

Reconstruction of the Scalp

Yadranko Ducic, MD, FRCS, FACS^{a,b,c,d,*}

KEYWORDS

• Scalp • Reconstruction • Free flaps • Tissue expander

The scalp represents the thick, durable covering that provides protection for the vital underlying calvarium and brain, serving as the first and likely most important barrier. It is composed of hair-bearing (temporal, parietal and occipital) and non-hair-bearing skin (frontal), underlying occipitofrontalis muscle (connected by the galea aponeurotica) gliding over a thin sheet of nourishing pericranium (**Fig. 1**). Most scalp avulsions occur within this loose areolar tissue plane, often leaving the pericranium nonviolated and facilitating reconstruction. The skin of the scalp is the thickest in the body, varying from 3 to 8 mm in depth. The neurovascular structures supplying the scalp traverse through the deep subcutaneous tissues overlying the galea aponeurotica. There is an extensive collateral network of vessels providing the scalp with its blood supply (**Fig. 2**), which enables the creation of a number of reliable random pattern flaps to be raised successfully. The supraorbital and supratrochlear vessels provide the anterior contribution to this network, joining the posterior auricular branch from the external carotid artery and the superficial temporal superficial artery laterally and the occipital arteries posteriorly. Scalp innervation is provided by the trigeminal nerve and by branches of the cervical plexus.

The skull itself is composed of inner and outer tables that are variable in thickness between the different parts of the skull; between individuals; and, that change as one progresses from infancy through adulthood. The calvarium is somewhat malleable in children, which is clinically relevant in terms of providing a source of easily contoured grafts used

in reconstructive surgery. Conversely, the skull of the elderly is more brittle and less amenable to alteration of its basic original shape. However, in adults, the overlying scalp is more pliable and occasionally slightly redundant as compared with the scalps of young children. At all ages, the scalp provides a relatively limited amount of excess tissue that can be used in reconstructing significant scalp defects, which arise most often from oncologic resection or traumatic loss.

In 1696, Belloste described perforating the bare skull to allow for granulation tissue formation and to promote subsequent epithelialization.¹ In the late 1800s, Netolitzky subsequently introduced skin graft placement on the granulation tissue bed to expedite the healing process.² Kazanjian and others espoused the use of local flaps.^{3,4} The area providing the most scalp mobility is in the region overlying the temporal fossa, making this region an ideal scalp flap donor area. Conversely, the lateral frontal region provides relatively little extra mobility, rendering the need for relatively large flaps to be elevated to close even small defects in this region. Radovan popularized tissue expansion of the scalp, enabling recruitment of more hair bearing adjacent scalp.⁵ Extensive defects or avulsive injuries of the scalp have been successfully treated for a number of years with microsurgical reattachment and free tissue transfer.^{6–10}

DEFECT ANALYSIS

There are many considerations when formulating a treatment plan for a given patient with a scalp

^a Otolaryngology and Facial Plastic Surgery Associates, Fort Worth, TX, USA

^b Baylor Neuroscience Skull Base Center, Dallas/Fort Worth, TX, USA

^c The Center for Aesthetic Surgery, Colleyville, TX, USA

^d University of Texas Southwestern Medical Center, Dallas, TX, USA

* Otolaryngology and Facial Plastic Surgery Associates, 923 Pennsylvania Avenue Suite 100, Fort Worth, TX 76104.

