3 Forehead

The forehead is a prominent element that constitutes the upper face. In its midsection, it is slightly convex, flatters laterally, and becomes concave as it transitions to the temple.

The anatomic boundaries of the forehead (Fig. 3.1) are the anterior hairline superiorly and inferiorly the nasion, the glabella, and the eyebrows. The lateral ends of the eyebrows determine the lateral borders of the main forehead. The temporal area extends beyond this borderline.

The anterior hairline defines the upper limit of the forehead and is the boundary between it and the scalp, but in the presence of alopecia, it cannot be a stable landmark. In this case, the superior border is determined by the superior edge of the frontalis muscle.

The glabella is a bony structure in the smooth elevation between the superciliary arches. As forehead subunit, glabella is the smooth and hairless area between the eyebrows. However, during the aging process, transverse and vertical glabellar rhytides begin to appear.

The supraorbital rims are palpable along their whole length as a sharp prominence in the lateral two-thirds and rounded in the medial third. At the junction of the medial third and lateral two-thirds, the supraorbital notch can also be felt.

The eyebrows are two arched, hair-covered skin ridges lying over the supraorbital rims, protecting the eyes from flowing forehead sweat and sunlight. The position and contour of this minor forehead anatomic feature play a major role in the aesthetic appearance and must be taken into great account, to avoid its distortion when planning forehead flaps. Eyebrow shape and position change depending on gender. In males, the brow is more horizontal and thicker and is found in a lower position at the level of supraorbital rim. In females, the brow is more arched, thinner, and in a somewhat higher position, above the level of the supraorbital rim. Approximately 200–250 short and thick hairs (without having arrector pili muscles) are set in the eyebrows. The number of eyebrow hair remains almost stable during life, with the exception of older males where, during the aging process, growth of eyebrow hair increases. When making incisions to the eyebrow and elevating a flap in this area, it is very important to know the direction of the hair in order to cut parallel to them. In the medial eyebrow part, hair follicles are all directed superiorly; in the upper portion of the central and lateral parts of the brow, follicles are directed inferiorly; and in the lower portion, follicles are directed superiorly (Lemke and Stasior 1982). Muscle fibers insert into the dermis of the eyebrow, moving it in several directions. The eyebrow mobility is significant in creating the full range of emotional expressions of the face. The frontalis muscle acting as a brow elevator achieves these movements, while the antagonistic procerus, corrugator, orbicularis oculi, and depressor supercilii act as brow depressor muscles.

Fig. 3.1 Boundaries of the forehead

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3.1 Layered Anatomy of Forehead

The forehead could be considered as the hairless frontal elongation of the scalp. Being an anatomic continuity of the scalp, it consists of the same five distinct layers: the skin, connective subcutaneous tissue, galea aponeurotica, loose areolar connective tissue, and periosteum (Fig. 3.2).

3.1.1 Skin and Subcutaneous Tissue

The skin and subcutaneous tissue of the forehead (first and second layer, respectively) are very firmly attached, and therefore it is very difficult to work with it individually from a surgical perspective.

The forehead skin, rich in sebaceous and sweat glands, is one of the thickest skins of the face with an average thickness of 2.4 mm. It varies from one individual to other but also changes by age and sun exposure. The skin of the forehead decreases progressively in thickness and sebaceous gland concentration, when moving from the suprabrow area toward the anterior hairline. This occurs in the same manner in the temporal region when moving from the lateral canthus to the scalp hairline. The central forehead skin is densely adherent to the abundant underlying subcutaneous tissue forming a soft tissue layer that is relatively thick, rigid, and minimally mobile. From the medial to lateral regions, the mobility increases. In the temporal area, the connections are loose, to the underlying temporalis fascia, which results in enhanced skin mobility over this area. Thus, the lateral forehead temporal region may act as a tissue reservoir for reconstruction of more medially located defects (Vuyk 2006; Sykes 2009).

The relaxed skin tension lines (RSTLs) on the forehead run horizontally slightly curving in a vertical direction laterally. At the glabellar region, they are vertically oriented (Fig. 3.3).

The subcutaneous tissue is richly vascularized containing a homogenous layer of adipose tissue. The subcutaneous fat of the forehead attaches to the underlying galea aponeurotica by fibrous septa, which contain vessels, nerves, and lymphatics. Also numerous transverse fibrous septa from the frontalis muscle to the dermis are found within this layer in the forehead (Sykes 2009). These septa are partially responsible for the deep, horizontal forehead lines providing excellent camouflage of scars (Seline and Siegle 2005).

3.1.2 Epicranial Aponeurosis-Forehead Muscular Layer

3.1.2.1 Galea

The epicranial aponeurosis named also galea or galea aponeurotica, as mentioned in the previous chapter, is the thin tendinous sheet of connective tissue that encompasses the entire dome of the skull, joining both the paired frontalis and occipitalis muscles. The galea at the forehead joins the two

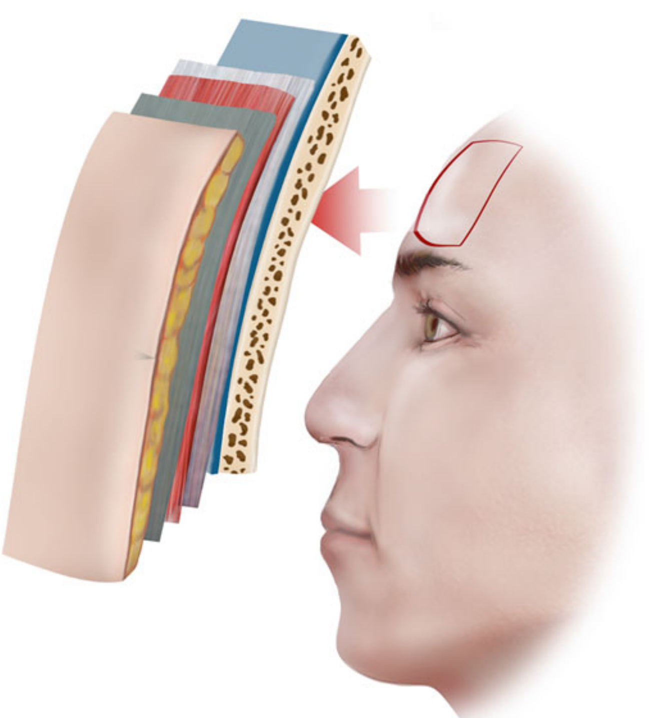


Fig. 3.2 The forehead consists of the same five layers of the scalp

Fig. 3.3 Relaxed skin tension lines (RSTLs) at the forehead

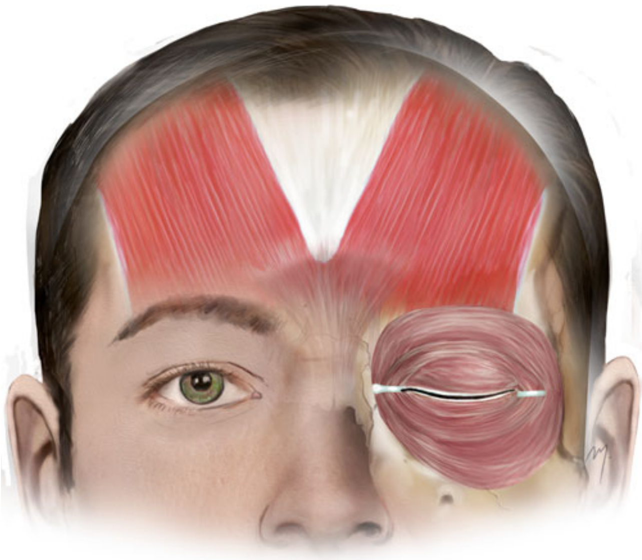


Fig. 3.4 Galea and frontalis muscle

frontalis muscles but also fills the gap between them sending a short, narrow prolongation between their two bellies (Fig. 3.4). On its course from the upper to the lower forehead, the galea splits several times in various layers, which reunite again to the supraorbital margin (Tarbet and Lemke 1997; Knize 2001, 2007; Sykes 2009). In actuality, the galea is the fibromuscular extension of the superficial musculoaponeurotic system (SMAS), which becomes continuous with the temporoparietal fascia in the temple (Mitz and Peyronie 1976). The galea is loosely connected to the underlying pericranium by the layer of loose areolar connective tissue enabling it to be mobile, thus moving and sliding freely over the pericranium.

As the galea passes into the upper forehead, it splits into two layers, the superficial galea layer and the deep galea layer which encompass the frontalis muscle.

The superficial layer of galea is thin and lies anteriorly to each frontalis muscle. It covers the surface of the frontalis muscle and continues over the surface of the orbicularis oculi muscle, as a single, filmy layer.

The deep layer of galea is thicker than the superficial and lies under the muscle. As the deep galea layer runs to the supraorbital area, it splits again and envelops a fat pocket, the retro-orbicularis oculi fat (ROOF).

3.1.2.2 Forehead Muscular Layer

The muscular layer of the forehead is composed of frontalis, procerus, corrugator supercilii, depressor supercilii, and the orbital part of the orbicularis oculi muscles. These muscles are arranged in three levels: the superficial level (frontalis, procerus, and orbicularis oculi muscles), the intermediate level (depressor supercilii muscle), and the deep level (corrugator supercilii muscle).

3.1.2.2.1 Frontalis Muscle

The paired frontalis muscles are the frontal parts of the two occipitofrontalis muscles. The frontalis muscles are thin, quadrilateral, and broader with longer fibers than the occipital part that extend from the anterior edge of the epicranial aponeurosis to the eyebrow (Fig. 3.4). The two bellies of the frontalis muscle are placed symmetrically and are vertically oriented, but they leave the mid-forehead region free of muscle fibers. The superior side of the muscle, which is its origin field, lies adjacent to the coronal suture line of the skull. The lateral side of the muscle extends slightly more cephalad than the medial side, and the lateral margin of frontalis muscle is thinner along the superior temporal line (Knize 1996a, b).

The frontalis muscle has no bony attachments and originates from the anterior edge of galea aponeurotica. Its muscle fibers extend toward the supraorbital rim where they merge with those of the adjacent muscles, entering the deep orbicularis oculi muscle surface. The medial fibers of the frontalis blend with those of the procerus muscle. Under the brow, the lateral fibers of the frontalis muscle interdigitate with the corrugator supercilii and the orbital portion of orbicularis oculi muscles.

The insertion of the frontalis muscle fibers represents more of a blend with the other muscle fibers than a direct dermal insertion.

Frontalis muscle receives its arterial supply from branches of the superficial temporal supraorbital and supratrochlear arteries and is innervated by the temporal branches of the facial nerve from its undersurface.

The frontalis muscles, with its fibers offering no true bony insertion but blending with neighboring muscles, are the primary elevators of the brow. Acting from above, they raise the eyebrows and the skin over the root of the nose (expression of surprise, fright, horror). These muscles are antagonistic to the brow depressor muscles (procerus, corrugator, orbicularis oculi, and depressor supercilii), which do have real bony insertions. Acting from below, they draw the scalp forward. Due to the multiple attachments of the vertically oriented fiber septa to the dermis of the forehead skin, they are responsible for the formation of horizontal forehead rhytides. Acting alternately with the occipital muscles, they move the entire scalp backward and forward.

3.1.2.2.2 Procerus Muscle

Procerus is a vertical, flat, thin, and pyramidal shape muscle (Fig. 3.5). Although the procerus belongs anatomically in the

Fig. 3.5 Procerus muscle

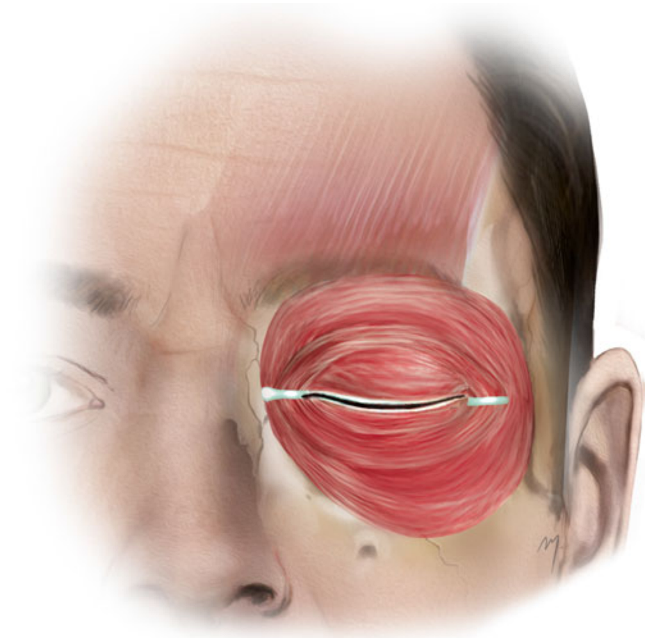


Fig. 3.6 Orbicularis muscle

group of nasal musculature, functionally it is much more a forehead muscle, involved in eyebrow movement.

It originates at the nasal bone and arises from the tendinous fibers attached to a fibrous fascia that covers the lower part of the nasal bones, the upper part of the lateral nasal cartilage, and the aponeurosis of the transverse part of nasalis (Keller and Mashkevich 2009). All these anatomic elements from where procerus originates are parts of the nasal SMAS (see Chap. 4). The muscle courses superiorly with its fibers oriented vertically, medial to the depressor supercilii muscle and the medial head of the orbicularis oculi muscle. As it courses superiorly, above the nose, the fibers of the procerus become continuous with the medial fibers of the frontalis muscle. The muscle fibers insert into the glabellar skin, in a varied width, over the lower mid-forehead and between the eyebrows.

Procerus receives its arterial supply mainly from branches of the facial artery. It is innervated by the facial nerve and more specifically the angular nerve (the buccal branch of the facial nerve, after receiving a contribution from the zygomatic branch; see Chap. 5) (Caminer et al. 2006). The frontal branch of the facial nerve contributes also to the innervation of the upper portion of the muscle.

The procerus is a brow depressor that draws down the medial angle of the eyebrow (frowning, "concentration," reduces the glare of bright sunlight) and forms horizontal glabellar furrows.

3.1.2.2.3 Orbicularis Oculi Muscle

The orbicularis oculi is a broad, elliptical, and flat muscle sheet that is regarded as a component of the superficial musculoaponeurotic system (SMAS). The muscle surrounds the circumference of the orbit sealing it (Fig. 3.6). Although it belongs in circumorbital and palpebral musculature group, it spreads into the forehead region interdigitating with the forehead muscles.

It consists of three parts, the palpebral, the lacrimal, and the orbital part. The palpebral part (divided topographically in a preseptal and a pretarsal portion), thin and pale, arises from the superficial surface of the medial canthal ligament and from the bone immediately above and below the ligament. The fibers sweep across the eyelids anteriorly to the orbital septum and interlace at the lateral commissure to form the lateral palpebral raphe. The lacrimal part lies behind the lacrimal sac, attached to the lacrimal fascia, to the upper part of the crest of the lacrimal bone, and adjacent part of the lateral surface of the lacrimal bone. The orbital part, thicker than the other two, is the part involved in the lower forehead. It lies over the supraorbital rim and interdigitates with the neighboring forehead muscle fibers.

Orbital Part of the Orbicularis Oculi Muscle

The muscle fibers of the orbital part arise from the superior edge of medial canthal ligament, the nasal component of the frontal bone, and the frontal process of the maxilla. The fibers arc superiorly and inferiorly over the orbital rim, without interruption on the lateral side, where there is no bony attachment. The upper muscle fibers extend superiorly and intermix with the frontalis and corrugator supercilii muscles. The fibers from the medial part are fixed to dermis under the medial head of the eyebrow (Knize 2000). Some of the

Fig. 3.7 Retro-orbicularis oculi fat (ROOF)

medial or lateral fibers of the orbital part of the orbicularis oculi may form distinct muscle bands (medial, lateral muscular bands of orbicularis oculi muscle) that are attached to the cheek skin, to the frontal muscle, or to the zygomatic arch (Park et al. 2011, 2012).

The fibers of the orbicularis, after completing their circular course, insert medially at the inferior edge of medial canthal ligament, just below their points of origin.

The orbicularis attaches only medially to the medial orbital margin and the medial canthal ligament. Elsewhere, the orbicularis is attached by retaining ligaments from the periosteum to the fascia on its undersurface (Keller and Mashkevich 2009).

The orbicularis oculi is innervated from the temporal, zygomatic, and buccal branches of the facial nerve. The nerves are horizontally oriented and gather to the undersurface of the muscle from its temporal and inferior side. The anterior and middle rami of the frontal branch run deep to the undersurface of orbicularis muscle and innervate the upper and superolateral part of orbicularis. The zygomatic branch innervates the lower and inferolateral part of the muscle. The buccal branch receives a contribution from the zygomatic branch and forms the angular nerve. The angular nerve, running cranially to the medial canthal ligament, sends rami to the undersurface of the low and medial part of orbicularis, on its way to reach the procerus and the oblique head of corrugator supercilii (Caminer et al. 2006). The innervation takes place by means of anastomotic neural plexuses formed by the involved nerves (Nemoto et al. 2001; Ouattara et al. 2004).

The orbital part of the muscle is used in forced eyelid closure. Furthermore, the medial head of this part acts by depressing the medial brow, along with the oblique head of the corrugator supercilii and the depressor supercilii (depressor muscle group for the medial eyebrow) (Knize 2000).

Just under the superolateral portion of the orbicularis muscle is situated a deep fat facial pocket, the retro-orbicularis oculi fat (ROOF).

Retro-Orbicularis Oculi Fat (ROOF)

The retro-orbicularis oculi fat (ROOF) is a transverse band of 5 mm thick fibroadipose tissue, which extends under the orbicularis muscle and the lower part of frontalis muscle enveloped by a split of the deep galea layer (Fig. 3.7). It extends above the orbital rims having a vertical height of approximately 1 cm and across the forehead for an additional 2–5 cm lateral to the supraorbital notch (foramen) (May et al. 1990; Hwang et al. 2007). It is situated superiorly to the orbital septum and the thinner, preseptal fat. In contrast with the orbital fat, which consists of fatty tissue, ROOF contains more fibro-fatty tissue (May et al. 1990; Hwang et al. 2007). Through this fat pocket, run the lacrimal nerve and anastomotic veins to the supraorbital vein (Zide 2006). Within ROOF lies the lateral part of the transverse head of corrugator muscle. It plays an

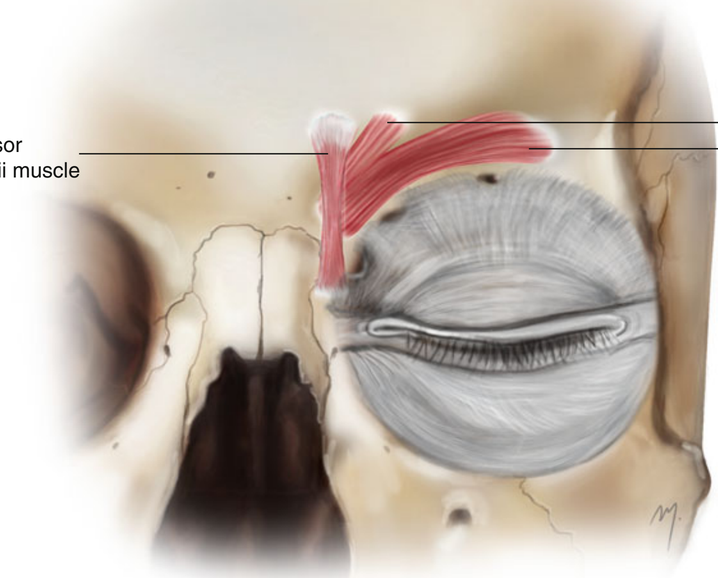


Fig. 3.8 The depressor supercilii and the corrugator muscles constituting the intermediate and the deep muscle layer of the forehead muscles, respectively

important role in eyebrow ptosis, as it slips downward during the aging process and is resected or reduced in aesthetic blepharoplasty operations. The ROOF is considered a part of the overall galea fat pad (which extends cranially for about 2–3 cm beneath the frontalis muscle and between the subdivisions of the deep galea layer) (Knize 2001; Zide 2006). These fat pads act as a brow pillow, allowing it to move freely.

3.1.2.2.4 Depressor Supercilii Muscle

There has been much confusion pertaining to the depressor supercilii muscle, because of the fact that it is difficult to discern whether or not the muscle is an extension of the medial head of the orbicularis oculi muscle or if it is a distinct muscle on its own (Lemke and Stasior 1982; Zide and Jelks 1985; Abramo 1995; Flowers 1998; Macdonald et al. 1998). Just in the late 1990s, Daniel and Landon (1997) confirmed that the depressor supercilii muscle is a distinct entity. Their findings reasserted later on, by Knize (2000, 2001) and Cook et al. (2001) who provided a description and a clear detailed schematic of the muscle.

According to these studies, the depressor supercilii lies anteriorly to the corrugator supercilii muscle and arises from the frontal process of the maxilla approximately 10 mm above the medial canthal tendon, near the edge of the bony medial orbital rim which is slightly posterior and superior to the posterior lacrimal crest, approximately 2–5 mm below the frontomaxillary suture line (Daniel and Landon 1997; Cook et al. 2001) (Fig. 3.8). After its origin, the muscle travels superiorly, toward the glabellar area, for 4–5 mm in the subcutaneous tissue. Its fibers are more vertically oriented than those of the corrugator. At its anterior side, the muscle comes in contact with the angular vessels. Cook et al. (2001) observed that the depressor supercilii appears to originate from two distinct heads in half of the cases studied. The two heads of the depressor supercilii muscle are located superiorly, while the angular vessels pass between them and merge before inserting in the dermis. The muscle fibers insert in the dermis near the medial eyebrow, at a point approximately 13–15 mm superior to the medial canthal tendon (Cook et al. 2001). The dermal insertion of depressor supercilii lies a few millimeters medial to the dermal insertion of the oblique head of the corrugator supercilii muscle (Knize 2000, 2001).

The depressor supercilii receives innervation from the angular nerve. It depresses the medial brow belonging to the depressor muscle group for the medial eyebrow.

3.1.2.2.5 Corrugator Supercilii Muscle

The corrugator supercilii muscle is comprised of two muscle bands (heads) that lie below the upper border of the superciliary arch and are located beneath the eyebrow. The corrugator muscle lies deep in the frontalis and orbicularis oculi muscles composing the deep muscular layer of the forehead (Fig. 3.8). It arises from the frontal bone at the superomedial orbital rim, slightly cranially to the trochlea. The origin has a wide base, with an average width of 10 mm being also 10 mm above the medial canthus. After arising from its origin, the muscle divides into its two heads, the small oblique head and the large transverse. The average thickness of the transverse head is 7.5 mm, while the oblique head 2 mm (Walden et al. 2005).

The small oblique head is situated underneath the depressor supercilii muscle. Its fibers run superiorly, parallel to the fibers of the depressor supercilii, across the glabellar region. After a short distance and interdigitation with neighboring muscle fibers of orbicularis and frontalis, it inserts in the dermis along the medial brow at a point approximately few mm, lateral to the insertion of the depressor supercilii muscle. A clear discrimination of the oblique head of the corrugator is not always possible, because occasionally, after its origin, its muscle fibers quickly parallel with the fibers of the larger transverse head (Janis et al. 2007).

The large transverse head passes laterally and slightly upward along the superior orbital rim and runs for about 3.5–4 cm lateral to the midline. The muscle lies beneath the orbicularis muscle, within the galea fat pad, between the layers of the deep galea plane. On the way to its dermal insertion, it becomes more superficial, piercing the frontalis and orbicularis oculi muscles (Knize 1996a, b).

The muscle fibers of the corrugator pierce and interdigitate with the fibers of the frontalis and orbicularis oculi muscles. The fibers of the transverse head usually insert into the deep surface of the middle eyebrow skin although more lateral extension has also been described (Isse and Elahi 2001). The fibers of the oblique head insert into the deep surface of the medial part of the eyebrow.

Corrugator supercilii has a dual nerve supply from both the frontal branch of the facial nerve and the angular nerve. The transverse head is innervated from the terminal branches of the frontal branch of the facial nerve. The oblique head receives its nerve supply from the angular nerve (Caminer et al. 2006). The angular nerve passes in front of the medial canthus reaching the muscle inferiorly.

The corrugator muscle is a brow depressor, which cooperates with the orbicularis oculi to draw the eyebrows medially and inferiorly (frowning, shielding the eyes in sunlight). The combined action of the two muscles produces vertical glabellar wrinkles.

This muscle is resected in forehead rejuvenation procedures and surgical treatment of migraine headaches.

3.1.3 Loose Areolar Tissue

The loose areolar tissue layer continues from the scalp to the forehead as the same subgaleal space, connecting the galea aponeurotica with the forehead pericranium. It also continues laterally at the temporal area as already examined, situated below the temporoparietal fascia and over the temporalis fascia. It receives blood from all the major forehead vessels due numerous tiny branches. The supraorbital and supratrochlear neurovascular bundles traverse this space within the supraorbital margin. Although this subgaleal space is vascular (as in the scalp) an effortless injection of a vasoconstrictive solution transforms it to an avascular dissection plane. Also here the areolar space is of great importance in forehead surgery because it can be easily dissected, creating a surgical dissection plane for large forehead flaps or allowing combined scalp-forehead flaps to be raised at the same plane.

3.1.4 Forehead Periosteum

The periosteum of the forehead is the same dense connective tissue layer over the frontal bone, which as pericranium covers the entire skull. In the frontal area, it is slightly thinner than in the other skull parts. It is loosely adherent to the outer surface of the frontal bone and lies just beneath the loose areolar layer. It becomes densely adherent to the bone over a transverse, 2.5 cm wide area, just above the orbital rims, and in a 6 mm wide band, medial to the superior temporal line (Knize 1996a, b, 2001).

Anteriorly, the periosteum becomes continuous with the periorbita (the inner lining of the orbital bones) at the orbital rims. The transition between the outer periosteum and the inner periorbita of the orbit is known as the arcus marginalis, a thickened connective tissue layer densely adherent almost to the entire orbital rim. Along the supraorbital rim at the arcus marginalis, the periosteum merges with the orbital septum (Zide and Jelks 1985).

At the forehead, Sullivan et al. (2006) described the presence of four retaining ligaments located around the orbit: an inferomedial (just medial to the supraorbital notch), a superomedial (13 mm lateral to the midline and 11 mm above the supraorbital rim), a superolateral (23 mm lateral to the midline and 10 mm above the rim), and a broad lateral one across the lateral aspect of the supraorbital rim.

