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Management of Scalp and forehead defects

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Abstract

Introduction: Scalp defects may result from various causes such as trauma, tumour excision, infections, or burns. Due to the scalp's distinct anatomical characteristics—including limited elasticity, tight adherence to the calvarium, and a convex contour reconstructive procedures pose both functional and aesthetic challenges.

Aim: To evaluate and compare scalp reconstruction techniques and assess outcomes in relation to defect size, aetiology, and anatomical site.

Materials and Methods: A prospective clinical study was carried out on 25 patients with scalp defects treated at a tertiary care centre between January 2018 and December 2022. Reconstruction technique used on the patients were primary closure, local advancement and rotation flaps, tissue expansion, or free tissue transfer. Surgical outcome, complication rates, healing time, and aesthetic satisfaction parameters were assessed.

Results: Trauma (45%) and post-tumour excision (35%) identified as the most common aetiologies. In 60% of cases local flaps were satisfactory. Medium to large or complex defects, especially those involving prior irradiation or infection, required tissue expanders (15%) or free flaps (10%). Minor complications reported in 7.5% of cases. Overall, 85% of patients reported good to excellent aesthetic and functional outcomes.

Conclusion: Scalp reconstruction requires a patient-specific, tailored, algorithmic approach. Transposition and local flaps remain the foundation for small to moderate defects, whereas for larger or complicated defects, tissue expansion and free flaps are recommended. A robust understanding of regional anatomy and reconstructive principles is essential to achieve optimal outcome.

Keywords: Scalp defect; Local flap; Tissue expansion; Free flap; Reconstructive surgery

Introduction

The management of scalp and forehead defects requires a comprehensive understanding of its' complex anatomy and extensive vascular network. The scalp extends from the superior nuchal lines and occipital turbulences to the supraorbital foramen, consists of five distinct layers: skin, subcutaneous tissue, galea aponeurosis, loose areolar tissue, and pericranium [1]. The forehead and scalp have different musculature and hair-bearing characteristics, despite frequently being viewed as one single entity [2]. The region is highly vascularized, with abundant arterial supply and venous drainage including the valveless emissary veins, that increases the risk of intracranial spread of infection [3]. While lymphatic drainage has no nodal barriers, allowing direct flow to cervical nodes [4], innervation involves both cranial and cervical nerves [4]. So, careful consideration of these anatomical features is of utmost importance before planning an effective reconstructive strategy in this region.

Historically, the techniques of scalp reconstruction have evolved significantly over the centuries from ancient Egypt to more recent microsurgical procedures and tissue expansion methods. Few such milestones include Orticochea's flap methods, Neumann's pioneering tissue expansion, and successful

total scalp replantation by Miller et al. in 1976 [5-7]. Scalp and forehead defects commonly result from trauma, burns, infections, tumours, or congenital anomalies [8-13]. As these regions pose unique anatomical and aesthetic challenges, effective management of scalp and forehead defects necessitates an individualized tailored approach, accounting for the size, depth, location of the defect, it's aetiology, surrounding tissue quality, and patient comorbidities. Such as, the integrity of the pericranium is essential for graft survival and calvarial protection [14]. For the best functional and aesthetic results, "like with like" replacement is recommended, especially when it comes to hair-bearing scalp tissue [15-21]. However, operative success largely depends on achieving meticulous haemostasis, proper incision orientation, and careful galeal scoring to maximize tissue mobility [22-26].

Tissue expansion is a suitable technique for reconstructing large defects with excellent aesthetic integration, though it requires staged procedures and carries a risk of complications [27-30]. In cases of scalp avulsion, microsurgical replantation remains the preferred approach whenever feasible [31,32]. For smaller defects (<3 cm), primary closure is often feasible, especially in areas having tissue laxity, aided by wide undermining and galeal relaxation incisions if necessary [14]. In select non-cosmetically critical, shallow defects without bone exposure, healing by secondary intention may be acceptable, though the risk of alopecia makes this less ideal for the scalp [33].