E-mail address: yducic@sbcglobal.net

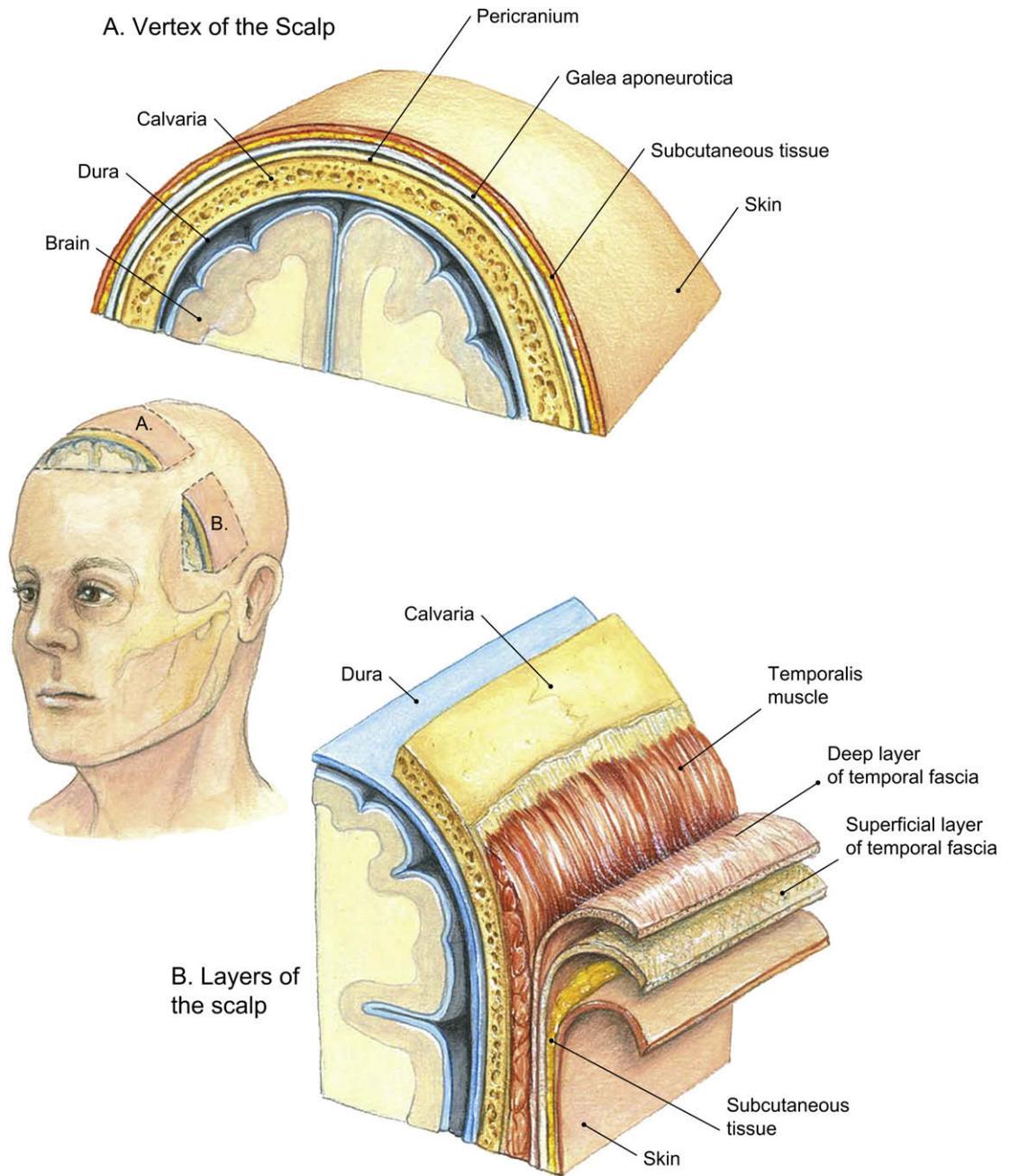


Fig. 1. Layers of the scalp in cross section.

defect. Patient expectations and comorbid conditions need to be taken into account. Patient tolerance for certain procedures may limit their utility—particularly in the case of prolonged tissue expansion. Far and away the best tissue for replacement of lost scalp is adjacent scalp tissue. Particular attention needs to be paid to the present hair distribution and its anticipated future. Small areas of alopecia or hairless flap may be covered

by hair transplantation. Hair transplantation is not feasible in large flap reconstruction and it is often not reliably successful in patients undergoing perioperative radiation therapy. Local flap reconstruction in this latter group of patients is more difficult due to regional fibrosis and diminished blood supply.¹¹ In this group of patients, there is a need for broader based, larger breadth local “scalping” flaps and free tissue transfer.^{12,13}

