1 General Considerations

The skin is the outer covering of the entire external surface of the human body. It is regarded as the largest organ of the body with a complicated structure that performs a great number of functions. It acts as a protective barrier preventing the internal environment against infection, trauma, ultraviolet radiation, and heat. In addition, it plays an important role in thermoregulation, stores water and fat, prevents and controls fluid loss, and constitutes the largest sensory organ.

1.1 Skin Anatomy

The skin exhibits a surface area that in the adult ranges from 1.6 to 2.0 m^2 with the surface area of head and neck in the adult occupying approximately the 9 %. Its thickness varies among gender, age, and anatomic location. Male skin is thicker than female skin in all anatomic regions. The skin becomes thinner in elderly individuals through changes that occur during the aging process. The thickest skin is found on the palms of the hands and soles of the feet and the thinnest on the eyelids. This depends primarily in the varying thickness of the dermis and in a lesser degree in the varying thickness of the epidermis.

Throughout the anatomic regions, the characteristics of skin vary significantly not only in thickness but also in color and in texture. All these characteristics constitute factors that have to be scrutinized when choosing the ideal donor site of a flap.

The skin consists of two interrelated layers, the epidermis and dermis, which along with the underlying subcutaneous fatty layer cover the entire body (Fig. 1.1).

1.1.1 Epidermis

The epidermis is the outermost thin layer of the skin. Its mean thickness is 0.1 mm but varies greatly, depending upon the type of skin, age, gender, and location. At the palms of the hands and the soles, it is 1.6 mm thick, while it can become very thin like in the eyelids where it is 0.04 mm. The epidermis is a stratified squamous epithelium consisting of five distinct layers. These layers from top to the bottom are the stratum corneum, the stratum lucidum, the stratum granulosum, the stratum spinosum, and the stratum basale. The epidermis contains primarily keratinocytes in progressive stages of differentiation. Starting from the cells of the stratum basale (basal cells), new keratinocytes are formed (squamous cells), through continuous mitosis, maturate, and move up, changing shape and composition. They replace the old ones that are dead and discarded. This process is called keratinization. Specialized epidermal cells as melanocytes, Merkel cells, and Langerhans cells are also contained in the epidermis. The epidermis contains no blood vessels, and its deepest layers are nourished by diffusion from the underlying dermis.

1.1.2 Dermis

The dermis consists of connective tissue and is tightly connected to the overlying epidermis through the basal membrane. It is much thicker than the epidermis (15–40 times) and also shows a variable thickness in different locations (e.g., 0.3 mm on the eyelid). The structural components of the dermis are primarily collagen and also elastic and reticular fibers. It is divided into a superficial region called the papillary and a deep region called the reticular dermis.

The upper papillary dermis contains a thin random arrangement of collagen fibers. The deeper reticular dermis is thicker and is made of coarse collagen fibers that are arranged parallel to the surface of the skin. The dermis contains capillaries at the papillary dermis and larger blood vessels at the reticular dermis, lymphatic vessels, hair follicles with the erector pili muscle attached to each follicle, sebaceous and sweat glands, nerve endings, and sensory

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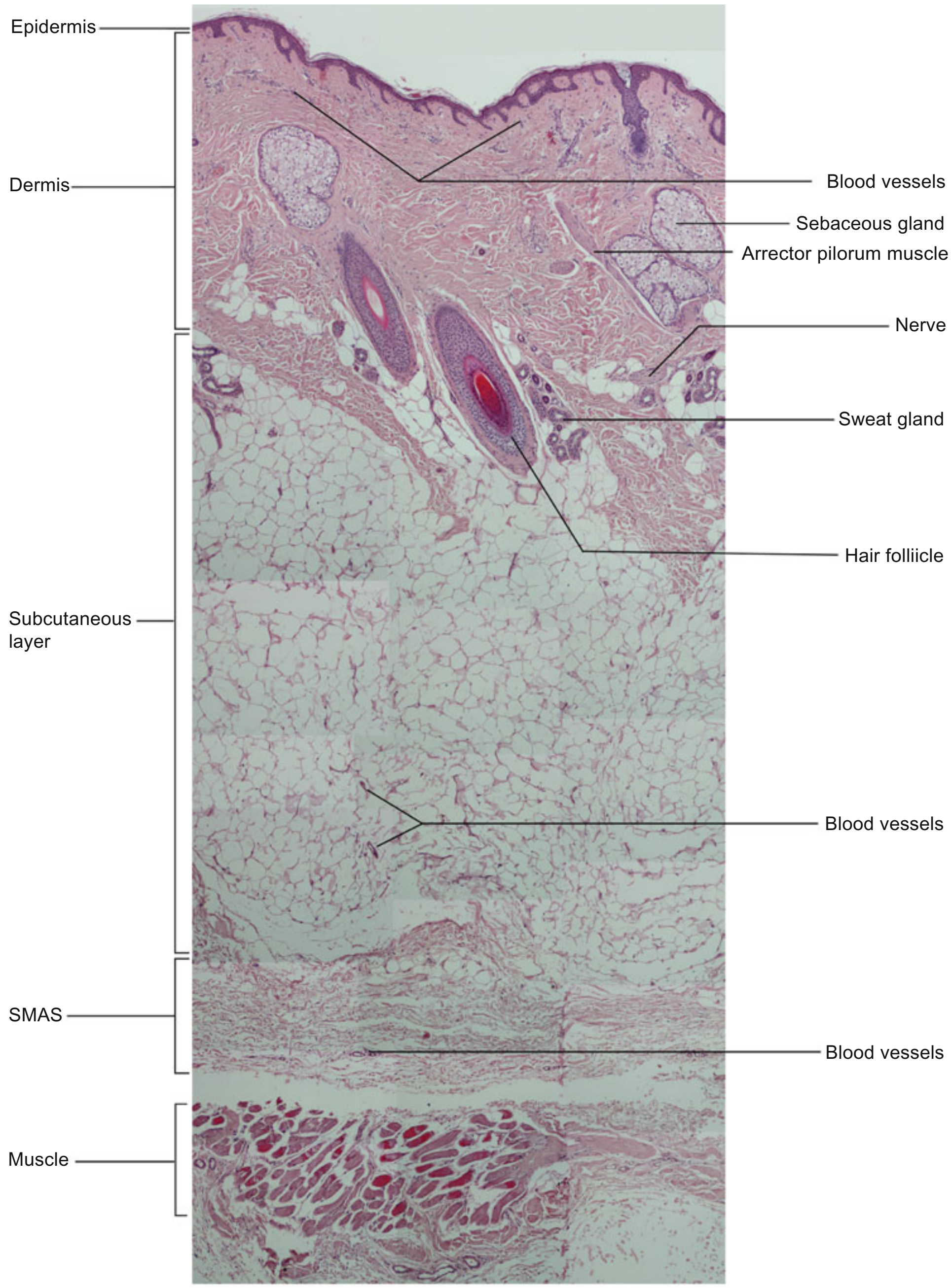


