FOREHEAD, TEMPLE AND SCALP RECONSTRUCTION

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INTRODUCTION

The forehead is a gently rounded, often smooth, area presenting certain reconstructive challenges. A large number of variables determine the method of reconstruction as well the final outcome. These variables include defect characteristics (etiology, location and size) and additional patient factors such as specific individual forehead anatomy, as well as health status and patients' expectation.

In order to appropriately prioritise these multiple factors, the 3 main goals of reconstruction should be kept foremost in mind[23].

1. Preservation of motor function (frontalis branch of facial nerve) and, if possible, sensory nerve function.
2. Maintenance of the normal boundaries of the forehead temporal esthetic unit, including position and symmetry of the brow as well as frontal and temporal hairlines.
3. Optimal scar camouflage by placement of scars in relaxed skin tension lines or adjacent to the hairline or brow whenever possible.

In this chapter anatomy and principles of forehead and temporal reconstruction will be reviewed. Practical and reconstructive suggestions will be made for each forehead/temporal subunit.

PERTINENT ANATOMY

Anatomic knowledge is a basic prerequisite to optimise the reconstructive procedure. The forehead temporal region may be considered an esthetic unit running from the anterior hairline superiorly, zygoma laterally and the brow inferiorly. Forehead reconstruction may be further conceptualised by dividing this region into a midline forehead, paramedian forehead, lateral forehead, temporal and glabella and brow region (Fig. 1).

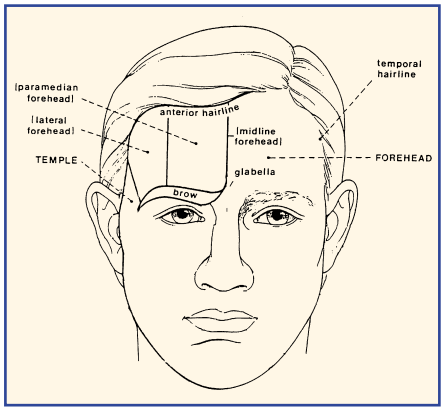

Fig. 1. Aesthetic units of forehead and temple region.

The area from the midline to the midbrow of the forehead tends to be convex, while the lateral forehead is flatter, smoothly blending into the more concave temporal region. The eyebrows are subunits onto themself with hairbairing skin.

The coverage of the calvarium includes skin, subcutaneous tissue, galea aponeurotica, loose areolar connective tissue and periosteum. The skin and subcutaneous tissue in the central forehead is relatively thick and inelastic and minimally mobile.From medial to lateral skin elasticity and mobility increases. Indeed the skin in the temporal area is extremely mobile because of its loose attachments to the underlying temporalis fascia. Thus, the lateral forehead temporal region may act as a tissue reservoir for reconstruction of more medially located defects. Skin thickness in the temporal region varies from thin at the lateral canthus to thick at the scalp hairline.
Underneath the skin-subcutaneous tissue, two symmetrically placed vertically oriented bellies of the frontalis muscle, leave the midforehead region devoid of muscle fibres. The loose areolar tissue underneath muscle and galea permits movement of the scalp over the periostium which is fixed to the cranial bone.

The forehead is a highly vascularised region. The vessels nourishing the forehead from medial to lateral include the dorsal nasal, supratrochlear and supraorbital arteries, which emerge from their respective foramen[22]. In addition, the temporal region is supplied by frontal branches of the superficial temporal artery. Sensory nerves include the supratrochlear and supraorbital nerves which course parallel to the arteries. After emerging from their respective foramen the supratrochlear and supraorbital neurovascular bundle pierce the frontal muscle and subsequently run in the subcutaneous plane. More laterally, a portion of the supraorbital nerve remains in a deeper plane in the galea and loose areolar tissues[14,15].