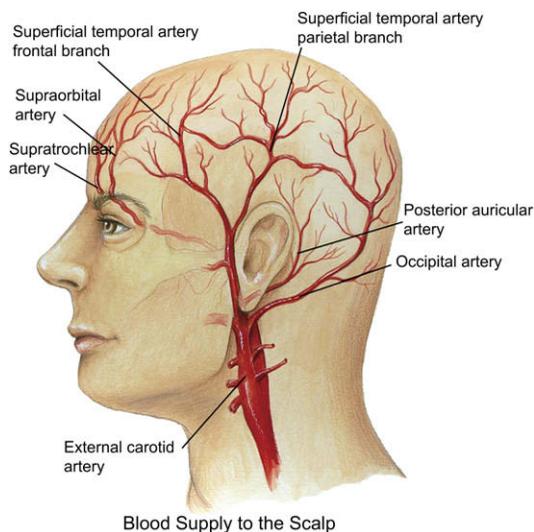


Fig. 2. Major vascular supply to the scalp that is used when designing scalp flaps.



Fig. 3. Intraoperative view of patient undergoing nasal reconstruction with a forehead flap following Moh's excision of basal cell carcinoma.



Fig. 4. Intraoperative view of patient following inset of forehead flap with persistent open wound forehead. Note that the underlying pericranium is intact.

RECONSTRUCTIVE OPTIONS

Wound Care and Healing by Secondary Intention

The simplest form of reconstruction is nonsurgical. Simple, good, meticulous and prolonged wound care has the ability to heal relatively large scalp defects surprisingly well. Healing by secondary intention works best in non-hair-bearing areas of the scalp or in relatively follicle-challenged areas of age related alopecia. It does cause some distortion of the immediately surrounding areas and should be used with caution in the periorbital region because of potential brow distortion. The scars themselves tend to be atrophic and contain telangiectasias, which may be visually distracting.¹⁴ Nevertheless, the final aesthetic result is reasonable. If there is overlying pericranium, the healing process may be completed in as little as 3 weeks for defects less than 2 cm and in as long as 2 to 3 months for larger defects. If there is no pericranial covering to the scalp, then consideration of burring the outer table to promote granulation tissue formation and then allowing for

secondary intention healing to take place is reasonable. Prolonged wound care with hydration-promoting antibiotic-impregnated gauze dressing is required in all of these patients. Prevention of desiccation is of paramount importance (Figs. 3–6).

Skin Grafting for Scalp Defects

In 1908, Robinson described successful skin grafting when these grafts were applied directly to an intact underlying pericranium.¹⁵ Traditionally, skin grafts have not done well when placed directly on exposed calvarium without first having had a granulation tissue bed beneath. The major difficulty with this has been lack of traction between the graft and underlying bare skull. Micromotion or macromotion will not allow for graft revascularization in time to save it from invariable desiccation and loss. Skin grafts may be used for temporary coverage, minimizing wound care issues while preparing the scalp for definitive reconstruction, as during prolonged tissue expansion. When used, skin grafts should be



Fig. 5. Postoperative frontal view of patient (as shown in Figs. 1–4) with dressing in position.

