Operative Techniques in Otolaryngology (2011) 22, 13-23

Operative Techniques in
Otolaryngology

# Concepts in local flap design and classification

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**KEYWORDS**
Facial reconstruction;
Local flaps;
Local facial flaps;
Reconstructive ladder

Facial reconstruction relies on the creativity of surgeons as well as a clear understanding in the properties of local flaps. Choosing the correct procedure begins with thorough analysis of the defect. Multiple reconstructive options often exist, which can then be narrowed and refined based on the specific qualities of the defect and the history of the patient. Careful planning ultimately leads to an excellent functional and aesthetic reconstructive outcome.


Flap design in facial reconstruction is particularly delicate given the face is the most visible structure of the body and has some of the most complex three-dimensional topography. The goals of facial reconstruction center on closing defects in an inconspicuous manner. Fortunately, the robust vascular supply of the face allows for many reconstructive options using flaps that are localized to the face. Flaps are classically categorized based on their vascular supply, composition, method of transfer, and design (Table 1).[1] Proper execution of facial reconstruction also relies on appropriate analysis and characterization of the defect. This article outlines the classification of local facial flaps as well as offers a systematic approach for reconstructive planning.

## Vascular supply

To ensure flap viability, a solid understanding of cutaneous anatomy is important (Figure 1). The epidermis represents the most superficial layer of skin. Beneath the epidermis lies the dermis, which is composed of the superficial papillary and deeper reticular layers. Within the dermis there are two distinct vascular arcades: a superficial vascular plexus that runs between the reticular and papillary dermis, and a more robust deep vascular plexus or "subdermal" plexus that runs between the reticular dermis and subcutaneous tissue. The skin also receives blood supply from direct cutaneous arteries that arise as perforators off deeper musculocutaneous arteries. Local flaps can be classified based on their blood supply (Table 2). Random flaps depend on the vascular supply of the subdermal plexus and not a named skin perforator. The length of the random flap depends on the intravascular resistance of the supplying vessels and the perfusion pressure. When the perfusion pressure drops below a critical closing pressure of the arterioles in the subdermal plexus, nutritional blood flow ceases and flap ischemia occurs.[2] Therefore, the traditional concept of a width-to-length ratio does not dictate flap survival, rather perfusion pressure does.[3] Axial flaps are flaps based off a specific direct cutaneous artery (also called septocutaneous artery) or musculocutaneous artery. These flaps have a more generous blood flow with improved survival lengths. Both regional flaps, such as the pectoralis major flap, and free flaps, such as the radial forearm flap, are considered axial flaps. Thus, free flaps represent the most extreme concept of axial flaps given the initial total blood supply is dependent on the revascularization of a single anastomosed artery.

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doi:10.1016/j.otot.2010.09.002

**Table 1** Classification of local flaps

| |
|---|
| 1. Vascular supply |
| 2. Composition |
| 3. Method of transfer and design |

## Composition

Local flaps are also categorized based on composition (Table 3). The composition of the defect to be reconstructed should dictate the correct composition of the flap used for reconstruction. The classification is self-descriptive. These include cutaneous, fasciocutaneous, musculocutaneous, and osteomusculocutaneous (Figure 2). Any variation of these flaps can exist with removal of the outermost layers. For example, many free flaps can lack skin or bone and be solely a musculofascial flap.

## Method of transfer and design

Flaps are most commonly described based on the method of transfer (action on the nutrient pedicle) and design (Table 4). Advancement flaps depend on the advancement of the surrounding tissue along a linear axis to close a defect (Figure 3A-F). The advancement of two skin edges from a fusiform skin excision represents the simplest of advancement flap design. Classically, advancement flaps have a length-to-width ratio of 1:1 or 2:1.[4,5] Advancement flaps often create standing cutaneous deformities or "dog-ear" deformities, which must also be addressed as part of the reconstruction plan.

Rotational flaps are pivoted around a fixed point at the base of the flap and rotated along an arc toward the defect (Figure 3G, H)). Classically, rotation flaps are designed to move along an arc of 30 degrees or less with the radius approximately two to three times the diameter of the defect and the arc length approximately four to five times the width of the defect.[5] Most rotational flaps possess a component of advancement and thus are more accurately labeled rotation-advancement flaps[6] (Figure 4).

Transposition flaps are versatile flaps whose design creates a second defect. The flap is raised from a donor

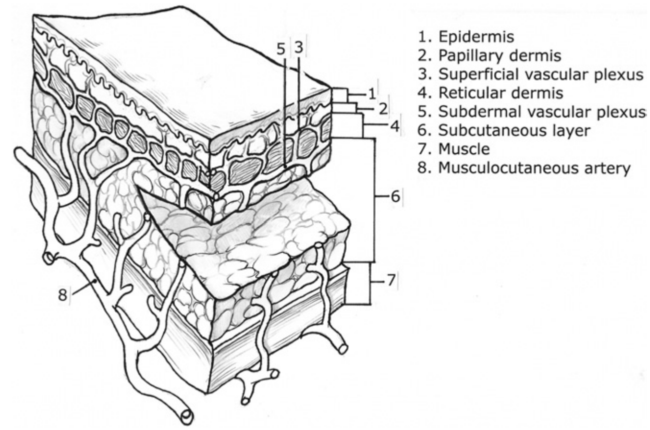


**Figure 1** A schematic depiction of the skin/soft tissue layers. A random flap is being elevated in the subcutaneous layer to maximize the blood supply to the skin flap by, including the subdermal plexus. The layers of the diagram illustrate the superficial vascular plexus lying between the superficial papillary and the deeper reticular dermal layers. The subdermal plexus lies between the reticular dermal layer and the subcutaneous layer. The vascular arcades communicate with each other through small perforating vessels. The subdermal plexus receives its blood supply from perforators originating off the deeper musculocutaneous arteries.