3.2 Arterial Anatomy

The forehead arterial system consists of a latticework of anastomoses mainly supplied from three pairs of arteries. These arteries are the supraorbital and the supratrochlear arteries and the frontal branches of the superficial temporal arteries. Additionally, the dorsal nasal artery (although anatomically belongs to the nasal arteries) contributes to the blood supply of the mid-forehead area.

The supraorbital and the supratrochlear arteries constitute facial branches of the ophthalmic artery.

3.2.1 Ophthalmic Artery

The ophthalmic artery arises from the cerebral part of the internal carotid artery (rarely it arises from the middle meningeal artery). After entering the orbit, through the optic canal, it gives off many small branches (posterior ciliary artery, muscular branches) and one large branch (the lacrimal artery) to the contents of the orbit.

The lacrimal artery runs forward at the junction of orbital roof and lateral wall and supplies the lacrimal gland. It is then distributed to the eyelids and conjunctiva. Terminal branches of the lacrimal artery are branched as superior and inferolateral palpebral arteries. They anastomose with the medial palpebral arteries. Within the orbit, the lacrimal artery gives also rise to the zygomatic artery, which subdivides further into the zygomaticofacial and the zygomaticotemporal arteries. In 1 %, the lacrimal artery rises from the middle meningeal artery via the superior orbital fissure, and in 2 % it arises from an abnormal ophthalmic artery.

Continuing its course, the ophthalmic artery passes over (or sometimes under) the optic nerve and gives off the supraorbital artery. It then reaches the medial orbital wall, in an anterior direction, below the superior oblique muscle, and gives off the anterior and posterior ethmoidal arteries. Anteriorly to the trochlea, the medial palpebral arteries arise, and the ophthalmic artery divides into its two terminal branches, the supratrochlear artery and the dorsal nasal artery.

The supratrochlear, supraorbital, lacrimal, medial palpebral, and dorsal nasal arteries are the branches of the ophthalmic artery that supply the face.

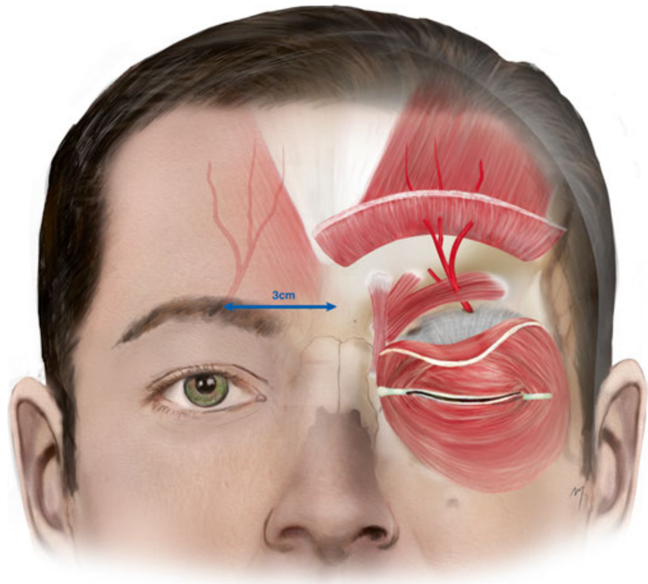


Fig. 3.9 Exit point of the supraorbital artery and the course of its superficial branch

3.2.2 Supraorbital Artery

The supraorbital artery, after arising from the ophthalmic artery, runs anteriorly, between the orbital roof and levator palpebrae superioris and in company of the supraorbital nerve. The supraorbital artery is slightly wider than the supratrochlear artery. Its mean diameter ranges from 0.84 to 0.87 mm (Erdogmus and Govsa 2007).

It exits the orbit (Fig. 3.9), through the supraorbital notch or foramen, together with the supraorbital nerve and supraorbital vein, which lies anterior to the artery. In 13 % of cases, the supraorbital artery and the supratrochlear artery exit the orbit as a single vessel and separate immediately after exiting from the foramen (notch) (Erdogmus and Govsa 2007).

3.2.2.1 Supraorbital Notch (Foramen)

The supraorbital notch (foramen) is situated approximately 2.5–3 cm from the midline (Webster et al. 1986; Miller et al. 2000; Park et al. 2003). Bilateral notches are present more often (60–90 %) than bilateral foramina (Webster et al. 1986; Chung et al 1995; Saylam et al. 2003; Cuzalina and Holmes 2005). Rarely, one notch may be found on one side and one foramen on the other side. The foramen often represents the exit of a small supraorbital canal from where the neurovascular bundle passes from the orbit to the forehead. When a foramen is present, it is located and usually palpated up to 15 mm in relation to the supraorbital rim. In cases where palpability is questionable, an additional landmark can be used; the vertical location of the foramen is situated approximately on the midpupillary line. Great diversity and variants of these notches (foramina) exist from one individual to the other due to sex and race differences (Chung et al. 1995; Kimura 1977; Cheng et al. 2006; Agthong et al. 2005; Jeong et al. 2010; Chrcanovic et al. 2011). In cases where a supraorbital notch is present, it transforms into a "foramen" by a ligament (supraorbital ligament).

The supraorbital artery continues running over the supraorbital rim slightly from medial to lateral and enters the corrugator muscle where it divides into a superficial branch, which supplies the superficial layers of the scalp, and a deep branch supplying the pericranium. The division of the supraorbital artery in 80–90 % of individuals happens at the level of the supraorbital rim or below. In the remainder, division occurs approximately 8.5 mm above the orbital rim (Yoshioka and Kishimoto 1991; Yoshioka and Rhoton 2005).

3.2.2.2 Superficial Branch of the Supraorbital Artery

The superficial branch of the supraorbital artery (Fig. 3.9) enters the corrugator, the orbicularis oculi, and the lowest part of the frontalis muscle, traveling for a short distance within these muscles and divides into 2–4 subbranches. In a distance approximately 2–3 cm above the supraorbital rim, they pierce the frontalis muscle and the galea, becoming more superficial, and travel within the subcutaneous tissue layer.

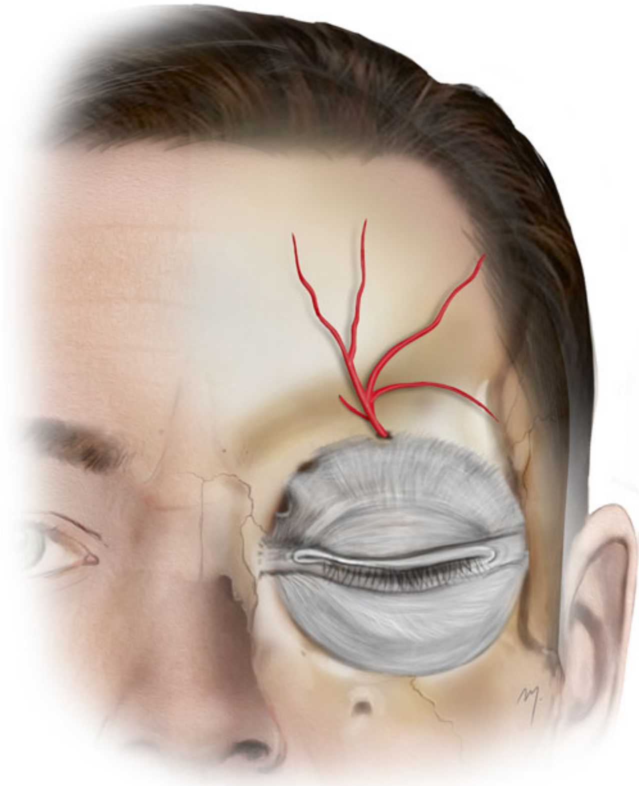


Fig. 3.10 Deep branch of the supraorbital artery

The superficial branch of the supraorbital artery does not have as long a course as the accompanying supraorbital nerve.

3.2.2.3 Deep Branch of the Supraorbital Artery

After dividing from the main trunk, the deep branch (Fig. 3.10) gives off 2–4 branches, with a mean diameter of 0.6 mm (Yoshioka and Rhoton 2005). These branches run axially as independent tiny vessels above the pericranium within the loose areolar tissue layer, for a distance of about 1.5–4 cm (Erdogmus and Govsa 2007).

Kleintjes (2007) demonstrated a detailed branching pattern of the deep supraorbital artery. According to his study, three branches usually exist: vertical branches, which run anteriorly and almost parallel; the oblique branch running anterolaterally over the periosteum, which anastomoses with the frontal branch of the superficial temporal artery; and the horizontal branch which runs laterally and above the orbital rim.

One vessel of the deep branches supplies the diploe of the frontal bone and the mucoperiosteum of the frontal sinus (Cormack and Lamberty 1994).

Both branches of the supraorbital artery supply the skin and the muscles of the upper eyelid, the forehead and scalp, the diploe and the periosteum of the frontal bone, and the mucous membrane of the frontal sinus.

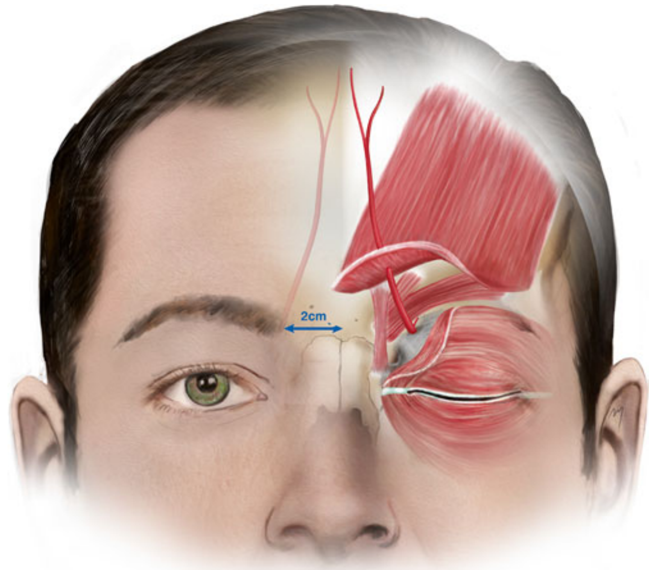


Fig. 3.11 Exit point of the supratrochlear artery and the course of its superficial branch

3.2.3 Supratrochlear Artery

The supratrochlear artery, after having divided from the ophthalmic artery, runs in the superomedial orbit to the orbital rim. It is usually the largest terminal branch measuring about 0.8 mm in diameter.

It exits the orbit (Fig. 3.11) approximately 2 cm from the midline through the supratrochlear notch, piercing the orbital septum, together with the supratrochlear nerve and vein. At this point, occasionally the artery bends sharply before getting under the muscles. In a small percentage (13 %), the supratrochlear and supraorbital arteries exit the orbit as a single vessel as mentioned above (Erdogmus and Govsa 2007).

3.2.3.1 Supratrochlear Notch

Medial to supraorbital notch/foramen lies a small notch, the supratrochlear notch, which represents the point where the supratrochlear nerve and artery exit the orbit. In about 2 %, this exit point is present not as a notch, but as foramen, known as the supratrochlear foramen. The supratrochlear notch is located approximately 2 cm lateral to the midline of the forehead and medial to the supraorbital notch/foramen.

After exiting the orbit, at the supraorbital rim, it travels over the periosteum and quickly, proximal to the corrugator muscle, divides into a deep branch and a superficial branch (Schumrick and Smith 1992; Reece et al. 2008).

3.2.3.2 Superficial Branch of the Supratrochlear Artery

The superficial branch (Fig. 3.11) initially lies over the corrugator muscle and deep to orbicularis and the lower part of

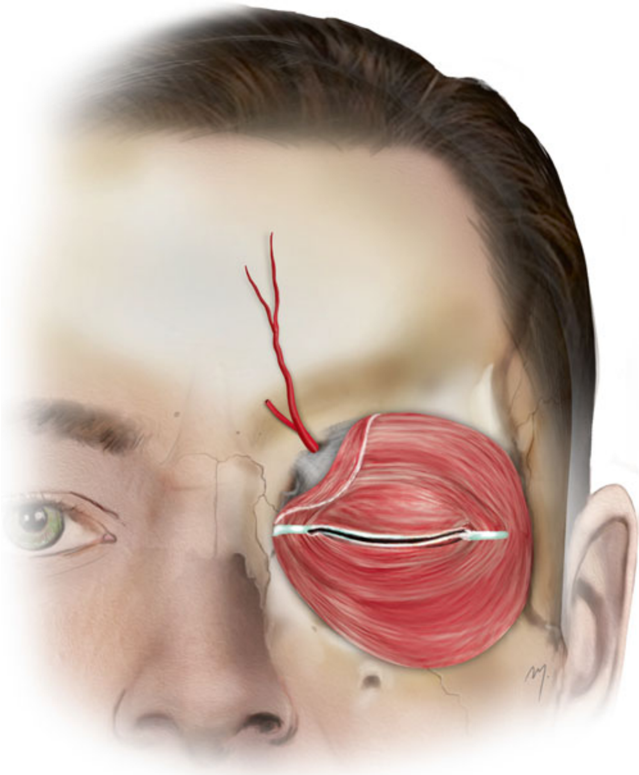


Fig. 3.12 Deep branch of the supratrochlear artery

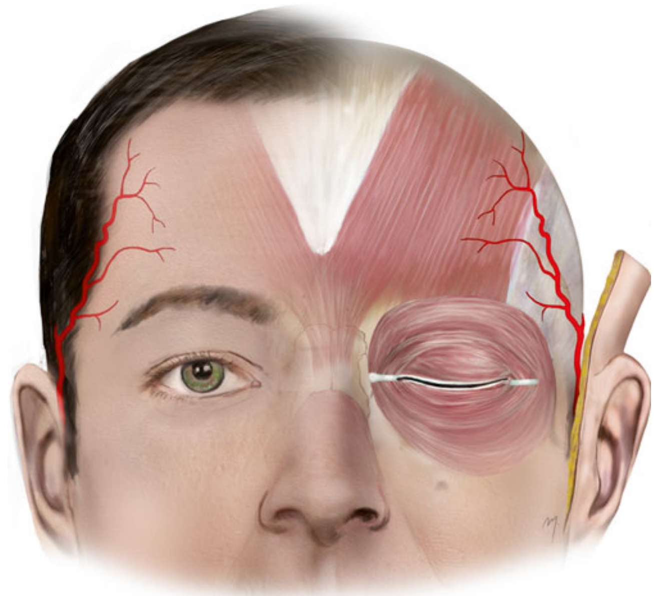


Fig. 3.13 Frontal branch of the superficial temporal artery

frontalis muscle. Approximately 1.5 cm above the supraorbital rim, it pierces the muscles and becomes subcutaneous. From this point, it runs superiorly and slightly medially in the subcutaneous plane. The superficial branch travels for about 7–10 cm above the supraorbital rim. When terminating its course, axial final branches sometimes slightly extend beyond midline while starting to communicate with the contralaterals.

3.2.3.3 Deep Branch of the Supratrochlear Artery

The deep branch of the supratrochlear artery, being its periosteal branch, continues on the periosteum for at least 3–4 cm (Fig. 3.12).

The supratrochlear artery, by both of its branches, supplies the central forehead skin, the forehead muscles, and the pericranium of the central forehead.

3.2.4 Frontal Branch of the Superficial Temporal Artery (Terminal Part)

The frontal branch of the superficial temporal artery after originating from the bifurcation of the superficial temporal artery runs at the temple tortuously upward and forward.

As it enters the forehead (Fig. 3.13), it usually gives a transverse branch, as the main continuation ascends superomedially. Its final part reaches the forehead at the inferior or middle forehead level, at the orbital rim vertical line (Kleintjes 2007). The artery travels superficially to the frontalis muscle, becoming shallow up to the subdermal level as it approaches the midline. The frontal branch is the main vascular supply for the temporal subunits of the forehead.

3.2.5 Glabellar Branch of the Dorsal Nasal Artery

The dorsal nasal artery (see Chap. 4) contributes in the forehead vascular supply by a superior glabellar branch (Fig. 3.14). The glabellar branch arises from the dorsal nasal artery, after its exit from the orbit, and extends cephalad to the glabella or even up to the inferior central forehead. This branch supplies the skin and periosteum of glabella and anastomoses with the supratrochlear artery and its contralateral. The dorsal nasal artery also gives off, from its initial part, small deep ascending branches that supply the glabellar periosteum. The superior branch of the dorsal nasal artery anastomoses with the supratrochlear artery and its contralateral.

3.3 Venous Drainage

The venous anatomy of the forehead exhibits significant variations, and the following description regatds those being relatively more constant (Fig. 3.15).

Venous drainage of forehead starts from a rich venous plexus that extends wide from the forehead to scalp. Small

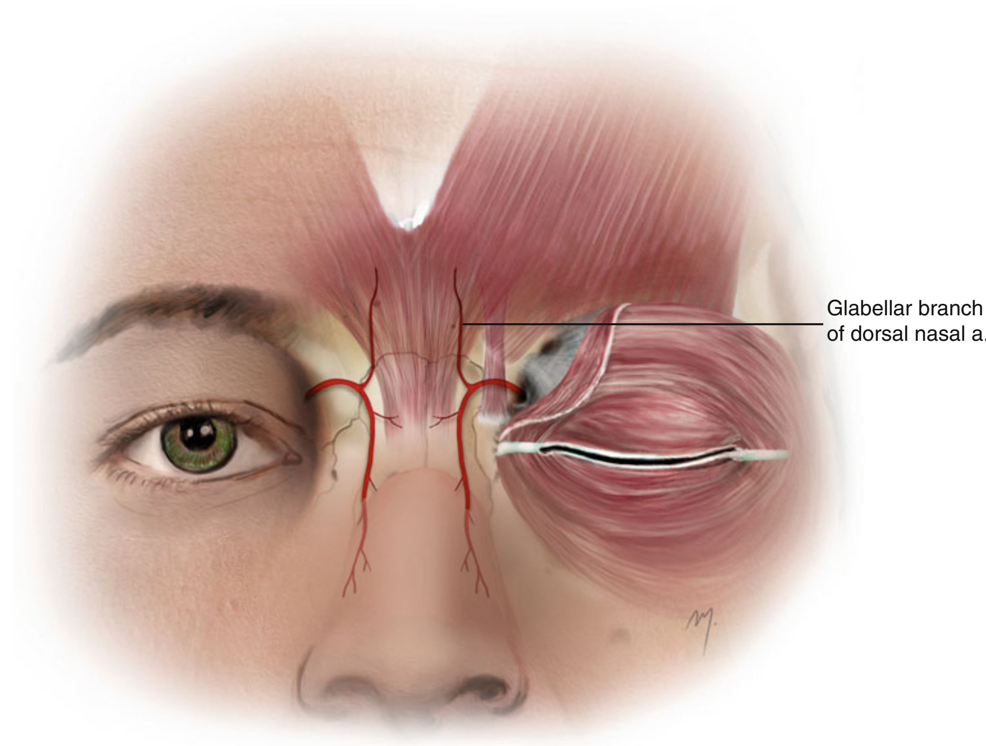


Fig. 3.14 Glabellar branch of the dorsal nasal artery

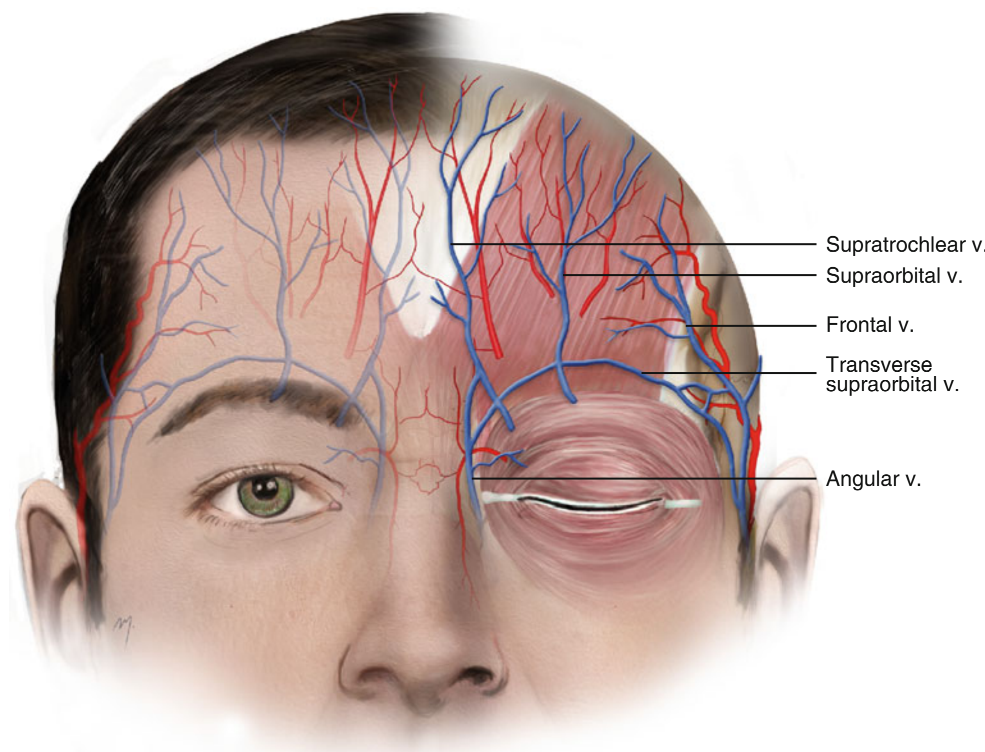


Fig. 3.15 The veins of the forehead

veins converge, forming gradually larger venous trunks. These trunks found in the middle forehead are the supratrochlear vein and the supraorbital vein, and in the lateral forehead the frontal vein.

3.3.1 Supratrochlear Vein

The supratrochlear vein starts from the venous plexus, near the forehead midline, and descends to the root of the nose, parallel with its contralateral. Across the nose, the two supratrochlear veins are connected with the transverse nasal arch, a small vein that drains the dorsum of the nose in this area and the glabella. It then divides, and one branch penetrates the orbital septum and enters the orbit through the supratrochlear notch, while the other subdivision joins the supraorbital vein near the medial canthus to form the angular vein.

The supratrochlear vein runs a course parallel and medially to its artery, but a distance between them exists that sometimes can range up to 10 mm. This is very important when designing paramedian forehead flaps. To ensure catching both artery and vein into the flap, the width, especially in its base, should not be narrower than 1.5–2.0 cm.

3.3.2 Supraorbital Vein

The supraorbital vein starts from the forehead venous plexus and descends to the supraorbital rim accompanying the supraorbital artery. Before entering the orbit through the supraorbital notch (foramen), it divides, and one branch runs medially to join the supratrochlear vein and form the angular vein. The intraorbital branch along with the intraorbital branch of the supratrochlear vein forms the superior ophthalmic vein that runs to the cavernous sinus.

The supraorbital vein is connected to the frontal branch of the superficial temporal and the middle temporal veins, through a transverse venous trunk, the transverse supraorbital vein. This venous arch courses in about 60 %, at the level of the supraorbital rim. The remaining 40 % lies approximately 9 mm above it (Erdogmus and Govsa 2007). This limb of venous drainage of the frontal region has the best chance of being preserved, with the condition that the dissection of the galea frontalis layer from the pericranium does not extend into 10–15 mm above the supraorbital rim (Yoshioka and Rhoton 2005).

3.3.3 Frontal Vein

The frontal vein starts from the converged veins of the frontolateral venous scalp plexus. Above the zygomatic arch, it joins with the parietal vein and forms the superficial temporal vein. The frontal branch of the superficial temporal vein is also connected to the supraorbital artery through the transverse supraorbital vein.

3.4 Nerves

Sensory innervation of the forehead and anterior scalp is supplied by the supraorbital and supratrochlear nerves, which are branches of the frontal nerve.

The frontal nerve is the largest branch of the ophthalmic division (V1) of the trigeminal nerve. It enters the orbit through the superior orbital fissure above the annulus of Zinn and runs forward between the levator palpebrae superioris muscle and the periorbita. About halfway between the apex and the orbital rim, it divides into its terminal branches, the small supratrochlear and the large supraorbital nerve. The motor nerve that is encountered to the forehead is the frontal branch of the facial nerve.

3.4.1 Supraorbital Nerve

After arising from the frontal nerve, the supraorbital nerve runs forward nearly to the midline of the orbit. It exits the orbit through the supraorbital notch (foramen) (Fig. 3.16). This point is marked grossly on the orbital rim at the junction of the medial and middle thirds of the supraorbital margin and as mentioned approximately 2.5–3 cm lateral to the midline. Sometimes the supraorbital nerve can leave the orbit with several branches through separate periosteal canals (Fatah 1991). In an extensive anatomic study of 1014 orbits, Beer et al. (1998) concluded that “(1) the exit point(s) of the supraorbital nerve are not at all constant; (2) the supraorbital nerve leaves the orbital rim either undivided or in its two branches via two separate exit points; (3) the exit point(s) can be either a notch or a foramen; (4) the exit point(s) can be located along the whole orbital rim and even laterally of it; and (5) the exit point(s) can be significantly cephalad to the orbital rim.” Due to these numerous variations and despite the mentioned supraorbital notch/foramen landmarks, it is very important when dissecting in this area during forehead or brow surgery to identify the notch (foramen) under vision in order to avoid nerve injury.

As the supraorbital nerve exits the orbit, it gives off small palpebral filaments to the upper eyelid and conjunctiva. Also, small branches supply the mucous membrane of the frontal sinus entering it through foramina in the floor of the supraorbital notch (foramen). After leaving the orbit, the supraorbital nerve trunk divides into a large, lateral deep branch and a smaller, medial superficial branch (Fig. 3.16). In 15 %, the supraorbital nerve leaves the orbital cavity already having those two branches (Beer et al. 1998). A variation to the above, is that the lateral deep branch exits the orbit from a separate foramen, located up to 1.5 cm, cephalad to the supraorbital notch (Erdogmus and Govsa 2007; Keller and Mashkevich 2009). Initially, these branches lie in the submuscular plane, deep to the orbicularis, frontalis, and corrugator supercilii muscles, in close approximation to the periosteum of the supraorbital ridge, in a position respectively in the middle third of the corrugator.