Fig. 1.1 Histologic cross section of the skin (cheek area) (hematoxylin-eosin, original magnification ×10) (With kind permission from Dr. Aliki Fiska)

receptors. Sebaceous glands are encountered over the entire body but in large concentration in the face and the scalp. Sweat glands are absent at the lip vermillion.

Hair follicles change their orientation across different ethnic groups. It is important to know the organization of hair follicles when performing incisions into the skin so as to avoid the onset of alopecia. In Caucasians, the follicles are oriented at an angle with regard to the skin surface. In Africans the follicles are more horizontal and thus run parallel to the sin surface, whereas in Asians the follicles are vertical with regard to the skin.

1.1.3 Subcutaneous Layer

The subcutaneous layer (subcutis, hypodermis, panniculus adiposus), also called subcutaneous fat layer, lies below the dermis. It consists of fat (almost the half of the body fat) and connective tissue and contains larger blood vessels, lymph vessels, and nerves. This layer attaches the skin to the underlying muscles and bones, houses the large vessels and nerves that supply the skin, and plays an important role in regulating body temperature. Its thickness varies considerably from individual to individual and among the different facial areas at the

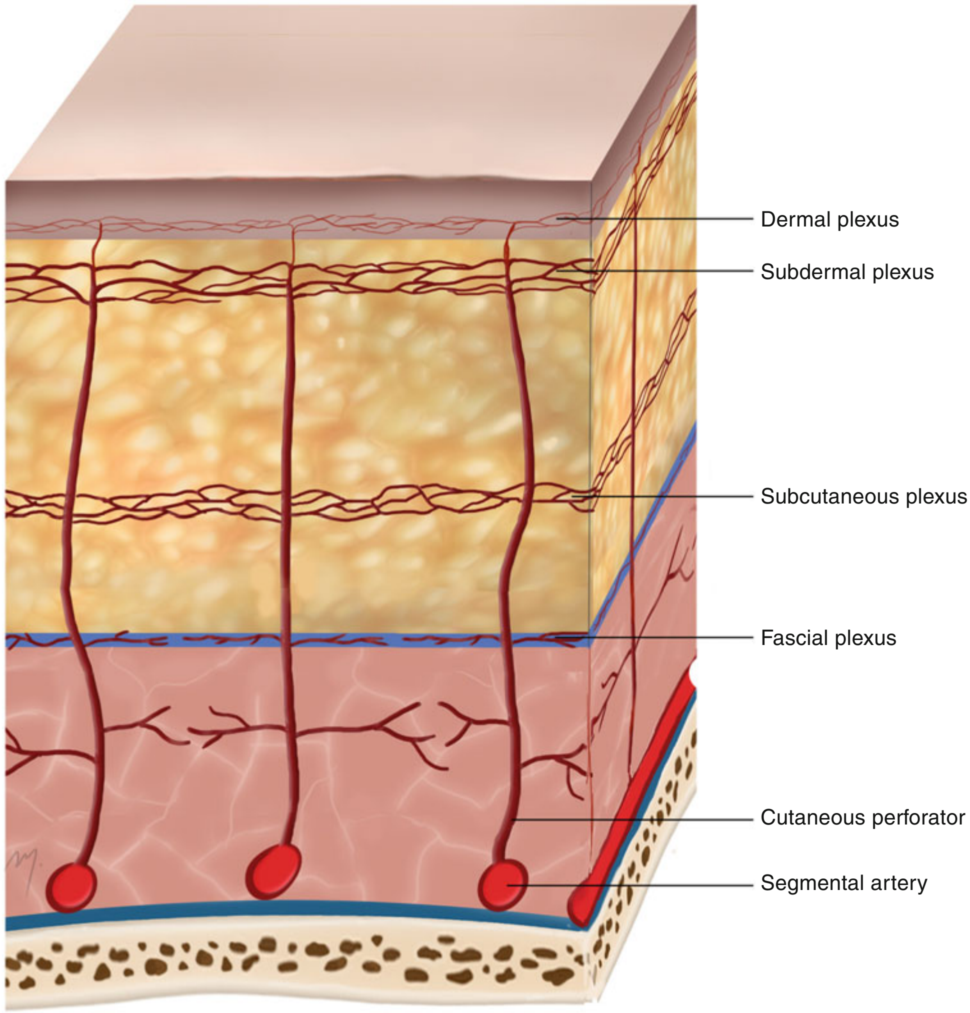


Fig. 1.2 The cutaneous circulation

same individual. It is thick at the cheeks and the neck but very thin or almost absent at the lips and the eyelids. The subcutaneous fat is divided into lobules by the fibrous septa, and in specific locations, it is sequestered in particular compartments forming the superficial fat pads (e.g., malar, submental).

1.1.4 Cutaneous Circulation

Knowing the skins' vascularization (Fig. 1.2) is crucial in the success of all flap designs due to the fact that flap survival is directly associated with adequate blood supply. The cutaneous vessels run from the underlying named vessels to the cutaneous surface as either septocutaneous or musculocutaneous arteries. The septocutaneous arteries (septocutaneous or fasciocutaneous perforators) arise directly from the underlying vessels and ascend through fascia or septa of muscles to the skin. The musculocutaneous arteries (musculocutaneous perforators) pass through the overlying muscle, and after giving small branches within the muscle mass, continue vertically to the skin. Named cutaneous vessels are direct vessels that run on top of muscles and parallel to the skin sending perpendicular branches to it. The portion of skin along with the underlying deep tissues that are supplied by a single segmental vessel, corresponding to a composite anatomic vascular territory, gave rise to the concept of angiosome that was first defined and introduced by Taylor and Palmer (1987).

