex artery, entering the muscle superiorly with a vertical course, and is liable to damage during muscle incision at the upper border of the flap.²⁸

Advantages in Head and Neck Reconstruction

Large defects of the head and neck are challenging to reconstruct as there may be a three-dimensional requirement of both volume and multiple surfaces of oral lining and external skin. In these situations, the chimeric ALT flap is particularly versatile. As the LCFA gives off lateral, medial, and descending branches, multiple components can be harvested based on the main pedicle. There are many combinations of chimeric ALT flaps, the majority of which are combined with the rectus femoris muscle, tensor fascia lata, anteromedial thigh skin, and vastus lateralis muscle.^{34,35} Double skin paddle flaps may also be used with each paddle based on separate perforators.³² Musculocutaneous flaps can also be raised with muscle and skin paddles based on separate perforators.

Figure 3 ALT flap dissection. (A) Flap design. (B) Dissection at medial border of flap. (C) Musculocutaneous perforator. (D, E) Intramuscular dissection. (F) Flap pedicle. (G, H) Views of skin paddle.

This versatility facilitates inset of the flap to complex three-dimensional defects (Fig. 6).

When there is no available second recipient vessel and a double free flap is required, the ALT flap can be used in a piggy-back arrangement with a second flap.

During flap dissection, the pedicle of the flap is dissected distally into the vastus lateralis to the required length, and this distal end can then be used for anastomosis of a second free flap. This arrangement thereby allows perfusion of two free flaps connected in series.

Figure 4 (A) Suprafascial ALT flap dissection. (B) Pedicle with small cuff of fascia.

Figure 5 Bi-paddled composite flap.

Figure 6 (A) Two skin paddles served by different perforators. (B) Central portion of bi-paddled ALT de-epithelialized for bulk. (C) Midface defect requiring oral lining and skin cover.

Figure 7 ALT flap donor site.

Donor Site Morbidity

One of the primary advantages of the ALT flap is the reduced donor site morbidity (Fig. 7). Few other donor sites in the body offer such an ample amount of sensate skin and muscle for the reconstruction of through-and-through tumor defects in the head and neck. To preserve maximal quadriceps function, a careful dissection and preservation of the nerve to the vastus lateralis should be performed. Kimata et al observed that weakness of the limb was related to the degree of muscle dissection and if a skin graft had been used.³⁶ Use of a V-Y perforator-based local advancement flap has been described to avoid use of a skin graft. Other authors have not found the donor site to be problematic. Even when the vastus lateralis was transferred as a free muscle flap, Wolff and Grundmann found that there was no motor dysfunction in their series, confirmed by clinical comparison of the load capacity of both legs.³³ In a further report, Kuo et al showed objectively, using a kinetic communicator machine, that patients who underwent a myocutaneous ALT flap showed minimal weakness of the donor thigh at long-term follow-up.³⁷

OTHER COMMON PERFORATOR FLAPS

Anteromedial Thigh Perforator Flap

Originally described by Song et al, the AMT perforator flap is based on the septocutaneous perforator from the medial branch of the lateral circumflex femoral vessels and the long saphenous vein.^{20,38} The vascular pedicle is thought to emerge at the intersection of the medial border of the rectus femoris muscle with the sartorius muscle.³⁹ A pedicle length of up to 12 cm can be obtained. The anterior cutaneous branch of the femoral nerve provides sensory innervation. The lateral border of the flap is formed by a line from the anterior superior iliac spine to the middle of the patella. When raising the AMT flap, the first incision is placed in this line and the flap raised medially until the main perforating vessels are

located. The pedicle is then dissected down to its origin from the descending branch of the LCFA.

The AMT perforator flap has been used mainly for lower-limb defects as well as in the head and neck region.^{23,35,38,40,41} It is a useful skin flap and can be modified for use as vascularized fascia graft or fasciocutaneous free flap.⁴² It can be de-epithelialized and used for contour correction and filling dead space.⁴¹ Koshima et al have used the AMT perforator flap for intraoral reconstruction.^{35,40,43} The saphenous vein can be included in the flap for venous charging. The dissection of the pedicle can be technically challenging but, in the event of problems with the vessels, the ALT perforator flap or the gracilis muscle flap can be harvested as alternatives through the same incision.