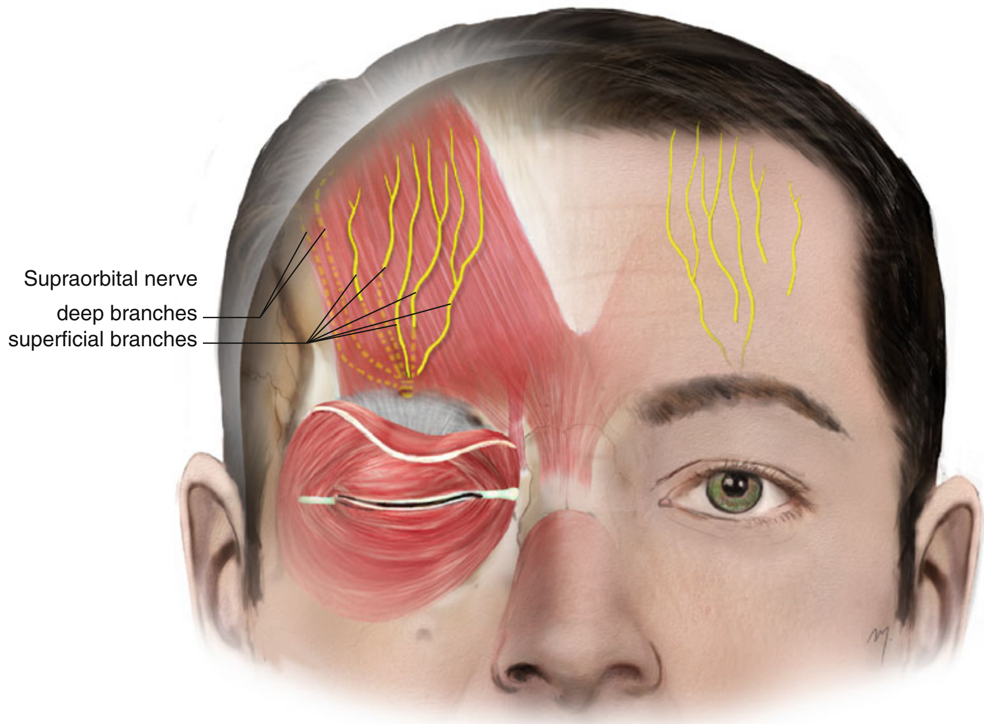


Fig. 3.16 The supraorbital nerve entering the forehead divides into its superficial and its deep branches

3.4.1.1 Superficial Branch of the Supraorbital Nerve

The superficial branch of supraorbital nerve quickly divides into multiple smaller branches. As they ascend, they pass through the corrugator supercilii and frontalis muscle, becoming more superficial. In 22 %, branching occurs more cephalad, close to the superior margin of the corrugator muscle (Janis et al. 2008). After perforating the frontalis muscle at various points from the orbital rim to the mid-forehead level, they run over its surface, along with the supratrochlear nerve branches, reaching and traveling into the subcutaneous plane. These smaller branches form a wide fan pattern, before entering the frontal scalp (Knize 1995). The length of the medial branches has been reported to be from 1.5 to 11.7 cm (Malet et al. 1997; Erdogmus and Govsa 2007; Andersen et al. 2001).

According to their length, they supply sensation to the forehead skin and to the frontal scalp in various ranges.

3.4.1.2 Deep Branch of the Supraorbital Nerve

The deep branch of the supraorbital nerve exits the orbit as one branch in 34 %, as two branches in 60 % and in the remaining 6 % of cases, as multiple branches (Knize 2001; Erdogmus and Govsa 2007). The one or two branches (being parallel each other) at first run laterally, above the periosteum and along the orbital rim or occasionally up to 1.5 cm superior to the rim. At the level of the lateral third of the eyebrow, they turn cephalad. After turning cephalad, the deep branch (single or double) runs in a superolateral direction, parallel and 0.5–1.5 cm medial to the superior temporal line (Knize 1995). It courses in the loose areolar tissue, beneath the frontalis muscle and the galea, and above the pericranium and gives off very small branches, which innervate the periosteum. In the cases where the deep branch presents two branches, one is larger than the other, and together they run without any further branching (Erdogmus and Govsa 2007). At the level of the hairline, near the coronal suture, it turns medially and pierces the galea becoming more superficial and then divides to its terminal rami (Knize 1995). The deep branch is longer than the superficial with a length ranging from 35 to 145 mm (Malet et al. 1997; Andersen et al. 2001). These branches supply scalp sensation to the frontoparietal region occasionally reaching the vertex of the skull.

The presence of a small, horizontal, additional branch of the deep branch of the supraorbital nerve has recently been described (Vestal et al. 1994; Hwang et al. 2005; Janis et al. 2008). This horizontal branch exits the supraorbital foramen (notch) as 1–2 rami. It runs upward about 10 mm and turns laterally parallel to the supraorbital rim, along the undersurface of the corrugator muscle, ending at the end of the brow. It supplies sensation in a skin area of 3 cm at the lateral mid of the eyebrow. In approximately half of individuals, this horizontal branch anastomoses with the temporal branch of the facial nerve (Hwang et al. 2005).

Both of the branches of the supraorbital nerve supply sensation to the skin of the lateral forehead, the anterior scalp, the frontoparietal scalp, the mucous membrane of the frontal sinus, and the pericranium of the forehead and anterior scalp region.

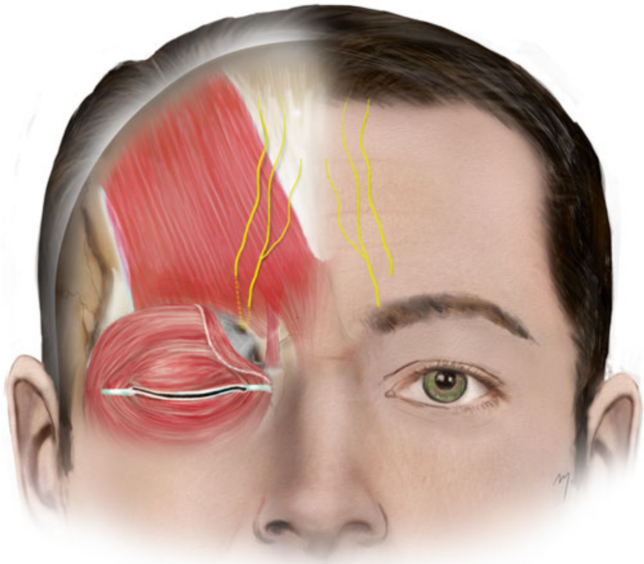


Fig. 3.17 Supratrochlear nerve

3.4.2 Supratrochlear Nerve

The supratrochlear nerve is smaller than the nearby supraorbital nerve. After dividing from the frontal nerve, it courses anteromedially in the roof of the orbit, passes above the trochlea of the oblique superior muscle, and gives off a descending filament to join the infratrochlear branch of the nasociliary nerve.

It exits the orbit at the superior orbital rim, between the trochlea and the supraorbital foramen through the supratrochlear notch (Fig. 3.17). At the supraorbital rim, it first pierces the orbital septum; then curves up on to the forehead close to the bone, in company with the supratrochlear artery; and ascends at first beneath and through the corrugator supercilii muscle. Within the corrugator muscle, the supratrochlear nerve divides into one to three branches. These branches as they run upward, these branches become more superficial, piercing the corrugator and frontalis muscle, and then enter the subcutaneous tissue of the central forehead. The terminal branches never cross the midline. The length of the supratrochlear nerve ranges between 23 and 70 mm (Andersen et al. 2001).

The supratrochlear nerve supplies cutaneous sensation to a central vertical strip of forehead and to the medial one-third of the upper eyelid skin and conjunctiva. There is an overlap of the supratrochlear nerve sensory area by the sensory area of the superficial division of the supraorbital nerve.

3.4.3 Forehead Regional Anesthesia

A great number of small to medium lesions at the forehead can be excised, and minor flap reconstruction is achieved by

Fig. 3.18 Supraorbital nerve block

a forehead block. The supraorbital nerve is blocked by its exit from supraorbital foramen (notch). The foramen (notch) is palpated at the supraorbital rim, and if this is unclear, its quite possible position 2.5–3 cm lateral to the midline is marked. At this point, about 1 ml of local anesthetic solution is injected just above the bone (Fig. 3.18). Direct injection within the foramen must be avoided because it may result in nerve damage. The supratrochlear nerve is blocked by infiltrating the same amount of local anesthetic solution along the supraorbital rim, 2 cm lateral to the midline or 1 cm medial to the previous point (Fig. 3.19). By blocking both nerves, complete anesthesia of the hemiforehead is achieved.

3.4.4 Frontal Branch of the Facial Nerve

At the forehead, the frontal branch of the facial nerve is present due to its final part (Fig. 3.20). As the frontal nerve comes from the temple, it reaches the forehead 1.0–1.5 cm above the lateral extremity of the brows. Situated at the temple along the undersurface of the temporoparietal fascia as it reaches the lateral border of the frontalis muscle, it pierces

Fig. 3.19 Supratrochlear nerve block

Fig. 3.20 Frontal branch of the facial nerve at the forehead

the fascia and continues to the undersurface of the frontalis muscle providing its innervation. A tiny ramus that runs medially to innervate the transverse head of the corrugator muscle has been found in 60 % of the individuals (Tzafetta and Terzis 2010).

3.5 Flaps Derived from the Forehead

The forehead constitutes a wide donor site of flap material that can be harvested in great quantity. Flaps derived from the forehead can be used in closing its own defects, but the forehead is also the ideal donor site of regional flaps in order to reconstruct medium and large nasal defects. In the past, the robust forehead flaps have been used also for cheek reconstruction, nowadays abandoned due to better reconstructive solutions.

3.5.1 Flap Design Concerning Vascular Anatomy

The supratrochlear, supraorbital, dorsal nasal, and frontal branches of the superficial temporal artery anastomose each other, forming a rich superficial (Fig. 3.21a) and deep arterial network (Fig. 3.21b), in the following way.

The supraorbital arteries anastomose with the superficial temporal arteries and the ipsilateral supratrochlear artery. The superficial branches of the supraorbital artery anastomose each other and with the frontal branch of superficial temporal artery and the superficial branches of the supratrochlear artery. The deep branches of the supraorbital artery anastomose each other and with the deep branches of the supratrochlear artery. Moreover, the deep oblique branch of the supraorbital artery, at the superior temporal line and at the junction of the inferior and middle forehead, pierces the frontalis muscle and anastomoses with the frontal branch of the superficial temporal artery (Kleintjes 2007). The supratrochlear artery, either the superficial or the deep branches, anastomoses with the supraorbital artery, the dorsal nasal artery, and its contralaterals.

The arteries that supply the forehead skin delimit clear vascular territories that the surgeon must have in mind when planning and designing cutaneous flaps (Fig. 3.21c). The deep arterial forehead network is related to the vascularity of the forehead pericranium, and a classic flap based on this rich deep network, which is used in various craniofacial procedures, is the frontal pericranial flap (Fig. 3.22). If a cutaneous flap from the forehead incorporates the underlying pericranium that will of course enhance its vascularity.

Based on the described rich cutaneous plexuses, all kinds of random pattern flaps can be designed on the forehead. The size and location of the defect, the RSTLs, and the skin laxity

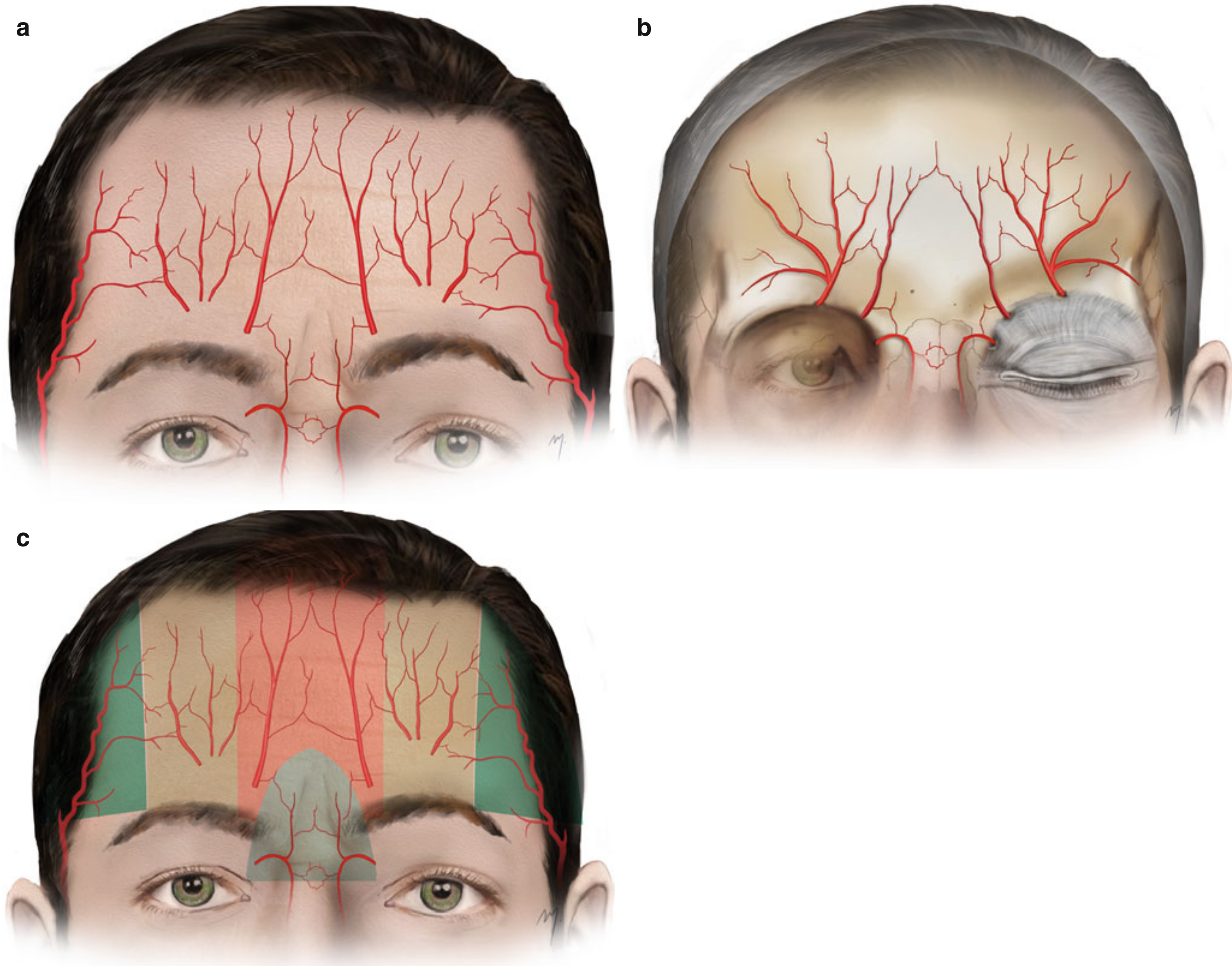


Fig. 3.21 (**a**) Superficial forehead arterial network. (**b**) Deep forehead arterial network. (**c**) Vascular territories of the arteries that supply the skin of the forehead

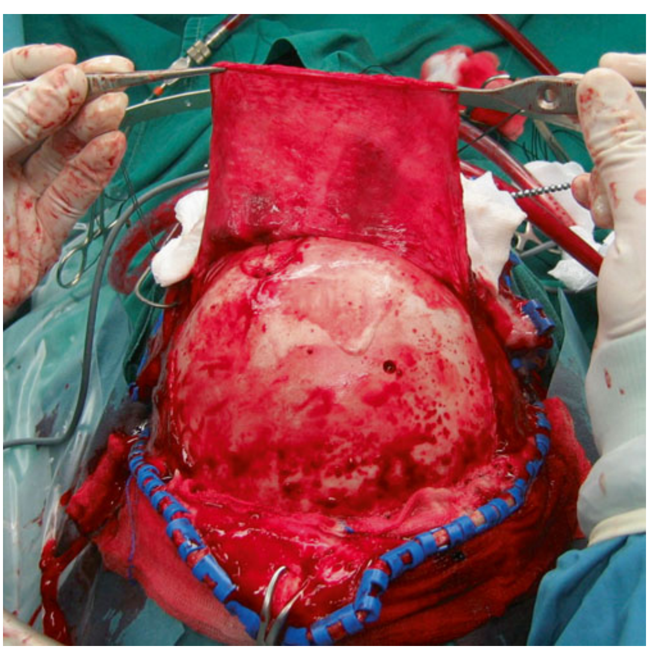


Fig. 3.22 The frontal pericranial flap is based on the rich deep anastomotic network of the forehead

of the forehead subunit to be reconstructed determine the choice of the best solution. All of the arteries of the forehead can provide axial supply to a great majority of flaps. On the side, the supratrochlear, the supraorbital, the dorsal nasal, and the frontal branch of the superficial temporal arteries, alone or in combination, can ensure axial flaps in various designs in order to reconstruct the forehead or nasal defects.

3.5.2 Flap Elevation Concerning Anatomic Planes

When raising a flap, the depth depends on the defect size, its location, and the type of the chosen flap. In forehead reconstruction, flaps are dissected in three different but certain anatomic planes. These are the subcutaneous plane, the loose areolar tissue plane, and the subperiosteal plane.

3.5.2.1 Subcutaneous Plane

The flap raised in this plane consists of skin and subcutaneous tissue, which preserve the subdermal vascular plexus. Small local flaps can be raised in this plane with vascular feeding safety. Dissection is performed sharply and creates more bleeding in comparison to working in the deeper forehead planes. Thus, it might be difficult at times and requires experience, because the tissue is dissected around neurovascular branches that need to be protected. Depending on the amount of subcutaneous tissue, dissection can be carried out through a midsubcutaneous or a deep subcutaneous level plane.

When no important anatomic structures have to be protected, the deep subcutaneous plane dissection located just above to the superficial galea layer is one of the choices. It strengthens vascularity or incorporates axial vessels into the flap. In the brow, this plane must be used exclusively, so as not to disturb the hair follicles, ensuring that cutting is carried out beneath them.

Midsubcutaneous plane dissection prevents damage of superficial running sensory and motor nerve branches. It should always be performed in the lateral eyebrow area and its extension to the temple. Even though this plane slightly impairs flap vascularity, however it reduces the possibility of injury of the temporal (frontal) branch of facial nerve that runs deep to the SMAS.

3.5.2.2 Subgaleal Plane (Loose Areolar Tissue Plane)

The subgaleal plane is also referred to, as the subgaleal-submuscular plane but in fact is actually only subgaleal. Anatomically this is recognized, as the deep layer of galea covers the under surface of the muscles of the forehead. This plane is used for raising large forehead flaps (rotation or advancement flaps, Worthen flap). Carrying the dissection below the frontalis muscle and its deep galea layer to the pericranium, undermining of the flap takes place within the areolar tissue, a very loose space. By blunt dissection, even with the finger, flaps can be raised at this level with ease and at a rapid pace.

Although numerous blood vessels run within this plane, injection of a vasoconstrictive solution creates a dissection plane with minimal bleeding.

Flaps raised in this plane are thick gaining (even the large) a robust vascular supply enhancing their viability. Additionally they are bulky enough to cover deep defects, and can reconstruct the contour for a more natural appearance. Depending on design, the position of transverse incision lines may lead to superficial sensory nerve transection.

3.5.2.3 Subperiosteal Plane

Even though raising a forehead flap at the subperiosteal plane, catching the pericranium and the deep arterial network, greatly enhances vascularization, this is not always necessary. The subperiosteal plane is of course the deep dissection plane of an anteriorly based pericranial flap (see Chap. 2) but in cutaneous forehead flaps is mostly used at the supraorbital zone where a flap may transition to this deeper level. Although the pericranium of the forehead is densely adherent to the underlying frontal bone at the supraorbital zone, it can be easily detached by means of periosteal elevators.

3.5.3 Bilateral Transverse Advancement Flap (H-Plasty)

The random pattern bilateral advancement flap is an ideal choice for closing moderate defects that are located in the central subunit of the forehead. The lesion is excised in a rectangular form, and two flaps from each of the lateral and the medial sides are elevated and advanced to close the defect. Its main advantage is that the long vertical incisions are camouflaged in the RST lines.

In the case presented, a basal cell carcinoma of the central forehead (Fig. 3.23a) is planned to be excised. After control of the transverse laxity (Fig. 3.23b), bilateral transverse advancement flaps are chosen to reconstruct the defect (Fig. 3.23c, d).

The lesion was excised, and clear margins were revealed by frozen biopsies (Fig. 3.23e). The flaps were raised by dissecting in the deep subcutaneous plane, just above the galea centrally and superficial to the frontalis muscle laterally (Fig. 3.23f, g). With advancement, both flaps reach the defect, share it (Fig. 3.23h) and are sutured into place without tension (Fig. 3.23i). The postoperative result is quite satisfactory (Fig. 3.23j).

3.5.4 Double Island Pedicle Flap

This versatile flap is very suitable in other facial areas with greater skin elasticity and plenty of subcutaneous tissue. In the forehead, it can be used in selected cases for closing small defects. The ability of advancing this flap in the forehead is limited, and thus it is better to design it as double than single flap. By this way, the two flaps share the defect area, each advancing halfway.

This technique is presented in a case of a basal cell carcinoma located at the forehead (Fig. 3.24a). A rectangular-shaped excision and the triangular flaps are outlined (Fig. 3.24b, c). The line of advancement of the flap is designed parallel to the forehead skin tension lines. Each flap is designed equal to the length of the diameter of the defect in the direction of the closure, thus both flaps being double the defect length.

The subcutaneous tissue beneath the triangular flaps is their pedicle. In contrast with other facial areas (e.g., cheek), the pedicle in the forehead cannot be extended very deep so as to enhance its mobility. The flaps are of random pattern, but on occasion, depending on where they need to be placed, they can be based over an axial vessel.

Each flap is undermined down to the subcutaneous tissue into the muscle, tapering outward so as to widen its base. After gaining sufficient mobility, they are advanced and sutured to the defect in a V-Y manner (Fig. 3.24d).

3.5.5 Hatchet Flaps

Hatchet flap, described by Emmett (1977), is a variant of V-Y flap. This triangular flap is not incised circumferential completely but keeps additionally a small skin pedicle except the subcutaneous one. The hatchet flaps in contrast to the V-Y flap are not exclusively advancement flaps, but they include also a slight rotation movement.

In the patient demonstrated, a malignant eccrine poroma is present in the lateral suprabrow area (Fig. 3.25a). Position and contour of eyebrow are the main goal of reconstruction. Even the lesion is small in size; a flap is necessary, because simple closure would lead to brow displacement.