site and rotated over an incomplete bridge of skin to be placed into the defect site. The donor site must also be closed as part of the design. The three classic transposition flaps include the rhombic flap, bilobed flap, and Z-plasty[5,7,8] (Figures 5-7). As with most reconstructions, rarely do flaps fit the classic design; therefore, many modifications of classic designs have been created. For example, the Dufourmental and the Webster modifications of the rhombic flap are designed to create smaller angels of rotation that result in less redundancy and smaller standing cone deformities.[4] Similarly, the original bilobed flap design was based on an arc of rotation of 180 degrees. Zitelli then redescribed the bilobed flap based on an arc of rotation along a 90-degree axis, which created less tension on the closure and less chance for a standing cone deformity.[9,10] Additionally, the complex design of transposition flaps often make it difficult to create scars that completely rest within relaxed skin tension lines.

**Table 2** Vascular classification

| | | | |
|---|---|---|---|
| I. Random supply | - Majority of local flaps | | |
| II. Axial supply | | | |
| | | Flap | Artery |
| | A. Local flap | - Paramedian forehead | - Supratrochlear artery |
| | | - Abbe | - Labial artery |
| | | - Melolabial | - Perforator of levator labii superioris |
| | | - Temporal | - Superficial temporal artery |
| | B. Regional flap | - Platysmal | - Branch of facial artery |
| | | - Sternocleidomastoid | - Occipital art., superior thyroid art., transverse cervical art. |
| | | - Deltopectoral | - Perforator of internal mammary art. |
| | C. Free flap | - Pectoralis major | - Thoracoacromial art. |

**Table 3** Composition classification

| |
|---|
| 1. Cutaneous |
| 2. Fasciocutaneous |
| 3. Musculocutaneous |
| 4. Osteomusculocutaneous |
| 5. Variations of the innermost layers |

Interpolated flaps are pedicled flaps that cross over or under intervening intact tissue (Figure 8). If the flap passes over intact skin, the flap must be divided and inset in a second stage of reconstruction. In contrast to transposition flaps, the base of interpolated flaps is not contiguous with the defect base. Interpolated flaps are often dependent on an axial blood supply. The most classic facial interpolated flap is the paramedian forehead flap, which receives blood supply from the supratrochlear artery. Additional examples are described in Table 4.

Free flaps represent the transfer of tissue based on an axial blood supply from a distant body site. These flaps require microvascular anatomosis of the arterial and venous systems for survival. In the correct patient, free flaps offer excellent survival rates with abundant tissue to fill any defect size and composition.

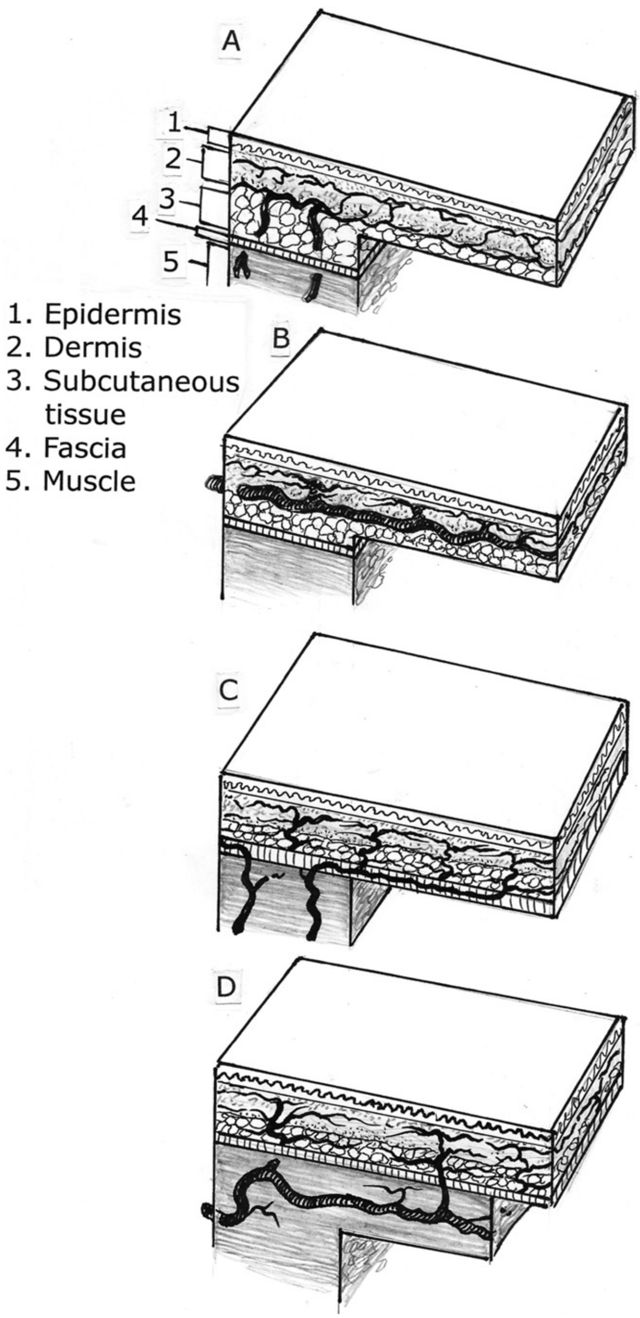


**Figure 2** Classification of skin flaps based on composition: (A) random cutaneous, (B) axial cutaneous, (C) fasciocutaneous, and (D) musculocutaneous. (Adapted from Baker.[3])