Deep Inferior Epigastric Artery Perforator Flap

The DIEP flap based on the deep inferior epigastric vessels is a large flap commonly used in breast reconstruction.^{10,44,45} Originally described by Koshima and Soeda,⁴⁶ it evolved as a modification of the transverse rectus abdominis muscle flap, providing a large amount of skin and subcutaneous tissue without the donor site morbidity.^{8,47} It has also been used more recently in head and neck reconstruction after cancer resection⁴⁸ and is particularly useful where soft tissue bulk is essential. It can be used to reconstruct tongue, floor of mouth, and cheek defects after parotidectomy and mastoidectomy. Koshima et al have used this flap to reconstruct the cheek regions after the resection of large arteriovenous malformations after selective embolization.⁴⁹ In this case, motor nerve from the rectus muscle was also harvested and coapted to the buccal branch of the facial nerve to provide movement of the upper lip. The perforator flap is used not only to reconstruct a complex surgical defect but also to improve the local hemodynamics of the surgical bed, thereby preventing recurrence of the vascular malformation. It has the added advantage of being raised at the same time as tumor resection without the need for patient repositioning. The DIEP flap has the potential for dynamic reconstruction of facial reanimation.⁴⁹

Gluteal Artery Perforator Flap

Gluteal soft tissue was first used to reconstruct the breast as early as 1975.⁵⁰ There were several drawbacks to using this flap. Flap dissection is difficult, and exposure of the donor vessels risks injury to the adjacent sciatic nerve. Partial resection of the gluteus maximus muscle resulted in weakness of thigh abduction and extension. Recently, the GAP flap, originating from the gluteal artery, has been used to repair sacral pressure sores.^{11,51} The free superior gluteal artery perforator (sGAP) flap has been used widely for breast reconstruction.^{52,53} The sGAP

flap has also been used for augmentation of depressed deformities of the face.⁴⁹ The fatty nature of the flap makes it ideal for filling contour deformities. This flap can be raised without repositioning of the patient when the defect is in the face.

The donor site can be closed directly and is easily concealed by underwear. The pedicle, however, is short and of small caliber. Harvesting of this flap for breast reconstruction usually involves dissection deep into the gluteal muscle to obtain a large enough pedicle to anastomose to large recipient vessels such as the internal mammary vessels. For reconstruction in the head and neck, a short pedicle is a disadvantage. However, a shorter pedicle is useful when anastomosing to the lingual and facial arteries, thereby reducing the operative time significantly.

Thoracodorsal Artery Perforator Flap

The TAP flap was initially described in 1995¹² and is based on one or more perforators from the thoracodorsal artery.^{54,55} Compared with the DIEP and sGAP flaps, the TAP flap is thin and pliable, making it useful for resurfacing shallower defects and filling contour deformities.⁵⁵ Flap thinning or debulking is rarely indicated. The flap has also been used for skull base reconstruction as well as resurfacing the face and oral cavity.^{56,57} It has a lengthy pedicle making it ideal for head and neck reconstruction; any vessel in the neck can be used without the need for vein grafts. A frequent complication of the latissimus dorsi free muscle flap is seroma formation. This is avoided with the TAP flap.^{58,59} The flap is large with reliable perforators. It can be raised as an extension of the subscapular territory to create a variety of composite flaps that include bone and muscle.⁶⁰ It can also be raised in combination with the latissimus dorsi muscle flap as a chimeric flap for reconstructing complex defects.⁶¹ The need to reposition patients during surgery makes this flap a secondary or tertiary reconstructive option. Also, because muscle is spared, there is more tension on the skin during closure, which can result in delayed healing and stretched scars. However, the donor site remains well hidden.

Peroneal Artery Perforator Flaps

Lower-leg flaps based on perforators from the peroneal artery (PAP flaps) have been used mainly for defect coverage in the extremities.⁶² These flaps are useful as pedicled or free flaps and have various applications as osteocutaneous flaps with the fibula, or as musculocutaneous flaps with soleus and peroneus muscles. The sural nerve can also be included to innervate the flap. The method of elevation is relatively simple but ultimately involves sacrificing the peroneal artery, one of the main arteries of the lower leg.

More recently, perforator flaps based on the peroneal artery have been used to reconstruct an extended anterior cervical scar contracture⁶³ and to cover small intraoral defects.⁶⁴ This flap is supplied by septocutaneous or myocutaneous perforators and has a small vessel diameter of 1 to 2 mm and limited pedicle length of 4 to 6 cm. However, the flap is thin and pliable making it extremely useful for covering superficial skin defects and for intraoral reconstruction. Because the flap is thin, the risks of damaging the perforator or reducing the blood circulation during radical thinning of flaps is overcome. The anatomic features of this flap are well known from previous studies.^{65–68} The donor site can be closed directly. The flap is limited to use in patients with minimal hair growth at the donor site. The lateral sural nerve can be included to create a sensate flap.