Preservation of the motorfunction of the temporal branch of the facial nerve is critical. Multiple anatomic studies offer insight into the multiple layered anatomy of the temporal region as well as the course of the temporal branch of the facial nerve[25,28]. Layers of the temporal region include skin, minimal subcutaneous tissue, superficial temporalis fascia, loose areolar tissue and a white shiny superficial layer of the deep temporalis fascia, covering the temporalis muscle. As the facial the nerve branch runs in the most medial layers of the loose areolar tissue, forehead undermining in the mid-subcutaneous tissue or alternatively below the superficial fascia and loose areolar tissue hugging the periosteum and the superficial layer of the deep temporalis fascia, should not compromise motor function. The temporal branch of the frontal nerve courses from the inferior edge of the tragus to a 1.5 – 2 cm above the lateral brow[10,19]. Indeed temporal facial nerve paralysis may devestatingly lead to a ptotic immobile brow.

Scalp skin and galea are thick, inelastic and bears hair in a variety of configurations. The scalp extends from the neck posteriorly to the pinna bilaterally and the frontal hairline centrally. The main supplying arteries are superficial, temporal and posterior auricular vessels.

RECONSTRUCTIVE PRINCIPLES

Most forehead defects result from tumour surgery and trauma. Treatment priorities in order of importance are: tumour cure, maintenance of function and maintenance or reestablishment of appearance.
The type of tumour and confidence in tumour free resection margins should influence the reconstructive plan. As a rule, local tissue arrangements should not be performed until successful tumour removal has been confirmed by histology. In this respect, Mohs surgery has major advantages giving immediate feedback concerning tumour margins while yielding the highest cure rates. The 4 main options for forehead temporal sclap reconstruction include: 1. Healing by secondary intention; 2. Primary closure; 3. Skin grafts; 4. Skin flaps.

Healing by secondary intention

The basis of secondary intention healing is epithelialisation and scar contraction. The main indication for healing by secondary intention is dictated by tumour control factors, depth and size of the defect, together with anatomical site and adjacent skin characteristics. Excisional defects of tumours with a significant chance of recurrence may best be managed by secondary intention healing. Secondary intention healing may give the best possibility of detecting early recurrence. This is especially important in young patients. From an aesthetic standpoint, a relatively small superficial wound in a concave anatomical area in a fairskin individual is considered ideal for secondary intention healing[30]. The forehead has 3 concavities, including both the lateral forehead-temporal regions as well as the glabellar region.
In concave areas, the centripetally oriented scar contraction forces will help decrease the defect, while diminishing the size of the final scar. Skin defects which lie in a convex area, tend to heal aesthetically less well with secondary intention healing. Wound contraction in the convex area may result in flattening of the contour.

The obvious advantage of secondary intention healing is the elimination of a the need for additional surgical procedure. As such, it avoids the creation of further scar tissue by reconstruction, all of which must be included in the excision if the tumour recurs. Possible distorsion by scar contraction may be avoided with proper patient selection. A primary disadvantage is the prolonged period required for final healing, which obviously depends on the size and depth of the defect. The size of the defect may be diminished intraoperatively by using preliminary closure sutures for example in a purse string fashion[5]. This may significantly decrease healing time (Fig. 2). The patient must be willing and able to perform wound treatment, including cleaning twice daily with tapwater, coating with antibiotic ointment and covering with non-adherent wound dressing. The paramedian and medial forehead itself is a suboptimal region for management with secondary intention healing. However, defects high on the forehead in the central and paramedian forehead region away from the brow may heal reasonably well with secondary intention healing[3]. However, in the large wounds of the forehead, the eyebrows and scalp line may become displaced with secondary intention healing. Secondary intention healing in the temporal area is far superior to skin grafting and large, sometimes staged procedures[27].

Fig. 2a. Large lateral forehead temporal defect.

Fig. 2b. Approximation to decrease wound size. Wound left to heal by secondary intention with appropriate treatment.

Fig. 2c. Final result.

Primary closure/incision placement

The major concern in the elective incisions are the relaxed skin tension lines (RSTL), described by Borgess[4] to guide the surgical incision placement. Forehead animation (vertically oriented frontalis muscle activity) does create horizontal wrinkle lines which serve ideally to conceal incisions. Frontalis activity on facial expression is reponsible for the wrinkle lines which run paralel to the transversely oriented relaxed skin tension lines[4]. These lines may be used to guide elective incision placement. The midline forehead is an exception as vertical closure is preferred because of the absence of frontalis fibres in the midline.