**Table 4** Method of transfer and design

| | Examples: |
|---|---|
| I. Advancement (Figure 3A-F) | - Primary fusiform closure<br>- A to T<br>- V to Y<br>- Unilateral or bilateral advancement<br>- Island |
| II. Rotation (Figures 3G, H and 4) | - Scalp (advancement-rotation)<br>- O to Z<br>- Cervicofacial (advancement-rotation)<br>- Karapanzic<br>- Glabellar/dorsal nasal/Rieger |
| III. Transposition (Figures 5-7) | Rhombic (Duformental and Webster modifications)<br>- Bilobed (Zitelli modification)<br>- Z-plasty<br>- Note<br>- Melolabial<br>- Nasofacial |
| IV. Interpolated (Figure 8) | - Paramedian forehead<br>- Melolabial<br>- Nasofacial |
| V. Free flap | |

**Table 5** Systematic approach to facial reconstruction

| |
|---|
| 1. Characterize defect: |
| - Skin color |
| - Skin thickness |
| - Tissue composition |
| - Internal lining (mucosa, conjunctiva) |
| - Structural layer (muscle, cartilage, bone) |
| - Outer lining (skin, vermilion) |
| - Location and subunits involved |
| 2. Design reconstructive ladder for defect (list multiple options) |
| 3. Account for key facial landmarks and ideal areas for tissue recruitment: (omit options that transgress nondistortable landmarks) |
| 4. Design flaps to align with resting skin tension lines |
| 5. Account for patient history |
| - Radiation, immunocompromise, tobacco abuse, risk of recurrence (narrow options based on increased survival/success of the flap) |

