Chapter 26: Reconstruction of Facial Defects

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Reconstruction of acquired defects of the face remains one of the most challenging tasks for the reconstructive surgeon. The face is the center of attention during communication and the expression of emotion. A perfect face has been an ideal since the beginning of recorded history. In recent times this has been reflected in a growing demand for facial aesthetic surgery. Often the surgeon is called on to improve relatively minor facial deformities or changes related to aging. When the face is marred by trauma or ablative surgery, the reconstructive surgeon's skills and resourcefulness are put to the greatest test. The public's awareness of facial surgery has been enhanced by a plethora of reports in the media of surgical success stories and failures. Although performing an important educational function, these media reports may lead to unrealistic expectations on the part of the patient and family.

Many facial reconstructive surgical techniques evolved during the early twentieth century as surgeons dealt with the injured soldiers of two world wars. These pioneers of facial reconstruction attempted to deal with horrifying facial injuries that previously had been considered untreatable. Currently, victims of motor vehicle accidents or those having undergone ablative tumor surgery comprise the vast majority of patients needing facial reconstructive surgery. Recent research into the physiology of cutaneous flaps, tissue expansion, free tissue transfer, and biomaterial implantation has helped to refine reconstructive surgical techniques and also expand the reconstructive options available. In addition, increased experience with facial aesthetic surgical techniques has enhanced the finesse and refinements of reconstructive surgery.

A particularly notable development in the treatment of cutaneous malignancies has been the widespread acceptance and employment of microscopically controlled excision techniques, also known as Mohs micrographic surgery (Lang, 1990). This concept was initially promoted by Dr. Frederic Mohs in the 1940s, but the clinical value of the technique was not widely accepted until recently. The technique involves the precise excision of a cutaneous malignancy employing horizontal sectioning techniques. With micrographic excision, unprecedented cure rates can be achieved. These techniques are particularly applicable in the face because of the high incidence of recurrence seen when conventional excisional techniques are employed (Land and Osguthorpe, 1990). A Mohs micrographic excision technique is essential in certain areas of the face (Fig. 26-1) and in most cases of recurrent tumor. Employing such an ablative approach allows the reconstructive surgeon to repair the resulting defect immediately without concern for "burying" missed tumor or hiding an early recurrence under a skin flap. Micrographic tumor excision is guided solely by the location of the neoplasm and as such may help to conserve normal tissue because one does not randomly remove a large "margin" around the tumor.

However, this approach may often result in defects that involve multiple areas of the face, each with different reconstructive challenges. The Mohs surgeon does not tailor the resection to fit the reconstructive needs for the defect, which might compromise the resection, but rather, the extent of the tumor solely dictates the amount and location of the resection. This can lead to some formidable reconstructive tasks.

This chapter addresses many aspects of facial reconstruction. Overall facial anatomy and functional requirements for reconstructive techniques will be discussed. The restoration of not only soft tissues but also bony structures will be addressed as well as specific examples of grafting techniques, flaps, implants, and adjunctive procedures. However, this chapter will not serve as a surgical atlas listing all possible options.

Facial Anatomy

The face can be broken down into various aesthetic and anatomic units or areas (Fig. 26-2). Initial descriptions of these units were based on differences in skin texture, color, and thickness. As can be seen in Fig. 26-2 these units are separated by natural highlights, shadows, lines, and functional areas of the face. Some areas of the face, most notably the nose, can be further divided into smaller subunits (Fig. 26-3). Whenever feasible, the reconstructive technique employed should attempt to replace an entire aesthetic unit or subunit. This may require the surgeon to remove some normal tissue in order to create a defect that fills that entire unit. This sacrifice of normal tissue is usually a small price to pay for an improved aesthetic result. If the defect involves more than one unit, each one may be repaired separately using a different flap, graft, or other technique. In this way, scars and junctions between repaired areas will lie within the normal junction between aesthetic units, and each unit can be repaired with tissue of a texture, color, and thickness that most nearly approximates the naturally occurring tissue.

Another important consideration in facial reconstruction is the concept of relaxed skin tension lines (RSTLs), which were initially described by Borges (1973; Fig. 26-4). The dominant force in the creation of these lines is the contractile action of the underlying facial muscles. Secondary forces include the pull of gravity, the orientation of the collagen bundles in the skin, the contour of the underlying bones, and the influence of aging changes on the skin and soft tissues. These lines are important because incisions made within the lines nearly always result in fine scars that are easy to camouflage. These lines should always be considered when planning a repair of a facial defect. When designing local skin flaps, attention should always be paid to orienting the incisions within RSTLs as much as possible.

Scalp

The scalp is the thickest skin of the head and neck and is rich in hair follicles and sebaceous glands. It is extremely vascular and relatively inelastic because of the close adherence of the epidermis to the underlying dense galeal aponeurosis. The blood supply is provided via a network of large regional vessels that arise from the external carotid system (for example, superficial temporal and occipital arteries). This extensive vascular network allows for the creation of long and large viable flaps that are necessary for scalp reconstruction and hair replacement. Most scalp flaps should be raised in a plane just deep to the galea because this is relatively avascular and it preserves the main blood supply that runs superficial to the galea. The inelastic nature of the scalp usually necessitates the raising of relatively large flaps to repair most defects. Occasionally, galeal incisions (galeotomies) made from the deep surface after the flaps are raised can appreciably increase the amount of stretch that can be achieved in scalp tissue. Tissue expansion may prove advantageous in scalp reconstruction since it can provide considerably more tissue area available for repair (Adson et al, 1987). Partial-thickness skin grafts are usually unsatisfactory for the repair of most scalp defects because even minor trauma frequently results in a breakdown of the graft, leading to bleeding, crusting, and discomfort. Microvascular free tissue transfer may be useful for large defects but should only be employed when other options have been exhausted (Ohmori, 1982). With all repairs of the scalp there should be an attempt to re-create the normal hairline contour and appearance.