The pedicle of this flap can be anastomosed to the lingual or facial arteries and concomitant veins lying close to the defects. This maneuver overcomes the potential problem of a short pedicle. Alternatively, the superior thyroid artery can be used. A branch of the perforator has been observed close to the fibula, supplying the peroneal muscles. The osteomyocutaneous PAP flap represents a further refinement of the fibula flap and increases its versatility, with multiple skin paddles, bone segments, and soleus muscle independently isolated. This flap therefore provides a good reconstructive option for composite maxillary or mandibular defects (Fig. 8).

Submental Perforator Flaps

The submental island flap is based on the submental artery⁶⁹ and is an ideal color and texture match for skin of the lower face and midface. It has the advantage of a well-concealed donor scar.^{70,71} Reversed submental perforator-based flaps have been designed to cover defects around the mouth and nose.^{69,72} In these cases, a separate venous anastomosis is sometimes recommended to prevent flap congestion as the tiny submental vein provides insufficient venous drainage. Alternatively, inclusion of the superficial vein that drains into the common facial vein precludes the need for an additional anastomosis.⁷² The submental area is hairy in men, making it an ideal choice for upper lip reconstruction. The submental perforator flap has the disadvantage of a short pedicle. However, elevating the flap can also provide an opportunity for the surgeon to examine submental and submandibular lymph nodes during reconstruction for cancer.

Deep Circumflex Iliac Artery Perforator Flap

The DCIA perforator flap has been used to supply musculocutaneous flaps for lower-limb and breast reconstruction.^{73,74} It can also be harvested with bone (iliac crest). The iliac crest is an important donor site

Figure 8 (A) Intraoral tumor. (B, C) Defect after surgical resection. (D) Mandible reconstructed with free peroneal artery perforator flap with fibula. (E) The external skin defect is resurfaced with a free ALT flap.

for reconstructing the mandible after resection. The iliac crest osteocutaneous free flap includes abdominal muscles, making the flap too bulky and immobile for intraoral reconstruction.⁷³ The omission of muscle by Safak et al reduced the volume of the flap making it more attractive for intraoral use.⁷⁵ It has since been proved to be a reliable option for mandibular reconstruction^{76,77} and is more pliable for easier contouring to complex oral cavity defects.

REGION-SPECIFIC RECONSTRUCTION

Tongue Reconstruction

The function of the tongue is generally maintained after partial glossectomy. However, after total or near-total glossectomy, speech and swallowing are disappointing. Larger subtotal defects of the tongue are generally reconstructed with a thin flap such as the radial forearm flap.^{78,79} Recently, the ALT flap has

largely replaced the radial forearm flap in reconstruction of tongue defects in some centers.²⁴ This flap is pliable, adapts well to three-dimensional defects in the oral cavity,³¹ and the donor site is superior to that of the radial forearm flap as primary closure is achieved. Hemi-tongue defects are reconstructed using a supra-fascial dissection to provide a thin sensate ALT flap incorporating the lateral cutaneous nerve of the thigh (Fig. 9A). Partial tongue defects involving more of the floor of the mouth can be reconstructed with a larger flap, part of which may be de-epithelialized and used to fill the dead space and augment the defect in the submandibular region. The AMT and sGAP flaps can also be used as alternative perforator flaps for small tongue defects requiring reconstruction. The relatively easy access to recipient vessels around the tongue allows for use of flaps with shorter pedicles.

Total glossectomy defects require significant bulk to restore height and volume to the reconstructed tongue, and a myocutaneous flap is therefore required.

Figure 9 Tongue reconstruction with ALT flap. (A) Hemi-tongue reconstruction. (B) Total tongue reconstruction.

Varying amounts of muscle can be included in the ALT flap to fill dead space in the neck from an associated neck dissection. The ALT myocutaneous flap can provide as much volume as a rectus abdominis myocutaneous flap, which previously was the most commonly used flap for total glossectomy reconstruction and has the added advantage of avoiding abdominal wall complications⁸⁰ (Fig. 9B). The other disadvantage of muscle flaps is that the initial bulk usually diminishes with time due to muscle atrophy, especially after radiotherapy. Alternatively, the DIEP flap can be used instead of the rectus abdominis flap, providing similar tissue without donor site morbidity.