Running toward the skin, the cutaneous vessels supply branches to each of the tissue layers they run through that anastomose each other forming extensive horizontal plexuses arranged in different levels in a complex network of blood vessels. The fascial plexus is formed at the level of the fascia, the subcutaneous plexus within the subcutaneous fat, and the subdermal plexus at the junction between the dermis and the subcutaneous fat. Within the dermis two plexuses are formed: the deep dermal plexus and the superficial dermal plexus just beneath the epidermis (subepidermal plexus, subpapillary plexus).

1.1.5 Relaxed Skin Tension Lines (RSTLs)

Any incision at the face that is placed within or parallel to certain skin tension lines offers the best cosmetic result and the narrowest scar line. These skin tension lines run horizontally in the midfacial zone changing to a vertical direction laterally. These lines generally run parallel to the dermal collagen bundles but perpendicular to the underlying muscle fibers.

The relaxed skin tension lines (RSTLs) (Fig. 1.3) are those skin tension lines that follow the furrows formed when the skin is relaxed, and as they are not visible, they are generated by the act of pinching the skin and observing the furrows and ridges that are formed (Borges and Alexander 1962). The lines of maximal extensibility (LMEs) represent the directions in which the skin can be advanced with the greatest ease and run perpendicular to the RSTLs.

The historically used Langer's lines were first described by Karl Langer, Ritter von Edenberg (1819–1887) an Austrian anatomist who at 1861 observed the lines produced by driving round pins into cadaveric skin (Langer 1861). As they represent the skin tension lines in rigor mortis, they do not always correspond with the RSTL lines (Borges 1984).

In contrast to the RSTLs, the wrinkle lines (rhytids) are visible features of the skin that correspond in most cases with RSTLs (and on occasion, with the exception of the glabella and temple). As skin ages it becomes more lax and supple, and wrinkles become more numerous and obvious, in contrary to the smooth and with almost obscure wrinkles in young skin, enhancing the places to camouflage an incision. A flap must be orientated so as its incision lines lie into the skin tension lines.

The skin of the face has been divided into units with similar skin color, texture, and thickness, the facial aesthetic units (Gonzalez-Ulloa et al. 1954, Gonzalez-Ulloa 1956). These facial aesthetic units correspond in a way also to the anatomic facial regions and as a general rule when possible flaps must be donated from the same aesthetic unit where the defect is located. Moreover when the planned incisions are placed at the boundaries of a subunit, the scars are camouflaged in a favorable way. The facial aesthetic units have been further subdivided into subunits introducing the "subunit principle" as approach in the reconstruction of face (Sherris and Larrabee 2010).

Fig. 1.3 Relaxed skin tension lines (RSTLs) of the head and neck

1.2 Types of Flaps

The flaps are classified in various ways. Firstly they are distinguished by the site of their origin and secondly by the distance of the donor site from the recipient site as local, regional, and distant flaps. According to their composition and the tissue type, they are classified as cutaneous, fasciocutaneous, musculocutaneous, osteomusculocutaneous, muscle, and bone flaps.

The most common classification of skin flaps is related to their blood supply and the method of tissue movement.

1.2.1 Flap Types According to Blood Supply

According to the way that blood vessels enter into the flap at its base, the flaps are distinguished in axial pattern and random pattern flaps.

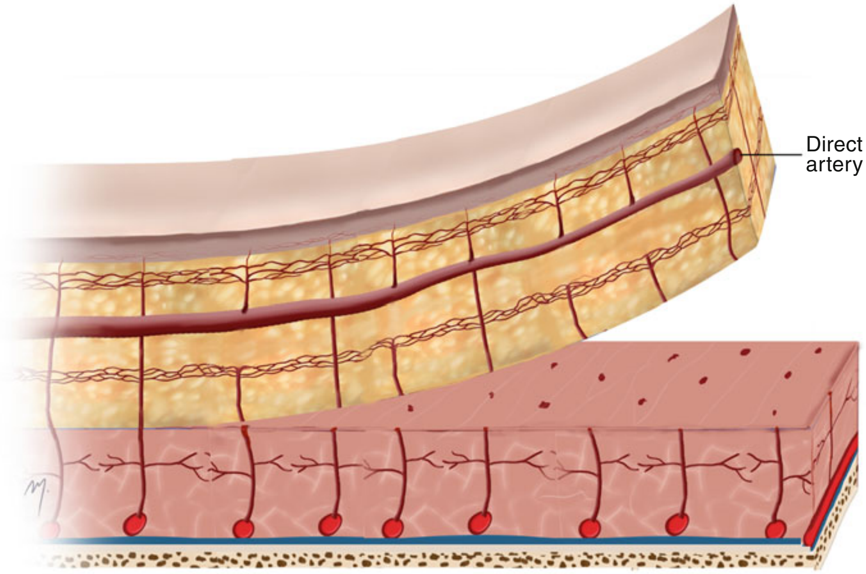


Fig. 1.4 Axial pattern flap

1.2.1.1 Axial Pattern Flaps

The axial pattern flaps (Fig. 1.4) are supplied by a named direct cutaneous (septocutaneous) artery and vein that is incorporated to the flap running along its long axis. This allows a large and long area to be freed from the underlying tissues with safety in a length at least equal to the length of the vessels, without obeying to the length to width ratio limitations of the random pattern flaps.

1.2.1.2 Random Pattern Flaps

The random pattern flaps (Fig. 1.5) are not based on named vessels but depend on the vascular supply of the subcutaneous and subdermal plexus fused from perforators at the base of the flap. Random pattern flaps of the face traditionally have been designed with a length to width ratio that must not exceed 3:1 to insure its survival. However, it is more likely that the survival of a flap does not depend solely on its length but the perfusion pressure and the intravascular resistance of their vascular constituents play a more significant role.

1.2.2 Flap Types According to the Method of Transfer

According to the method of transfer, the flaps are distinguished in the following general types.