Forehead

The forehead also is made up of relatively thick skin and is influenced by the tightly attached underlying musculature. Frontalis muscle contraction leads to the usually prominent horizontal skin lines, and the procerus and corrugator supercilii muscles cause vertically oriented creases in the glabellar and brow areas. Because of these prominent lines, flaps can usually be designed to repair the forehead with minimal deformity. Even large forehead defects can usually be repaired with horizontally oriented single or double advancement flaps. Tissue expansion may also be beneficial here. The underlying firm bony surface is well suited to tissue expansion and may provide additional forehead tissue for reconstruction. It is important that the reconstructive technique chosen not alter the position of the anterior hairline or the brow position because this can be very disfiguring. Any vertical incisions required for reconstruction will be best camouflaged if left in the midline of the forehead. Defects of the underlying frontal bone can usually be repaired with alloplastic materials such as methyl methacrylate (Remsen et al, 1986).

Brow

When the hair-bearing brow tissue is lost, the resulting defect is quite deforming. This is particularly true in men who are less likely to be satisfied with cosmetic camouflage (for example, brow pencils) than are women. It is important not only to replace the missing brow tissue, but also to restore the remaining brow to a normal position. Small advancement flaps of adjacent brow may occasionally be useful, but free punch or strip grafts of hair-bearing scalp are usually required. It should be remembered that any surgical trauma to the brow may result in the temporary or permanent loss of brow hairs, and one should *never* shave the brows during surgery. One should carefully orient the hairs of free grafts or flaps so that they are parallel to the remaining brow hairs. Occasionally, pedicled, hair-bearing flaps from the temple may be of benefit (Kasai and Ogawa, 1990).

Eyelid

The eyelid may be divided into anterior and posterior lamellae for the purposes of discussion and reconstruction. The anterior lamella consists of the skin and orbicularis oculi muscles. The posterior lamella is made up of the tarsal plate and conjunctiva. The skin of the upper and lower lids is extremely thin, lacks subcutaneous fat, and is tightly bound to the underlying muscle. The eyelids must be mobile yet firm and well supported. The lower lid in particular must remain well suspended medially and laterally via the canthal tendons. This lid support must be carefully preserved or reconstituted during reconstruction since many reconstructive techniques place a downward pull on the lower lid and tend to pull it down and away from the eye. One must also protect the lacrimal drainage system or create an alternative drainage pathway. Defects in the medial canthal region are especially well suited for healing by secondary intention. Full-thickness skin grafts from the other eyelids are by far the best reconstructive option for superficial eyelid defects. A full-thickness defect of up to one third of the width of the lid can be repaired with primary layered closure only. Larger lower lid defects of the anterior lamella can best be repaired with cheek rotation-advancement flaps, taking care to provide good support for the lower lid margin.

Cheek

Reconstruction of the cheek (zygomatic arch to mandibular margin and preauricular crease to melolabial fold) allows the surgeon many options and much flexibility. The cheek skin is intermediate in thickness and varies considerably in different locations on the face. It is thinnest in the preauricular area and thickest nearer the melolabial folds. The skin of the cheek also varies tremendously among ethnic groups, between males and females, and at different ages in an individual. The surgeon should be aware of these skin differences when reconstruction is being planned. The cheek skin fortunately is quite elastic and malleable, so there can be great flexibility in flap design. Skin grafts are rarely necessary and should be avoided since the aesthetic result is usually poor. However, a huge array of local flaps can be employed. The RSTLs are particularly important and helpful in the selection and design of local flaps on the cheek. In general, rotation or transposition flaps (for example, rhombic, bilobed) are the most commonly used flaps. Examples of these will be shown later in this chapter (see Figs. 26-11, 26-12, 26-15, 26-16, 26-20, and 26-22). Tissue expansion plays a limited role in cheek reconstruction since a firm, flat skeletal structure directly under the skin is lacking. Large cervicofacial flaps can provide tremendous amounts of tissue for reconstruction, and in recent years, free flaps have been beneficial for some large defects, particularly when underlying bone is also required. Most commonly used free flaps are the radial forearm, scapular, dorsalis pedis, and groin flaps (Banis and Schwartz, 1990).

Nose

The nose is the central focal point of the face, and as such, any deformity here is devastating to the patient. The nose represents a particular challenge to the reconstructive surgeon. Frequently, structural framework has been lost along with the overlying soft tissue. The aesthetic subunit principle (as shown in Fig. 26-3) is especially relevant to nasal reconstruction (Burget and Menick, 1985). Small defects near the nasal tip or dorsum may lend themselves to repair with full-thickness skin grafts, especially those from the melolabial fold, or with perichondrial cutaneous grafts from the auricle. Alar and columellar defects may be repaired with composite grafts taken from the auricle (Walter, 1969). Alar defects may be repaired with superiorly based nasolabial flaps, and a variety of rotation and advancement flaps may be used for defects of the nasal dorsum. The "workhorse" of nasal reconstruction is the midline forehead flap (Thomas et al, 1988). This flap is useful for a wide array of nasal defects including the total loss of nasal soft tissue. This flap will be discussed in detail later in this chapter. The structural framework of the nose can be reconstructed using cartilage or bone grafts, although both have some limitations. The nose also lends itself well to prosthetic replacement in those patients who do not desire reconstruction.