Reconstruction of Intraoral Lining and Buccal Defects

The radial forearm flap has been the flap of choice for intraoral lining, but perforator flaps are now a useful alternative. Defects requiring reconstruction of oral lining alone are relatively straightforward for which thin ALT flaps may be used (Fig. 10A). The PAP flap is also potentially an ideal substitute as this flap is thin, pliable, and relatively easy to anastomose to vessels close to the mouth. Larger defects in the buccal region may involve external cheek skin resulting in through-and-through defects (Fig. 10B). In this situation, a folded ALT flap can be used with the intervening

Figure 10 Cheek reconstruction. (A) ALT flap reconstruction of buccal lining. (B–D) Through-and-through cheek defect reconstructed with ALT flap.

Figure 11 ALT for temple defect. (A) Preoperative lateral view. (B) Postoperative lateral view. (C) Preoperative anteroposterior view. (D) Postoperative anteroposterior view.

folded portion being de-epithelialized (Fig. 6B). These defects have a significant volume deficit, which often results in a long-term sunken appearance of the cheek. In our experience, this can be improved by incorporating muscle with the ALT skin to provide extra bulk that augments the cheek and improves cosmesis (Fig. 10C, D). If two suitable perforators are present, the skin paddle can be split as a chimeric flap, allowing for a more elegant reconstruction.³² If the oral commissure is involved in the defect, the fascia lata can be split and sutured into the upper and lower orbicularis oris muscle as a static sling.³²

External Skin Defects

The latissimus dorsi myocutaneous flap is the most commonly used flap for reconstructing the scalp.⁸¹ It

matches the scalp in thickness and is large enough to resurface most of the scalp. The donor site is acceptable where a small flap is needed. However, harvesting a large flap necessitates the grafting of the donor site, which is unsightly. Alternatively, for large scalp defects, a latissimus dorsi muscle-only flap is used with an overlying skin graft, leaving an unsightly scalp flap. The TAP flap could be substituted for this flap to provide an excellent skin match for small defects. However, large TAP flaps may still require skin grafting.

The rectus abdominis flap is another alternative commonly used for midsize scalp and calvarial defects.⁸² This flap tends to be thicker than the scalp defect, although this is said to improve with denervation atrophy.⁸³ The problems with excessive flap bulk and donor site problems could be avoided by using a DIEP flap.

Figure 12 ALT reconstruction of extensive temple and cheek defect. (A) Preoperative lateral view. (B) Defect. (C) ALT flap.

The ALT flap provides an extremely large surface area of skin²⁹ and lends itself to resurfacing extensive external skin defects in the head and neck region (Fig. 11 and Fig. 12). It is particularly useful for resurfacing large scalp defects with bone exposure.⁸⁴ An excellent contour of the scalp is achieved (Fig. 13) without the excessive bulkiness that can result from use of other flaps with a wide skin territory such as the rectus abdominis and latissimus dorsi flaps. It has also been used for reconstruction of severe post-burn anterior cervical neck contractures after failure of other surgical modalities.⁸⁵ In this situation, free thin ALT flaps provide pliable tissue

of large surface area that contour well to the cervico-mental angle when combined with a cervicoplasty.⁸⁵ This flap therefore offers potential for the correction of a severe functional disability from neck contractures with a low recurrence rate and an excellent aesthetic outcome.

Extensive Composite Defects of the Mandible

More extensive composite defects involving segmental resection of the mandible often result in extensive soft tissue loss of the cheek. The skin islands of the osteo-septocutaneous flap may be adequate for coverage of both

Figure 13 (A–D) Scalp defect reconstructed with ALT flap.

inner and outer lining but inadequate to replace soft tissue loss. Soft tissue reconstruction in these situations has at least as great a significance for the functional result as does the bony reconstruction.^{86,87} The dead space left by extirpation of the masseter muscles, buccal fat, and the parotid gland must be obliterated to prevent fluid accumulation and secondary infection and to prevent further soft tissue contraction. A two-flap procedure in these

situations provides adequate volume to prevent these complications and also avoids a sunken appearance of the cheek, which may occur after radiotherapy⁸⁷ (Fig. 8).