Skin grafts, including split- and full-thickness types, offer quick and technically simple coverage for larger defects, provided a well-vascularized bed is present [34-36]. In cases lacking pericranium or vascularized tissue, dermal substitutes such as Integra or Alloderm can provide a scaffold for neodermis formation before grafting [37,38]. Additionally, negative pressure wound therapy (NPWT) can support granulation tissue formation and improve graft take, especially over calvarial surfaces [39-42].
For medium to large defects, a variety of local flaps including rotational, transposition, pinwheel, Orticochea, and Juri flaps etc. can be designed based on vascular networks and relaxed skin tension lines [26,43-48]. In larger or complex cases where local options are inadequate, tissue expansion may be used to generate additional hair-bearing scalp tissue, although it requires staged procedures and carries a moderate complication rate [27-30].

When local or regional flaps are unsuitable due to history of previous radiation, infection, or insufficient vascularity, free tissue transfer becomes necessary. Commonly used free flaps include the latissimus dorsi, serratus anterior, anterolateral thigh, and radial forearm flaps, each chosen based on defect size, location, and required pedicle length [49-51]. In cases where the calvarial bone is lost, reconstruction with autologous bone grafts (parietal or rib) or alloplastic materials (titanium mesh, methyl methacrylate, hydroxyapatite) is performed to protect intracranial contents and restore skull contour [52,53]. Presence of a stable soft tissue coverage remains essential to prevent future complications.

Postoperatively, careful patient positioning, graft protection, and use of drainage or bolster dressings are essential, especially for large flaps or reconstructions in high-tension areas. In microvascular free flap cases, pedicle protection and head elevation are crucial to preserve flap viability and minimize pressure-related complications [54,55].

Overall, successful reconstruction of scalp and forehead defects hinges on a deep understanding of regional anatomy, meticulous planning, selection of the most appropriate reconstructive modality, and individualized patient-centered care. In this study, we aimed to evaluate the epidemiology, etiology, type and distribution, management modalities, postoperative complications, and long-term outcomes associated with surgical treatment of scalp and forehead defects.

Materials and Methods

This prospective observational study was conducted over a period of 30-month from September 2018 to February 2021 in the Department of Plastic Surgery at our tertiary care institution. The patients treated here were either directly admitted to the Plastic Surgery Department or referred from other departments within the hospital or from outside facilities. Approval for the current study was obtained from the Institutional Ethics Committee.

A. Patient Selection and Data Collection

A total of 25 indoor patients with scalp or forehead defects treated surgically during the study period were included in this study. Written informed consent was obtained from all participants prior to enrolment in the study. Data collection was done using a predesigned proforma, which entailed variables such as age, sex, aetiology, anatomical site and size of the defect, reconstructive technique employed, and postoperative complications. A preselected team from plastic surgery department was in charge of Clinical assessment, surgical planning and management.

A.1. Initial Management and Resuscitation

In cases of trauma-related defects, initial management included a primary survey following the standard trauma protocols, with particular attention to airway, breathing, and circulation (ABCs). Once hemodynamic stability was ensured, detailed information regarding the type and cause of injury, time since trauma, primary wound care received, and relevant medical history was recorded. Emergency care included administration of tetanus toxoid, systemic antibiotics, analgesics, and appropriate wound debridement etc.

A.2. Investigations

Baseline investigations included complete hemogram, serum electrolytes level, renal function tests, liver function tests, fasting and postprandial blood glucose levels, urine routine and microscopy test, radiograph of chest and the wounded area etc. Patients over 40 years of age also underwent electrocardiography. Wound swabs were collected for culture and sensitivity testing. High definition Multislice computed tomography (CT) with three-dimensional reconstruction was performed (as and when indicated) to assess the extent of bony involvement and guide subsequent surgical planning.

B. Clinical and Diagnostic Evaluation

A thorough clinical examination was performed, with particular attention to comorbidities such as diabetes mellitus, coronary artery disease, smoking history, prior radiation therapy, immunosuppressive states etc. In suspected oncological cases, staging workup including biopsies, MRI, PET-CT, or bone scans was performed to assess for local invasion or metastatic disease.