Lip and perioral area

The lips are important from both an aesthetic and functional standpoint. Free mobility, muscle function, and intact sensation are important for the mouth to remain functional and competent. This is an area in which mucosal (vermilion) and cutaneous surfaces abut. Each of these tissues should be reconstructed separately as needed, because the reconstructive demands of each are very different. In addition, the reconstructive options for the two surfaces are quite dissimilar. The vermillion can be replaced with advancement flaps or grafts of oral mucosa and on occasion with tongue flaps. A defect or misalignment of the vermilion-cutaneous junction is quite visible. Therefore every attempt should be made to carefully reconstitute this important relationship with exacting symmetry. The philtrum with its ridges and furrows is a very important landmark to preserve or reconstruct. The skin of the lips is moderately thick and tightly attached to the underlying orbicularis oris muscle. Since there is very little tissue resistance to the spread of malignancy in this area, many cutaneous tumors invade the muscle early in their growth. Therefore most excisional defects include both skin and muscle.

As much as one third of the width of the lower lip (as measured before excision) can be repaired with only a primary, layered closure. Larger defects (up to two thirds of the width) can usually be repaired with a cross-lip flap (for example, Abbé flap) or an Estlander flap where the lateral commissure is involved. Subtotal or total loss of the lip usually requires a flap such as the Karapandzic flap or more extensive cheek flaps (Tobin and O'Daniel, 1990). Skin grafts are of little value in the perioral area. Y-V and V-Y advancement flaps or Z-plasty interposition flaps are often useful in correcting small residual deformities around the philtrum and the nasal columella. When the vermillion border is perfectly aligned, it provides an excellent line in which to place and camouflage incisions. The ala-labial crease provides an excellent camouflage as well, as do the multiple RSTLs of the lips. Occasionally, large regional myocutaneous flaps (free or pedicled) are required for extensive defects (Holt, 1987; Jewer et al, 1989).

Chin

Reconstruction of defects in the chin region is made difficult by the great thickness of subcutaneous tissue that is frequently lost or injured. The projection of the underlying bone can easily be modified with either implants or with genioplasty techniques. If possible, one should avoid crossing the prominent sublabial crease with incisions or flaps because this tends to produce webbing across the concavity. The multiple circumferential RSTLs around the chin are helpful in planning incision placement. The best results are usually obtained with adjacent tissue flaps, particularly of the rotational type. Flaps of adjacent neck skin should be avoided whenever possible.

Neck

The skin of the neck is relatively thin and quite elastic and malleable. There is usually abundant subcutaneous fatty tissue separating the epidermis from the platysma muscle. The blood supply is not as robust as in the face, so flap design should take this into consideration. Many large defects can be repaired primarily using only wide undermining. If needed, adjacent rotation or advancement flaps can be employed. As elsewhere, the design of these flaps should consider the RSTLs, which in the neck are principally oriented horizontally. Vertical scars in the neck are unsightly and have a great tendency to cause webbing, which restricts movement. When vertically oriented incisions are employed, it may be wise to incorporate Z-plasties into the design to minimize these problems. Occasionally, flaps are employed that extend down onto the chest wall, allowing for a large amount of skin to fill large defects (Friedman et al, 1987; Wallis and Donald, 1988). The neck is not a very favorable place to use tissue expansion because of the lack of a firm base on which the expander can rest. Still, this technique may have some application in selected cases (Niranjan, 1989).

Functional Restoration

Reconstruction of the face not only must replace lost tissues but also should restore lost function. Facial tissues also serve to protect vital structures such as the eyelids, providing a protective cover for the globe. In addition, the eyelids are essential components of the lacrimal pump apparatus. Thus a functional eyelid reconstruction not only will provide for coverage of the globe, but also will provide effective lubrication and nutrient flow (via the tears) to the cornea.

The face must also provide a nasal and oral airway. The nose requires not only a soft tissue envelope, but also a rigid structural frame to support it and to keep the airway patent. The lips and mouth are important both for deglutition and for speech. Proper oral function requires functioning muscle bulk, cutaneous coverage, and intact sensation. The skin and facial musculature perform mimetic functions unconsciously as well as voluntarily. Intact facial muscle tone and static support are important for the brows, eyelids, and mouth. When facial muscle function is lost, one should strive to replace this function with an acceptable substitute. Often regional muscle slings such as those from the temporalis or masseter muscles are helpful (Baker and Conley, 1979). Recent work with microneuromuscular free tissue transfer also appears to offer benefit to selected patients (O'Brien et al, 1990). All of these functional aspects should be considered when the reconstructive procedures are being planned.

Skeletal Structure Reconstruction

The bony skeleton of the face is the foundation for the soft tissues that attach to it. Functionally, the facial bones are foundations for the powerful muscles of mastication and the muscles of facial expression. Loss of the mandible can have profound aesthetic and functional sequelae even though there has been an adequate soft tissue repair. Fortunately, cutaneous malignancies invade the facial skeleton only infrequently, so most facial skeletal defects seen today are secondary to trauma or ablative surgery for mucosal malignancies of the upper aerodigestive tract.

Defects of the bone of the upper face can often be corrected with alloplastic implants or calvarial bone. The bony prominences of the orbit and zygoma are particularly amenable to these techniques. As mentioned previously, defects of the frontal bone can readily be repaired with molded methacrylate implants. The nasal framework can be restored with a variety of materials, including autogenous costal cartilage (Tardy et al, 1986), calvarial bone grafts (Posnick et al, 1990), homograft cartilage (Murakami et al, 1991), or alloplasts. Each of these materials has advantages and disadvantages, and all have limitations.