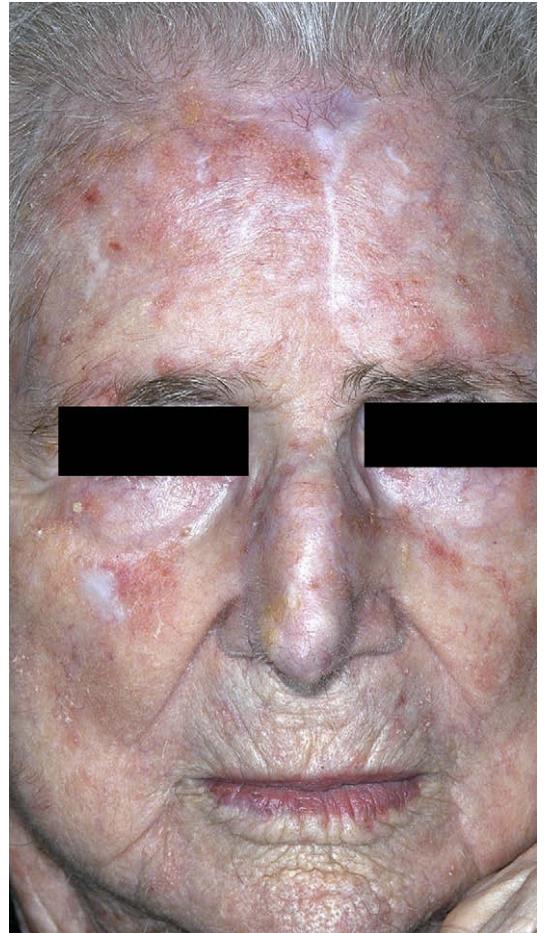


Fig. 6. Final postoperative result. Note well-healed forehead wound with thin scar.

unmeshed to give the best possible appearance. (Figs. 7–9).

Primary coverage with a skin graft, followed by serial excision, is an option for patients not desiring tissue expansion and wanting to maintain a relatively normal hair distribution. Skin grafts may also be used to provide coverage for free muscle flaps to decrease the flap bulk that would otherwise be seen in patients if the muscle and full thickness skin were transplanted as a single unit as in the case of latissimus or rectus free flaps (Fig. 10).

Primary Closure of Scalp Wounds and Rapid Intraoperative Tissue Expansion

Temporal scalp defects or low central frontal scalp defects, especially in elderly patients, may often be closed by simple, wide undermining in a subgaleal plane. Galeal incisions placed parallel to the incision may help recruit 1 to 1.5 cm of tissue to



Fig. 7. Preoperative view of patient with history of chronic nonhealing wound for over 2 years following excision of basal cell carcinoma.

help decrease wound tension during closure. For small defects up to 3 cm in nonradiated patients, undermining in a subcutaneous tissue plane may allow for more recruitment of skin into the defect. This strategy is at the expense of tensile strength and vascularity, limiting its use in larger defects or for radiated individuals.

Rapid intraoperative tissue expansion (RITE) produces no additional collagen formation, instead working on the principle of mechanical creep.¹⁶ With RITE, there is deformation of the three-dimensional structure of the collagen fibrils,



Fig. 8. Early postoperative result following skin graft placement following excision of the nonhealing wound to the level of the calvarium.

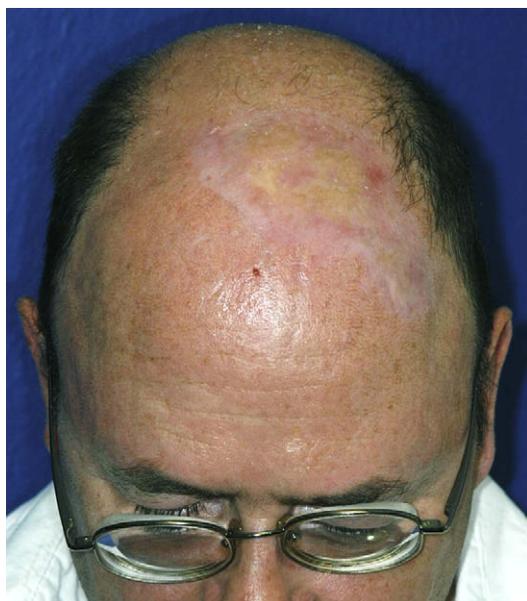


Fig. 9. Long-term (1 year) result demonstrating well-healed skin graft with reasonable color match to surrounding tissue. Some atrophic changes, as seen here, are to be expected. This result is adequate in an individual with advanced alopecia as in this patient.

which allows for increased length of these fibrils, recruiting additional adjacent tissue. An expanded Foley catheter balloon may be inflated and maintained for at least 5 minutes. It works best if it is placed adjacent to the defect and if mechanical tension is maintained along the wound edges with either sutures or clamps during the expansion process. This is primarily a technique that will help reduce tension across the closure line in defects that are closed with local or regional flaps and where the skin closure is taut.