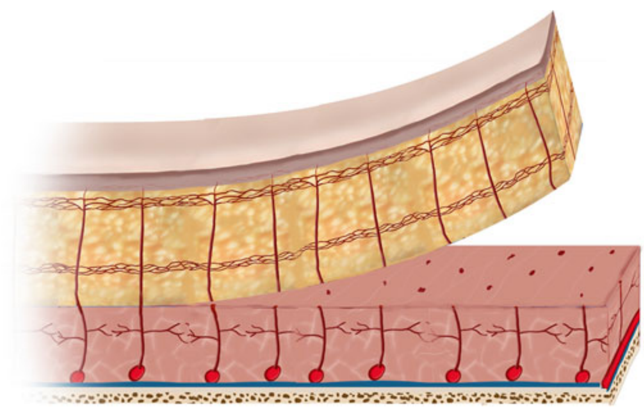


Fig. 1.5 Random pattern flap

1.2.2.1 Pedicle Flaps

The tissue to be transferred remains attached to the donor site through a pedicle, as a bridge of tissue, which ensures its vascular supply and depending on the flap movement and flap design they are subdivided into:

Advancement Flaps

The flap moves directly forward and is positioned into the defect.

Transposition Flaps

The flap moves laterally in relation to a pivot point and is positioned into an adjacent defect.

Rotation Flaps

The flap rotates around a pivot point and is positioned into an adjacent defect.

Many flaps combine more than one elements of transfer in their design. In these cases the predominant movement is used to describe the flap.

1.2.2.2 Free Flaps

The tissue to be transferred is fully detached, along with its vascular pedicle as an isolated artery and vein from the donor site, and is transferred to the recipient site where its blood supply is gained by rejoining the artery and the vein through microvascular anastomosis to a new vessel adjacent to the recipient site.

1.2.3 Specific Types of Pedicle Skin Flaps

1.2.3.1 Rotation Flaps

The defect is triangulated and the flap is classically a semicircle that rotates in an arc to reach the defect (Fig. 1.6). The rotation flap has a wide base where its pivot point is located. The defect must be triangulated into a narrow isosceles triangle of 30°.

In areas with enhanced tissue laxity (e.g., cheek, neck), the rotation flap can be designed as an arc with a length three to four times the width of the defect or even more depending on the laxity of the donor site (Fig. 1.7). A dog-ear that is most of times formed at the base of the flap is adjusted by the excision of a small Burow's triangle.

A specific type of rotation flap with a unique geometry, very effective for use at the highly inelastic scalp, has been designed by Worthen (1990) (Fig. 1.8). This converts the defect to an isosceles triangle with its apex no more than 30°. From one of the triangle sides, a projection line 1,5 times its length is outlined. This line plus the triangle side is the diameter of the semicircular flap that rotates to close the defect.

1.2.3.2 Advancement Flaps

The advancement flap, the most simple in design, is moved directly along a linear axis to the recipient size (Fig. 1.9a). Classically it has a length to width ratio of 2:1–3:1. Two Burow's triangles are excised at each lateral site of the flap base preventing standing cone formation.

Two advancement flaps facing opposite one another can share a larger defect in form of bilateral advancement flap (Fig. 1.9b)

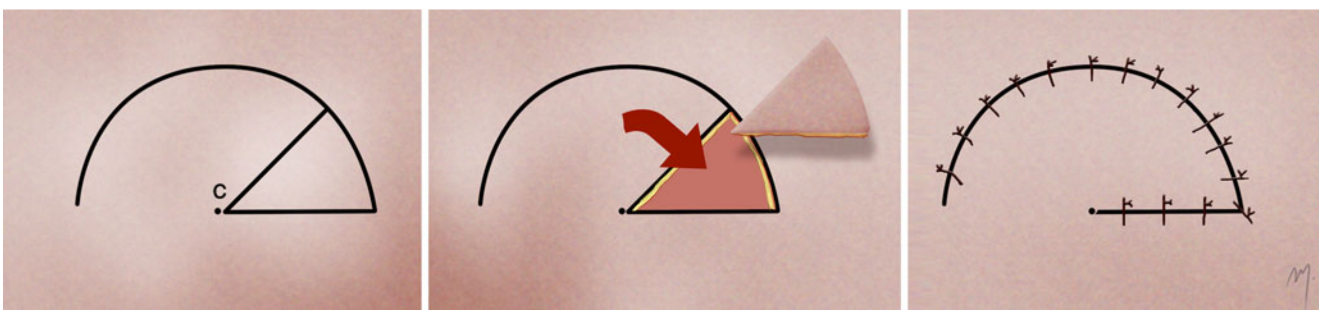


Fig. 1.6 Rotation flap designed as a semicircle

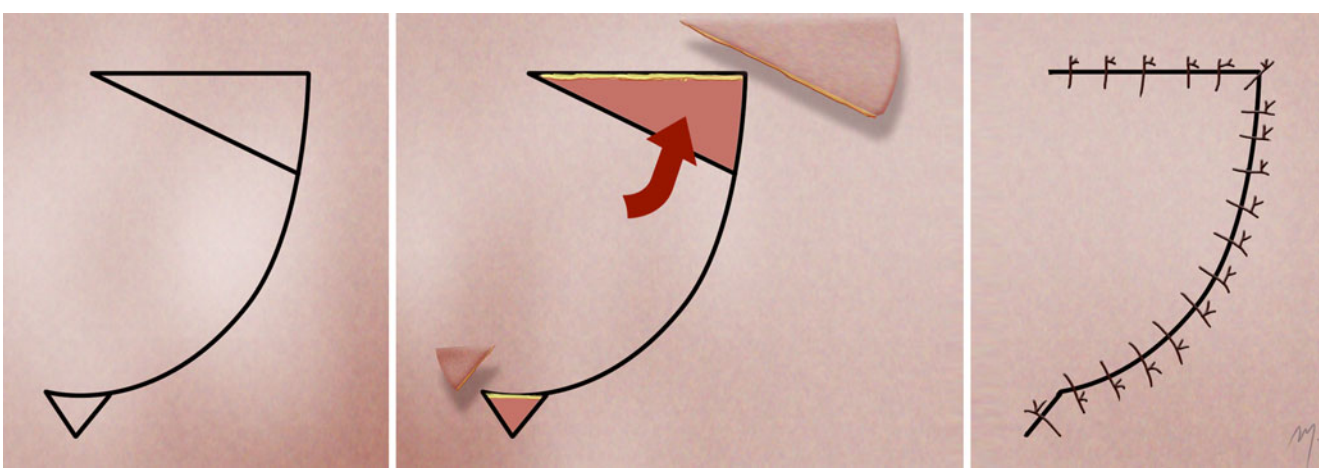


Fig. 1.7 Rotation flap designed as an arc

1.2.3.3 Island Pedicle Flap (V-Y Advancement Flap)

By this design the defect is rectangulated, and in one of its pleura, a triangular flap due to a V-shaped incision is designed (Fig. 1.10). The flap is elevated as an island, fully detached from its surrounding tissues, that is based only to its underlying subcutaneous tissue (island subcutaneous pedicle flap). It is advanced to the recipient site forming a Y-shaped suture line.