Restoration of the mandible is a challenging undertaking because of the extreme mechanical stresses placed on the bone. Numerous techniques have been employed for mandibular reconstruction. Free autogenous bone grafts have enjoyed many years of clinical acceptance (Albert et al, 1988). Most often iliac crest or rib is employed. More recently, vascularized free bone grafts have been employed, using a segment of fibula (Hidalgo, 1989a), radius (Boyd et al, 1990), scapula, or iliac crest. Rigid plate and screw fixation has enhanced many bone grafting techniques (Hidalgo, 1989b). Alloplastic reconstruction of the mandible is not widely accepted.

Timing of Reconstruction

The timing of reconstructive surgery should be well planned by the surgeon and well understood by the patient. It should be emphasized *before any surgery is done* that multiple procedures may be required to obtain the optimal result. Rarely can complex reconstructive surgery be accomplished with a single procedure. The timing and goals of each step should be well explained to the patient and family. Comprehensive photographic documentation is essential and should be obtained before any surgery is done and after all stages of surgery are completed. Photography is important not only from a medicolegal standpoint, but also because it allows the surgeon to critically evaluate the reconstructive efforts.

Following ablative surgery it is best to repair soft tissue defects immediately or at least within 72 hours. Excessive delay may lead to infection or wound contracture that may cause deformation of facial structures so that future correction is more difficult (for example, ectropion of the lower eyelid or stenosis of the nostril). Structural reconstruction is usually delayed for 2 or 3 months. This allows for the development of a healthy vascular bed and helps the surgeon to accurately estimate the amount of structural support needed. A disadvantage of delaying structural repair is that the soft tissue may contract enough to make skeletal changes difficult. Fortunately this is rarely a problem in the upper and mid face. The employment of vascularized bone grafts along with soft tissue repair prevents this problem.

Augmentation of deep soft tissues (muscle, fat) is usually delayed for several months following repair of the superficial soft tissues. Dermal fat grafting or alloplastic implants may be useful in the midface region Nosan et al, 1991). Facial reanimation procedures are usually performed 3 to 6 months after the skeletal and superficial reconstruction is well healed.

The final stages of reconstructive surgery involve surface scar revision and camouflage. Patience on the part of both the surgeon and the patient is important at this time. Scar revision should rarely be performed sooner than 6 months after the reconstruction and preferably not until 1 year has elapsed. The techniques employed range from Z-plasty to geometric broken line closure to dermabrasion (Thomas and Ehlert, 1990). The reconstructive surgeon should also be well versed in the application and uses of corticosteroids in scar revision (Goslen, 1989).

Skin Grafts

Skin grafting remains an essential part of facial reconstruction. However, local flaps usually provide a better aesthetic result in most areas of the face. A full-thickness skin graft (FTSG) will usually be more desirable than a split-thickness one. The skin of the face varies considerably in thickness in various areas, so ideally, the thickness of the skin graft should be chosen to match the thickness of the skin defect as closely as possible. There are several good donor sites for FTSGs (Fig. 26-5). Table 26-1 lists the various thicknesses of facial skin and the thicknesses of some of the potential donor sites for skin grafts. For example, a graft from the melolabial fold can be ideal for the nasal tip because of a similar thickness and texture. This is particularly true for those patients with thick sebaceous skin. The upper eyelids are excellent donor sites for grafts, with a considerable amount of skin available for harvest even in children.

Table 26-1. Reconstruction of facial defects (full-thickness skin graft recipient and donor site thickness)

Recipient (defect)	**Thickness (microm)**	**Donor (graft)**	**Thickness (microm)**
Lobule	2400	Melolabial	2900
Dorsum	1300	Preauricular	2000
Lateral wall	1200	Supraclavicular	1800
Glabella	1000	Postauricular	800.

The technique of skin grafting has changed little over the years. However, recently developed suture materials now allow some refinement in the technique. For a graft to survive, several criteria must be met. The graft must be in close apposition with the underlying vascular bed. There should be minimal motion of the graft to allow rapid capillary ingrowth, there should not be any blood or serum between the graft and its recipient bed, and finally, there should not be any localized infection.

Most FTSGs should be perforated as a "pie crust" to allow the egress of fluid from under the graft (Fig. 26-6). The perforations should be aligned with the relaxed skin tension lines (RSTLs) around the recipient site in order to camouflage the graft by mimicking the RSTLs within the graft itself. The perimeter of the graft is then sewn in place with a rapidly dissolving suture (Fast Absorbing Plain Gut, Ethicon Corp). Multiple "quilting" sutures are usually placed across the graft to hold it securely in place; this is particularly important on the face where the surface is mobile because of the action of the facial musculature. Then either a semiocclusive dressing (Vigilon, Bard Corp) or a bolster is applied to prevent desiccation of the graft and to reinforce the quilting sutures. If a bolster is used, it is best to place the tie-down sutures beyond the perimeter of the graft (Fig. 26-7). In this way, the edge of the graft will not be pulled up to form a "crater" deformity. When careful grafting techniques are applied to appropriate defects, predictably good results can be expected.