Tissue Expansion

Tissue expansion over a prolonged period of time results in the phenomenon of biologic creep. As opposed to mechanical creep with simple distortion of the three-dimensional collagen fibrils, with biologic creep there is actually deposition of new collagen over time. By necessity, scalp tissue expansion takes a prolonged period of time, perhaps even months for large defects. Approximately 50% of the scalp can be reconstructed with extended periods of tissue expansion.¹⁷ It is important to provide for safe coverage of the defect during the time of expansion. This need is often facilitated by skin graft placement at the time of expander insertion.

There are various shapes and sizes of expanders that are commercially available



Fig. 10. Well-healed skin graft placed on a latissimus muscle–only flap used to cover a large area of frontotemporal scalp that had undergone post radiation soft tissue necrosis.

(**Fig. 11**). In general, the largest expander possible should be chosen and it should be placed in a sub-galeal plane. The shape of the expander also affects the amount of tissue gained in the

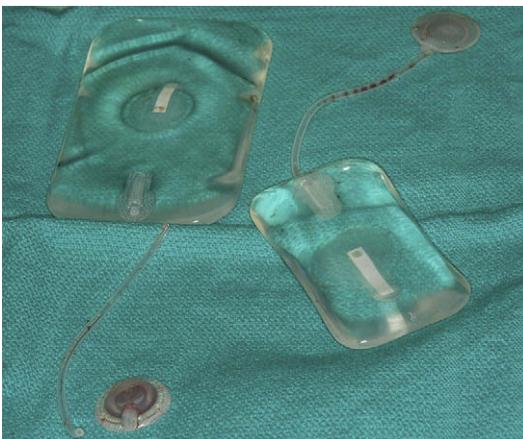


Fig. 11. Commonly used rectangular tissue expander with attached injection port is most efficient for scalp reconstruction. Size selection depends on defect dimensions and should be carefully planned.

expansion process, with more biologic creep noted as one goes from round to crescent-shaped to rectangle-shaped expanders.¹⁸ Also, it is best to choose a single large expander than multiple smaller ones because this results in maximal gain of tissue per volume of expansion. In laterally placed defects, a central adjacent large expander works well. However, in more centrally placed



Fig. 12. Surgical defect left following excision of neglected massive melanoma of postauricular scalp.

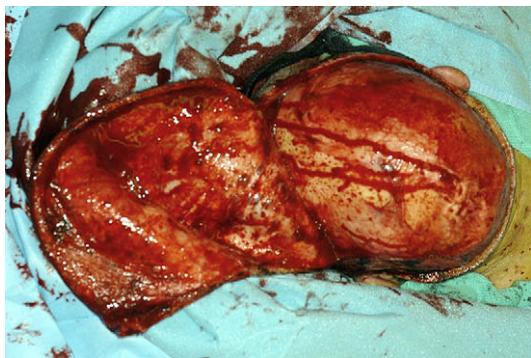


Fig. 13. Transposition flap being elevated in patient who is shown in Fig. 10.

defects, multiple expanders placed lateral to the defect tend to work more effectively. The expander is typically inserted and inflated to 10% to 20% of its volume at insertion, which eliminates any dead space and the need for drain insertion postoperatively. Tissue expansion is begun after 2 weeks and continued until the desired tissue gain has been achieved. One can estimate the amount of tissue gained with expansion by subtracting the base of the expander from the length over top of the expander and adding an extra 20% to 25% to counteract the recoil that is seen



Fig. 14. Postoperative view following rotation flap coverage of postauricular scalp wound and skin graft application to donor site.