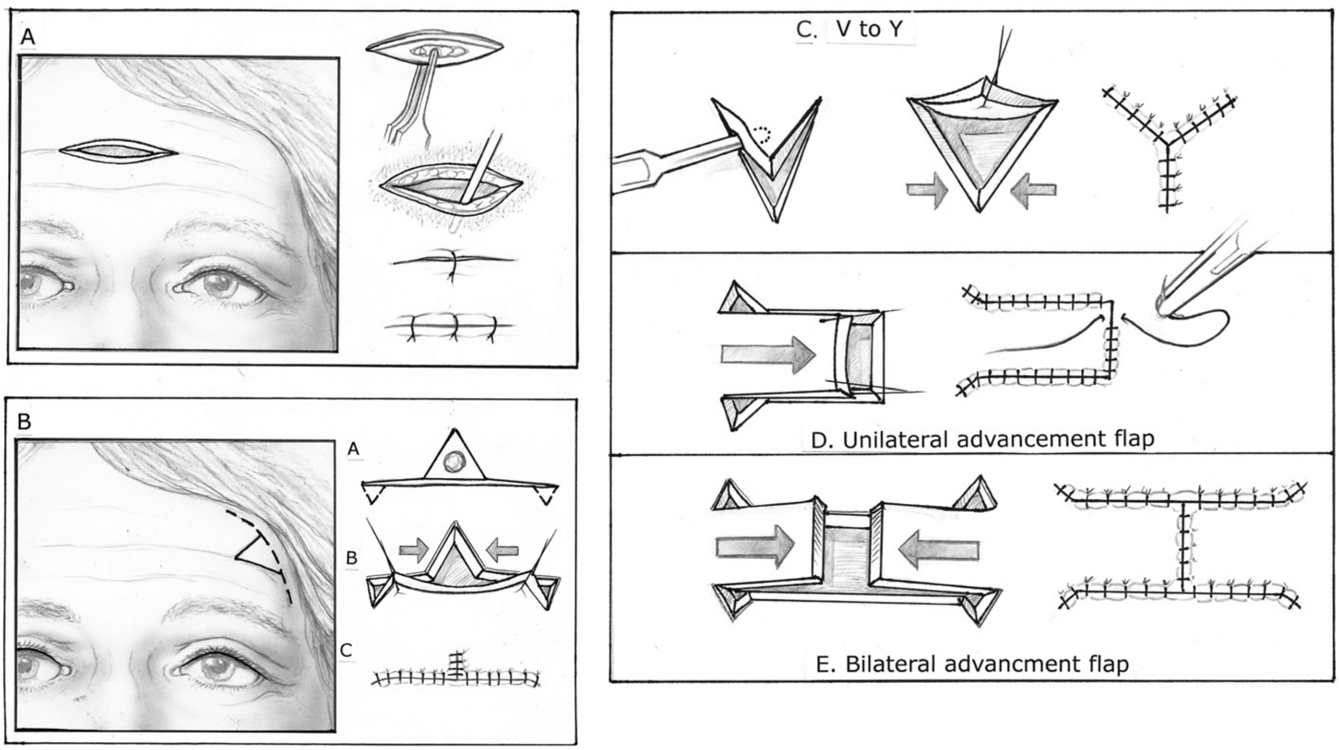


**Figure 3** Schematic representations of local advancement and rotation flaps. Small solid black arrows represent the vector of advancement or rotation needed for closure of the defect. Larger gray arrows show the progression of the defect before and after closure. The postclosure figure reveals the resultant incisional scar created based on the type of closure performed.(A) The most basic advancement flap is represented by closure of an ellipse. (B) A to T advancement closure. Because one side of the closure has excess soft tissue compared with the side with the defect, standing cone deformities will be created by closing the defect. This is managed by excising small Burow's triangles along the longer edge, depicted by the smaller black arrows pointing to the removal of triangular tissue. (C) V to Y advancement closure. V to Y closure is often used to increase length along the lower limb axis. (D) Unilateral advancement flap. Because there will be a discrepancy of length along the edges, Borow's triangles will need to be excised to prevent standing cone deformities. (E) Bilateral advancement flaps. Similar to the unilateral advancement closure. (F) Island advancement flap. Island flaps maintain a subcutaneous pedicle from the original skin paddle sight that is transferred into the defect. The tissue adjacent to the island flap is then closed over the subcutaneous pedicle. (G) Rotation Flap. The vector of closure is along an arc. (H) O to Z rotation flap. This represents two opposing rotation flaps that are closed toward the same central point of the defect. Additional rotation limbs may be added to close the defect site.