Local Flaps

General principles

The majority of facial defects, both large and small, are nearly always best repaired with local flaps. Local flaps can provide skin for reconstruction that closely matches the missing skin in texture, color, and thickness. When properly designed, the local flap should result in a minimal, acceptable secondary deformity with minimal scarring. To achieve this the flap must be carefully designed to take into account the orientation of the secondary defect as well as the degree to which the flap matches the primary defect. The planned incisions should be made along, or parallel to, RSTLs.

Flaps are classified according to their blood supply. They can be random, axial, pedicled, or free depending on the nature of the principal feeding blood vessels (Fig. 26-8). In the face, the blood supply is abundant, with excellent collateral circulation, so that most flaps can be designed in a random fashion. Delay of flaps is usually unnecessary.

Facial skin flaps should be elevated in a subdermal plane in most situations. Exceptions are flaps that need to provide extra thickness or island flaps. The principal danger with deeper flap elevation is injury to the facial nerve. The surgical dissection plane must be carefully designed so that the facial nerve is not at risk.

Good soft tissue surgical technique should be utilized throughout. The skin edges should only be handled with skin hooks and not crushed with forceps. Sharp undermining should be carried out on all aspects of the flap and defect at a uniform depth (Fig. 26-9). As a general rule, undermining should be carried out 1 to 2 cm beyond the wound edge. Wide undermining helps to reduce the size of the defect, helps to distribute the tension at the wound closure, and allows the skin to stretch and give. This helps to minimize any discrepancy in length along the sides of the flap and thus reduces the need for the excision of Burow's triangles or standing cones ("dog-ears"). Caution should be exercised whenever a standing cone is excised so that the blood supply to the flap will not be compromised.

Most incisions should be closed in layers, with the deep, subdermal closure performed to remove all tension from the epithelial closure. An absorbable suture such as polygalactin or polydioxanone is appropriate for this layer. The epithelial closure should function to approximate and slightly evert the wound edges. There should be little if any tension in this layer. Drains are used at the surgeon's discretion but are usually only necessary for the largest flaps. A temporary pressure dressing is helpful for most flaps.

The most common complications of local flaps are hematomas with subsequent necrosis. Hematomas can usually be avoided with careful intraoperative hemostasis and the appropriate use of drains and/or pressure dressings. Flap necrosis may be caused by excessive flap tension, poor flap design, hematoma, or infection (Daniel and Kerrigan, 1990). Reducing the trauma to the flap and wound edges by employing careful soft tissue handling techniques will reduce the chance of flap necrosis. Much research has been done in a search for pharmacologic agents that will enhance the viability of flaps and reduce flap necrosis. However, no agent has thus far received widespread clinical acceptance.

Excessive scarring is another undesirable sequela that can occur with local flaps. This can be minimized by proper flap design and careful attention to proper soft tissue handling techniques. Scar contracture is more profound when the scarring is excessive or when the scar crosses a bony prominence such as the mandible. Contracture around the circumference of a rounded flap or "trap door" scar can lead to lymphedema or "pincushioning". Pincushioning can be minimized by selecting inferiorly based flaps whenever possible, by undermining widely on all sides of the defect as the flap is inserted, and by carefully suturing the flap down against the raw surface of the defect to minimize deep scar formation.

Fusiform excision and closure

The most simple local flap consists of a fusiform excision followed by wide undermining and advancement of adjacent tissue for closure (Fig. 26-10). The fusiform excision should always be designed so that the long axis parallels RSTLs. The length/width ratio is between 2.5:1 and 3:1. A well-designed fusiform excision will be particularly effective in the cheek and forehead. This simple technique is frequently overlooked in favor of more complex designs.

If a benign lesion, such as scar or congenital nevus, is too large to be excised and closed in a single stage, then several staged procedures can be done with serial excisions until the entire lesion has been removed. This time-honored method of skin expansion is slow but effective. Tissue expanders may sometimes be employed preoperatively to allow a one-stage excision and repair.

Unilateral advancement flap

Single advancement flaps (Fig. 26-11) are commonly used about the head and neck. The forehead, brow, lips, and cheeks are areas in which these flaps are particularly useful. In the midface the flaps are seldom designed with straight sides but rather are designed to conform to natural contours, furrows, and lines in that particular area. Their length/width ratios may extend up to 4:1 given the excellent blood supply in most areas of the face. Burow's triangles are usually not needed at the base because of the abundant elasticity of facial soft tissue. The major incisions should follow RSTLs whenever possible.

A useful variation of the single advancement flap is the V-Y or Y-V flap (Figs. 26-12 and 26-13). The Y-V flap shortens a defect along the long axis of the flap while expanding tissue laterally (at right angles to the long axis). Conversely, the V-Y flap advances tissue along the long axis while compressing it laterally. Rarely is a defect shaped as a Y or V, but it is frequently beneficial to convert the defect into a triangular shape to take advantage of this technique.

Bilateral advancement flap

Bilateral advancement flap offer considerably more design flexibility than single advancement flaps (Fig. 26-14), although in general, the same design parameters apply. The flaps may be of unequal length so that the central scar comes to lie in the most favorable location. For example, the vertical scar may lie within the normal philtral ridge (Fig. 26-14). Burow's triangles are usually unnecessary when wide undermining is employed around all the edges and under the base of each flap. These paired flaps are particularly useful in the forehead, brow, and upper lip. Occasionally, this approach is useful for small defects of the nasal dorsum.

Rotation flaps

Rotation flaps are semicircular flaps that rotate skin around a pivot point into a triangular defect. Typically, the diameter of the flap should be at least twice the width of the defect. This allows the tissue to be transposed into the defect without the creation of a secondary defect or a Burow's triangle. Rarely is the flap designed as a true semicircle. Rather, the flap should be drawn to conform to facial anatomic features (Cook et al, 1991). For example, the melolabial fold, preauricular crease, and subciliary lines can all function as the outer circumference incisions (Fig. 26-15). As always, RSTLs should be considered when making all incisions.