Double hatchet flaps were chosen in this diabetic patient because the additional skin pedicle would enhance circulation and flap viability. Excision line and bilateral Hatched flaps are

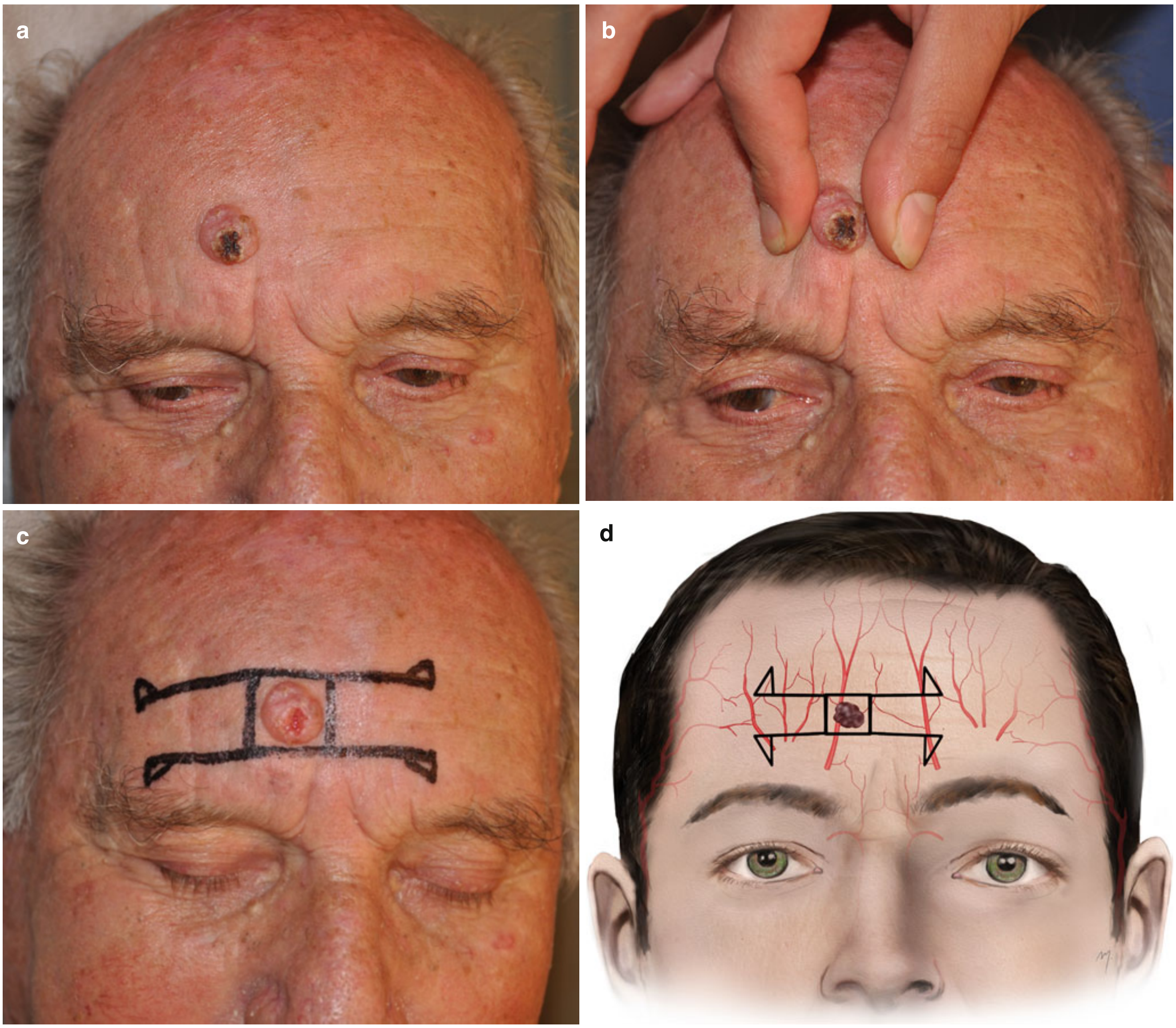


Fig. 3.23 (**a**) A cystic-type basal cell carcinoma at the central forehead. (**b**) Control of transverse skin laxity. (**c**) Outline of bilateral transverse advancement flaps. (**d**) By this flap, the supraorbital and supratrochlear arteries are transected, and the random pattern flap is perfused by branches of the frontal artery. (**e**) The lesion is excised in the plane just above the galea. (**f**) Flap is incised and Burow's triangles excised. (**g**) Flap raised at the deep subcutaneous level. The galea and the frontalis are clearly seen. (**h**) The flaps advanced. (**i**) Final closure. (**j**) Result at 4 months

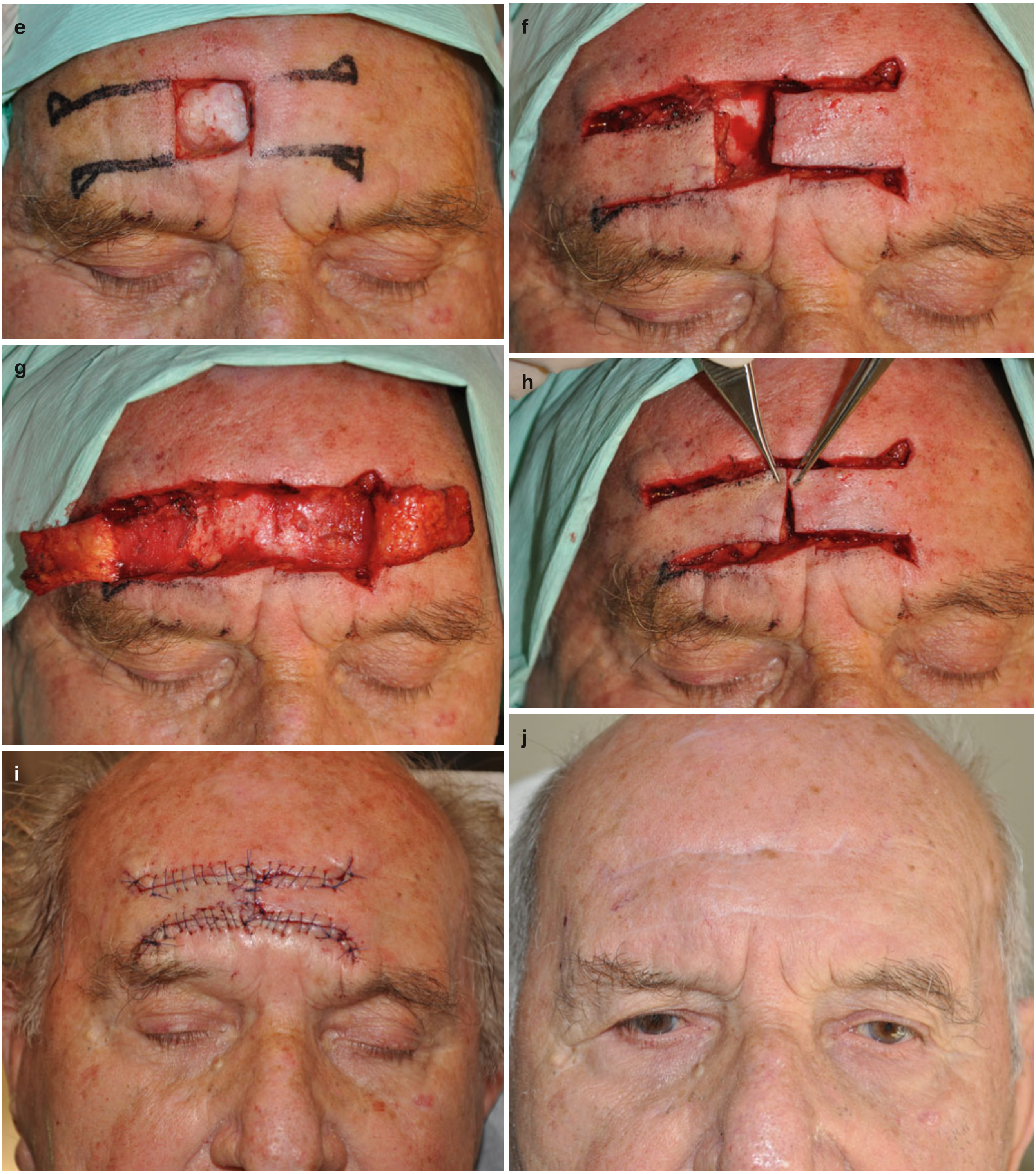


Fig. 3.23 (continued)

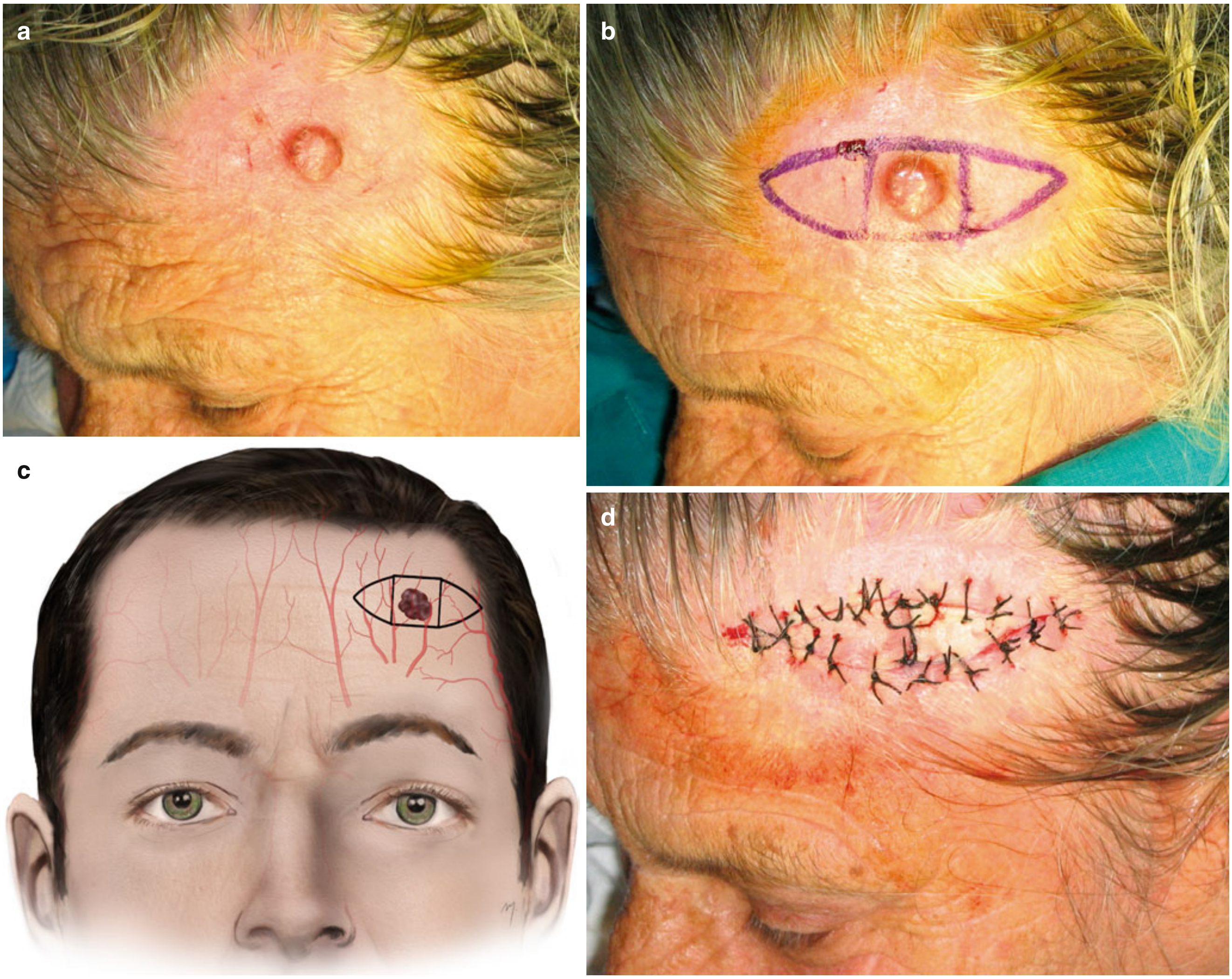


Fig. 3.24 (**a**) A cystic basal carcinoma located at the lateral forehead. (**b**) A double island pedicle flap is outlined. (**c**) The flaps are random pattern, but depending on where they need to be placed, they can be based over an axial vessel. (**d**) Flaps advanced and sutured to the defect in a V-Y manner

outlined as two triangles keeping two small skin pedicles facing each other (Fig. 3.25b, c). The lesion is excised in a circular fashion (Fig. 3.25d). Flaps are undermined to the deep subcutaneous plane, creating the subcutaneous pedicle. Dissection in this area and at this plane must be done very carefully, to protect the facial nerve. In addition, the small skin pedicle is maintained. Staying at a subcutaneous level by carefully dissecting the frontal branch of the facial nerve is protected.

After advancing the flaps, the first two sutures transfix (or nail) the apex of each flap into the middle of periphery of the round-shaped excision site (Fig. 3.25e).

Suturing continues at the bases of the triangle flaps and the rest is closed in a V-Y manner (Fig. 3.25f). The defect is closed without tension. Contour and position of the brow are not disrupted.

3.5.6 A to T Flap for Brow Defects

This advancement flap is a simple but an ideal reconstruction of small- and medium-sized defects of the eyebrow. The defect is excised in a triangular manner with its base inferiorly, and two horizontal incisions on opposite sides of the base are outlined within the brow (Fig. 3.26a, b). By this, nearby tissue is advanced to the defect in a horizontal manner, thus not disturbing the eyebrow position.

The goal of the restoration is not only to maintain brow position but also to prevent brow alopecia. This is achieved by carrying the horizontal incision parallel to the multidirectional hair follicles and undermining the flaps to the deep subcutaneous plane. The flap shifts eyebrow hair in the defect, fully restoring the brow continuity (Fig. 3.26c).

Fig. 3.25 (**a**) A malignant eccrine poroma located at the lateral brow area. (**b**) Hatched flaps are outlined. (**c**) In this case, the frontal nerve must be considered at the lateral triangle of the flap. (**d**) Lesion excised. (**e**) The flaps advanced. (**f**) Final suturing

The horizontal scar line is totally hidden within the brow. Finally, the reconstruction results in a normal brow (Fig. 3.26d).

3.5.7 A to T Flap for Suprabrow Defects

A- to T-plasty is a commodity solution for reconstructing small to medium defects of the supraorbital subunit.

The excision of this basal cell carcinoma of the case presented leads to a midsized supraorbital defect. The defect is excised in a triangular manner with its base inferiorly. The two horizontal incisions are outlined lying within a relaxed skin tension line (Fig. 3.27a, b).

The flap is raised in the midsubcutaneous plane by blunt dissection (Fig. 3.27c). This reduces the possibility of injury of the frontal branch of facial nerve that runs at the distal side of the flap. Dissecting the proximal side, there is no danger for the facial nerve, as this exists under the frontalis muscle.

The two triangular sides of the flap are advanced and cover the defect (Fig. 3.27d). The horizontal incisions are camouflaged into the RSTL, and the vertical one heals always well without a noticeable scar.

Postoperative result at 3 months achieved a good cosmetic and functional result (Fig. 3.27e, f).

3.5.8 Bilateral Forehead Rotation Flap

A large basal cell carcinoma of the upper part of mid-forehead is presented in this case (Fig. 3.28a). An exceptional method to reconstruct this medium-sized defect is the use of bilateral rotation flaps.

Fig. 3.26 (**a**) Outline of the flaps. (**b**) No danger of the frontal nerve exists when dissecting in the deep subcutaneous level as the nerve travels at the undersurface of the frontal muscle. (**c**) The flaps advanced and sutured in place. (**d**) Postoperative result at 6 months

The excision line and flap design outlined with the defect triangulated with its base superiorly (Fig. 3.28b). Both rotation flaps are inferiorly based so as to catch the axial feeding vessels (Fig. 3.28c). They receive their blood supply from the supraorbital arteries in their middle third, the frontal branch of superficial temporal arteries in the lateral third, and the supratrochlear arteries in the medial portion. The horizontal incision lies slightly posterior to the frontal hairline within a relaxed skin tension line.

Although the lesion does not extend into the deep tissues, excision is carried out deep to the subgaleal plane so as the two large flaps will be raised in the same loose areolar tissue anatomic plane (Fig. 3.28d). Subgaleal dissection is carried out bluntly in the subgaleal plane, within the loose areolar tissue. This provides safe and sufficient mobilization and easy rotation of the flaps to the donor site (Fig. 3.28e). By making the horizontal incision in that depth, all of the terminal branches of the superficial sensory nerves are transected,

Fig. 3.27 (**a**) Outline of the flap. (**b**) In this case, the frontal nerve must be considered at the lateral limb of the flap. (**c**) Flaps raised. (**d**) Suturing in place. (**e**) Result at 3 months following surgery. (**f**) Frontal nerve is intact

Fig. 3.27 (continued)

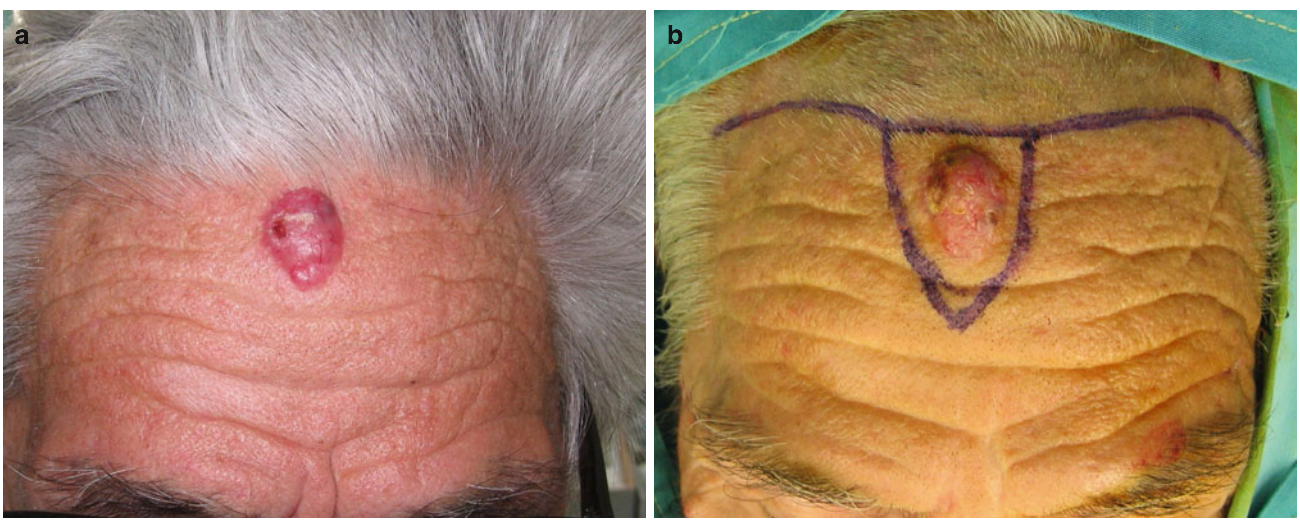


Fig. 3.28 (**a**) A basal cell carcinoma located at the upper part of the mid-forehead. (**b**) Excision line and flap design outlined. (**c**) The rotation flaps catch the axial feeding vessels but transect all of the superficial sensory nerves. (**d**) Lesion excised. (**e**) Flaps raised at the subgaleal plane. Small vessels running over the periosteum are seen. (**f**) Final suturing. (**g**) Satisfactory result after 3 months

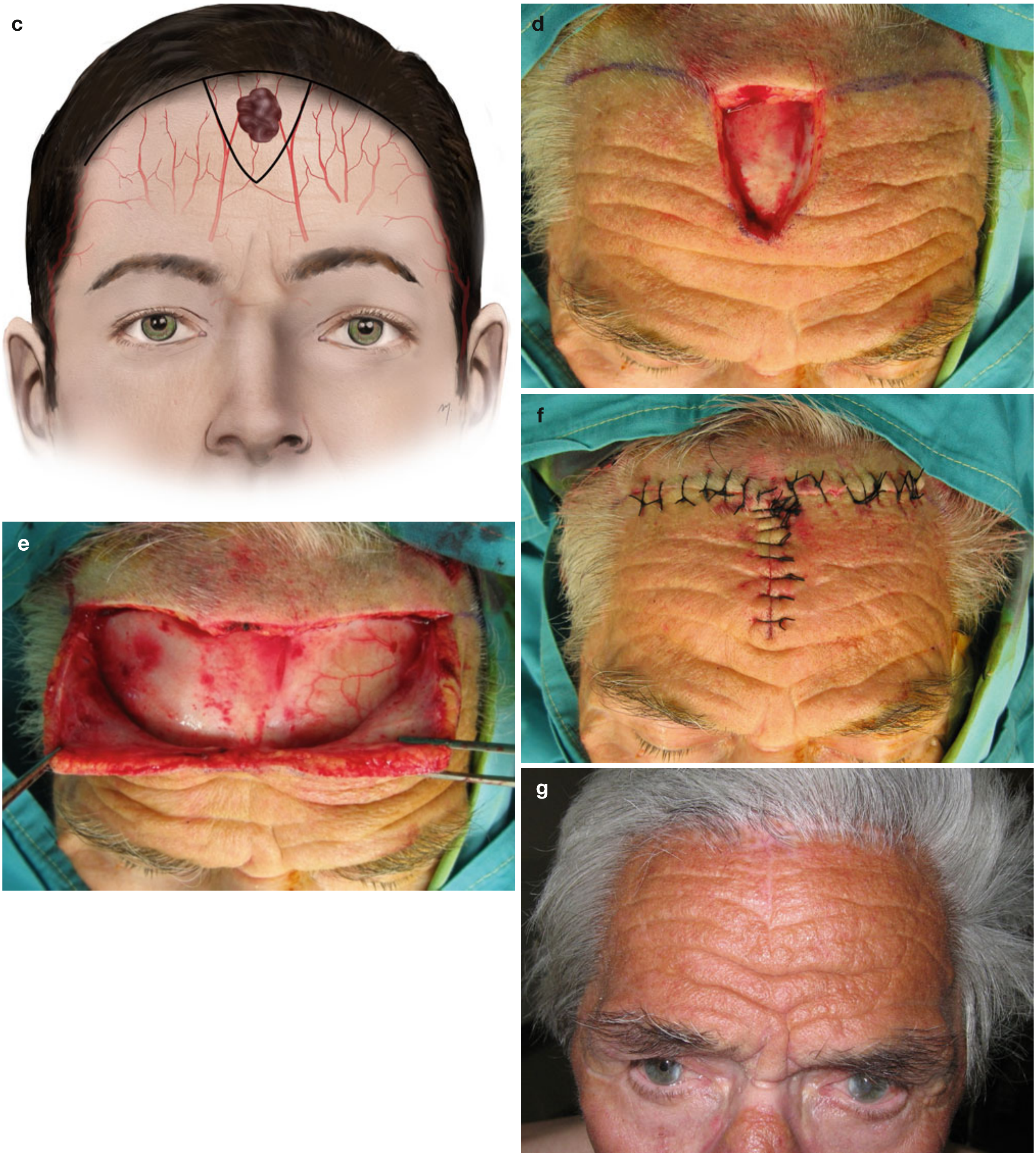


Fig. 3.28 (continued)

resulting in temporary numbness of the anterior scalp for usually 9–12 months. As dissection proceeds laterally, care must be taken to avoid the deep branches of the supraorbital nerve that run approximately 1 cm medially to the superior temporal line, preserving the sensation of the upper forehead and bregma.

The flaps are rotated to the defect and suturing is achieved without tension (Fig. 3.28f). If approximation is under tension, the incisions can be extended to the temporal hairline and the flaps undermined to a larger area of tissue reservoir in lateral forehead and temple. The postoperative result is satisfactory (Fig. 3.28g).

3.5.9 Worthen Forehead Rotation Flap

This large flap, used to reconstruct large lateral, almost hemiforehead, defects, was first described by Worthen in 1974. Resurface is gained by rotating the entire remaining healthy forehead to the recipient site. The flap is an axial flap based on the supratrochlear, supraorbital, and frontal arteries.

The following case demonstrates a recurrent forehead squamous cell carcinoma after two times surgery and radiotherapy. Scar tissue and multiple operations demand a wide excision so as to ensure clear margins and vasculized tissue.

The flap was outlined as its incision line was placed behind the frontal hairline (Fig. 3.29a,b). The flap catches ipsilateral to the defect side supratrochlear artery and the contralateral supratrochlear, supraorbital, and frontal arteries (Fig. 3.29c).

A large lateral forehead defect is created after tumor excision (Fig. 3.29d). Periosteum beneath the tumor was also excised. Clear margins were determined by frozen section biopsies.

The flap is elevated by blunt dissection in the loose areolar tissue plane carried out to the supraorbital area. At a line 2 cm above the supraorbital rims, the dissection transitions to a subperiosteal plane (Fig. 3.29e). At this point, injury prophylaxis of supratrochlear and supraorbital bundles is mandatory. The flap incorporates the frontalis, galea, and supraorbital muscles. Scoring the galea in its undersurface is a useful maneuver to gain extra flap length.

After rotation, the flap is sutured in place (Fig. 3.29f). Wide undermining of the frontal scalp is necessary to achieve closure in the periphery of the flap.

Even though this flap is very reliable, it is stiff, sometimes resulting in a moderate degree of difficulty regarding the closure of large wounds without tension, even after scoring the galea. This may lead to scar formation and brow asymmetry of the recipient side, needing secondary correction (Fig. 3.29g, h).

3.5.10 Paramedian Forehead Flap

The forehead has been acknowledged as one of the most ideal donor sites in nasal reconstruction, after the nose itself. The forehead is adjacent to the nose, and its skin is pliable enough to fold, thus allowing it to be crafted into the complicated contour of the nose. The big tissue availability of the forehead allows the flap to receive not only suitable width but also the adequate length in cases where columella and alar rims should be reconstructed. The complexion and texture of the forehead skin have a considerable resemblance to that of the nose, and the reconstruction is very satisfactory aesthetically, avoiding a “patch” impression (Coleman 1959; Millard 1966).

The axial flaps that are based in the forehead vascularity and are used in nasal reconstruction emerged during the years as improvement of the ancient Indian flap.

These basic variabilities of the flap appear in the literature with a confusing nomenclature. A clear and brief definition of them according to the feeding vessels and the flap axis follows.

The median forehead flap (Fig. 3.30a), according to the classic India design, was drawn along a straight vertical axis and extended from the glabella to the hairline. It has a wide pedicle gaining axial supply from both supratrochlear arteries. The skin paddle is oriented vertically in the mid-forehead.

The paramedian flap has a narrower pedicle, based laterally to the previous. Its base is located at the medial brow capturing one supratrochlear artery. The flap paddle can be vertically (Fig. 3.30b) or obliquely (Fig. 3.30c) oriented beyond the midline, where its distal part becomes random pattern.

The midline forehead flap (Fig. 3.30d) mixes the median and paramedian flaps. It has its pedicle like the paramedian flap, at the medial brow having its axial supply from one supratrochlear artery, and its paddle in the central forehead like the median flap.

The “gull-wing” flap (Fig. 3.30e) is a modification of the paramedian forehead flap and was first described by Gillies (1920) and refined by Millard (1974). With this design, transverse extensions are created on the standard paramedian flap. These can be used to cover extensive bilateral nasal tip, infratip, and lobule defects. The donor site can be closed primarily in a T-form. Its main vascular supply is the supratrochlear bundle based on the medial aspect of the one brow. The circulation to the distal portions of the flap is primarily random pattern.

No other flap has focused so much interest than the Indian forehead flap. The Indian flap in nasal reconstruction has been used for thousands of years, and its development and modifications reflect each time the knowledge of the anatomic vascular pattern of the forehead. In an attempt to understand the reliability and viability of this ancient flap and to develop further modifications, surgeons rather than anatomists performed research on this topic. This is obvious in classical anatomic textbooks and illustrations where the anatomy of forehead vessels is poorly described. Knowing the history of the flap leads to a better understanding not only of the flap itself but also of forehead vascular anatomy.