B.1. Assessment of the Defect and Surrounding Tissue

Defects were classified based on size, shape, depth, and anatomical location for facilitating an algorithmic approach to reconstruction. Parietal defects offered greater mobility and were more amenable to primary closure, whereas occipital and temporal defects often required flap-based reconstruction due to limited laxity. Defects involving the calvarium underwent debridement of devitalized bone and were assessed for pericranial preservation, which was essential for graft adherence.

Quality of the surrounding tissue including thickness, elasticity, vascularity, and presence of any scarring from previous surgeries, burns, or radiation was carefully evaluated. In oncological cases, confirmation of negative margins was required before proceeding with definitive reconstruction. Hairline involvement was also considered when planning local flaps or tissue expansion.

B.3. Patient Considerations

Patient-specific factors such as overall health, level of function, compliance, and personal preference were key in surgical decision-making. Patients undergoing complex or staged procedures were evaluated for their ability to endure prolonged recovery and follow-up period, and possible cosmetic disfigurement. In oncological patients, the timing of surgery was adjusted accordingly with the chemotherapy or radiotherapy schedule.

Surgical Management and Postoperative Care

Surgical planning was individualized based on the characteristics of the defect and patient related factors. Reconstructive options included primary closure, healing by secondary intention, split- or full-thickness skin grafting, local or regional flaps, tissue expansion, and free tissue transfer. Multistage reconstructions were performed as per requirement.

Postoperative management included elevation of the head to reduce edema, use of bolster dressings for skin grafts, and protection of flap pedicles from pressure. Negative-pressure wound therapy was used in selected cases to reduce skin graft loss. In non-compliant patients, temporary halo devices were employed to prevent inadvertent flap compression.

Patients were monitored regularly in the outpatient department following discharge. The wound status, healing progression, associated complications, and patient satisfaction were recorded at each visit. Readmission, revision surgery, or additional wound care was advised as needed.

Data collected using the standardized proforma were compiled in Excel sheet for final analysis. Descriptive statistics including frequency and percentages were calculated for the quantitative Variables.

Results

A total of 25 patients with scalp and forehead defects were managed surgically between September 2018 and February 2021.

Demographic Profile:

The age of the patients ranged from 5 to 67 years, with a mean age of 30.04 years. About 56% of the patients were in the third and fourth decades where a majority (36%) belonged to the 31- 40-year age group. Of the 25 patients, 13 (52%) were male and 12 (48%) were female, resulting in a near-equal gender distribution (male-to-female ratio of 1.08:1) **(Table 1)**.

Table 1: Distribution of scalp and forehead defects according to patient's age and gender.

Age group (years)	Number of patients (n=25)	Percentage (%)
0-10	5	20
11-20	2	8
21-30	5	20
31-40	9	36
41-50	1	4
51-60	1	4
>60	2	8
SEX		
Male	13	52
Female	12	48

Table 2: Aetiology of the scalp and forehead defects.

Aetiology		No of Patients (n=25)	Percentage (%)
Direct trauma		11	44
Post decompressive surgery	Exposed mesh	1	16
	Exposed bone	3	
	Total	4	
Electrical injury		3	12
Avulsion injury		3	12
Benign lesions		3	12
Burns		1	4
Total		25	100

Table 3: Age group affected vs. Aetiology of scalp & forehead defects with gender distribution.

Age Group (Years)	Patients affected	Aetiology
0–10	4	Direct trauma (3), post-decompression (1)
11–20	3	Direct trauma (1), Electrical (2)
21–30	5	Direct trauma (3), Avulsion (2)
31–40	9	Mixed: all types
41–50	1	Direct trauma (1)
51–60	1	Direct trauma (1)
>60	2	Benign lesion (1), Others

Table 4: Aetiology of scalp & forehead defects with gender distribution.

Aetiology	Gender	
	Male	Female
Direct trauma	6	5
Avulsion injury	0	3
Electrical injury	3	0
Post decompressive surgery	1	3
Benign lesions	3	0
Burns	0	1
Total	13	12

Aetiology of Defects

The most common cause of scalp and forehead defects was direct trauma, accounting for 44% (n=11) of cases. Other aetiologies included post-decompressive neurosurgical exposure (16%), electrical injuries (12%), avulsion injuries (12%), benign lesions (12%), and burns (4%) respectively **(Table 2)**.