Rotation flaps can vary considerably in size and shape. A relatively small lip defect may be well repaired with a small rotation flap. Large cheek defects can be repaired with large rotation flaps that extend down into the neck (Wallis and Donald, 1988). Rotation flaps are particularly well suited to scalp defects. In this instance, the flap should have a large (for example, five to six times the defect) circumference because of the inelastic nature of the scalp.

Transposition flaps

Transposition or interposition flaps are quite useful throughout the head and neck. These flaps reorient adjacent tissue to fill a defect or to change the direction of a scar. These flaps vary from very simple to complex. Examples include the basic interposition (Fig. 26-16), Z-plasty, nasolabial, glabellar, bilobed, and rhombic flaps. Each of these will be discussed separately below.

Z-plasty flap

A Z-plasty is simply a pair of equal triangular flaps that are raised and then interposed (Fig. 26-17). A Z-plasty can perform several functions, including the reorientation of scars, the lengthening of a scar, or the interposition of tissue into a defect. A Z-plasty may allow tissue to be brought into a defect without the distortion of adjacent anatomic features (Gahhos and Cuono, 1990). This is particularly important around mobile facial structures such as the eyelids and lips. An additional benefit of the Z-plasty is that the final scar is not a straight line, which helps to prevent longitudinal scar contracture and distortion. The Z-plasty is most often used in scar revision but remains a versatile, essential part of the reconstructive surgeon's armamentarium (Davis and Boyd, 1990).

Nasolabial flap

Nasolabial flaps are very useful for defects of the lower nose and lips. They may be inferiorly or superiorly based, although the latter are more commonly used. The flap is centered over the melolabial fold and has a vigorous blood supply allowing for long, thin flaps (Fig. 26-18). After elevation, the flap is transposed medially to reconstruct the alae or upper lip. The flap may also be folded on itself either transversely or longitudinally to rebuild the alar margin. Broad, superiorly based flaps can effectively reconstruct large defects of the upper lip. The secondary deformity generally lies in a very favorable location along the melolabial crease or the nasofacial groove. The primary difficulty with superiorly based flaps is their tendency to thicken as a result of lymphedema.

Glabellar flap

The glabellar flap is actually a combination of a rotation and a transposition flap. This flap takes advantage of the relatively abundant tissue in the glabellar area and is particularly useful for defects in the medial canthal region are well as the upper portion of the nasal dorsum. Reiger (1967) described a modification of this flap that incorporated a V-Y advancement. This technique may allow for the reconstruction of relatively large defects of the nasal dorsum. It is not, however, ideal for nasal tip or alar reconstruction (Fig. 26-19). Glabellar flaps receive blood supply from both the supratrochlear and supraorbital arteries. As a result, rather long and narrow flaps can be safely raised for large defects.

Bilobed flap

A bilobed flap is a combination of a rotation and a transposition flap. The bilobed flap consists of a primary lobe and a secondary lobe that share a common pedicle (Fig. 26-20). A bilobed flap has two advantages: first, a 40% to 50% area advantage and, second, the fact that although the tissue is effectively transferred 180 degrees, the pedicle is rotated only 90 degrees. The primary lobe is roughly 20% smaller than the original defect, and the secondary lobe is approximately one half the size of the original defect. The angle between the flaps varies from 45 and 90 degrees. Zitelli (1989) described a modification of the classic bilobed flap that separated the two component lobes by approximately 45 degrees and excised a small triangle of normal tissue at the base of the defect, thereby reducing the standing cone deformity caused by the flap rotation (Fig. 26-21). It is imperative to preserve and protect the common pedicle of the two lobes. These flaps are most useful in the midface, cheek, and glabella and over the nasal dorsum (Cook, 1982).

Rhombic flap

The rhombic transposition flap enjoys wide application in reconstruction of the head and neck. Originally described by Limberg (Limberg and Wolf, 1984), the flap is basically a parallelogram (rhomboid). The rhombic flap allows tremendous design flexibility since the flap can usually be developed in several different directions about the defect (Fig. 26-22). The flap should be carefully designed within RSTLs with careful attention to the surrounding facial features. The rhombic flap "borrows" tissue primarily from one direction. Thus the flap should also be designed so that the movement of tissue into the defect will not distort nearby anatomic landmarks. The flap is designed with all sides of the flap equal in length to those of the defect. After incision and elevation with wide undermining, the flap is transposed into the defect. The point of greatest tension is across the two Xs shown in Fig. 26-22. The secondary defect should therefore be closed first, allowing the flap to be sutured into position with virtually no tension. Several useful modifications of the basic rhombic flap have been introduced (Gahhos and Cuono, 1990). These flaps are particularly useful in the cheek, temple, neck, and nasal dorsum.

Island flap

An island flap is composed of an "island" of skin that derives its blood supply not from a contiguous pedicle of skin, but rather from an attached subcutaneous pedicle (Fig. 26-23). These are useful when transfer of the pedicle skin might lead to an unacceptable secondary deformity or when it is important to keep the pedicle intact permanently. Island flaps have been used in the head and neck primarily as modifications of glabellar or nasolabial flaps. Examples of island flaps are shown in Fig. 26-23. Myocutaneous flaps are examples of island flaps in which the skin derives its blood supply from perforating vessels of the underlying muscle. These flaps are discussed in detail elsewhere in this text.