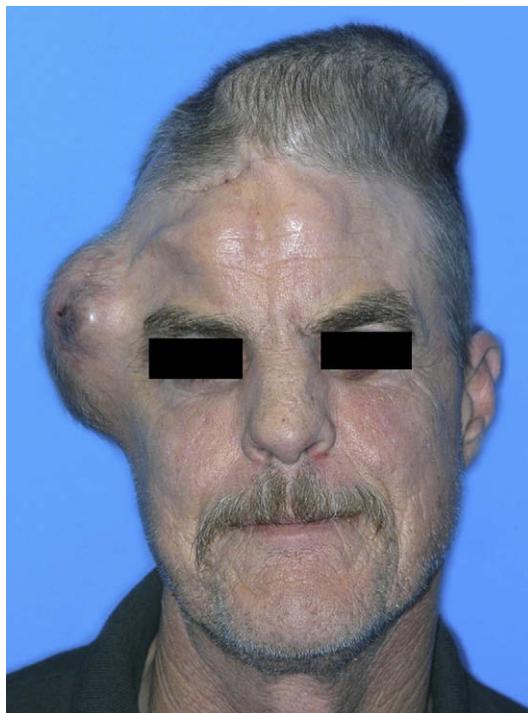


Fig. 15. Tissue expanders in position and maximally inflated.

during flap advancement. The ideal flap is raised as an advancement type flap along the sides of the implant.

After the desired amount of flap gain has been achieved, an additional 2 weeks should be allowed before flap harvest to allow for the biologic creep achieved by the last round of expansion. Infectious complications with tissue expanders are uncommon and they can usually be salvaged with antibiotics but may require implant replacement if the infection progresses. Implant exposure may occur. If it occurs late in the expansion process, the implant should be maintained in its expanded state, antibiotic-impregnated gauze covering of the exposed area, and antibiotic coverage maintained for two weeks following exposure to take advantage of the tissue gain maximally.

Meticulous planning is required when placing tissue expanders. If at all possible, one should aim to recreate or improve the existing hair distribution. There is some controversy about skin incision placement relative to the hair follicles. Incisions that cut across the hair follicles because of perpendicular placement will result in a softer appearance but may result in localized alopecia, whereas incisions placed parallel to the follicles may be more discernible—especially when the