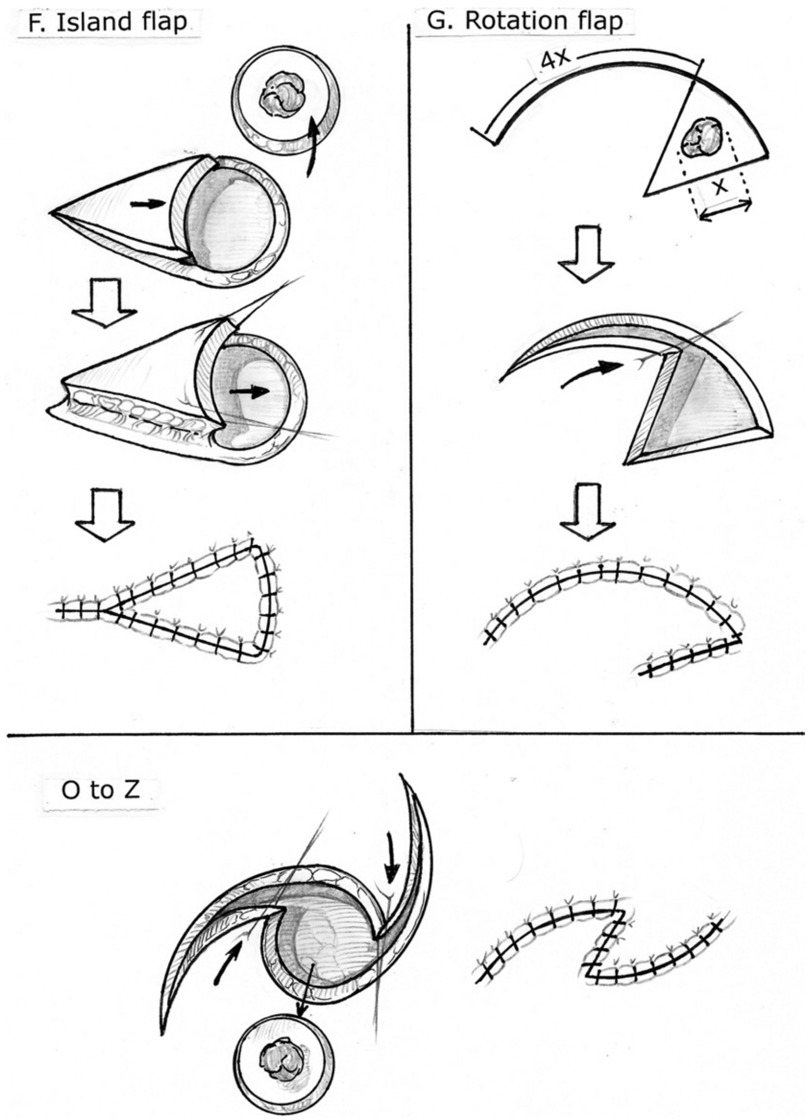


**Figure 3** Continued

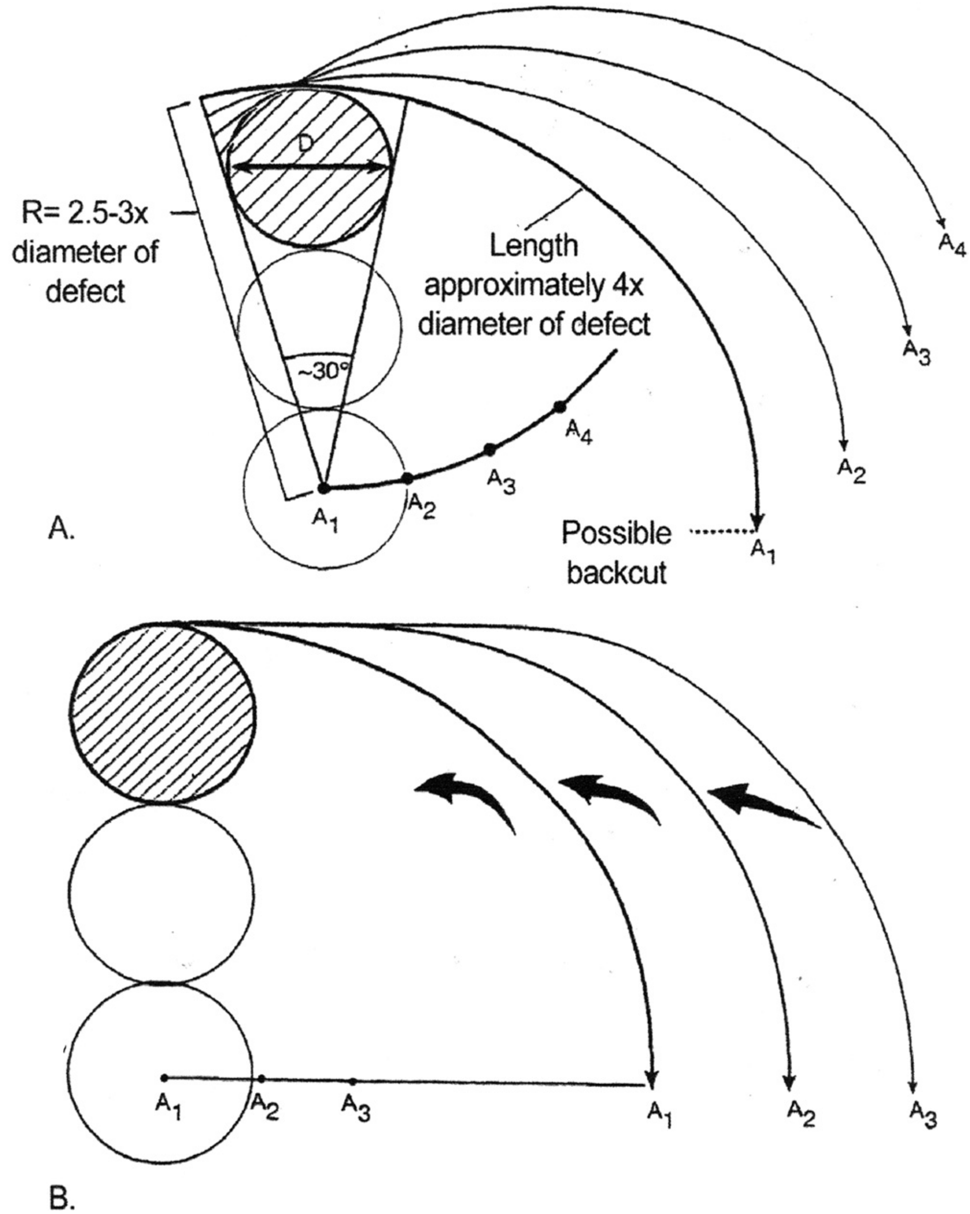


**Figure 4** Schematic representation of an advancement-rotation flap. (A) The basic rotation flap ideally has an arc of closure that is less than 30 degrees. The radius (R) used to create the arc of closure is 2.5-3 times the diameter (D) of the defect. The length of the arc should be approximately 4 times the diameter (D) of the defect. The axis of rotation ($A_1$-$A_4$) can be moved along an arc to allow for greater rotation and less advancement. (B) If the axis of the rotation ($A_1$-$A_3$) is moved along a linear line, the flap will have a greater advancement component and less rotation. (Reprinted from Murakami and Nishioka.[4])