Regional Flaps

This section discusses a few examples of regional flaps of particular utility in the reconstruction of massive facial defects. These flaps can be considered extensions or modifications of some of the local flaps discussed previously.

Cervicofacial rotation flap

The cervicofacial rotation flap is an extension of a facial rotation flap. This flap is useful when there are extensive tissue defects in the cheek, lower eyelids, or buccal area. An incision along the melolabial fold functions as a "back cut" that facilitates flap rotation and advancement (Fig. 26-24). The superolateral edge of the flap should curve above the lateral canthus to allow for good support of the lower lid and help to prevent the development of an ectropion (Becker, 1985). The leading edge of the flap that will abut the eyelid should be thinned of all subcutaneous fat. The incision follows the preauricular crease down to and around the lobule. At this point, two options are available to provide additional tissue for reconstruction. One utilizes a flap of postauricular skin as in a bilobed flap (see Fig. 26-24; Cook et al, 1991). Alternatively, the incision can course down into the neck following a gentle curve with a natural crease. The facial flap should be elevated in the same plane as a face-lift flap. The cervical portion, however, may be elevated deep to the platysma to enhance the flap's blood supply (Horowitz et al, 1983). Care should be taken to avoid injury to the facial nerve. Large flaps benefit from the placement of drains to help to prevent the accumulation of a seroma or hematoma.

Posterior cervical flap

Posterior cervical or nape of neck flaps are superiorly based flaps useful for posterior facial defects (Fig. 26-25). When large amounts of tissue are required, it is best to incorporate the underlying trapezius muscle to form a myocutaneous flap. The secondary defect is usually difficult to close primarily and mobilization of the trapezius muscle may limit shoulder mobility. These flaps should generally be used only when other options are not feasible.

Forehead flap

The scalping forehead flap now has limited application in head and neck reconstruction. Initially described by Converse (1969), this flap has largely been replaced by other flaps that cause less severe secondary deformities. This technique entails a transfer of forehead tissue to a defect elsewhere on the face (Fig. 26-26), followed 3 weeks later by division of the pedicle. The principle objection to this flap is the secondary deformity of the forehead, which is aesthetically unacceptable. The flap may occasionally be useful for extensive defects of the midface and nose when other options are not available.

The flap derives its blood supply from a combination of the superficial temporal, supraorbital, and supratrochlear vessels, depending on the length of the flap. It is usually a very robust flap when the entire forehead is incorporated into the flap. If only a portion of the forehead is used, the donor defect may be even more unsightly. In those patients who may have a compromised blood supply (for example, smokers, persons who have had radiation therapy or persons with peripheral vascular disease), initial delay of the flap may be advantageous. After elevation and transposition of the forehead flap, the forehead is resurfaced with a thick split-thickness skin graft. Beveling the edges of the forehead defect outward may smooth the transition from normal forehead tissue to graft. The forehead may be allowed to granulate for several days before skin grafting, since this may reduce the disparity in thickness between normal forehead tissue and skin graft. However, in spite of these techniques the forehead deformity is usually unacceptable and other options should be utilized whenever possible.

Midline forehead flap

The midline forehead flap is one of the oldest reconstructive surgical procedures known. This flap was initially described in ancient Indian medical writings about the reconstruction of noses that were mutilated as a punishment for adultery (Menick, 1990). This flap is now the preferred flap for most cases in which significant dorsal defects of the nose exist. The forehead skin is nearly ideal in texture, color, and thickness for nasal reconstruction, and the secondary defect in the forehead is quite unobtrusive in most cases. Recent modifications in the design and execution of this flap have further enhanced the aesthetics of the nasal reconstruction that can be obtained (Menick, 1990). The reliability, flexibility, and superior aesthetics of the midline forehead flap have virtually eliminated the need for a scalping forehead flap in nasal reconstruction.

The midline forehead flap is considered an axial flap that derives its principal blood supply from the supratrochlear artery. This flap also has a secondary pedicle from the angular branch of the facial artery (McCarthy et al, 1985). As such, it is a very robust flap with a durable and reliable blood supply. This rich blood supply allows the reconstructive surgeon considerable flexibility in flap design. The midline forehead flap was classically described as a bipedicled flap attached to both supratrochlear vessels. However, experience has shown that this flap can safely be based on only one vascular pedicle (Thomas et al, 1988), which allows for a greater rotation of the flap base and hence greater reach and length. The midline forehead flap can provide enough tissue for total nasal reconstruction, often without a need for tissue expansion. Several authors have reported good results when forehead flaps are enlarged with either conventional or rapid intraoperative tissue expansion (Adamson, 1988; Baker and Swanson, 1990a). However, tissue expansion techniques, particularly rapid intraoperative expansion, remain controversial (Mackay et al, 1990). These techniques should be used with caution and only by those well versed in their application.

The nasal defect to be reconstructed is carefully defined, and if possible, the defect should be made to conform to aesthetic nasal subunits. A template of the defect is then made and transferred to the midline forehead skin above the vascular pedicle. The contralateral vascular pedicle should be utilized so that the angle of rotation of the flap base is minimized (Fig. 26-27). The distal skin is then elevated sharply in a *subcutaneous* plane. If needed, the flap can extend up into the hear-bearing scalp to gain added length. If this is done, the hair follicles should be transected during flap elevation to devitalize them. The remainder of the pedicle is then elevated in a subgaleal plane in order to preserve the vascular pedicle. The elevation at the pedicle base is done carefully with blunt technique to prevent injury to the supratrochlear vessels. The flap is transposed and carefully sutured into position. The forehead defect is usually closed primarily, since defects of up to 5 cm in width can be closed primarily. Adjunctive procedures such as galeal incisions and tissue expansion may be helpful in closing larger forehead defects. Alternatively, a portion of the forehead defect can be allowed to heal by secondary intention, often with an acceptable aesthetic result. The pedicle is divided after 3 weeks, and only the most proximal part of the pedicle is returned to the forehead. The forehead flap can be augmented with cartilage grafts or nasal mucosal flaps as required (Burget and Menick, 1989).