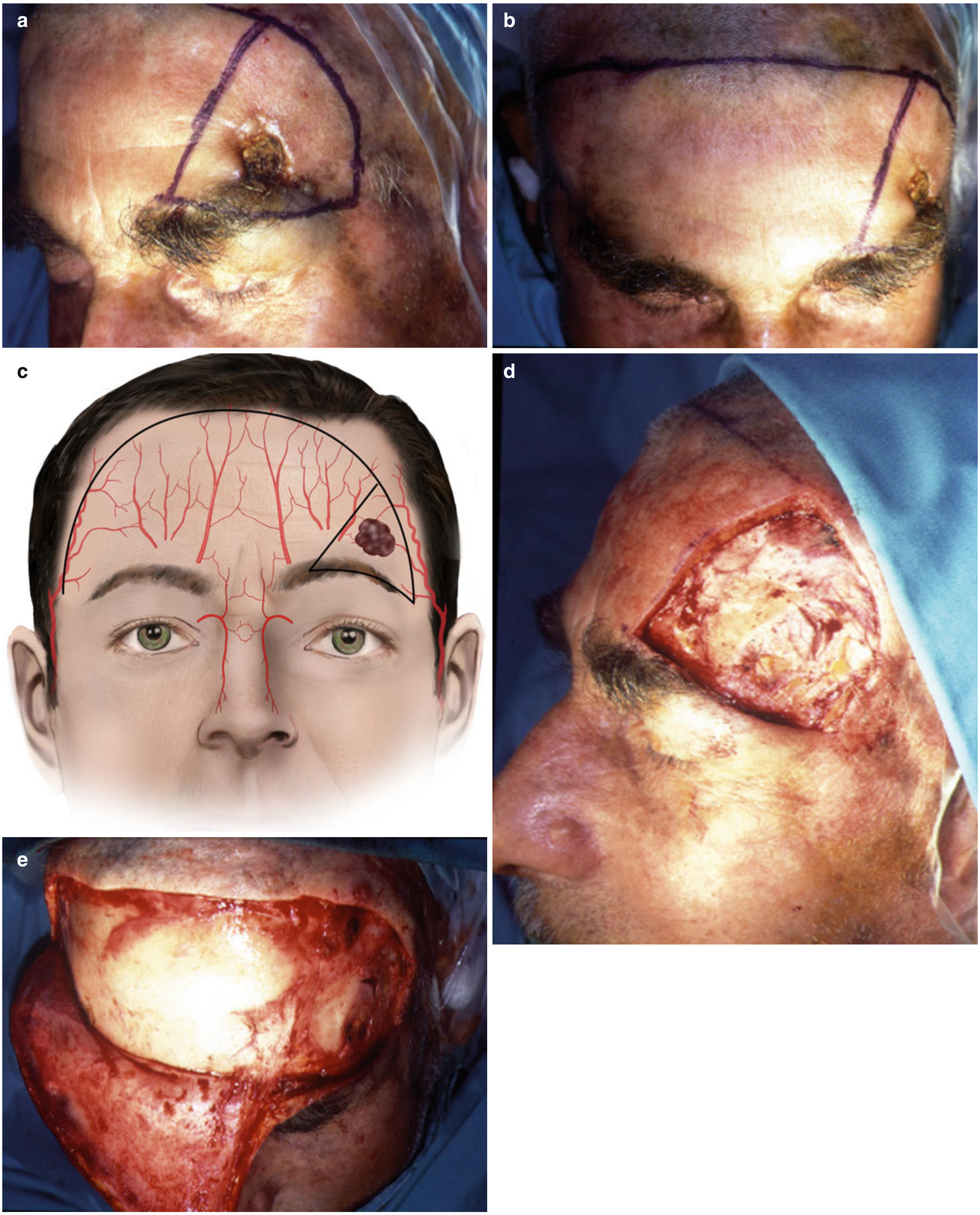


Fig. 3.29 (**a**, **b**) Excision line and flap design outlined. (**c**) The flap is based on the supratrochlear, supraorbital, and frontal arteries. (**d**) Lesion excised. (**e**) The flap is elevated at the subgaleal plane and 2 cm above the supraorbital rims proceeds to the subperiosteal plane. (**f**) Immediate postoperative view. (**g**, **h**) Result at 6 months. Scar formation and brow asymmetry, needing correction, are evident

Fig. 3.29 (continued)

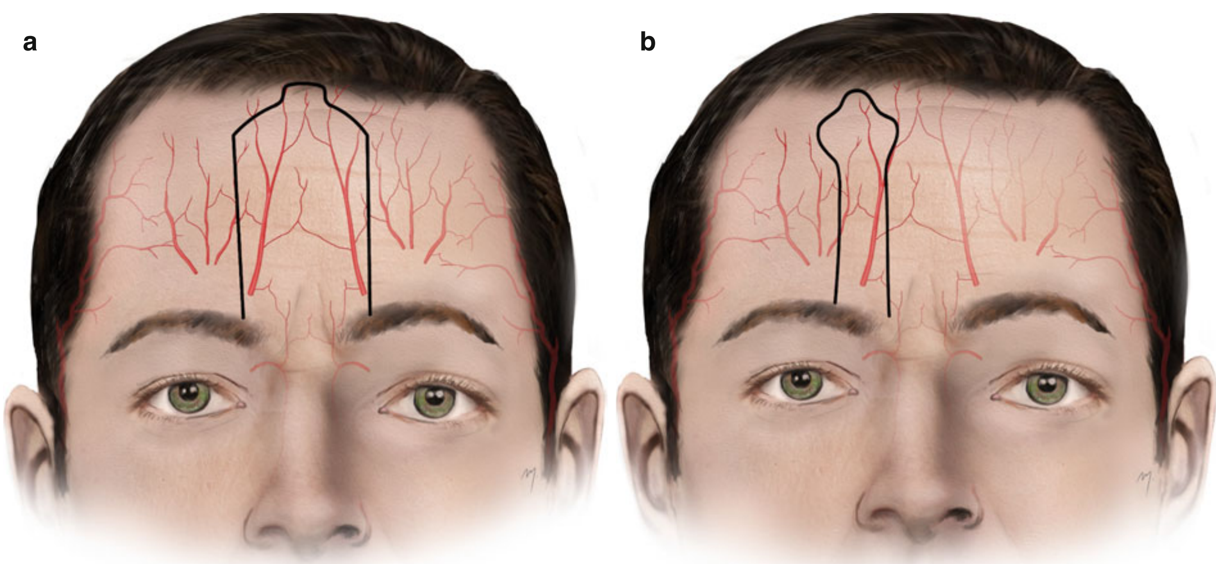


Fig. 3.30 (**a**) Median forehead flap (India flap). (**b**) Paramedian forehead flap (vertical). (**c**) Paramedian forehead flap (oblique). (**d**) Midline forehead flap. (**e**) "Gull-wing" flap

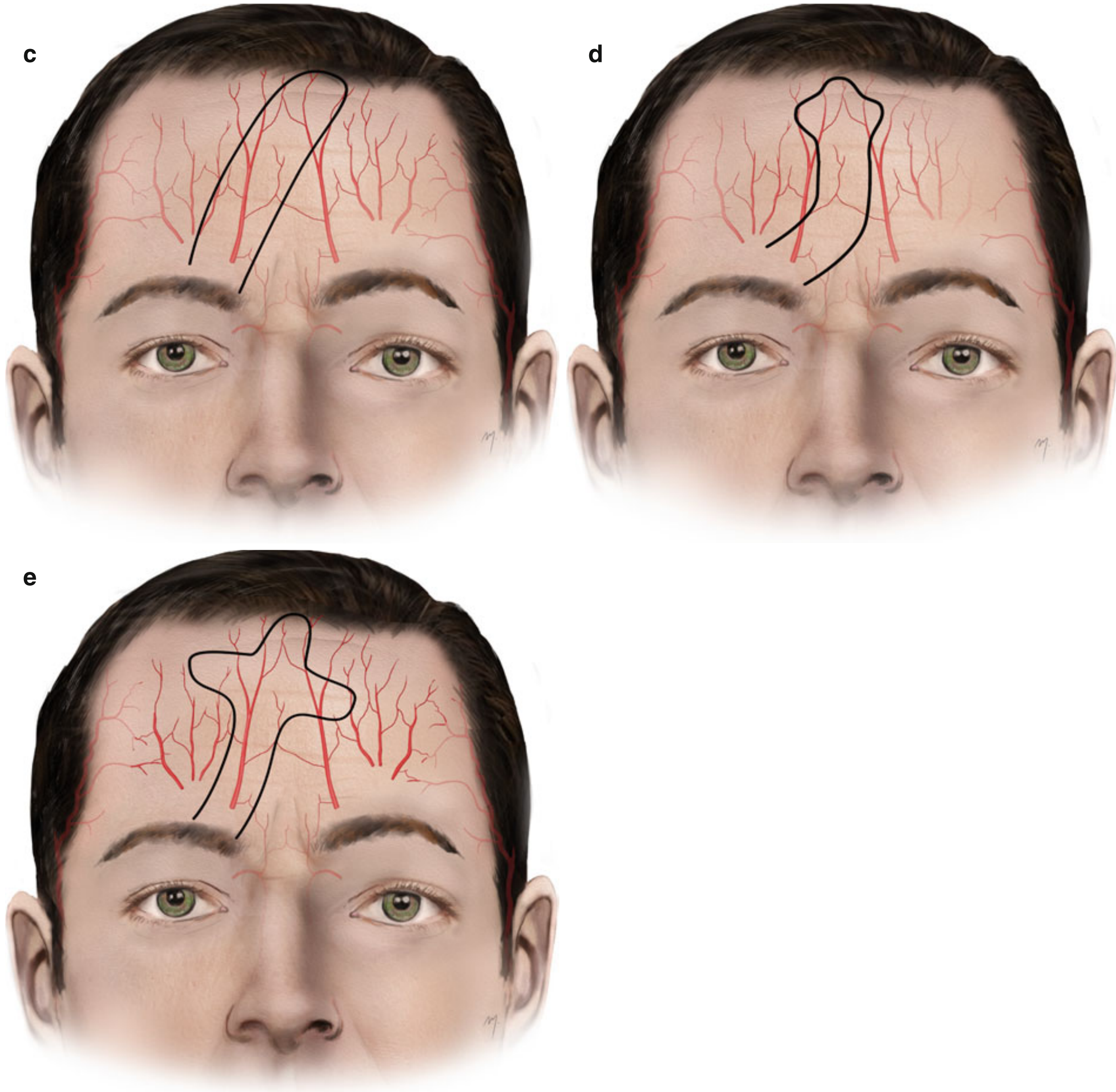


Fig. 3.30 (continued)

3.5.10.1 History of the Indian Flap

The first description of nasal reconstruction is found in India in the Sanskrit text Sushruta Samhita (600 BC), a Brahmin holy text, where nose amputation was a way of punishment. The operation of reconstruction was performed by a caste of Indian potters and bricklayers. Buddhist missionaries who practiced Ayurvedic medicine probably spread this technique to Greece during the Golden Age. After a very long period, this knowledge possibly influenced Gaspare Tagliacozzi, who developed a technique in 1597 known as the Italian flap, by using a pedicle from the inner arm for nasal reconstruction. The forehead flap technique was not performed in Western medicine for hundreds of years. An editorial published in the "Gentleman's Magazine of London" (1794), describing the reconstruction of an amputated nose with a forehead flap, inspired J.C. Carpue to perform two successful medial forehead flaps in England (1814), spreading the method through Europe (Reece et al. 2008; Whitaker et al. 2007).

In the twentieth century, during World War I, a young surgeon (who became later a legend in surgery and Sir) named Harold Delf Gillies treated war injuries and burns by using forehead flaps. These first forehead flaps, named by Gillies "up and down flaps," were based in both supraorbital arteries, having a U shape. Gillies standardized his techniques and established the discipline of "plastic surgery." In 1920, his textbook "Plastic Surgery of the Face" was published, setting down the principles of modern plastic surgery, principles which were adopted by surgeons from every part of the world (Gillies 1920, 1935; Gillies and Millard 1957).

In 1946, Kazanjian popularized the midline forehead flap in the American literature. Kazanjian designed the forehead flap in the midline, determining that the blood supply of the flap was the supratrochlear and supraorbital arteries and closed the donor site primarily enhancing the final esthetical result (Kazanjian 1946). Since then, many surgeons based on detailed vascular anatomic studies of the forehead developed many alternative modifications to the India forehead flap.

In the decade of the 1960s, Converse and Wood-Smith (1963), in an attempt to reconstruct nasal dorsum defects, based the forehead flap in a subcutaneous pedicle, developed thus the first forehead island flap. Some years later, Millard (1966, 1967) designed a large standard paramedian forehead flap with two transverse extensions, called the "gull-wing flap." This flap can be used to cover extensive bilateral nasal tip, infratip, and lobule defects. The donor site can be closed primarily in a T-form. Its main vascular supply is the supratrochlear bundle based on the medial aspect of one brow. The circulation to the transverse distal portions of the flap is a primarily random pattern.

Converse (1969) described the scalping forehead flap. This flap, originally described by Converse in 1942, harvests a large area of lateral forehead skin, based on a wide pedicle of hair-bearing scalp. The flap is actually the improvement of classic Indian flap, constituting one of the best techniques for total and subtotal nasal reconstruction. The flap is long and supple enough to fold on itself, so that recreates the alar rims and the lobular portion of the nose (Converse 1977; Converse and McCarthy 1981; McCarthy 1990). The reliability of this flap is ensured by the rich arterial vascularization from supratrochlear and supraorbital arteries as well as by the anterior branch of the superficial temporal artery of its base.

Having already gained trust in the forehead flap and after the modifications in design that were developed, research interest became oriented in the deeper anatomic understanding of flap vascularization and as a result in total forehead vascularity.

The importance, not only of the supratrochlear artery but also of the dorsal nasal artery in the vasculature of the forehead flap, begins to become apparent both in clinical (Sawhney 1979) and in anatomic reports (Mangold et al. 1980).

Mangold et al. (1980), in latex-like injection studies and cadaveric dissections, showed that the branches of the ophthalmic artery—dorsal nasal artery, supratrochlear artery, and supraorbital artery—are the vessels that supply the forehead skin. All of them anastomose with the frontal branch of the superficial temporal artery.

Furthermore Mangold et al. proved the importance of the forehead branch of the dorsal nasal artery in supplying the central part of the forehead. These vessels along with the supratrochlear artery that lies on the paramedian line communicate with each other and are the primary nutrition vessels of the paramedian forehead flap.

In 1985, McCarthy et al. studied the median forehead flap blood supply in a cadaveric study. They injected the facial arteries of six fresh cadavers with disulfine blue dye and Microfil, after the supratrochlear and supraorbital arteries had been ligated. Nevertheless, sufficient flow into the forehead, by the anastomotic relationship between the angular artery and the dorsal nasal artery, was demonstrated. The results confirmed in a way Mangold's studies. The authors suggested that the median forehead flap could be elevated without incorporation of the supratrochlear vessels.

In an attempt to gain additional length to the paramedian flap, Burget and Menick (1985, 1986, 1989) extended the incisions for the pedicle below the orbital rim. This usually is necessary in nasal tip reconstruction, where otherwise the need for extra length would extend the flap into the hair-bearing scalp. Intraoperatively, they also noticed that the terminal branches of the supratrochlear artery lie over the superficial fascia of the frontalis muscle, immediately under the dermis. Thus, they stated that fat and frontalis muscle could be removed without danger from distal flap skin necrosis. In 1990, Menick further refines the design of paramedian flap, by making the pedicle narrower and so gaining a suppler flap.

An extensive anatomic evaluation of the arterial system of the face was performed by Whetzel and Mathes (1992). By using numerous anatomic techniques (selective ink injections, dissection and measurement of latex-hardened perforators, and radiographic examination of transverse sections of barium-injected specimens) in cadavers, they defined 11 vascular territories and the dominant arteries of the face and scalp. Regarding the vasculature of the forehead, they delimited the perforators of supratrochlear, supraorbital, and superficial temporal arteries and found among other findings that the anastomosis between the supraorbital artery and the superficial temporal artery occurred through its deep branch.

At the same time, Schumrick and Smith (1992) carried out an important cadaveric study to define the precise arterial basis for the forehead flap design, concerning the vascular topography of central forehead. By means of roentgenographic examinations of injected cadaver heads, anatomic dissections of injected cadaver heads, and Doppler examination of normal subjects, they described the course of the supratrochlear artery in detail. Moreover, they evinced the anastomosing network between the angular, supratrochlear, supraorbital, and superficial temporal arteries.

Fukuta et al. (1994) and Potparic et al. (1996), being in mainly the same research group, investigating the blood supply of galeal flaps, demonstrated a detailed arterial branching pattern of the supratrochlear, supraorbital, and superficial temporal arteries.

As forehead vascular research progresses, branches now from the dominant arteries of the forehead begin to be used as axis of additional flaps (Capizzi et al. 1999).

Still at 2000, the exact role and contribution of the angular artery in median and paramedian flaps were not been clarified (Fan 2000; Park 2000). Relation of the anatomic location of the supratrochlear artery with regard to the glabellar frown lines, studied by cadaveric dissection and Doppler imaging, begins to serve as novel anatomic landmark for the pedicle position of paramedian forehead flap (Vural et al. 2000).

In a static and dynamic anatomic study of the vascular system of forehead, Reece et al. (2008) revealed that, despite of the forehead arterial anastomosing network, a certain supraorbital arterial plexus exists above the supraorbital rim. This plexus connects the dorsal nasal, supratrochlear, and supraorbital arteries. The superior margin of this plexus extends to a maximum of 7 mm above the supraorbital rim.

This is an important anatomic structure reclaimed in designing and raising the paramedian forehead flap with a distal cross forehead transverse limb (Rohrich's modification). According to the anatomic study of Kelly et al. (2008) an abundant vascular arcade exists within the medial canthal and paranasal region. This is comprised of the supratrochlear, supraorbital, and dorsal nasal arteries above and further down by the angular, infraorbital, and lateral nasal arteries. This anatomic feature allowed Jackson (2007) to base median forehead flaps, with a narrow pedicle, at the level of or even below the medial canthus, gaining much longer and safe forehead flaps. It seems that the forehead flap has not revealed all of its secrets during the past 2,500 years. Questions regarding the exact arterial pattern of it's pedicle remain unclarified and answers resulting from different experimental methods, differ from writer to writer.

Through this development, the paramedian design of the forehead flap becomes the most useful and popular in the reconstruction of medium and large nasal defects. The paramedian forehead flap is based in one supratrochlear and dorsal nasal artery, and its paddle can be oriented in a straight or a vertical orientation. The length of the flap needed and the position of the frontal hairline determine the vertical or oblique design of the flap. In patients who have a high hairline, the flap can be in such a length as to reach even the tip of the nose.

3.5.10.2 Vertical Paramedian Forehead Flap

3.5.10.2.1 Flap Design

The patient that is demonstrated in Fig. 3.31 presented with a basal cell carcinoma located at the tip of the nose. Resection of the lesion and reconstruction with a paramedian forehead flap was planed. Due to patient's high forehead, a vertically directed paramedian forehead flap can be designed (Fig. 3.32a). The area of excision is outlined and transferred to a template that is used to outline the exact needed forehead skin (Fig. 3.32b, c).

Fig. 3.31 A basal cell carcinoma located at the tip of the nose

The proposed flap length is controlled, and the flap must be outlined slightly longer than actually seems to be necessary (Fig. 3.32d, e). Since the flap is to be turned (almost 180°), some length is lost in rotation, but in spite of this, it must be rotated without any tension so as not to compromise its blood supply.

The base of the flap is centered over the supratrochlear artery. The origin of the artery is usually found to be 2 cm lateral to the midline (Fig. 3.32f, g). Palpation of the artery is also useful to ensure its position, but if the surgeon lacks experience and still feels uncomfortable, a Doppler amplifier can be used to find the location of the supplying vessel. A pedicle width of 1.5–2 cm is enough to incorporate the vessels and to allow easy rotation of the flap, without strangulating them (Fig. 3.32h). The width of a paramedian forehead flap, which allows primary closure of the donor site, is approximately 2.5–3 cm.

3.5.10.2.2 Flap Elevation

After the resection of the lesion, the flap is elevated. Initial incisions are made inside the marked lines through the skin, subcutaneous tissue, and muscles (frontalis, procerus, and the upper part of orbicularis muscle) leaving the corrugator intact at this stage. Elevation starts at the cephalic end of the flap in the subgaleal plane and proceeds quickly by either sharp or blunt dissection (Fig. 3.33a, b).

Proceeding to the base, 1 cm above the supraorbital rim, the periosteum is incised, and dissection transitions in the deeper subperiosteal plane (Fig. 3.33c, d). Before incising the periosteum, the corrugator muscle fibers are carefully separated by blunt dissection, so as to preserve the vascular branches, while restricting bands of muscle are released and sectioned (Fig. 3.33e). The supratrochlear neurovascular bundle now is well protected, being above the periosteum.

3.5.10.2.3 Donor Site Closure

Donor site defects of the forehead up to 3 cm can be closed primarily. Primary closure of the donor defect usually requires extensive mobilization of the forehead. This is done at the subgaleal plane by wide blunt dissection up to the forehead borders (Fig. 3.34a, b). Primary closure is then easy and is done in two layers (Fig. 3.34c).

3.5.10.2.4 Thinning of the Flap

If the flap is too bulky to resurface the nose defect, elevation is followed by the thinning of its borders and no more than its distal 2 cm (Baker 2011). The galea, frontalis muscle, and

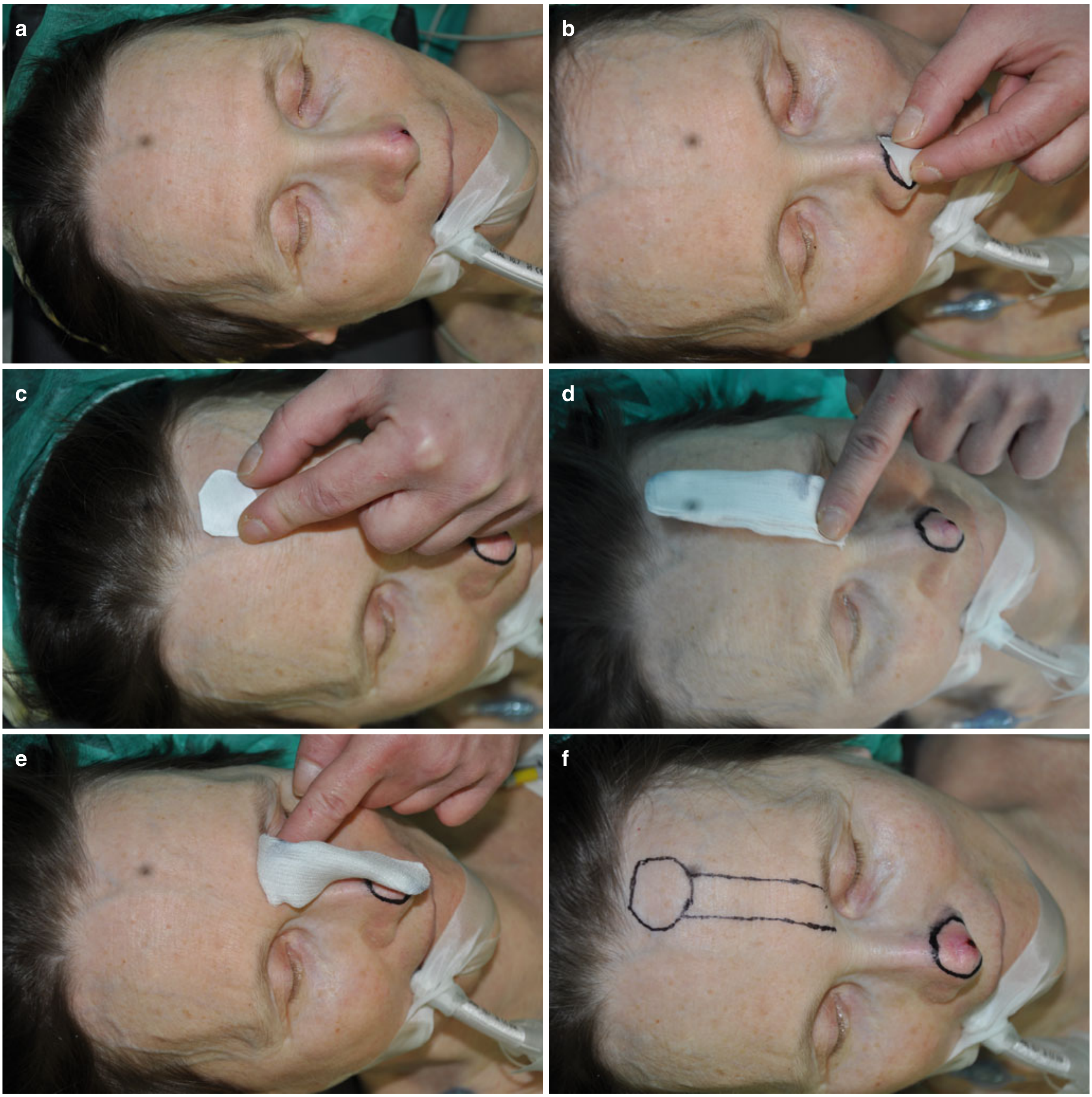
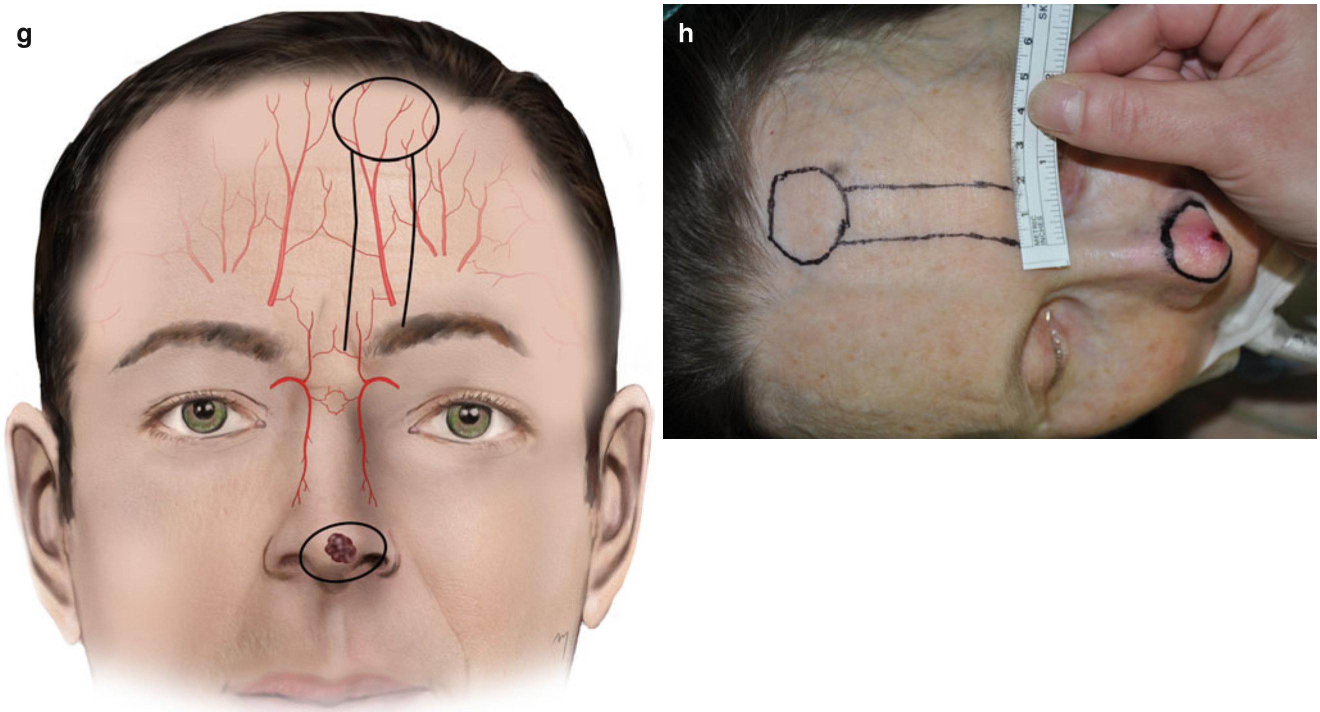