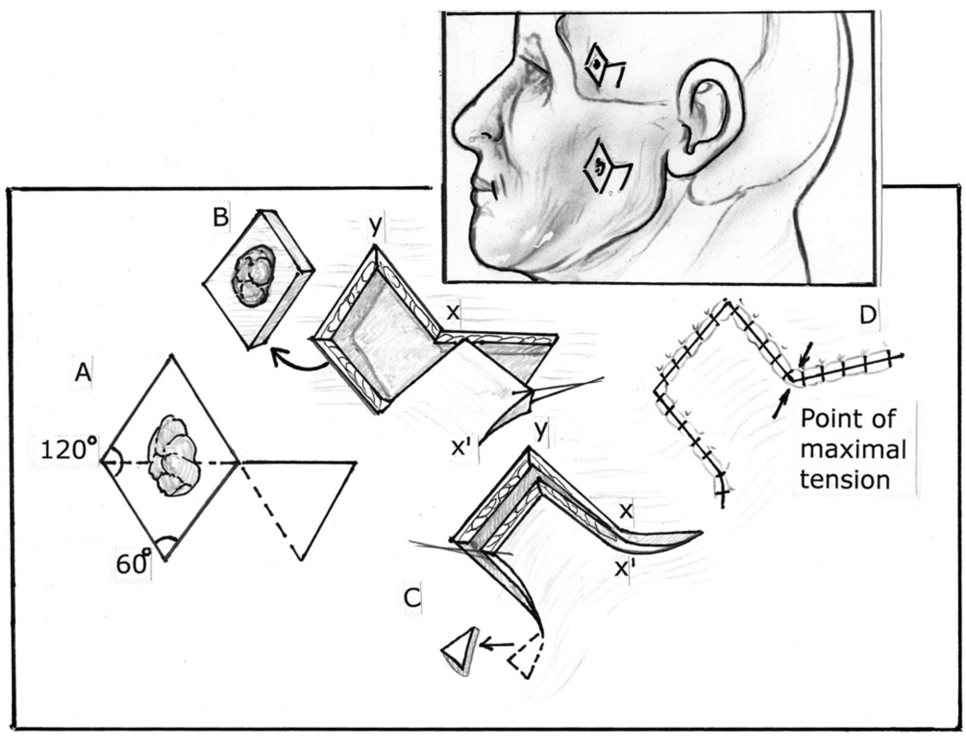


**Figure 5** Limberg rhombic flap. (A) The Limberg rhombic design is based on designing a rhombus around the defect with angles of 60 and 120 degrees. The flap designed for closure extends off the 120-degree corner with an additional limb drawn parallel to the closest edge of the rhombus. (B) Once the rhombus defect is excised, the transposition flap is elevated. x and $x_1$ will be juxtaposed for closure and represent the point of maximal tension on the closure. (C) The flap is transposed and the standing cone deformity is excised with a Burow's triangle excision. (D) Incisions remaining after the closure of the defect. The arrows represent the point of maximal tension on the closure. (Adapted from Baker[3].)

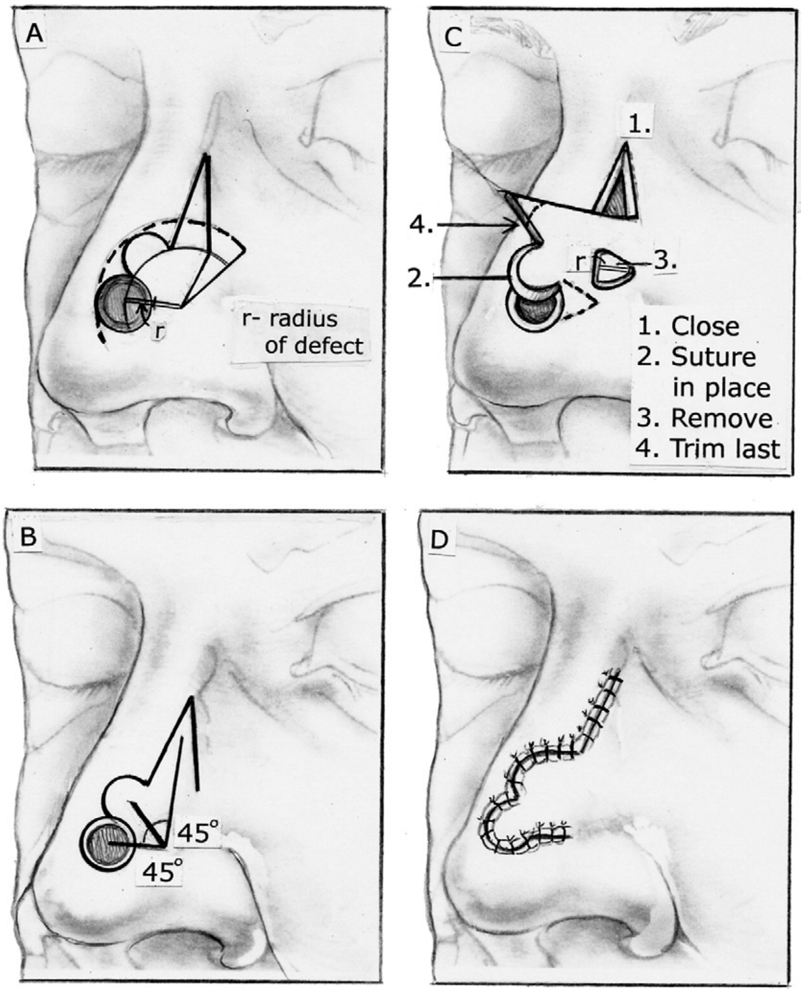


**Figure 6** Schematic drawing of a Zitelli bilobe flap. (A) Design of the bilobe begins with drawing two arcs. One arc equals two times the radius (r) of the defect with the arc passing through the center point of the defect site (thin dotted arc). The second arc equals three times the radius (r) passing along the outer edge of the defect (thick dotted arc). Both arcs originate from the same point. The bilobe is drawn with the first lobe equalizing the same width of the defect and extending its borders to the edge of the second arc. The second lobe is drawn in a cone shape with the diameter less that the first lobe and the height twice the length of the first lobe. (B) The axis of the defect and the two lobes of the flap are 45 degrees apart. (C) The bilobe flap is transposed into the defect site. The defect from the second lobe is closed first, followed by approximating the edges of the bilobe flap into the defect site. Third, the standing cone deformity created at the base of the first bilobe may be excised and lastly the excess tissue at the tip of the second bilobe may be trimmed. (D) Residual incisions remaining after closure of the defect. (Adapted from Baker.[3])

**Table 6** Reconstructive ladder

- Healing by secondary intention
- Primary closure
- Delayed primary closure
- Skin grafts
  - Split-thickness skin graft
  - Full-thickness skin graft
- Tissue expansion
- Local tissue transfer
  - Random
  - Axial
- Distant pedicled tissue transfer
- Free flap

**Table 7** Facial landmarks

| Nondistortable landmarks | Tissue good for recruitment |
|---|---|
| - Hairline | - Forehead (tight skin) |
| - Eyebrow | - Cheek (lax skin) |
| - Eyelid and canthi | - Chin |
| - Nasal tip | - Submenton |
| - Nasal ala | - Neck (lax skin) |
| - Earlobe | |
| - Philtrum | |
| - Vermilion | |
| - Oral commissure | |