Myocutaneous Flaps

A thorough discussion of myocutaneous flaps is beyond the scope of this chapter and is dealt with elsewhere in this text. Myocutaneous flaps from the neck or chest are usually used in facial reconstruction only when there is massive tissue loss after tumor ablative surgery or trauma. The flaps may be needed when there has been an associated resection of loss of mandible or maxilla. In general, these flaps provide tissue that matches the facial skin poorly. Thus, whenever an appropriate local flap is available, it should be used. When needed, however, myocutaneous flaps can provide massive amounts of well-vascularized tissue for facial reconstruction (Baker, 1990).

Microvascular Flaps

In recent years, microvascular free tissue transfer has become a well-accepted technique for facial reconstruction (Ahn et al, 1991). These "free flaps" are basically skin island flaps with a well-defined vascular pedicle that are carefully dissected from the donor site while preserving the pedicle and then transferred to the recipient (defect) site. The vascular pedicle is transected and then anastomosed to an appropriate recipient artery and vein with microvascular techniques. The flaps most commonly employed in facial soft tissue reconstruction include radial forearm (Swanson et al, 1990), groin (Dunkley and Stenson, 1990), latissimus dorsi (de la Fuenta and Jiminez, 1989), and scapula (Schwartz et al, 1988). New flaps are being developed regularly. When needed, these flaps can be designed to include vascularized segments of bone as well. These flaps usually provide skin that matches the facial skin poorly, so they should only be considered after all other reconstructive options have been exhausted. For a more detailed discussion of microvascular free flap facial reconstruction, the reader is referred to the suggested readings at the end of this chapter.

Adjunctive Procedures

Tissue expansion

Tissue expansion can be accomplished with either conventional (long-term) or rapid (intraoperative) techniques. Conventional tissue expansion was first popularized by Radovan in the 1980s (Radovan, 1984). This technique entails the placement of a subcutaneous balloon (expander) that is gradually inflated with sterile saline over a period of weeks or months. This results in histologic and metabolic alterations in the tissue as well as additional soft tissue area (Pasyk et al, 1987). Rapid, intraoperative tissue expansion as described by Sasaki (1987) is performed by cyclically inflating a subcutaneous balloon over a period of a few minutes. Rapid expansion does not result in metabolic or histologic changes in the tissue, but rather a mechanical stretch or "creep" is thought to occur (Sasaki, 1987).

Conventional tissue expansion can provide additional soft tissue for reconstruction with local flaps, and there is enhanced vascularity developed in slowly expanded tissue (Pasyk et al, 1987). However, there is a relatively high incidence of complications with tissue expansion, most commonly an extrusion of the expander and infection (Argenta and Austad, 1990; Baker and Swanson, 1990b). In the case of facial reconstruction, the deformity caused by the expander itself during the period of conventional expansion may be unacceptable to the patient. In addition, the reconstructive surgeon may not be able to fully anticipate the extent of the soft tissue defect that will result from the resection.

Rapid, intraoperative tissue expansion was developed to overcome some of these limitations. This technique employs successive, cyclic inflation of a subcutaneous balloon to stretch an area of skin. Typically, the expander is sequentially inflated for a period of 3 to 5 minutes with a rest period of 3 to 5 minutes between each inflation. Usually three inflation periods are employed (Sasaki, 1987). Immediately thereafter, the flap is raised and the defect is reconstructed. Considerable controversy has surrounded rapid tissue expansion. The mechanism of the rapid expansion and the clinical applicability of the technique have been questioned. In addition, concerns have been raised about the viability of the rapidly expanded tissue and the "stretch back" or contraction of the expanded tissue frequently encountered after the balloon is deflated (Mackay et al, 1990). Only with additional research and clinical experience with this technique will these questions be answered. In spite of this, some authors have had favorable experiences with this technique (Baker and Swanson, 1990a).

Prosthetics

Prosthetic devices often provide a rapid and less expensive alternative to surgical reconstruction. Prostheses may be particularly appropriate in debilitated patients with extensive defects. Recently, osseointegrated (bone anchored) facial prostheses have enjoyed wide success in Europe and are being used more commonly in North America (Tjellstrom, 1989). These devices consist of a titanium osseointegrated implant with a percutaneous abutment. The devise is surgically implanted into the bone with direct bone-to-metal contact without intervening fibrous tissue. Therefore a strong and long-lasting unit is created that is well tolerated. These implants can be used in both nonirradiated and irradiated bone (Jacobssen et al, 1988). The prosthesis itself is then attached to the titanium abutment with a strong magnetic device eliminating the need for adhesives. A talented prosthetist can thus fashion a cosmetically superior device that can often appear quite natural. These prostheses may be particularly applicable for orbital, auricular, and total nasal defects (Tolman and Desjardins, 1991). These osseointegrated prostheses will certainly be a desirable reconstructive option for many patients and should be part of the reconstructive surgeon's armamentarium.