Off the lateral forehead the transverse forehead wrinkles become curvelinear, arching and radiating into crow feet[26]. Squinting and brow elevation of the patient may help to define the wrinkle/elective incision lines. Except for the midforehead, vertical scars should be minimised or at least broken into smaller components for a shorter length[7]. The appearance of vertical scars in the paramedial and lateral forehead are greatly accentuated by the movement of the frontalis muscle. Vertical curverlinear and oblique incisions which do not follow the relaxed skin tension lines are to be avoided. Obviously, for small lesions, conversion of the deformity into a fusiform defect and primary closure is practical, simple with optimal scar camouflage.

The forehead esthetic unit borders, including hairline and brow, may be used to hide incisions for improved scar camouflage. However, the incision should parallel the hairfollikels to avoid trauma and hairloss. If closure tension is minimal, then technically advanced techniques aiming at hair growth through the incision at the natural scalp hairline border may be incorporated in the reconstruction.

Skin grafts

Grafts on the forehead are generally avoided and used only when primary closure, secondary intention healing or flap closure cannot be attained.

Skin grafts provide a poor match in thickness and colour and thus should be considered a temporary measure[17]. Serial excision may be used to replace the skin-graft with alike tissue.

A skin graft is most often applied in massive forehead defects (Fig. 3). If the woundbed is allowed to granulate for 3-4 weeks, some additional thickness in covering may be obtained with adequate results[17].

Fig. 3a. Massive forehead defect.

Fig. 3b. Split thickness skin graft applied.

Fig. 3c. Final result with help of make-up artist.

Skin flaps

Local skin flaps are a mainstay for forehead reconstruction. Local flaps in this region permit the replacement of soft tissue losses with like tissue, yielding very acceptable results[20]. When considering skin flap reconstruction, three major determinants include 1. *sources of recruitable tissue*, 2. *mechanisms of tissue movement* and 3. *positioning of scars.*

As the forehead cosmetic units share similar skin characteristics ideally tissues should be obtained from the same cosmetic unit or subunit to optimise the skin colour and texture match. Depending on the age, elasticity and degree of wrinkling of the patient's skin, a significant amount of recruitable tissue may be found within the wrinkles and relaxed skin tension lines of the forehead/temporal unit. A definite area of skin excess lies in the temporal and glabella region.

Tissue may be moved into the defect by advancement, rotation or transposition. It is important to remember that flaps often incorporate more than one of these types of movement and that secondary movement of tissues surrounding the primary and secondary defect may occur. The forehead is one of the facial esthetic units where advancement flaps are often applied. Rotation flaps are usually designed as large flaps

with lengthy incisions, which may run diagonal to the horizontal crease of the forehead. Rotation flaps are preferably used when defects are at the border of the esthetic units. Transposition flaps may be designed within the forehead unit or in order to move glabellar or temporal skin into the defect. Transposition flaps play a lesser role in forehead repairs, because of the resulting complex scars.

Fig. 4a. Just off midline defect.

Fig. 4b. Primary closure with subgalial undermining.

Fig. 4c. Final result.

REGIONAL FOREHEAD RECONSTRUCTION

Midline forehead

The midline is the void of muscle fibres and may be considered the boundary between both paramedian forehead sub-units. The natural dehiscence and/or attenoution of the frontalis muscle in the midline center offers possibilities to close a defect in a vertically oriented fashion with predictably good esthetic results[3].
Fusiform closure may be performed by recruiting tissue laterally after subgaleal undermining. Even tissue from the temporal region may be mobilised by extending the subgaleal undermining into the temporal region while hugging the superficial layer of the deep temporalis fascia. Care should be taken to preserve the integrity of the facial nerve, while detaching the temporal line and supra-orbital ligament[15]. Deep fascial scoring for enhanced advancement should only be performed in between the course of the two supraorbital nerves.