In edentulous patients or for massive mandibular resections, a free osteoseptocutaneous fibula flap may be used for mandibular reconstruction and inner lining together with a free radial forearm flap or rectus abdominis flap for the cheek.⁸⁸ Alternatively, the iliac crest has

been used as the flap of choice in dentate patients. These combined vascularized bone grafts and cutaneous flaps with "chain-link" vascular anastomoses are ideal for massive defects in the head and neck.⁸⁹ The radial forearm flap, however, is usually too thin to cover the fibula and reconstruct the palate and has an inferior donor site compared with that of an ALT flap. The rectus abdominis flap may be too bulky and has disadvantages with regard to the abdominal donor site. Also, flap elevation may be prolonged because the donor sites are not in the same area.

The ALT flap combined with a DCIA flap is more suitable in these situations.^{25,38,87} It has a large cutaneous area,²⁹ and the volume is easily adjustable by incorporating part of the vastus lateralis muscle.⁸⁷ The vascular pedicle to the bone graft can be separated from that of the skin allowing easier inset of both flaps into the defect. Various tissues such as rectus femoris and sartorius muscles and fascia lata can also be included in the flap.

Alternatively, chimeric flaps consisting of multiple different flaps or tissues can be used in the head and neck. These flaps are supplied by their own independent pedicles from the same source. An example of this is the rectus femoris muscle and overlying ALT, supplied by different branches from the same source vessel.⁹⁰ Similarly, the AMT flap and anterolateral femoral flap are both based on septocutaneous perforators from the lateral circumflex femoral system²¹ and can be combined with a DCIA flap to reconstruct massive composite defects.

Midface Reconstruction

These defects are complex because they generally involve more than one midfacial component and often require skin cover, mucosal lining, and bony support. Although various free flaps have been used for midface reconstruction, the commonly used flaps include the radial forearm flap for small defects and the rectus abdominis or latissimus dorsi myocutaneous flaps for larger defects combined with bone grafts for orbital support if indicated.^{91,92} Small defects involving palate alone or midfacial skin alone can be reconstructed with a cutaneous or fasciocutaneous ALT flap. Larger defects after maxillectomy require muscle to obliterate the dead space; a DCIA flap with internal oblique is commonly used. A myocutaneous ALT flap provides sufficient volume⁹³ in these cases.

An important consideration in midface reconstruction using free tissue transfer is use of recipient vessels. The pedicle has to be long enough to reach donor vessels in the neck. The ALT flap is ideal under these circumstances as a 10- to 15-cm pedicle is easily provided.⁹³ Flaps harvested according to volume requirement from this single donor site can therefore replace the radial forearm, rectus abdominis, or latissimus dorsi

flaps, which have been commonly used for midface reconstruction.

Skull Base Reconstruction

Skull base surgery is complicated and multifaceted, often resulting in facial disfigurement, functional impairment, and cranial nerve destruction.⁹⁴ Resection of tumors around the anterior and middle skull often involve the removal of bone and dura. This can result in leakage of cerebrospinal fluid and exposure of intradural contents to infections from the surrounding sinuses.^{95,96} Vascularized tissue is used to provide tissue for dural seal.⁹⁷ The resulting defects are often beyond the capacity of local flaps, making free flaps the ideal choice for skull base reconstruction.

Historically, the rectus abdominis muscle or musculofasciocutaneous flap, the radial forearm flap, the latissimus dorsi muscle system flap, the scapular and parascapular flaps, and free omentum have been used for skull base surgery.⁹⁴⁻⁹⁸ The DIEP and ALT perforator flaps are now being used for this purpose.⁵⁷ The TAP flap can be used where less bulk is required but involves changing the patient's position.⁵⁶ The tumors involved are complex, and the lengthy resection required allows adequate time for perforator flap dissection by a second team. Compared with myocutaneous flaps, the contour of perforator flaps is maintained as there is no muscle atrophy. The same flap can serve many purposes including; the separation of intracranial and extracranial cavities, providing a dural seal, obliteration of dead space and cover of exposed vessels.⁹⁸ Furthermore, postoperative radiotherapy and chemotherapeutic agents can be delivered to the resected area without deleterious effects to the anastomosed vessels.^{99,100}

Neck Augmentation after Tumor Excision and Radical Neck Dissection

Resection of floor of mouth tumors and radical neck dissections often leave a significant contour defect in the submandibular region and in the neck. These contour defects are often neglected when it comes to free flap reconstruction. At the same time as reconstructing the primary intraoral defect, a larger skin paddle of an ALT flap may be used, part of which is de-epithelialized; this portion is then laid into the submandibular area and even down into the neck to augment the soft tissue defect after resection. In a similar manner, muscle may be used for soft tissue augmentation, in which case a myocutaneous ALT flap is required. In this situation, raising the flap as a chimeric flap with the muscle component supplied by a separate perforator to the skin paddle allows more freedom during the inset. This versatility afforded by the free ALT flap therefore allows greater aesthetic

refinements to be made simultaneously with reconstruction of the primary tumor site.