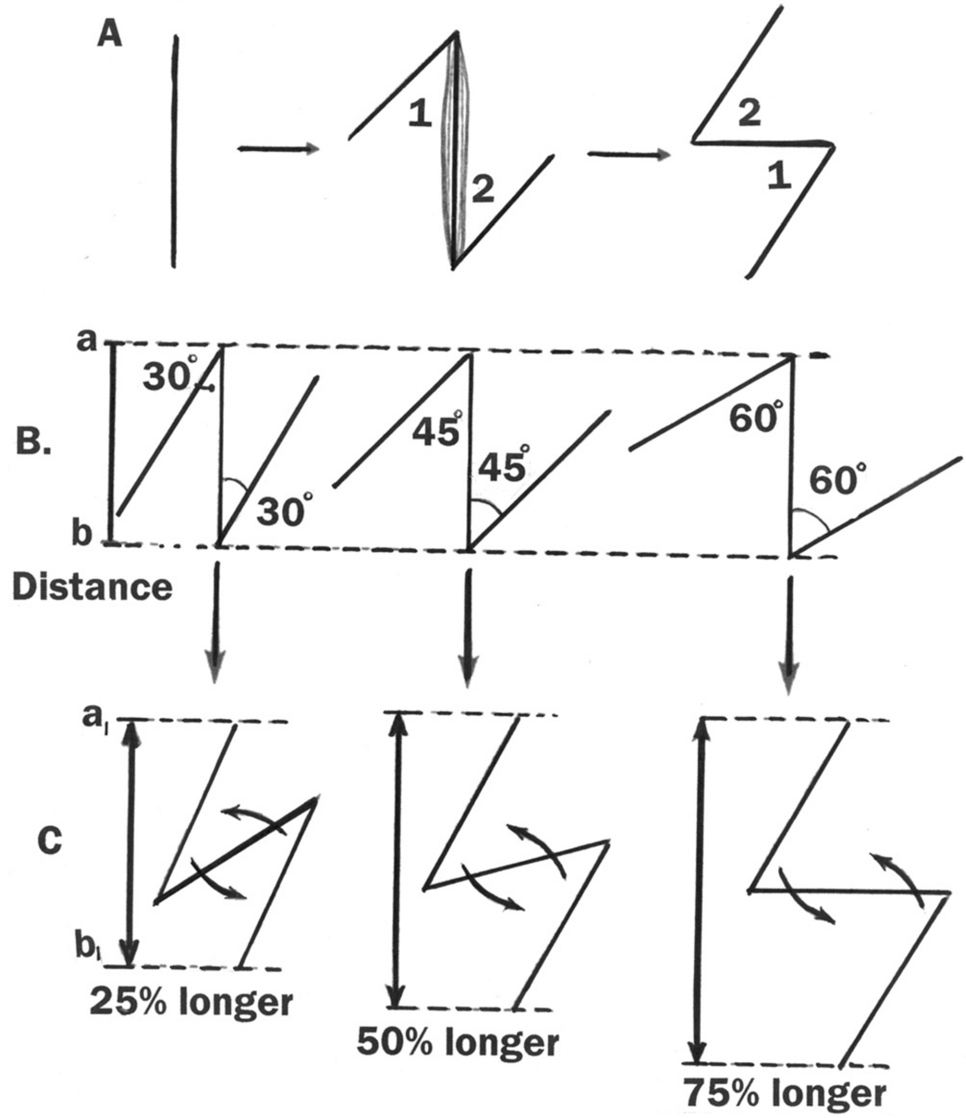


**Figure 7** Schematic of a Z-plasty transposition flap. (A) Single Z-plasty flap is composed of three limbs. Classically, the central limb contains the area that scar tissue is excised. The two limbs along the edges of the central limb are equal in length and drawn at equal angles from the central limb. This creates two equal 0 sized triangles (1 and 2) that are elevated and transposed. This reorients the tissue and lengthens the height of the scar. (B) Depending on the angle that the outer limbs are drawn from the central limb, the height of the scar (A to B) is lengthened ($A_1$ to $B_1$). Classically, angles of 30 degrees increase the height of the scar by 25%, angles of 45 degrees increase the height of the scar by 50%, and angles of 60 degrees increase the height of the scar by 75%. Ideally each limb should at least be 1 cm. (Adapted from Murakami and Nishioka.[4])

Classification of flaps provides a clear understanding of the flap properties. However, with so many reconstructive options, choosing the correct reconstructive plan relies on a systematic approach to analyzing the patient and facial defect.[11] Below are key points that aide in organizing and optimizing reconstructive planning (Table 5).

1. Analyze the facial defect and characterize the defect based on skin color, skin thickness, tissue composition, location, and subunits involved[12,13] (Figure 9). If the defect involves greater than 50% of the subunit, resection of the entire subunit may allow for improved aesthetic outcomes by camouflaging the incisions at the borders of the esthetic subunits. Composition is especially important when dealing with full thickness defects of the eyelid, nose, and lip. Define the composition with respect to existence of an internal layer (such as conjunctiva or mucosal lining), structural layer (which may be represented by muscle, cartilage and/or bone), and external skin layer. Failure to reconstruct all layers ultimately results in collapse or retraction of the original reconstruction. Therefore, all layers absent must be reconstructed to receive optimal functional and aesthetic outcomes.
2. Once the defect has been well characterized, options for reconstruction can be considered using a graduated approach (Table 6). The reconstructive ladder represents techniques used to close defects that become progres-