Vertical closure may be contraindicated if the medial brows are brought too close together, which causes a worried look. For defects slightly off centre, sufficient tissue should be removed to the medial edge of the wound to create a symmetrical defect position, preferably directly over the midline[23] (Fig. 4).

To shorten the incision an M-plasty, that has its limbs tucked into the natural fold of the glabella, would be acceptable in preventing too much narrowing of the eyebrows. In the vertical midline closure tension on the skin edges should be reduced using various types of burried galeal and subcuticular sutures.

Large rotation flaps may be created, by extending incisions in the relaxed skin tension lines on either side of the defect, while excising a burrow triangle at the base of the defect, thus the round defect is converted to an A-shaped defect and subsequently to a T-shaped closure line with the vertical limb in the midline and the horizontal limb in the relaxed skin tension lines (Fig.5). Rectangular advancement flap in the midline are not very useful because of the inelasticity of the skin and the described alternative of vertical midline closure.

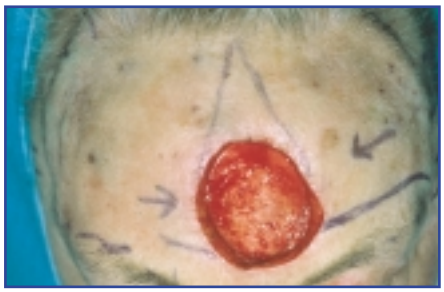

Fig. 5a. Midline forehead defect. Bilateral rotation flap and midline burrow triangle outline.

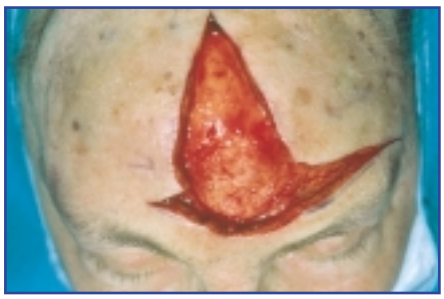

Fig. 5b. Flaps undermined.

Fig. 5c. Closure.

Fig. 5d. Final result.

Paramedian forehead

The paramedian forehead runs from the midline to the midbrow area. If the defect is too large for primary repair or has a lengthy vertical orientation, advancement flaps are usually the preferred method of closure[23]. Given the inelasticity of the forehead skin a bilateral advancement flap (H-plasty) offers improved redistribution of tension but creates more complex scarring. Flaps are usually created with an approximate 4 : 1 length to width ratio. The depth of dissection of these flaps is determined by the depth of the defect as well as the weighted risk of sensory loss. Dissection in the midsubcutaneous plane aims to maintain the neurovascular bundle. If the defect extends to the depth of the galea-periosteum, the flaps are incised to the depth of periosteum, vertically oriented nerve fibres are sacrificed and a

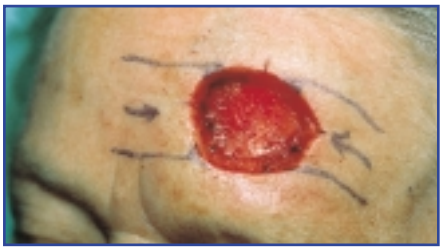

Fig. 6a. Paramedian forehead defect. Bilateral advancement flaps outlined.

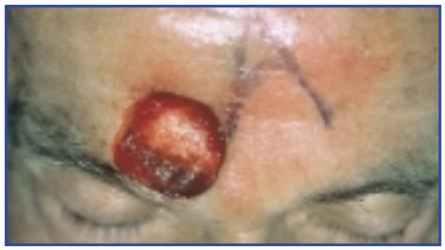

Fig. 7a. Paramedian suprabrow defect. Transposition flap outlined.

Fig. 6b. Closure with tension and midline with some flattening of contour.

Fig. 7b. Closure with suture lines in midline and RSTL. Lower portion oblique to RSTL in glabella.

Fig. 6c. Final result.