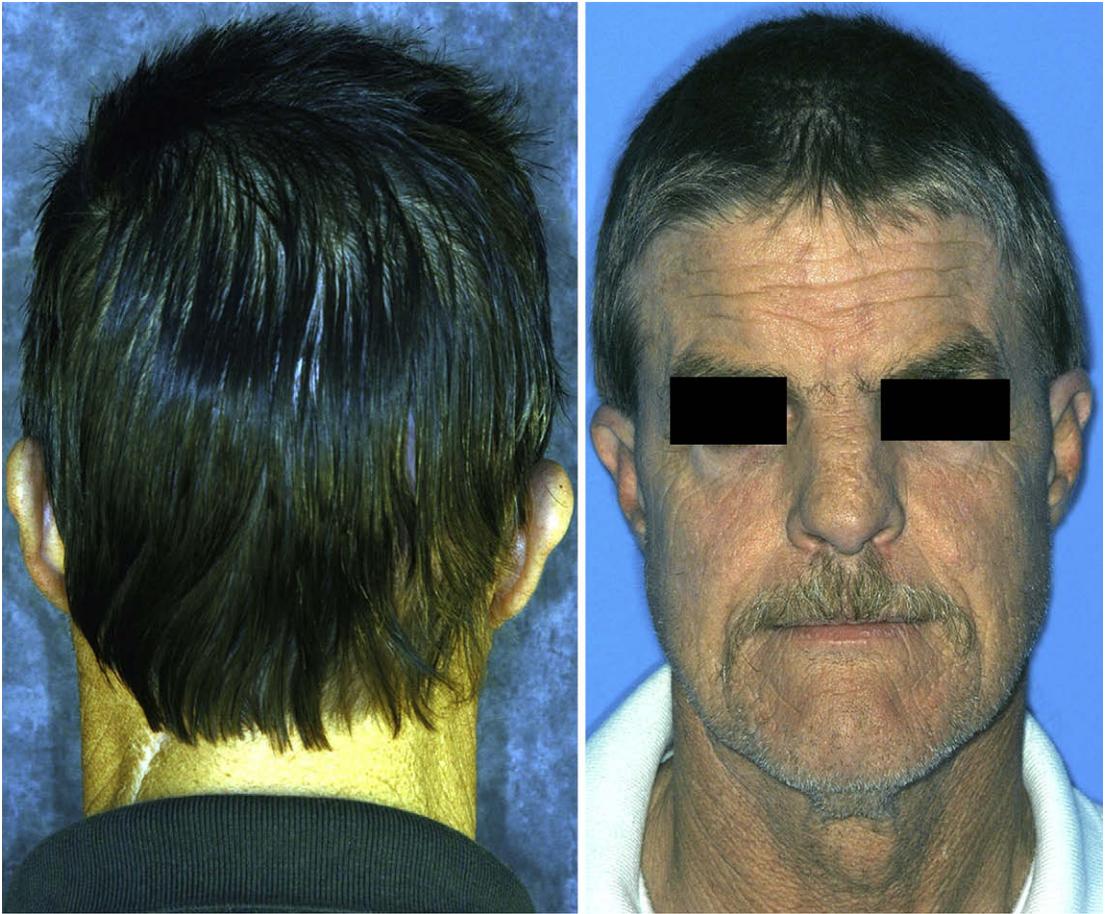


Fig. 16. Postoperative views of patient who is shown in **Figs. 10–13**. Note normal hair distribution and removal of the skin grafted area.

hair is wet—but will result in the disruption of fewer hair follicles and thus decrease the risk of alopecia (**Figs. 12–16**).¹⁹

Local Flap Reconstruction: Advancement, Rotation and Transposition

Designing local flaps for scalp reconstruction is based on same basic principles as in other parts of the body except that the flaps are generally longer for a given size defect because of the relatively inelastic nature of the scalp.²⁰ For small defects of generally less than 3 cm in the forehead and temple regions and even smaller in the parieto-occipital scalp, simple wide undermining and advancement flap closure is feasible with or without RITE to decrease wound closure tension. Most other flaps are either rotation or transposition. Ideally, one should design both of these latter two flaps with a named vascular pedicle entering its base. In addition, sufficient consideration must be given to maintenance of as normal

a hairline and hair distribution pattern as possible. Multiple rotation flaps may be designed particularly in vertex defects.⁴ Generally, transposition flaps should be transposed from the posterior donor region to an anterior recipient region to allow for hairline maintenance in most individuals.



Fig. 17. Preoperative view of large post-traumatic wound of frontotemporal scalp.

If a patient has severe alopecia and a posterior scalp defect, it is acceptable to go in the reverse direction. Rotational flaps, and to a lesser extent, transposition flaps, result in significant standing cutaneous cones. These should be trimmed only very conservatively—and never in the region of the blood inflow tract—to decrease the risk of flap compromise. They will universally settle over a couple of months. If undesirable fullness is noted long-term, it is easily and safely dealt with secondarily after complete healing and peripheral neovascularization has occurred (Figs. 17–19).

Microvascular Free Tissue Transfer Reconstruction of the Scalp

Free tissue transfer of the scalp was first described by Mclean in 1972 when he covered a scalp wound with omentum.²¹ Broad excision of many scalp malignancies results in removal of underlying periosteum as well, leaving the subsequent wound unsuitable for skin grafting. Defects of more than half of the forehead in patients with an intact hairline are well reconstructed with radial forearm free flaps because scalp flaps would result in movement of hair follicles into a hairless



Fig. 18. Rotation scalping flap raised and ready for inset. Design was made to optimize frontotemporal hairline.