The island pedicle flap can be used as double when a larger area has to be reconstructed (Fig. 1.11).

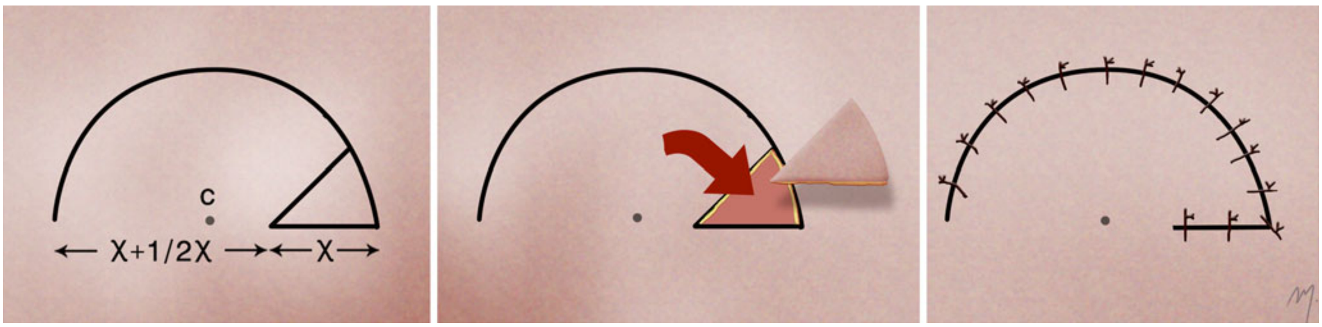


Fig. 1.8 Worthen rotation flap

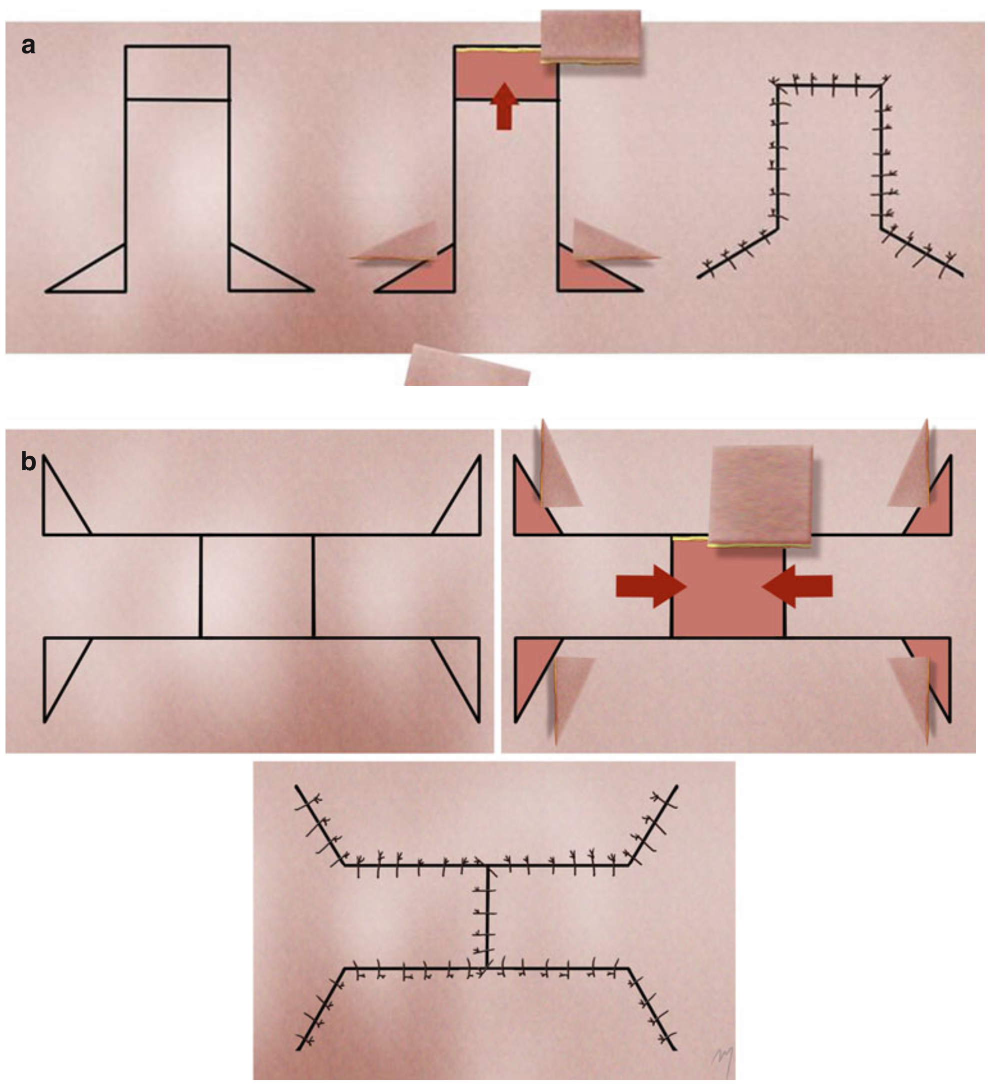


Fig. 1.9 (**a**) Advancement flap (**b**) bilateral advancement flap

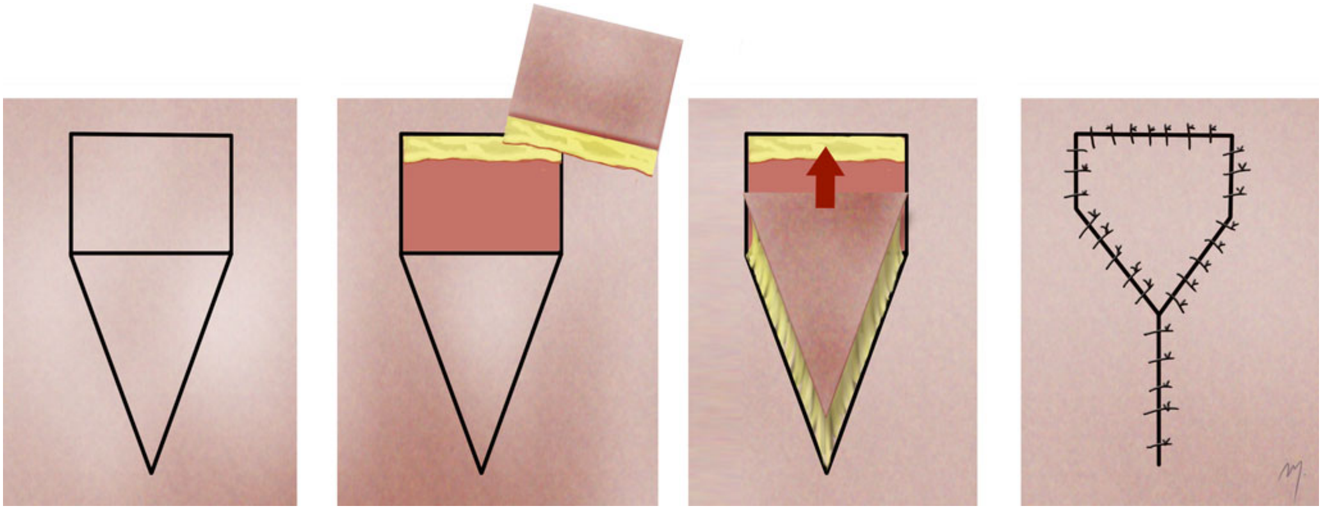


Fig. 1.10 Island pedicle flap

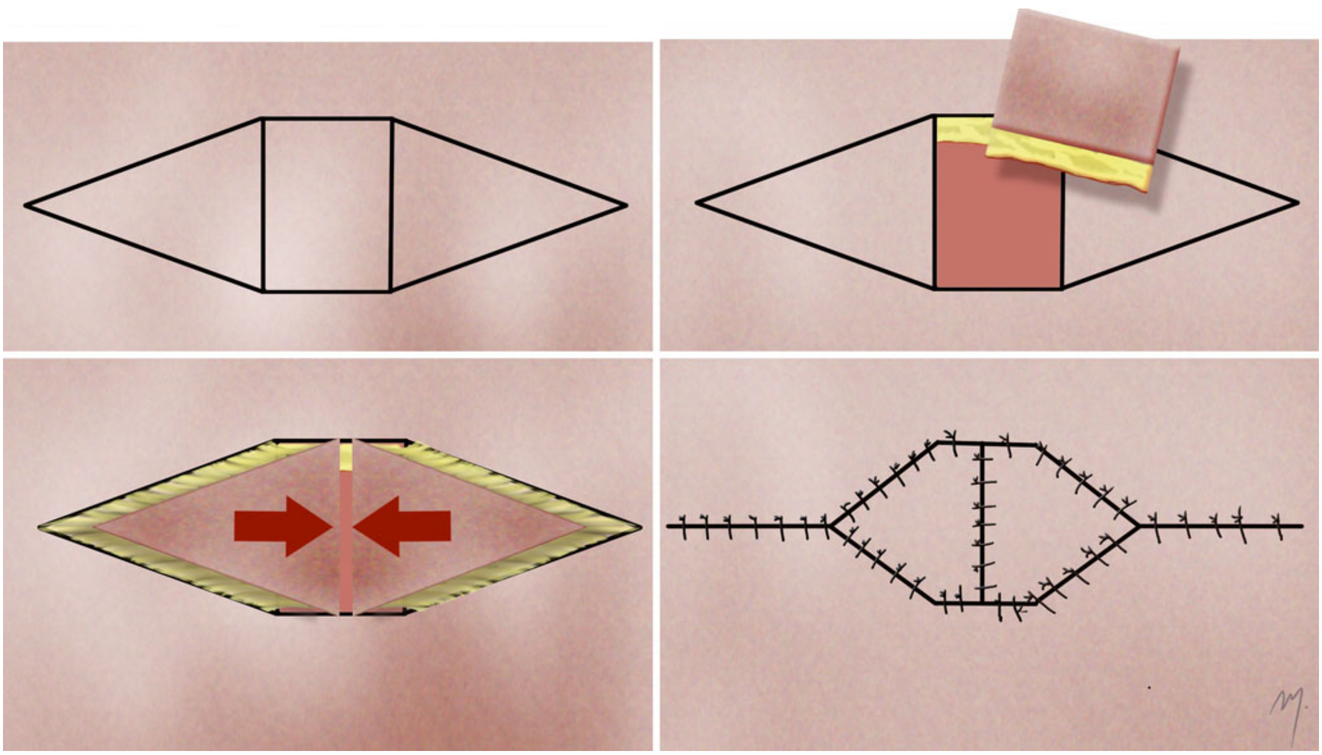


Fig. 1.11 Double island pedicle flap

1.2.3.4 Transposition Flap

The transposition flap is used to close an adjacent defect by moving laterally from its donor site, leaving thus a secondary defect, which must be closed. Depending on the surrounding tissue elasticity, the donor site defect may be closed primarily or may be closed by grafting (Fig. 1.12).

Interpolated flap is a transposition flap where the donor site not adjacent to the defect but intervening normal tissue separates the donor from the recipient site. The flap then passes over or underneath the intervening skin to reach the defect but still connected to the donor site via its vascular pedicle. In a second stage, after revascularization has formed, the pedicle is divided. Typical examples of widely used interpolated flaps in the head and neck reconstruction are the paramedian forehead flap and the deltopectoral flap.