Fig. 7c. Final result.

deep-layer galeal closure is utilised[17]. Thinning of the flaps should be avoided. The horizontally oriented closure tension on the convex surface of the forehead may pull the natural wound edges of the defect inward, while pushing the relative excess tissue above and below the former defect upward (Fig.6).
The vertical portions of the flaps are usually closed by the rule of halfs, allowing mini-dog-ears to resolve over time. This prevents burrowtriangle excisions on either side. Again, vertical curverlinear and oblique incisions do not follow the relaxed skin tension lines and are to be avoided.

Transposition flaps from the midforehead tissue reservoir may be used for suprabrow defects in order to maintain brow position and shape (Fig.7).

Defects at the border of the anterior hairline may be closed with rotation flaps, making use of the curve of the forehead while the additional incision comes to lie in the esthetic junction of the forehead and hairline. Bilateral rotation flaps may be used in an A-T fashion.

Lateral forehead

The lateral forehead begins at the midbrow and extends to the lateral brow where it joins the upper temple.

The enhanced elasticity of the lateral forehead compared to the central part of the forehead yields a number of reconstructive alternatives. Primary closure may be possible. The flat surface of the lateral forehead may yield reasonable results with secondary intention healing. Elevation of the brow by scar contraction must be prevented. For example the brow may be tacked down by sutures to the supraorbital rim.

Multiple types of transpositions flaps may be oriented so that donor site closure takes advantage of temporal laxity latero-inferiorly.
Designing skin flaps in the lateral forehead temporal region must take the course and integrity of the temporal branch of the facial nerve as an extremely important landmark. Subsequently dissection should be in a subcutaneous plane to prevent injury to the motor nerve of the forehead. Furthermore, flaps should be designed in order to prevent distorsion of the eyebrow. A burrow wedged advancement flap is created
by extending an incision unilaterally along the base of the triangular defect and creating a smaller triangular-burrow excision on the other side of the incision opposite the defect. The lateral burrow triangle may be hidden in the crowfeet. The wound may even be extended to the brow margin in order to camouflage the releasing incision in the suprabrow transion zone. A number of other variations such as O-Z repair may yield satisfactory results in the concave surface of the lateral forehead.

Temporal reconstruction

The eyebrow, scalp hairline and lateral canthus as well as zygoma compromise the esthetic boundaries of the temporal region.
When excisions and flap reconstruction are performed in the temporal region, the frontal branch of the facial nerve which courses very superficial, may be at risk. Moreover, the skin and subcutaneous soft tissues over the zygoma are very thin. In the lateral forehead proper, the nerve is better protected by the frontalis muscle.
The temporal region is an ideal indication for secondary intension healing[30] (Fig. 2). Given its skin laxity primary closure may definitively be an option. A variety of skin flaps are useful to close smaller defects within the esthetic subunit or to recruit tissue for a larger defect. For example, tissue may be moved over a larger area using single or bilobed transposition flaps (anteriorly or posteriorly based)[26].

drawback because of the considerable temporary deformity of the forehead during the expansion process[2]. However, relatively large defects may be closed after preoperative progressive tissue expansion. For example the contralateral forehead tissue may be expanded and transposed to achieve ipsilateral tissue replacement (sail flap)[12].
Central and paramedian forehead defects may be amendable to closure after intraoperative expansion of the scalp and forehead skin[11]. A 30 mm Foly catheter is placed subgaleally and inflated until the tissue blanches. Two or three cycles of 3 minutes volume maintenance and 3 minutes decompression yield additional tissue stretch. The enhanced tissue mobility often results in less wound-closure tension. By placing the balloon in a deep layer, vascular compromise of the skin is very unlikely (Fig.8). Alternatively mechanical creep (distension) may be promoted, either by multiple skin retraction[1] or technically advanced devices, such as the sure-closure skin stretching system[20].

SCALP

Scalp defects are notoriously difficult to close, due to the inelasticity of the skin and galea. However, the vascular supply of the scalp makes wound closure under tension acceptable. Thus primary closure may be obtained for scalp defects, measuring 3 cm[21]. It is of importance to know that wide undermining in the subaponeurotic space of loose fibrous tissue may provide little additional tissue[6].