Fig. 3.32 (**a**) The patient has a high forehead allowing the flap to be directed vertically. (**b**) A template imprints the area of excision. (**c**) The template is transferred to the donor site and used to outline the exact needed skin. (**d**, **e**) Flap length controlled. The flap must be outlined slightly longer than the measured distance. (**f**) The exit point of the supratrochlear artery to the forehead is marked 2 cm lateral to the midline and the paramedian flap outlined. (**g**) Flap centered over the supratrochlear artery. (**h**) The flap base is about 1.5–2 cm wide



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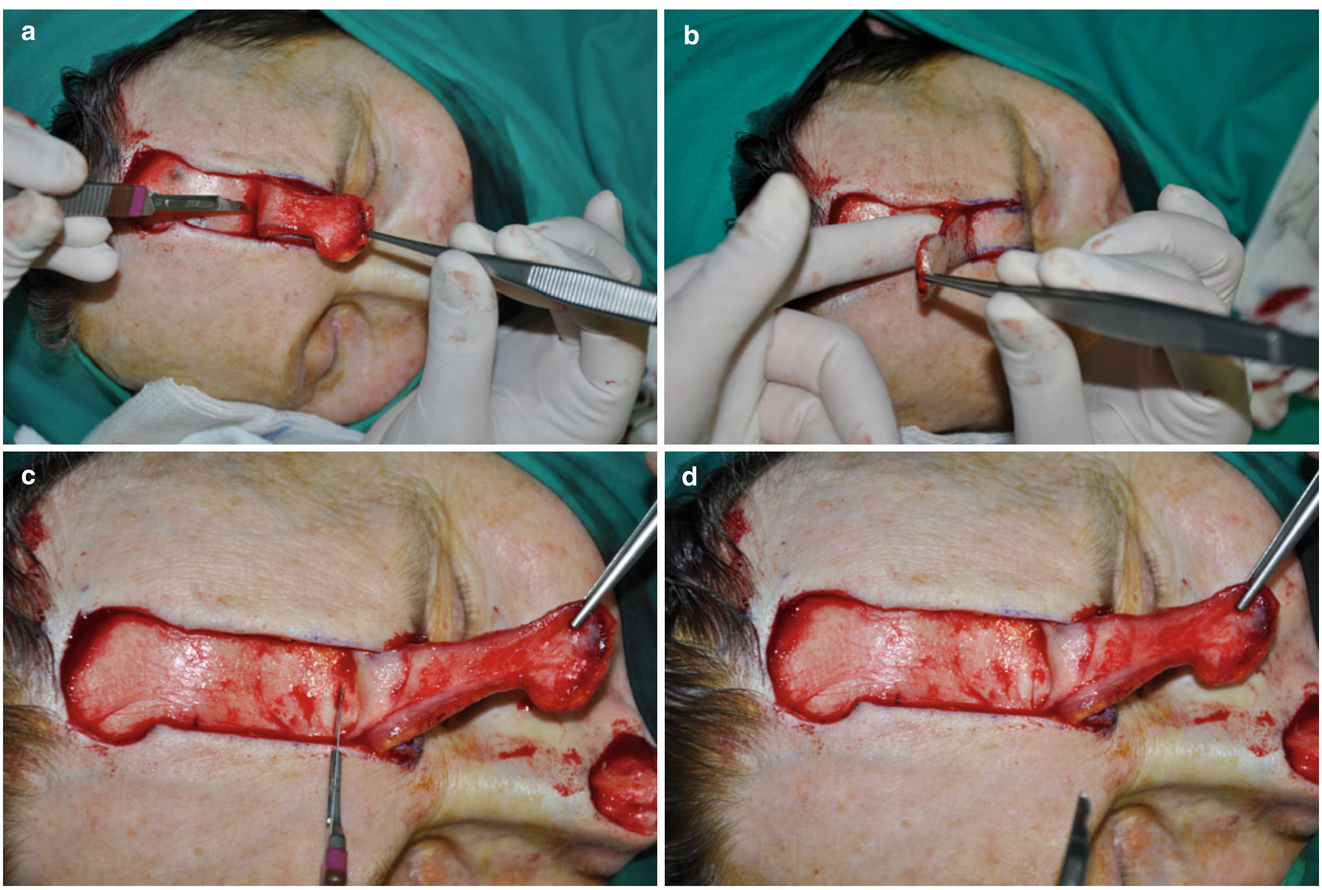


Fig. 3.33 (**a**, **b**) Elevation starts at the cephalic end in the subgaleal plane, and dissection is performed sharply or bluntly either with the finger. (**c**, **d**) 1 cm above the supraorbital rim, the periosteum is incised, and dissection deepens to the subperiosteal plane. (**e**) Corrugator muscle fibers are separated

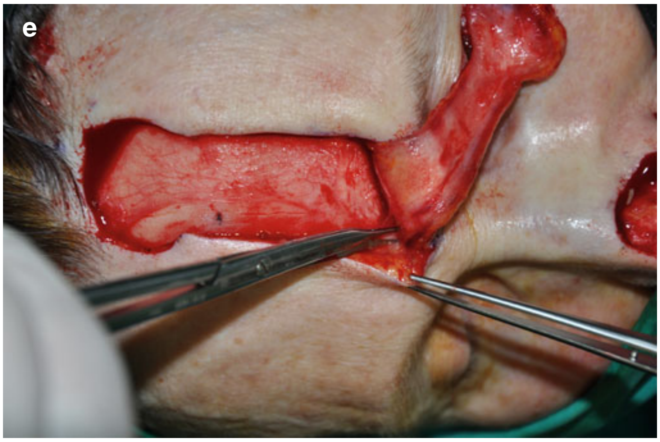


Fig. 3.33 (continued)

subcutaneous fat are removed (Fig. 3.35a). During this procedure, axial terminal branches of the arteries may be visible in the subcutaneous tissue very close to the dermis and thus can be carefully preserved (Fig. 3.35b). If the surgeon feels that the thinning imperils the safety of the flap, it is better to perform it in a later surgical correction. The flap is then sutured in place resurfacing the initial defect (Fig. 3.36a, b).

3.5.10.2.5 Pedicle Division

The skin pedicle remains for a period of 2–3 weeks (Fig. 3.37a, b) and at the second surgical stage is divided and the final reconstruction takes place.

The base of the pedicle is divided, at a level that leaves sufficient glabellar skin (Fig. 3.38a). It is inset as a Greek letter Λ, 1 cm high, just medial to the eyebrow (Fig. 3.38b). Thus, the inter-eyebrow distance and glabella wrinkle lines are restored to normal. The distal part of the flap that surrounds the superior part of the defect has a vascular efficiency that allows it to be elevated from the nasal defect for approximately 1 cm. By this, it can be thinned of fat and muscle, trimmed, and shaped to an ideal nose contour.

Even in the early postoperative period, the result is excellent (Fig. 3.39a, b).

3.5.10.3 Oblique Paramedian Forehead Flap

In the patient presented, a basal cell carcinoma of the tip was excised, and reconstruction was performed with the use of an oblique paramedian flap (Fig. 3.40a–m). The axis of the paramedian flap was determined by the relative low position of the frontal hairline. The difference in this design is that the oblique paramedian flap is of axial pattern except the portion that extends midline. In this case, the deep infiltrating tumor determined a wide and deep resection of the tip that needed bulky tissue to restore completely its contour. For this reason, no flap thinning was done, resulting in a normal postoperative appearance.

3.5.10.4 Paramedian Forehead Flaps Combined with Lining Flaps

The robust forehead flap can safely lie on a bed even if it is the undersurface of a random pattern turn-over flap that lines the nasal mucosa of a through and through defect. In certain cases, flap thickness is able to round the nose contour and shape. The flap is stiff enough to provide a stable restoration, with no need of cartilage grafting, and does not collapse, acting as a valve, in breathing function. Two examples of such cases in different nasal defect locations are presented.

3.5.10.4.1 Through and Through Nasal Tip Defect

The patient that is presented had a full-thickness nasal defect after resection of an ulcerative basal cell carcinoma located at the tip of the nose (Fig. 3.41a–g). A turn-over flap of the adjacent nasal skin adjacent to the defect was used to reline the nasal cavity. The external skin coverage was restored by a paramedian forehead flap. No cartilage grafting was used. The combination of forehead skin and lining skin provided adequate tissue bulk to round out nasal contour.

3.5.10.4.2 Full-Thickness Alar Defect

In the deep invasive recurrent basal cell carcinoma demonstrated, wide and full-thickness resection of the ala was needed to get tumor-free surgical margins (Fig. 3.42a–g). A paramedian flap based contralaterally was designed for external cover. A turn-over flap was outlined to provide the internal cover. The presence of a nevus located at the side of the nose modified the axis of the turn-over to a slightly oblique position.

The alar rim contour was reconstructed by not folding the distal part of the forehead flap but folding the turn-over flap. Folding the turn-over flap to reconstruct the alar rim, skin closer in color and texture to the area was provided, even though an additional linear scar is "endowed." The final result of this leads to the enhanced concealment of the "new" alar rim and a more normal appearance in this aesthetically crucial nose part. The paramedian flap resurfaced the rest of the defect, and an aesthetically and functionally postoperative result was obtained.

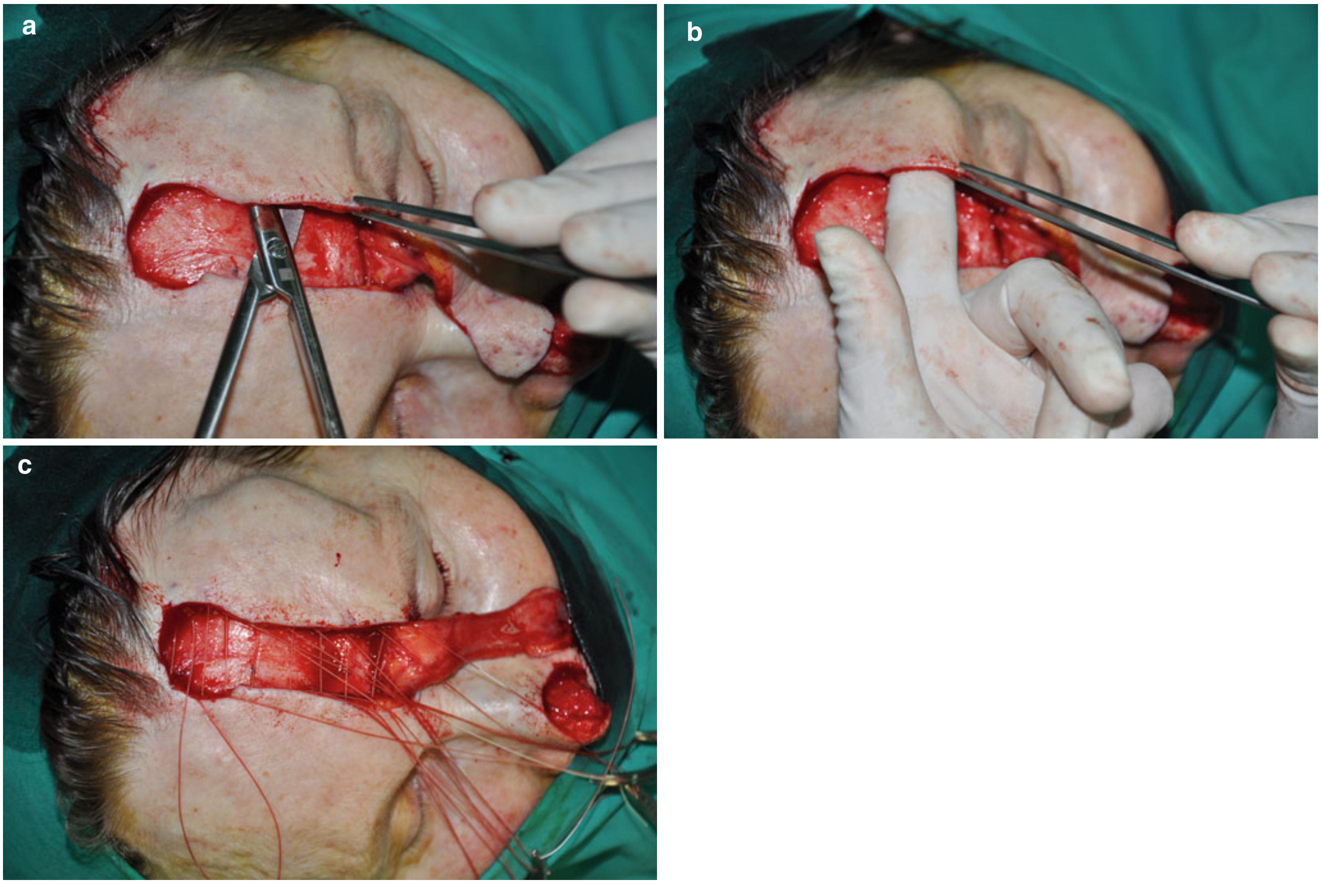


Fig. 3.34 (**a**, **b**) Wide undermining of the donor site in the subgaleal space. (**c**) Donor site is closed in two layers. Forehead muscle and galea are approximated by interrupted absorbable sutures

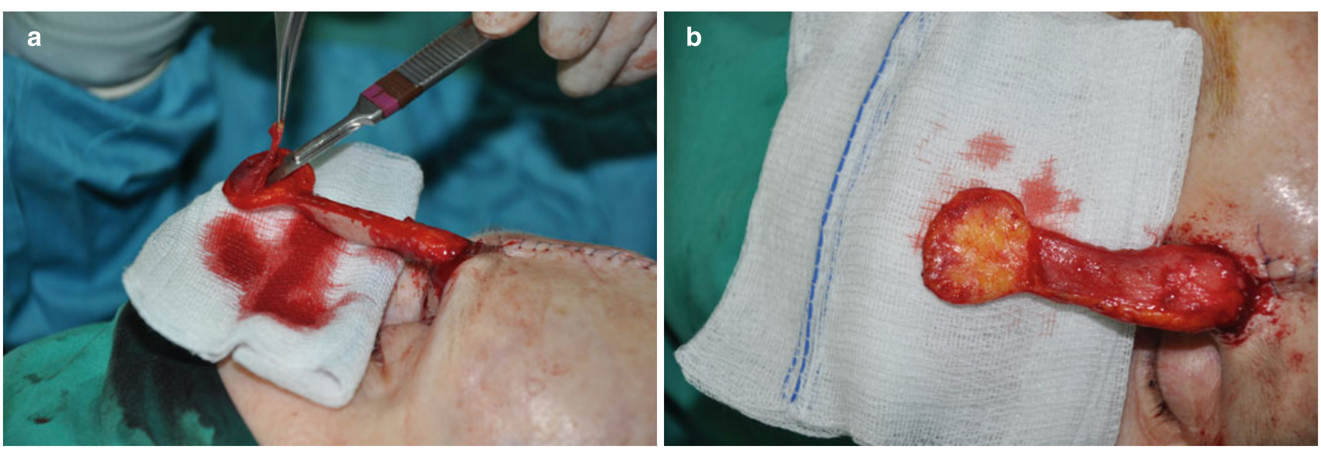


Fig. 3.35 (**a**, **b**) Thinning of the flap

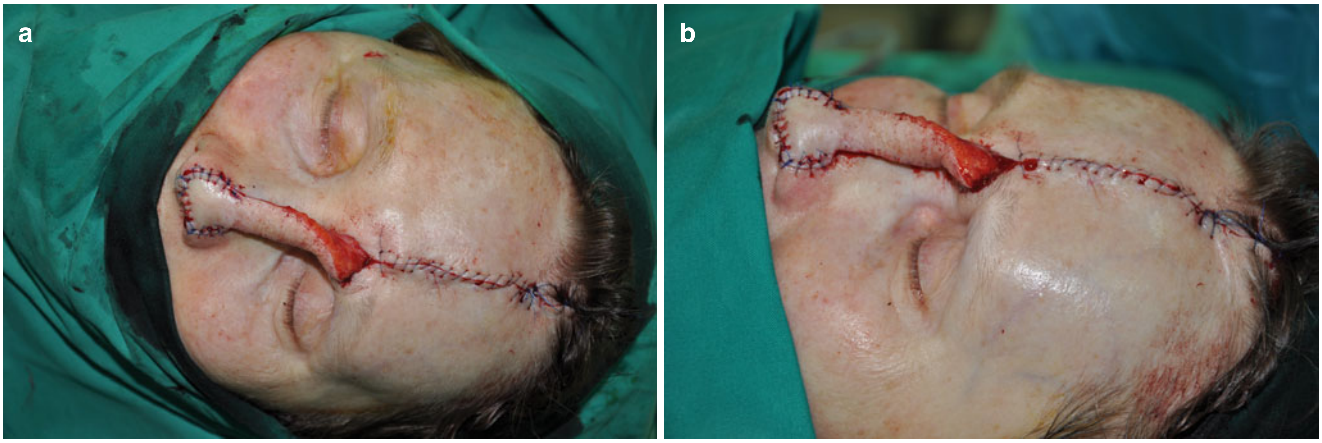


Fig. 3.36 (**a**, **b**) The forehead flap sutured in place reconstructing the nose defect

Fig. 3.37 (**a**, **b**) Skin pedicle remains for 2–3 weeks

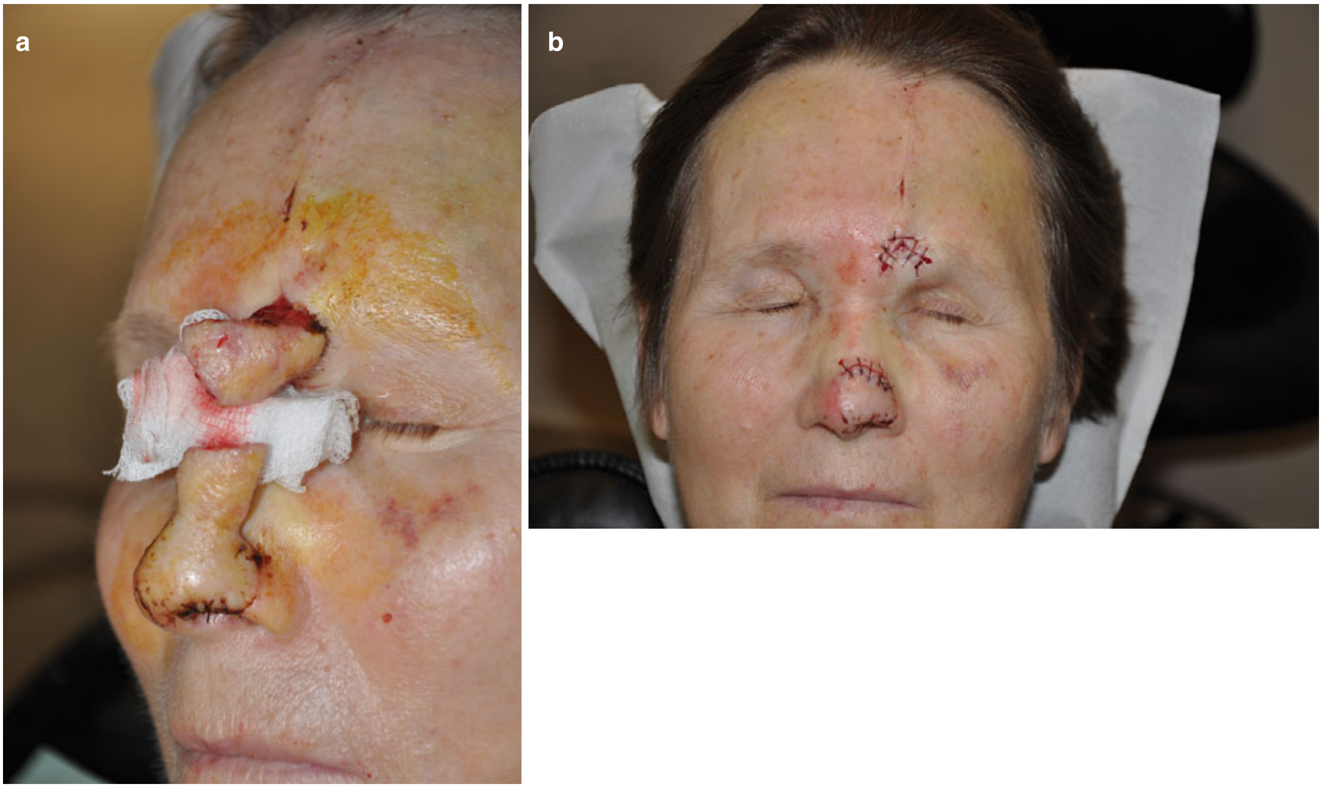


Fig. 3.38 (**a**, **b**) Pedicle divided

Fig. 3.39 (**a**, **b**) Result at 3 months

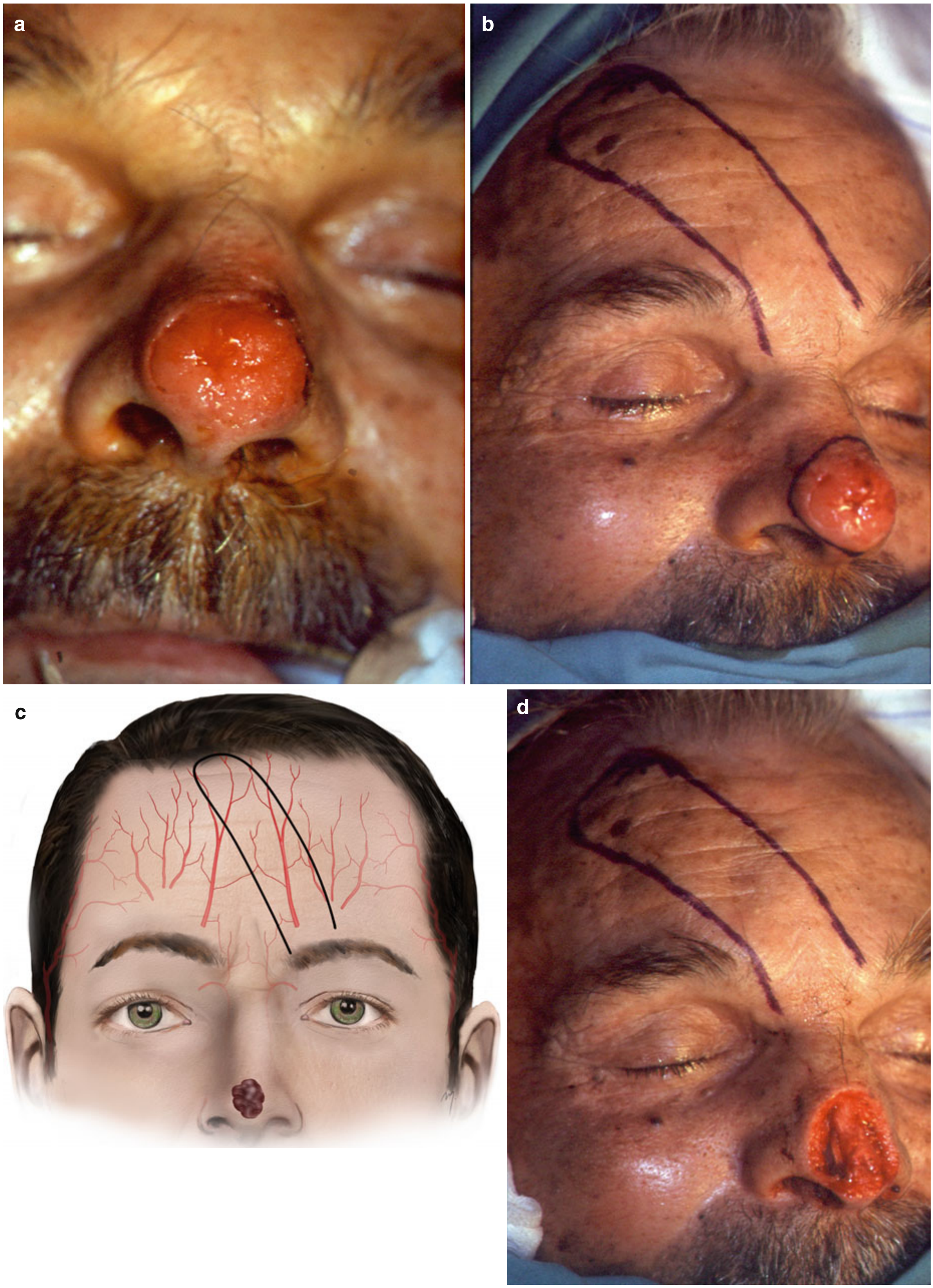
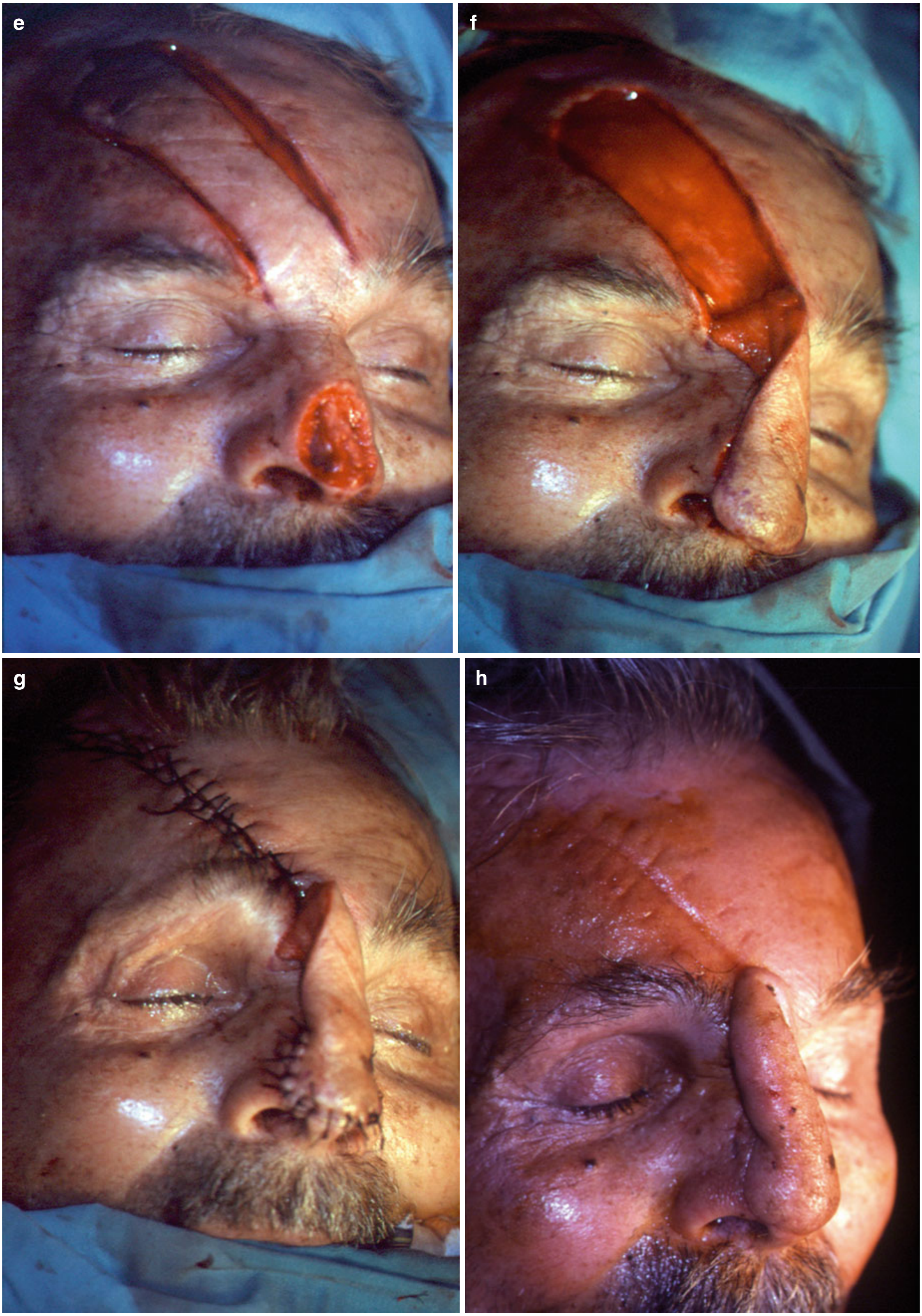