DISCUSSION

The advantages of using perforator flaps in head and neck reconstruction have been highlighted at length in this article. With adequate training and microsurgical skill, these flaps can be raised by a second team of surgeons at the same time as the primary surgical resection. The beauty of perforator flaps lies in the ability of the surgeon to raise flaps from almost any part of the body based on the presence of suitable perforating vessels as located by a Doppler ultrasound probe. This provides a choice of donor sites limited only by the skill of the surgeon.

Of all the perforator flaps discussed here, the ALT flap remains the most versatile and the most reliable. A previous series of 672 ALT flaps demonstrated a total flap failure rate of 1.79% and a partial flap failure rate of 2.53%.²⁴ A meticulous technique with respect to the method of perforator dissection¹⁰¹ and careful inset to avoid twisting and kinking of the perforating vessels ensure flap survival. In this series,²⁴ the majority of flaps were used for head and neck reconstruction, and the low failure rate demonstrates the reliability of this flap.

Although the ALT flap may be adapted to most indications for soft tissue reconstruction in the head and neck region, its versatility may be limited in a minority of patients who are particularly obese or hirsute. In the obese patient, excessive thinning of the flap may cause marginal necrosis, and direct closure of the donor site, even when the flap width is narrow, may be impeded, thus requiring a skin graft. Also, an excessively hairy thigh needs to be considered when the flap is being used for intraoral reconstruction, and an alternative donor site in this situation may be necessary.

A unique attribute of the ALT flap is the design of multiple flaps with variable composition. This can encompass all forms of compound flaps, including composite flaps (e.g., musculocutaneous, fasciocutaneous), chimeric flaps of which more than 100 possible combinations have been calculated from this one donor site by Hallock,¹⁰² and flow-through flaps for sequential or chain-linked flaps. Although flaps based on the subscapular axis have similar attributes, the ALT flap donor site is superior for head and neck reconstruction as the patient is maintained in the supine position to allow a two-team approach.

In patients for whom the ALT flap is not suitable, it is useful to have other perforator flaps as an alternative option. The DIEP and sGAP flaps have been popularized by surgeons reconstructing the breast. The anatomy of these flaps is well known, and they have large skin paddles of pale skin often suited to head and neck

surgery. The DIEP flap is particularly useful where soft tissue bulk is crucial, and it is becoming popular in the reconstruction of tongue, floor of mouth, and cheek defects. It can be raised at the same time as tumor ablation without the need to reposition the patient. The sGAP flap can be harvested (albeit with a shorter pedicle) with the patient in the spinal position, and the flap can be raised without a change in the patient's position. The AMT flap is based on a similar arterial supply to the ALT flap, producing a similar size of tissue; this flap makes a good alternative where the ALT flap is not available.

The PAP flap has been used in a short series for head and neck reconstruction. The perforators are easily mapped preoperatively by Doppler. The main advantage over the ALT flap for intraoral reconstruction is that the PAP flap is thin and pliable. Flap debulking is not required, and thus there is no risk to the flap from radical thinning. Like the ALT flap, a sensate flap can be created if the lateral sural nerve is included in the flap. The PAP flap has low donor site morbidity and avoids the sacrifice of a main artery in the lower limb. The short pedicle can be a disadvantage when anastomosing to the small-caliber vessels found in the head and neck, particularly after neck dissection.

CONCLUSION

There have been significant advances in perforator flap surgery over recent decades. The ALT flap seems to be revolutionizing head and neck reconstruction. These flaps have been shown to be reliable, offering versatility in design and composition, as well as improved donor site morbidity when compared with other soft tissue free flaps. These flaps can often be raised using a two-team approach, without change of the patient's position, thereby reducing operative times. They can be harvested as thin, pliable, and innervated flaps for intraoral reconstruction in one patient or modified with muscle incorporated to reconstruct a massive perioral defect in another patient. The perforator flap, in particular the ALT flap with its diversity, can replace most of the other commonly used soft tissue free flaps in head and neck reconstruction.

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