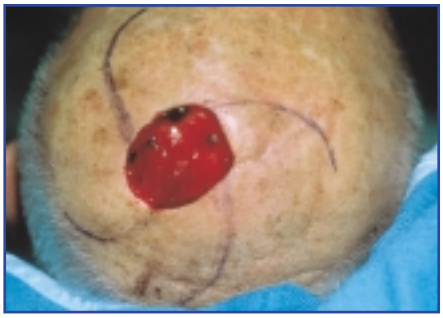

Fig. 9a. Scalp defect.

Defects larger than 3 cm almost always require flap movements, relaxing incisions, and/or the application of skin grafts[8]. Multiple rotation flaps using a subgaleal dissection plane are the mainstay for scalp wound closure (fig. 9). Flaps may be raised in any region of the scalp without regard for specific anatomical distribution of the blood vessels[8]. A number of additional procedures help in decreasing closure tension.

Fig. 9b. Four rotation flaps slided into defect after wide undermining.

Fig. 9c. Three months postoperative result.

Eyebrow reconstruction

In reconstructing the eyebrow the goal is maintenance of acceptable symmetrical position and continuity of the eyebrow hairgrowth. Hair thickness and growth direction show individual differences as well as differences between men and women. Small eyebrow defects may often be closed with bilateral hairbearing advancement flaps. Incisions are made paralel to the hair follikels. Flaps are created bilaterally while placing a superior and inferior incision for these flaps in the suprabrow and infrabrow margins.
The advancement flaps result in a pull from a lateral direction aiming to maintain natural brow position.
If any of the hairs are lost traumatically or are shaved off, there is usually a prolonged period before regrowth occurs[29]. A subcutaneous pedicled flap from the ipsilateral eyebrow area may also be used to reconstruct moderate to small sized eyebrow defects[13].

Tissue expansion

Tissue expansion enables the surgeon to reconstruct the sizable forehead defect with a more simple layered reconstruction, which in the past could only be repaired by skin grafts. Intraoperative tissue expansion may assist in wound repair by primary closure. Controlled prolonged tissue expansion can be used to reconstruct defects by expansion of the temporal/forehead skin in a 6-12 weeks interval. This two stage procedure has a

Fig. 8a. Mohs defect of recurrent tumour. Central skin graft uninvolved. Wide undermining and advancement outline.

Fig. 8b. Intraoperative tissue expansion demonstrated.

Fig. 8c. Closure lines RSTL or hidden at forehead junction hairline or in hairline.

Fig. 8d. Final result.

Increased incision length may allow easier closure under less tension and short incisions[8]. Galeal closure should be performed with deeply burried sutures. Scalp skin may be combined with forehead and neck of large size defects[16]. Galeal incisions at 5-10 mm interval allow increased flap stretching. However, there is a significant increase risk of necrosis. Pre- and intraoperative tissue expansion are options to be considered. Rotation puckers developing as a result of a rotational movement should usually be left intact, with focal undermining of the area allowing significant postoperative adjustment and smoothing[8].

Large size wounds may heal by secondary intention healing, even with exposed facial-scalp bone[24]. Fenestration of the exposed bone, outer table of the calvarian bone, may help to stimulate wound healing[18]. However, healing by secondary intention is less satisfactory in a scalpwound than in other areas, forming thin atrophic scars, susceptible to minor trauma[17]. But, in older patients with extensive wounds, secondary intention healing is a definite option despite of the time needed for postoperative care. Skin grafts may also be a viable alternative in a large defect. However, the esthetic deficiency if used on hair bearing skin is considered to be similar to secondary intention healing.

SUMMARY

Several characteristics inherent to the forehead/temporal scalp unit provide unique reconstructive challenges. These include maintenance of motor and sensory nerve function as well as maintenance or reestablishment of the esthetic boundaries by recreating a camouflaged surface and optimal surgical scar.
Only with a thorough knowledge of forehead anatomy, function and principles of tissue movement can the optimal reconstructive procedure be designed and performed.

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