Fig. 3.40 (**a**) A deep invasive basal cell carcinoma located at the tip of the nose. (**b**) Excision line and flap are outlined. (**c**) The oblique paramedian flap is of axial pattern except the portion that extends midline. Based slightly medial, it catches also the glabellar branch of the dorsal nasal artery. (**d**) Tumor excised. (**e**) Flap periphery incised. (**f**) Flap elevated. (**g**) Final suturing. (**h**, **i**) Pedicle remained for 3 weeks. (**j**) Pedicle divided. (**k**) Result at 3 months. (**l**, **m**) No flap thinning was done. The bulky flap restored the contour of the nose tip



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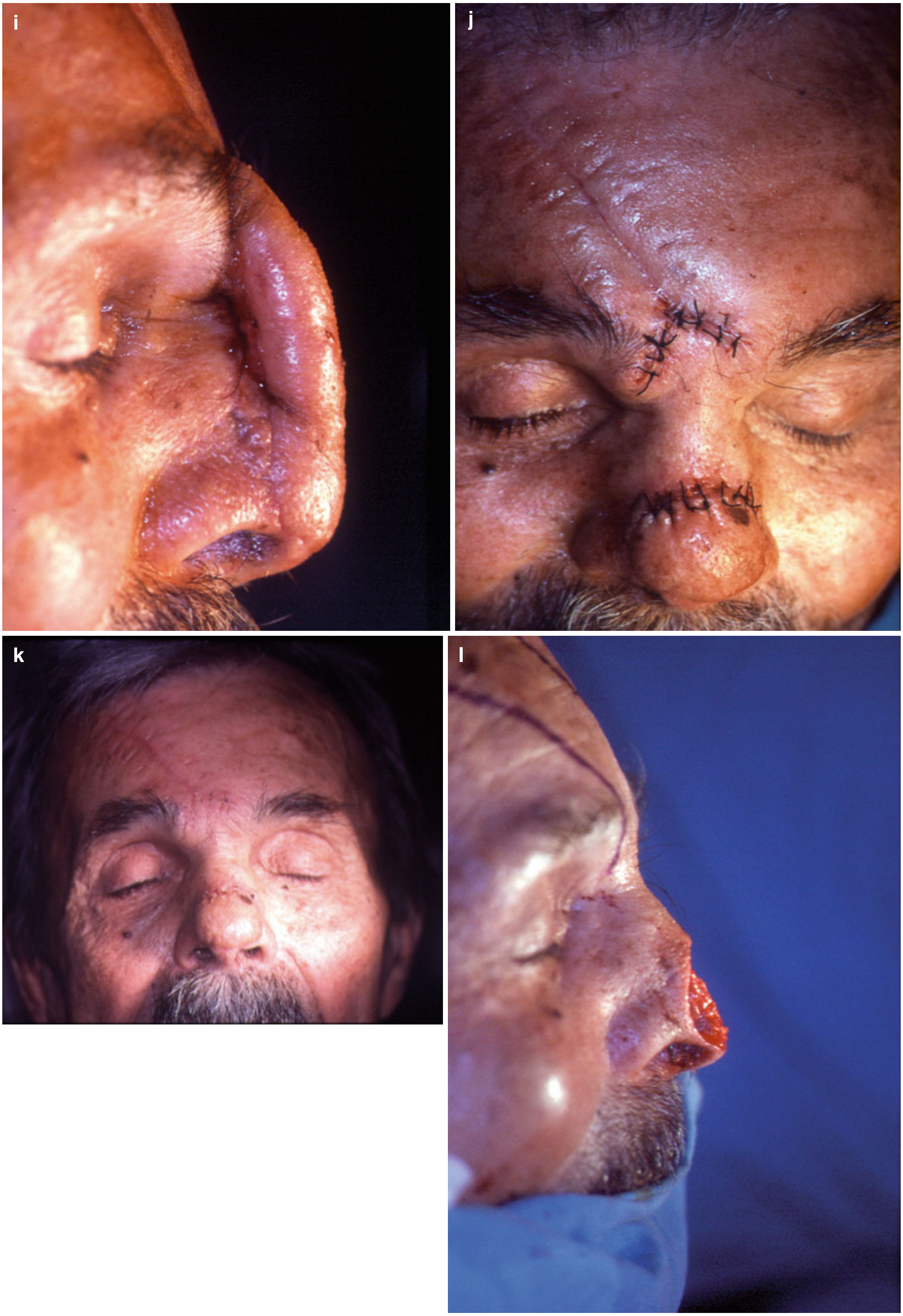

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Fig. 3.40 (continued)

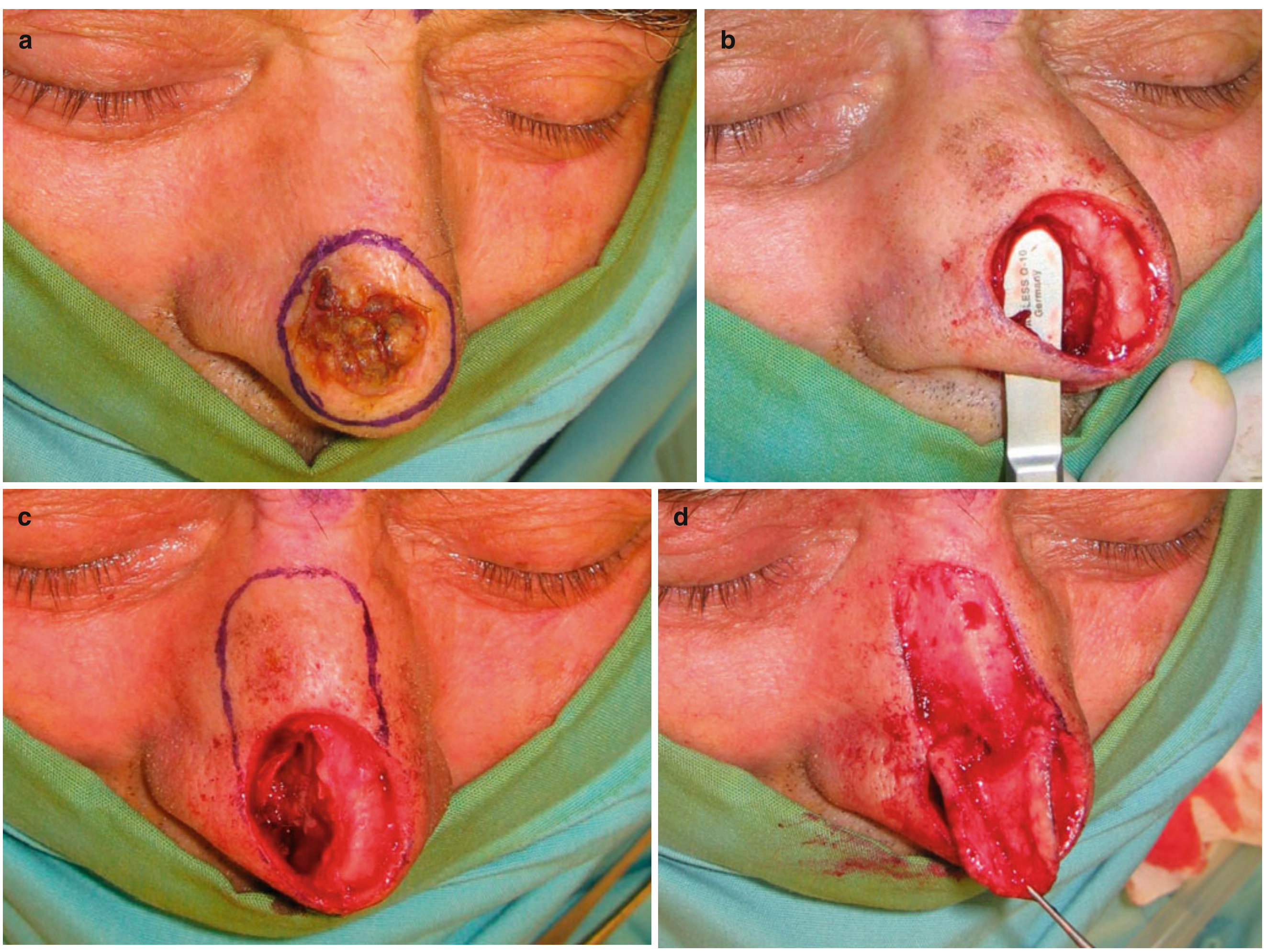

Fig. 3.41 (**a**–**g**) A through and through nasal tip defect restored with a combined paramedian forehead and turn-over flap

Fig. 3.41 (continued)

3.5.11 Paramedian Forehead Flap with a Transverse Limb (Rohrich's Modification)

Rorich modified the paramedian forehead flap by designing a long transverse limb in its distal portion so that more length could be gained (Reece et al. 2008). Although the suggestion is not to design in the forehead the general rule is not to design random flaps with length more than five times the base. Contrary to this, Rohrich`s modification at the transverse limb often exceeds the guideline without distal flap necrosis. His research group found out that a certain supraorbital arterial plexus exists above the supraorbital rim connecting the dorsal nasal, supratrochlear, and supraorbital arteries and that the supratrochlear vessels ran axially into the forehead flap continuing for a short distance across its transverse limb so preventing it from distal necrosis (Reece et al. 2008). Moreover, the deep periosteal branch of supratrochlear artery is incorporated to the flap optimizing its blood flow.

The patient of Fig. 3.43a had traumatic large nasal defect with total loss of the ala, a portion of the nasal tip, and nasal sidewall. A paramedian forehead flap with a transverse limb, according to Rorich, was planned to reconstruct the mixed skin and lining defect (Fig. 3.43b, c).

The flap initially was raised in the subgaleal plane. Attention was needed during its preparation to the base by incorporating the periosteum in its proximal 3 cm and preserving 7 mm of tissue above the supraorbital rim as a zone of safety for the base.

This ensures the capture of the deep (periosteal) branch of the supratrochlear artery and preservation of the superior orbital plexus.

The distal portion of the flap was folded on itself to provide both skin cover and lining (Fig. 3.43d). Cartilaginous grafts were used for skeletal support. The donor site was closed primarily, and a silicon tube was used to provide support in the early stages of healing of the lining, cartilage

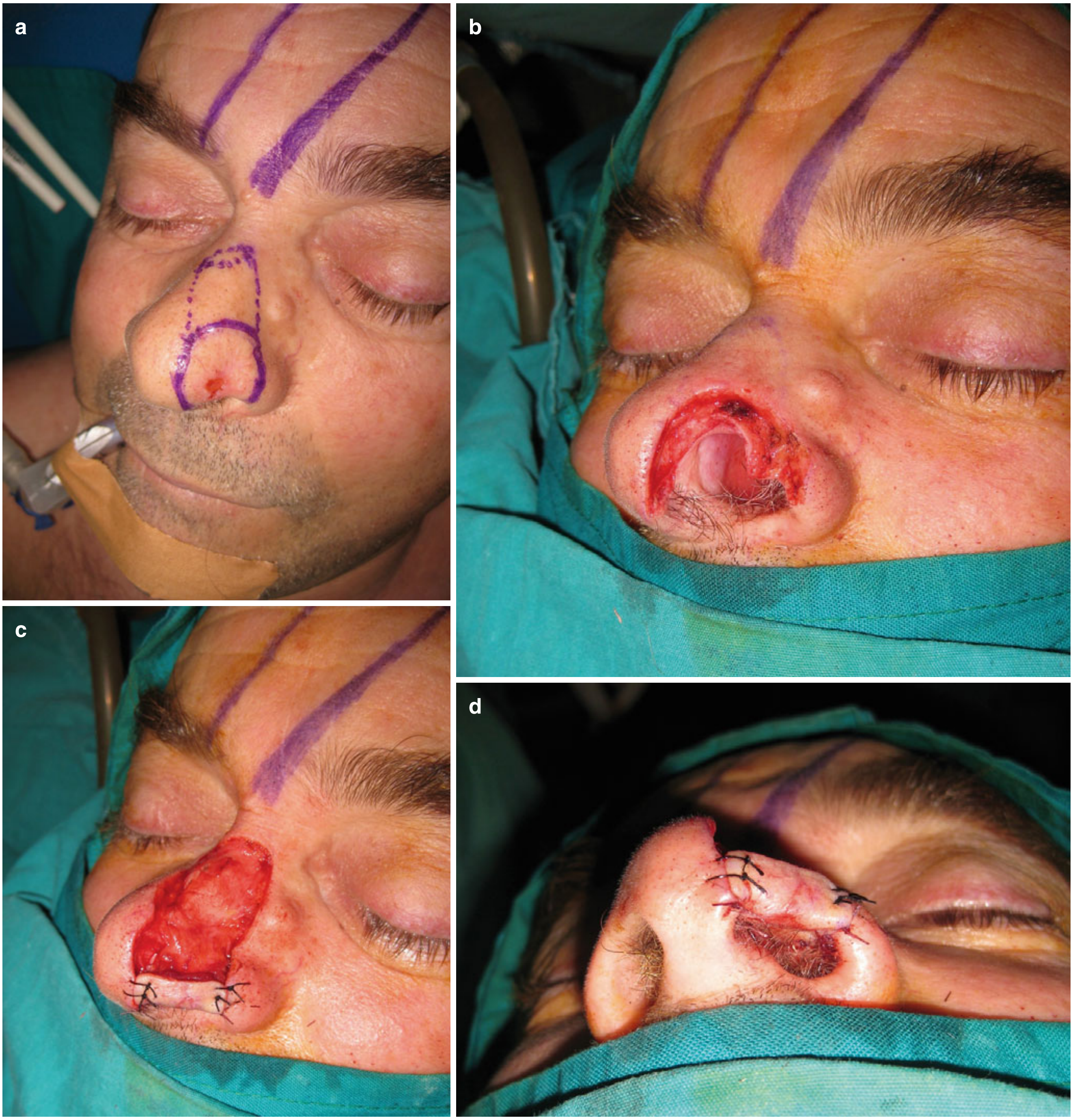

Fig. 3.42 (**a**–**g**) A full-thickness alar defect restored with a combined paramedian forehead and turn-over flap

Fig. 3.42 (continued)

graft, and forehead flap. The flap reconstructed fully the defect without any sign of necrosis (Fig. 3.43e).

3.5.12 Forked Forehead Flap

In complex nasal-medial canthus-eyelid defects, a forehead flap can be a very useful tool used to reconstruct the whole structure at once (McGregor and McGregor 1986; Jackson 2007). In these cases, a paramedian forehead flap is designed slightly wider and larger than the standard one. The distal part is incised to create a fork, and the limbs of the fork are then set into the lid defects, as the rest of the flap resurfaces the nasal and medial canthus defect.

It is of crucial importance to reconstruct the inner canthus, after the completion of the excision. In particular, the inner canthus should be placed and fixed in the correct anatomic position. Failure to do this will lead to obvious asymmetry. Lacrimal reconstruction at this stage could be postponed, since it may not be necessary because epiphora may not be a long-term problem. There is always the possibility that the tumor will recur. If recurrence does not occur, reconstruction is indicated and can be preformed in a later stage (Jackson 2007).

A forked flap was used to a patient with a basal cell carcinoma of the nasal-canthal area and involvement of the medial parts of the upper and lower eyelids (Fig. 3.44a). The forehead flap was slightly wider and larger than the standard one so as to adapt properly to the concave and the convexities of the area under reconstruction (Fig. 3.44b).

The tumor was resected and clear margins were revealed by frozen section biopsies. The medial canthus and the medial parts of the upper and lower lids were sacrificed (Fig. 3.44c). The medial conjunctival pocket was recon-

Fig. 3.43 (**a**) Traumatic loss of a big part of the nose. (**b**) Outline of the paramedian forehead flap with a transverse limb. (**c**) Schematic representation of the flap. (**d**) Flap raised in position. Its distal portion is folded providing skin cover and lining. (**e**) Result at 6 months. Scar and nostril minor revisions are planned for a second-stage surgery

Fig. 3.43 (continued)

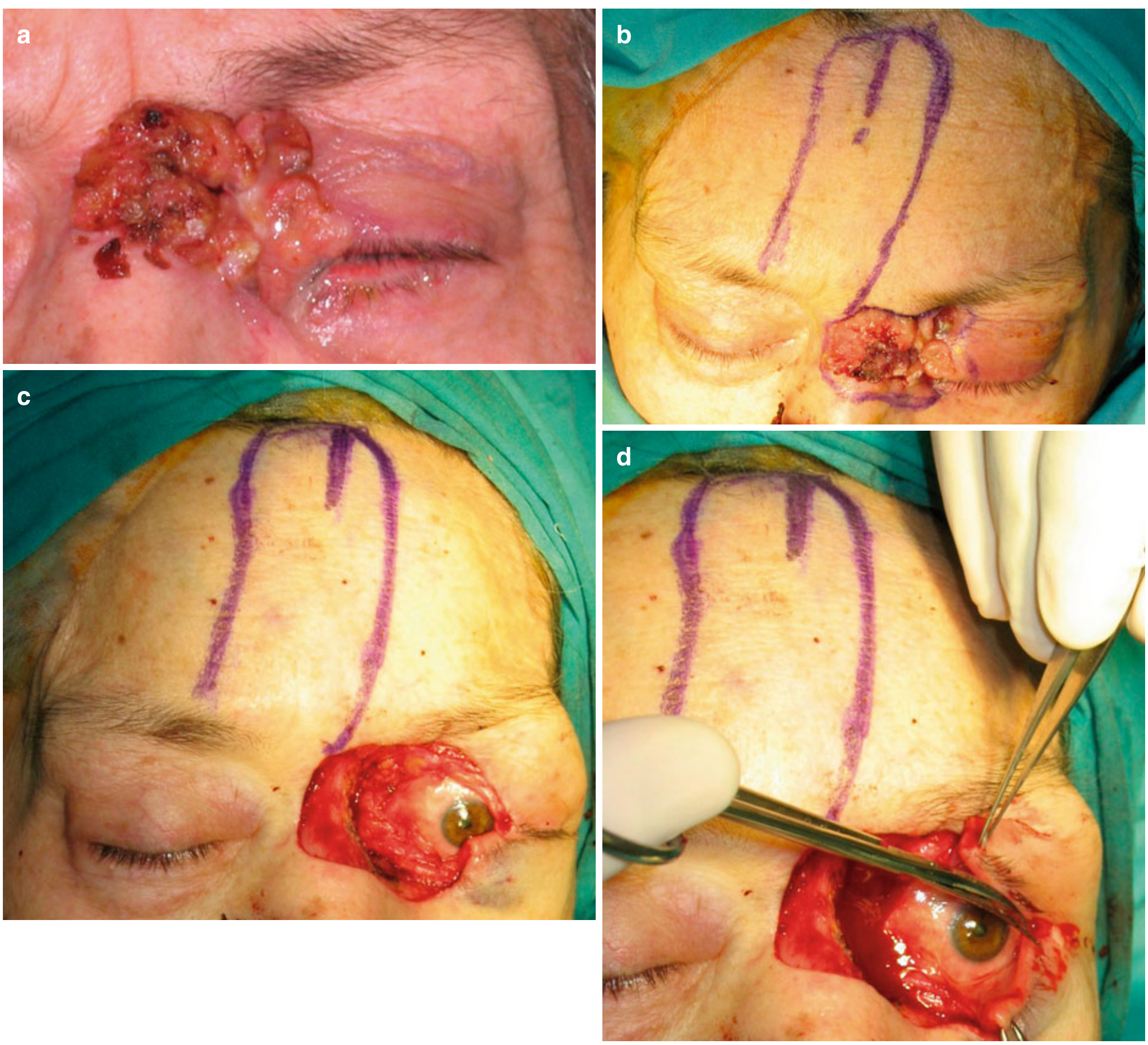

Fig. 3.44 (**a**) A lesion involving the nasal-canthal area and the two eyelids. (**b**) A long forked forehead flap outlined. (**c**) The defect after tumor resection. (**d**) Lateral canthotomy. (**e**) Flap is transposed into the defect and splits into two limbs. (**f**) Final suturing. (**g**) Result at 3 months

Fig. 3.44 (continued)

structed by mobilization of the conjunctiva to the limbus. At this point, the lateral canthal ligament was divided with sharp scissors to allow lid advancement (Fig. 3.44d).

After lateral canthotomy, it was easy to move the whole lids medially to reduce the defect. The flap was then transposed into the defect and split at its free end, until the correct position for the new medial canthus was obtained (Fig. 3.44e).

The flap was sutured in place covering the nose-canthal-eyelid defect, and the forehead defect was closed directly (Fig. 3.44f). The combined defect was reconstructed easily and by one flap led to a quite acceptable postoperative result (Fig. 3.44g). Revision procedures can be performed at a later stage.

3.5.13 Scalping Forehead Flap

The scalping forehead flap constitutes one of the best techniques for total and subtotal nasal reconstruction. This flap, which was originally described by Converse in 1942, is actually also an improvement of the classic Indian flap (Converse 1942, 1969, 1977; Converse and McCarthy 1981).

The flap is supple enough to fold, for the recreation of the lobular portion of the nose; it is similar in color and texture to the nasal skin and satisfies the requirements in length, in cases where creation of alar rims and columella is needed as in the presented case (Fig. 3.45a–c).