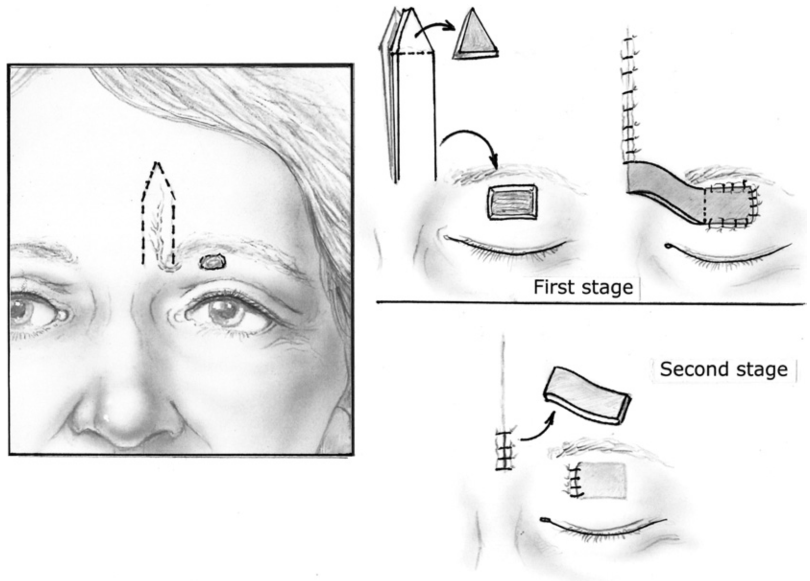


**Figure 8** Schematic of an interpolated flap. The first stage demonstrates that the base of the interpolated flap is not shared with the defect site. The flap is elevated and passed over a complete bridge of skin to lie within the defect. The defect created by the elevated flap is also closed. The second stage involves excising the pedicled tissue that was overlapping the intact skin bridge. (Adapted from Baker.[3])

sively more complex. The ladder from simplest to most complex is healing by secondary intention, primary closure, skin grafting, tissue expansion, local tissue transfer, distant tissue transfer, and free flap. The character of the defect, including composition and thickness, should be considered to determine the most appropriate match for reconstruction. It is important to create more than one plan for closure to allow for unpredictable findings during surgery.

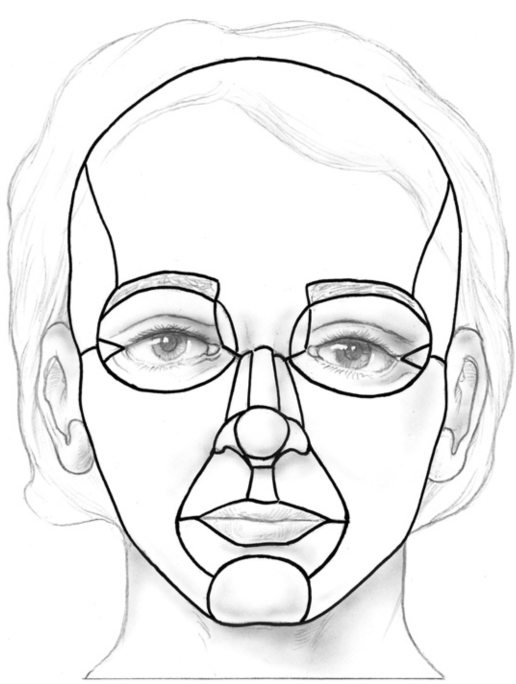

**Figure 9** Schematic drawing of the aesthetic subunits of the face. For optimal camouflaging, planned incisions should rest along the subunit edges.

3. When designing the surgical options for reconstruction, it is crucial to consider the surrounding anatomy. Determine acceptable areas of tissue recruitment and respect facial landmarks that do not tolerate distortion (Table 7). Landmarks that should not be distorted include hairline, eyebrow, eyelid and canthi, nasal tip, nasal ala and alar rim, earlobe, philtrum, vermilion, and oral commissures. Areas that provide a good source of tissue for recruitment include the forehead, cheek, chin, submenton, and neck.[11]
4. Once the ideal areas for tissue recruitment have been chosen, flaps should be designed such that the scars rest within the relaxed skin tension lines and close parallel to the lines of maximal extensibility[14] (Figure 10). Incisions designed along subunit borders will fall within the relaxed skin tension lines. Ideal borders to camouflage scars include the melolabial creases, supratarsal creases, mental crease, philtral crests, vermilion borders, and anterior hairline.
5. It is important to consider the patient's medical condition while formulating the reconstructive plan. History of radiation, immunocompromise, diabetes, and smoking increase complication risks of the reconstruction. Therefore, in the setting of compromised tissue, opt for improved survival over improved esthetic outcomes. This often translates into using reconstructive options lower in complexity on the reconstructive ladder. Following these key steps will allow for an organized approach in designing reconstructive plans for facial defects.

In summary, facial reconstruction relies on the creativity of surgeons as well as a clear understanding in the properties of local flaps. Choosing the correct procedure begins with thorough analysis of the defect. Multiple reconstructive options often exist, which can then be narrowed and refined

**Figure 10** Schematic drawing of relaxed skin tension lines (RSTL) of the face. Lines of maximal extensibility run perpendicular to the RSTLs. (Adapted from Baker.[3])

based on the specific qualities of the defect and the history of the patient. Careful planning ultimately leads to an excellent functional and esthetic reconstructive outcome.

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