Fig. 19. Postoperative frontal view demonstrating adequate hairline distribution and relatively hidden scars.

region. Scalp flaps are still a good option in patients with significant alopecia. Latissimus and rectus free flaps, muscle only or with overlying skin in thin individuals, represent a nice reconstructive in the patient with massive soft tissue loss. When there is nonviable bone (eg, osteitis) secondary to radiation therapy beneath the area of marginal or absent scalp, free flap coverage should be considered. Free flaps appear to be able to tolerate therapeutic doses of radiation well (Fig. 20).²²

The aforementioned free flaps all have reasonable length vessels that can reach the superficial temporal vessels and, if these are unavailable, performing anastomosis directly in the neck to branches of the external carotid artery.²³ The author of this article does not use the occipital vessels because postoperative positioning issues renders them at continued risk of compression. Postoperative positioning is very important in preventing loss of the flap or portions thereof. In a 10-year review of free tissue transfer reconstruction of scalp defects at MD Anderson, a complication rate of 59% was noted in the study group.¹² Most of these complications represented issues with delayed wound healing, particularly in larger flaps. This author has employed halos in large posterior reconstructions to decrease the risk of early



Fig. 20. Preoperative view (*left photo*) of patient status post craniectomy for metastatic prostate carcinoma. Neurosurgical flap design resulted in unfortunate loss of access flap. Postoperative view (*right photo*) demonstrating well healed radial forearm free flap reconstruction of the vertex of the scalp.

postoperative compression from patient positioning (see **Fig. 20**).

Skullbase Microvascular Reconstruction with Anastomosis at the Level of the Scalp

The majority of patients undergoing skullbase extirpative procedures do not require free tissue transfer reconstruction. There is a small subset of patients in which it is invaluable, consisting of the multiply-operated-on patient who has had loss of the pericranium as a potential flap and who has a large, often post-traumatic bony defect of the base of skull and ongoing cerebrospinal fluid leak. In such cases, a radial forearm fascial flap or a rectus muscle flap secured across the skull base from an intracranial approach is valuable. A key hole is made in the calvarium ipsilateral to the anastomosis that is performed in the temporal region of the scalp.²⁴ The edges of these flaps need to be inset with transosseous tunnels to prevent flap prolapsed inferiorly.

Adjunctive Techniques

Hair transplantation is often beneficial for areas of alopecia, reconstitution of the anterior hairline, or

scar camouflage. Standard single and multifollicle grafts may be used with success.

When oncologic resection results in loss of scalp and underlying calvarium, there are a number of options for reconstruction. Autografts using rib, split calvarium, or iliac crest represent good alternatives and they may be preferable in the patient who has had osteitis or radiation therapy because of the increased risk of infection of alloplasts in these cases.¹² In fact, it may not be necessary to reconstruct the calvarium at all if there has been good free tissue transfer scalp coverage of the defect—even in patients who have a history of persistent scalp osteomyelitis.¹³ In cases of chronic osteomyelitis of the calvarium arising as a sequela of either prior radiation therapy or a non-healing wound resulting from previous failed reconstruction or trauma, it is necessary to excise the necrotic bone. Systemic antibiotic therapy is clearly not going to penetrate necrotic nonvascularized bone or bone sequestra.²⁵ Free-tissue transfer can also incorporate bone stock as a single source for coverage of both scalp and calvarium.²⁶ In this author's experience, it is difficult to orient the bone graft portion of the flap to provide for an ideal bony reconstruction because

of the relatively fixed orientation of the bone in relation to the pedicle and planned anastomosis. It is likely best used infrequently and with only small osseous defects. Alloplastic reconstruction of the skull, including methylmethacrylate, titanium mesh, hydroxyapatite cement, and CT-generated prefabricated acrylic, all represent viable options for replacement of the calvarium and protection of the underlying brain.^{27,28}

SUMMARY

Scalp reconstruction encompasses a broad spectrum of flaps, grafts, and techniques that should be readily available to the facial plastic surgeon treating this patient population. Meticulous attention to detail, particularly in the planning and early postoperative periods, will be associated with gratifying results in the majority of patients.

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