1.2.3.5 Rhomboid Flap (Limberg Flap)

The rhomboid flap is a transposition flap with a strict geometrical design introduced by Limberg in 1946 (Fig. 1.13). The lesion is excised as a rhomboid with internal angles of 60° and 120°. The first side of the rhomboid flap is designed by drawing a line from the outer point of the 120° angle that

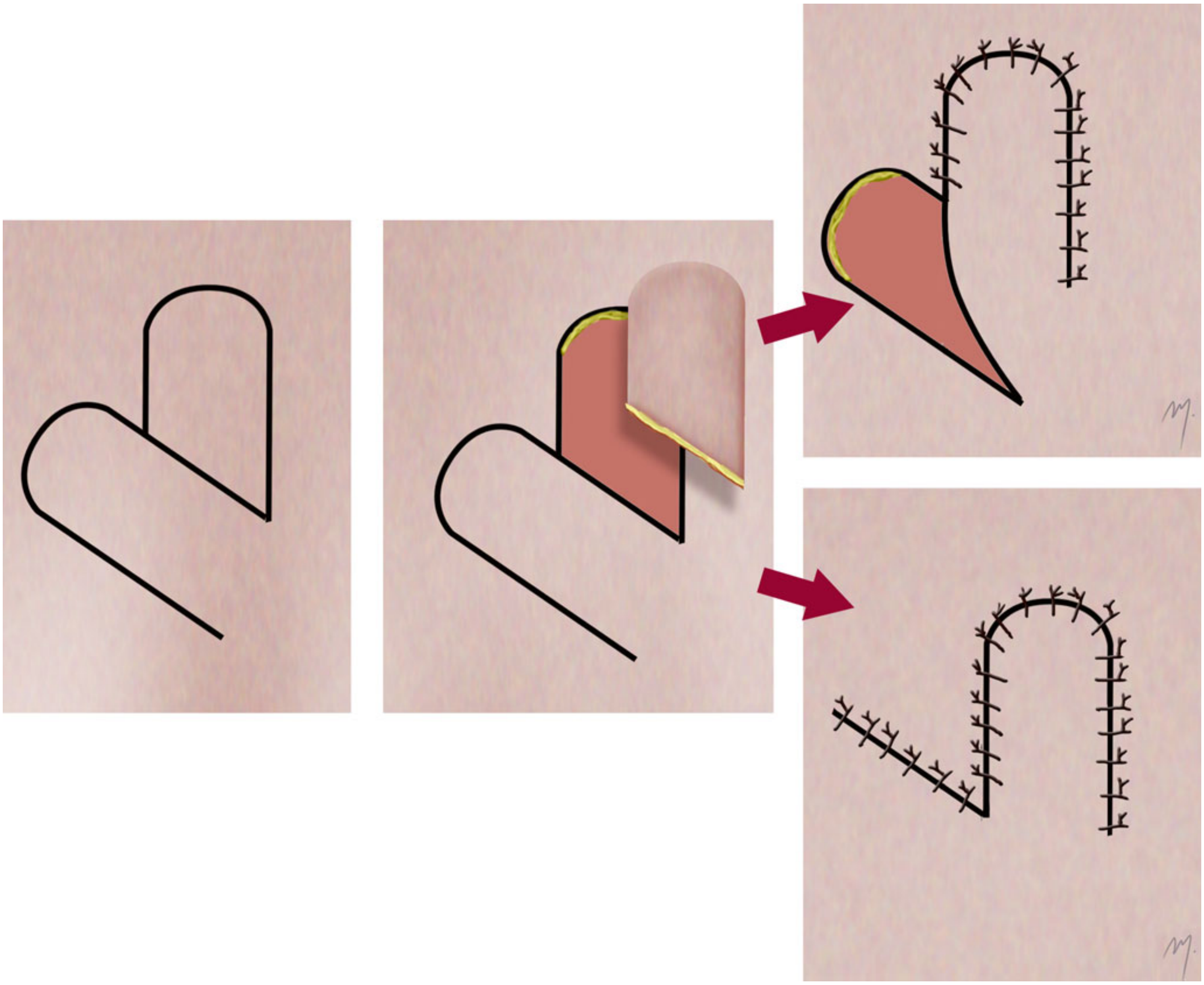


Fig. 1.12 Transposition flap

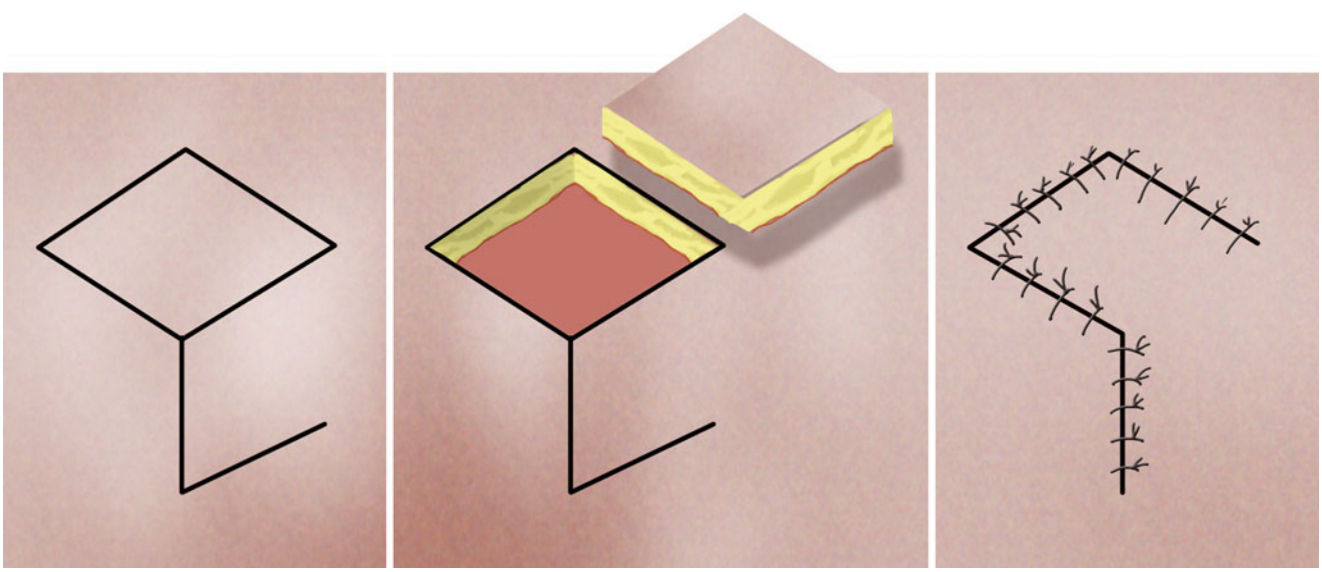


Fig. 1.13 Rhomboid flap

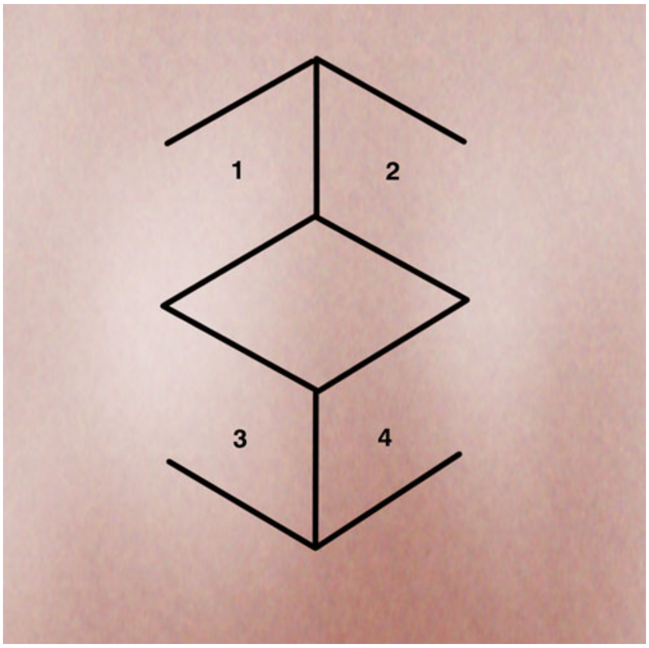


Fig. 1.14 Four potentially rhomboid flaps can be produced

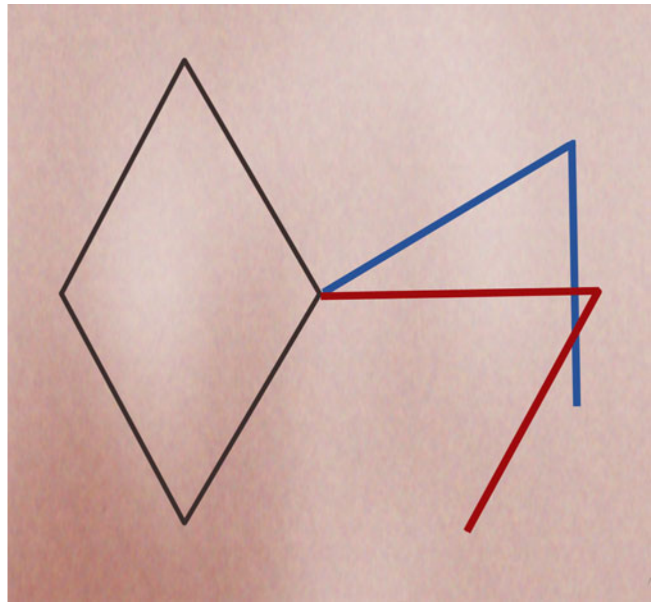
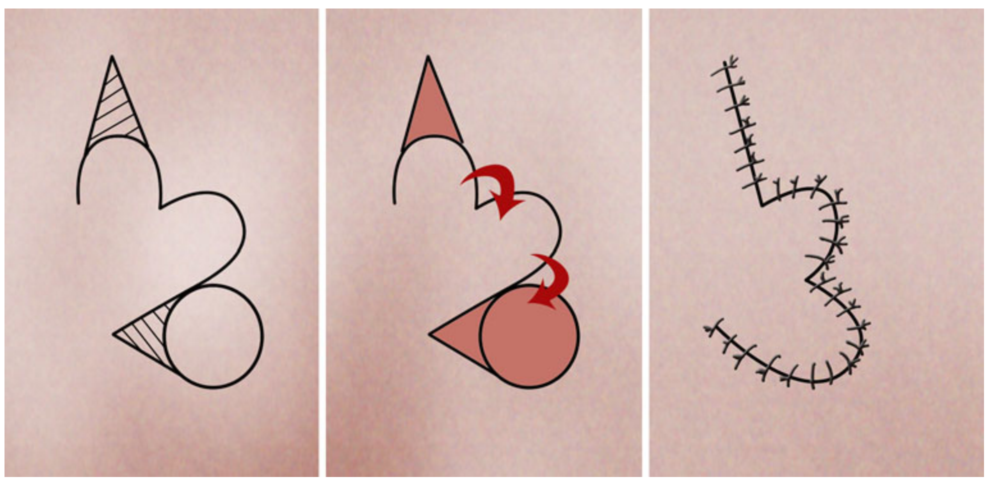


Fig. 1.15 Dufourmentel flap (*blue line*). Classic design of the rhomboid flap (*red line*)

Fig. 1.16 Bilobed flap



bisects the angle, and its length is equal to the rhomboid side. The second side of the flap is drawn from the outer point of the first side parallel and equal to the side of the rhomboid. An angle of 60° is thus produced at the apex of the rhomboid flap.

For each rhomboid defect, four possible rhomboid flaps can be designed (Fig. 1.14). Selection of the most appropriate one depends on location of the defect, the skin thickness of the donor site, and the orientation of the relaxed skin tension lines.

1.2.3.6 Dufourmentel Flap

Doufourmentel (1962) modified the classic Limberg rhomboid flap design changing the flap angles so as not to correspond to the 60–120° dimensions and widening the base of the flap (Fig. 1.15). This modification is suitable in a wider variety of defects, and closure of the donor site defect is much easier accomplished.

1.2.3.7 Bilobed Flap

The bilobed flap (Fig. 1.16) is a double transposition flap that was first described by Esser (1918) for nasal reconstruction.

The lesion is excised in a circular manner, and the bilobed flap is designed as two transposition flaps with a common pedicle. The first lobe of the flap is designed lying in an axis of 45–90° to the axis of the primary defect and at the same or slightly smaller size. This lobe will rotate to the primary defect creating a secondary one. The secondary defect will be closed with a second limb that is situated to an axis of 45–90° to the axis of the first limb and about half of its size. Thus, the total angle of transposition of the bilobed flap ranges from 90° to 180° (with a prevailing trend of 90°–100°). A Burow's triangle is outlined to be excised, at the point of rotation to the base of the flap. The excision of this triangle prevents the formation of the standing cone. A second smaller Burow's triangle is also excised at the distal part of the second limb, preventing a same dog-ear.

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