Based on defect dimensions that would occur, a scalping forehead flap was planned considering the width and length, so that the reconstruction of the columella and the alar rims would be allowed (Fig. 3.45d–g). The flap is drawn initially in form of semicircle with coronary direction which starts from the tip of the auricle. It continues in the anterior part of

Fig. 3.45 (**a**–**c**) A large basal cell carcinoma located at the tip of the nose. (**d**–**g**) Resection lines and scalping forehead flap outlined. (**h**) The flap id fused by both supratrochlear arteries and the supraorbital and the anterior branch of the superficial temporal arteries of its base. (**i**–**k**) The defect after tumor resction. (**l**, **m**) Elevation of the flap. (**n**) Flap length control. (**o**) Flap sutured at place. (**p**, **q**) Pedicle division. (**r**–**t**) Result at one year (From: Thomaidis et al. (2007), with permission)

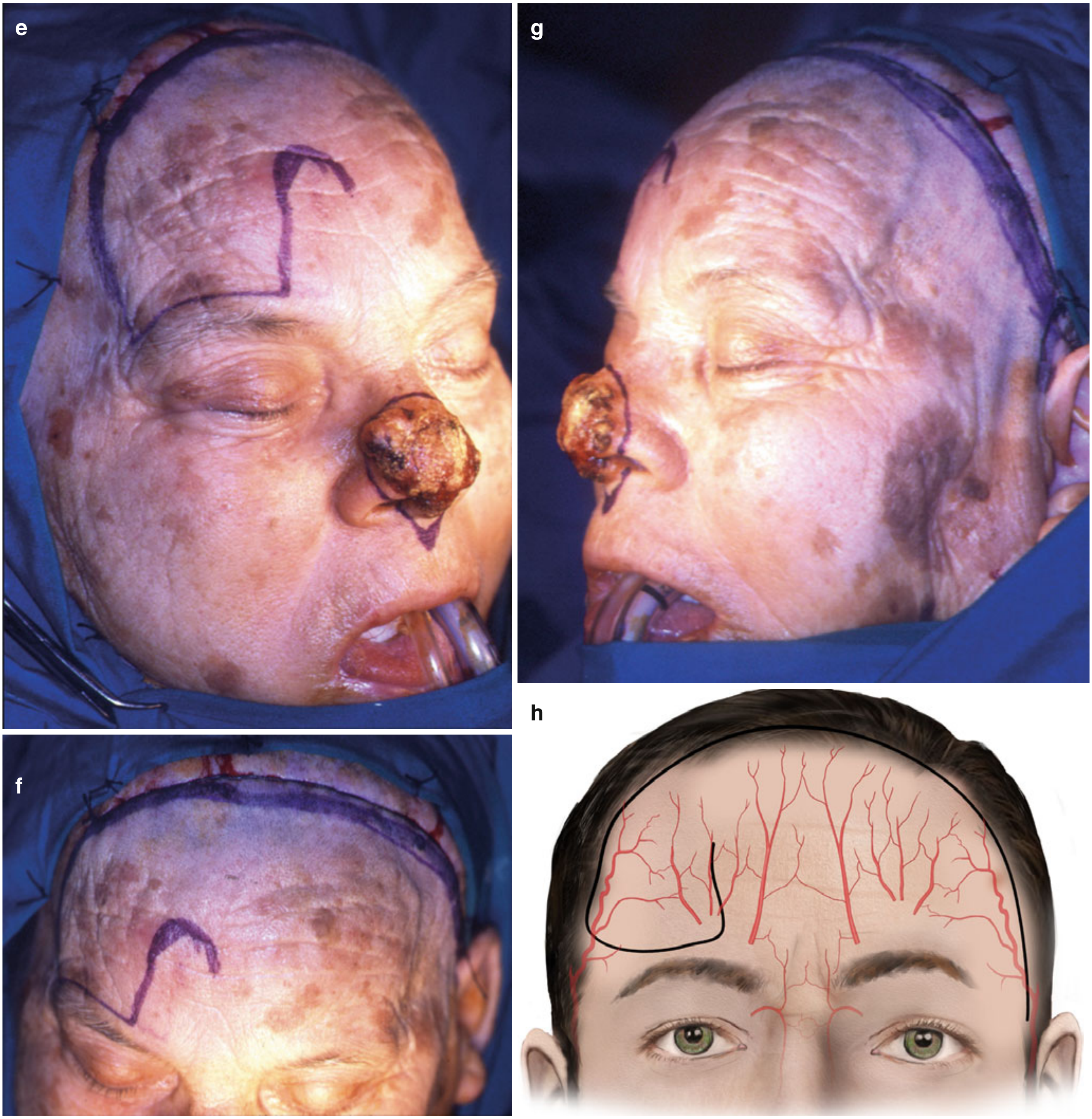

Fig. 3.45 (continued)

Fig. 3.45 (continued)

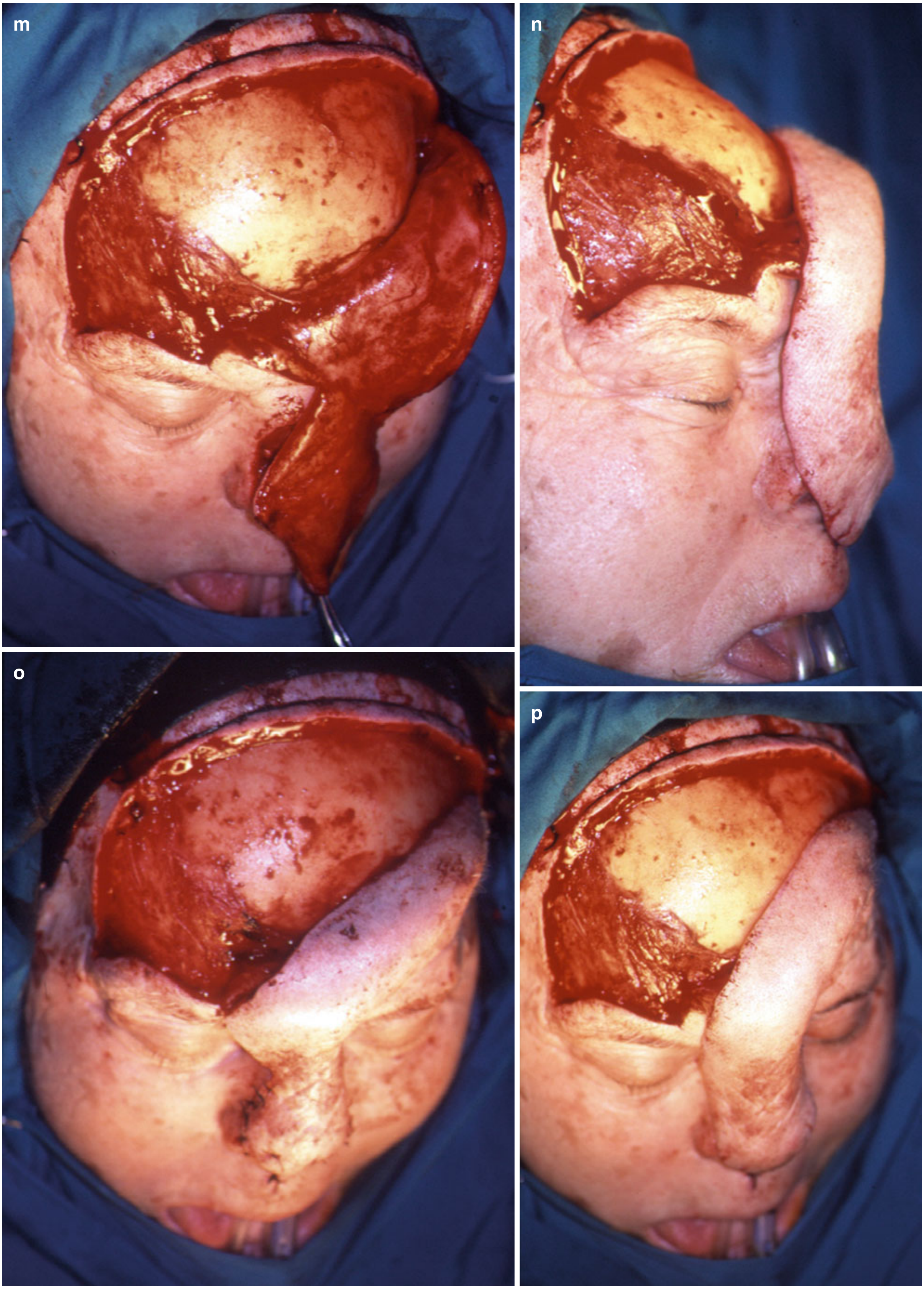

Fig. 3.45 (continued)

Fig. 3.45 (continued)

the hair-bearing skin, and it curves at the contralateral forehead, above the eyebrow and along it, while the final part is drawn with cephalic direction throughout the extent of the forehead, depending on the extent of skin that is required to cover the defect. Its reliability is ensured by rich arterial vascularization from both supratrochlear arteries and the supraorbital artery as well as by the anterior branch of the superficial temporal artery of its base (Fig. 3.45h).

A complete tumoral resection was performed, including the skin and nasal muscles, the medial crus of the greater alar cartilages, part of anterior edge of cartilaginous diaphragm, and small mucosal area into the mucocutaneous junction of nostrils, leaving intact the lateral cartilages and the lateral crus of greater alar cartilages (Fig. 3.45i–k). Clear margins were revealed by frozen section biopsies.

The flap is raised beginning from the donor portion of the forehead, superficial to the frontalis muscle, leaving the muscle in its place. It is important that this part of the frontalis muscle be not raised with the flap, as it constitutes the bed of free skin graft, in the second surgical stage, ensuring the expressive movements of the forehead in this point. Next, the coronary incision of the hair-bearing skin takes place, and the flap is elevated to the level of loose areolar tissue, between the galea and the pericranium. The elevation is continued with the dissection of the flap into the loose areolar tissue plane in the remaining part of the forehead being this time underneath the frontalis muscle (Fig. 3.45l, m). In the temporal region, elevation proceeds to the same level, and the frontal branch of the superficial temporal vessels is incorporated to the flap. In the pedicle base, in a dissection ending 3–4 cm above the supraorbital rim, the flap usually gains its necessary length, ensuring also the integrity of the supraorbital and supratrochlear vessels.

After the flap length control, the distal portion of the flap is trimmed, proportionally folded, and stitched in the recipient site, so that the alar rims, mucocutaneous junction, and columella are reconstructed (Fig. 3.45n, o).

Three weeks later, the pedicle is divided, and the transferring portion of the flap is repositioned to the forehead (Fig. 3.45p, q). The defect at the donor site is covered, in this stage, with full-thickness skin graft. The postoperative result is satisfactory (Fig. 3.45r–t).

3.5.13.1 Scalping Forehead Flap Combined with Lining Flaps

When extended parts of nasal mucosa are invaded by a skin tumor and need to be excised, folding of the scalping flap may not be adequate to provide the optimal lining reconstruction. In these cases, the scalping forehead flap can be combined with lining flaps providing most of the time a bulky reconstruction that may not need nasal support by immediate cartilage grafting.

The patient that is demonstrated in Fig. 3.46a presented with an extended lesion of the right half of the nose and is the same patient of the case presented in subchapter "forehead forked flap." She had been operated for the basal cell carcinoma of the inner canthus and eyelids, with defect restoration with the paramedian forehead flap, 4 years ago. In the meantime, she had not attended the scheduled follow-ups and seek medical help only after the recently and rapidly progressed appeared lesion. Biopsy specimen revealed this time a squamous cell carcinoma.

The surgical reconstruction was planned with defect coverage with the scalping forehead flap, as a second paramedian forehead flap from the other side would be risky due to the previous operation (Fig. 3.46b). Moreover, a scalping flap would provide enough skin transferred into the defect by a flap, which catches three supplying arteries.

A complete tumor resection was performed, including a big part of the right nasal sidewall, in full-thickness defect. Clear margins were revealed by frozen section biopsies. An ipsilateral nasolabial flap was used for lining, which was lifted on its medial subcutaneous pedicle, turned over, and sutured in the mucosal defect (Fig. 3.46c, d).

The scalping forehead flap was performed as previously described (Fig. 3.46e, f).

The aesthetic and functional results, 2 years postoperatively, were reasonably satisfactory (Fig. 3.46g).

3.5.14 Glabellar Finger Flap

This transposition flap is the first choice in reconstruction of moderate-sized, medial canthal defects. The flap is inferiorly based, is adjacent to the defect, and provides non-hair-bearing skin of same color and texture. The feeding artery of the flap is the small glabellar branch of dorsal nasal artery, and thus the flap can be regarded as an axial one.

In the patient of Fig. 3.47a, a middle-sized basal cell carcinoma was located at the medial canthal area. The flap was designed in a finger-shaped manner, inferiorly based, and a Burow's triangle was planned to be excised to allow primary closure of the donor site (Fig. 3.47b, c). After the lesion was excised, the flap was elevated by dissecting deep to the subcutaneous layer and above the nasal bone periosteum (Fig. 3.47e, f). Thinning of the flap is necessary, to provide tissue that has been adjusted to the thickness of the thin medial canthal region. Thinning can be performed, with safety up to the distal half of the flap, without compromising its feeding branch of the dorsal

Fig. 3.46 (**a**) Squamous cell carcinoma of the nose. (**b**) Scalping forehead flap outlined. (**c**, **d**) Excision completed, and a nasolabial flap is used to reconstruct the mucosal defect. (**e**, **f**) The scalping forehead flap provides external cover. (**g**) Final result (From: Thomaidis et al. (2007), with permission)

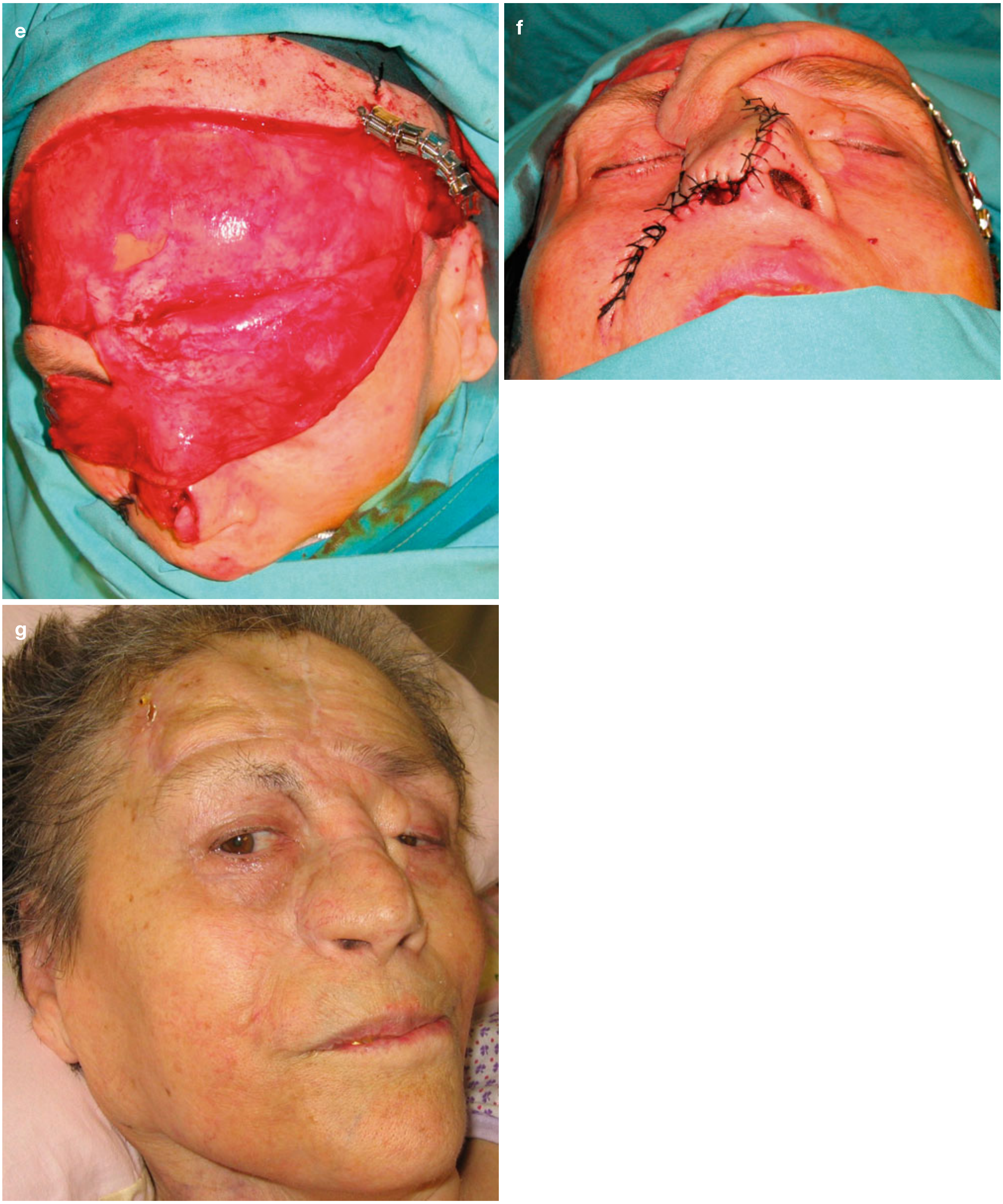

Fig. 3.46 (continued)

nasal artery. After thinning and trimming, the flap is placed to the defect and fixed by sutures (Fig. 3.47g). The excised Burow's triangle led to a donor site primary closure without a standing cone. The result after 9 months is excellent (Fig. 3.47h).

3.5.15 Vertical Mid-forehead Advancement Flap Superiorly Based

This flap, donated by the mid-forehead, was used to reconstruct the defect after excision of a basal cell carcinoma, in

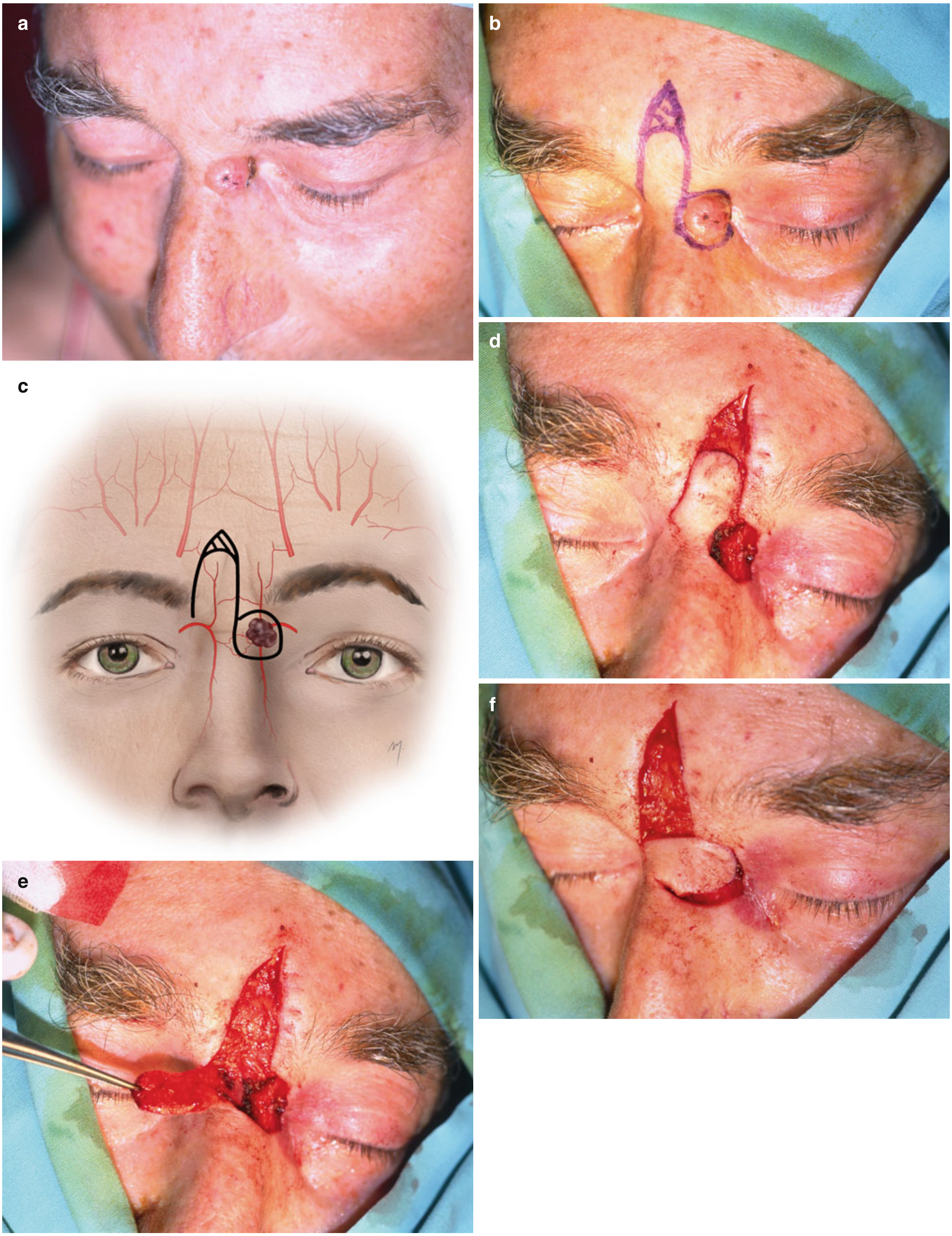

Fig. 3.47 (**a**) Cystic basal cell carcinoma at the medial canthal area. (**b**) Flap outlined. (**c**) The flap can be regarded axial based at the glabellar branch of the dorsal nasal artery. (**d**) Lesion excised. (**e**) Flap raised at the deep subcutaneous level. (**f**) Positioned into the defect. (**g**) Sutured in place. (**h**) Result 9 months after surgery

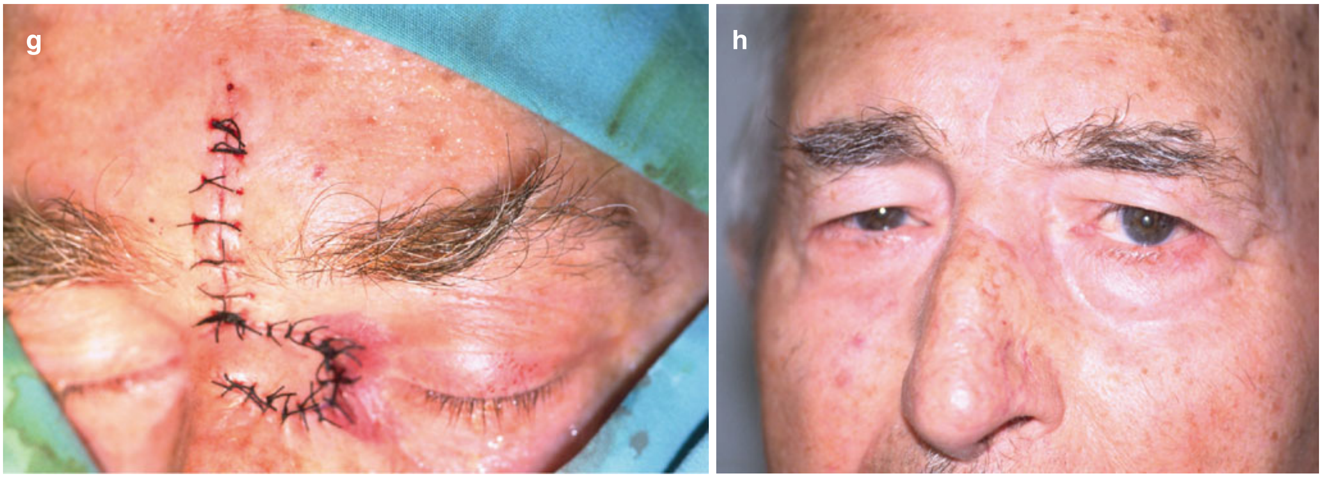

Fig. 3.47 (continued)

the root of the nose (Fig. 3.48a). The advancement flap outlined in that direction is of random pattern (Fig. 3.48b, c) and could be described as an "overmounted" Rintala flap, a flap usually used to reconstruct nasal defects (see Chap. 4). The flap is designed with an approximate 3:1 ratio of length to width. Bilateral Burow's triangles are excised to allow advancement and avoid creation of dog-ears.

The lesion is excised rectangularly, and some bleeding occurs when cutting the horizontal and ascending branches of the dorsal nasal artery (Fig. 3.48d). The flap is undermined with dissection plane down to the periosteum (Fig. 3.48e, f).

By dissecting in this plane and including a part of the procerus muscle and the galea superiorly, vascularization of this long random pattern flap is enhanced.

The flap is advanced downward and sutured in place (Fig. 3.48g). The short suture lines of Burow's triangles are hidden into the transverse forehead rhytides. The postoperative result is excellent (Fig. 3.48h, i). Slight shallow of the frontonasal angle is expected leading to a "classic ancient Greek profile" appearance (McGregor and McGregor 1986).

3.5.15.1 Vertical Mid-forehead Advancement Flap Superiorly Based in Through and Through Nasal Dorsum Defects

In cases of small- to moderate-sized but deep tumors in this area, where nasal bone and mucosa have to be excised leading to a through and through defect, the flap alone can cover the defect and survive, without any other deep (mucosal or bony) restoration (Fig. 3.49a–e). As long as the flap is anchored, it can be overlapped to an all round zone of rigid and healthy bone margin. This prevents contraction, and the rough, bare undersurface of the flap heals by epithelization from the edges of mucosal defect.

Fig. 3.48 (**a**–**i**) Reconstruction of a defect located at the root of the nose with a vertical mid-forehead advancement flap superiorly based

Fig. 3.48 (continued)

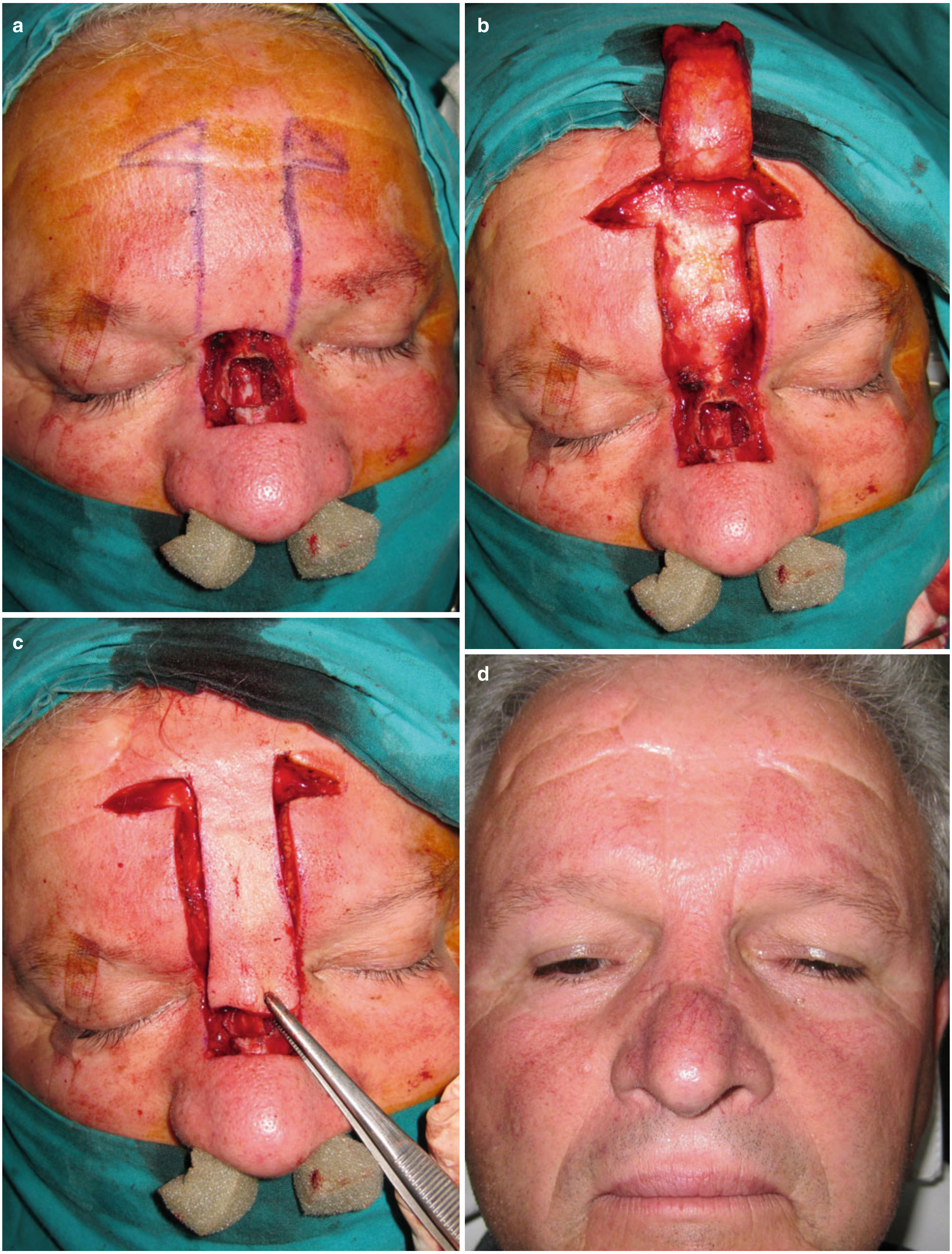

Fig. 3.49 (**a**–**e**) The superiorly based vertical mid-forehead advancement flap was used in a through and through defect of the nasal dorsum without any other mucosal or bony restoration

Fig. 3.49 (continued)

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