Among these cases, patients aged 11–40 years were most affected, accounting for 68% (n=17) of the total study groups, consistent with the high-risk nature of injuries seen in this working-age population **(Table 3)**. Gender-based aetiology patterns indicated that avulsion injuries were exclusive to females, whereas electrical injuries occurred only in males **(Table 4)**.

Site of Defects

The frontal region was the most commonly affected site (20%), followed by the right and left parietal regions and right parieto-temporal areas (12% each) **(Table 5)**. Associated injuries were present in 24% of patients, with head/neck injuries being the most common (12%), followed by skeletal injuries (8%), and abdominal/chest trauma (4%) **(Table 6)**. Bone was exposed in 32% (n=8) of cases, while no patients presented with exposed dura or brain tissue **(Table 7)**.

Reconstructive Procedures and Postoperative Complications

Transposition flaps were preferred in moderate to large defects; STG was often employed when pericranium was intact. The choice of procedure was largely determined by the aetiology: direct trauma cases mostly required flaps, while avulsion injuries often needed grafting **(Table 8)**.

The most frequently used reconstruction method was the transposition flap (44%), followed by split-thickness skin grafting (24%) and primary closure (24%). Complications were observed in 20% of cases involving transposition flaps, including partial necrosis (n=2), flap retraction (n=2), and donor site infection (n=1). One case of partial graft loss was also reported **(Table 9)**.

Hospital Stay

The average hospital stays varied by procedure, with primary closure patients typically discharged within 1–2 weeks, whereas flap or graft patients required longer hospitalization **(Table 10)**.

Table 5: Distribution of site of scalp and forehead defect.

Site of defect	Number of patients	Percentage (%)
Right parietal	3	12%
Right temporal	1	4%
Left parietal	3	12%
Left temporal	1	4%
Frontal	5	20%
Right fronto-temporal	1	4%
Right fronto-parietal	2	8%
Right parieto temporal	3	12%
Left fronto-parietal	1	4%
Occipital	2	8%
Entire scalp all regions	3	12%

Table 6: Associated injuries with scalp and forehead defects.

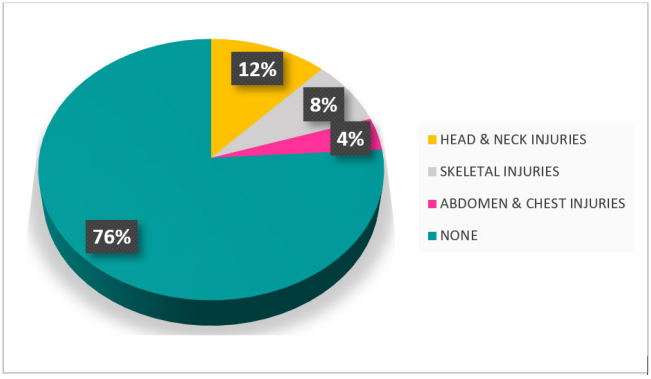
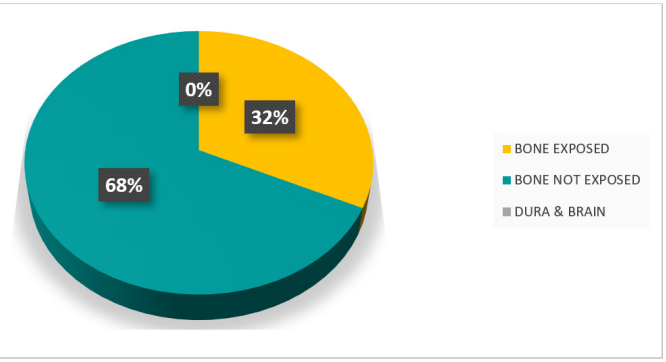


Table 7: Underlying structure exposed in the scalp and forehead wound.



Discussion

Reconstruction of scalp and forehead defects remains a unique surgical challenge due to the complex anatomy of this region, functional significance, and high cosmetic visibility. The aetiology of such defects is diverse, encompassing trauma, oncologic resection, burns, electrical injuries, and congenital or iatrogenic causes. In the present study, trauma was the most frequent cause of scalp and forehead defects (44%), consistent with the findings of Memon et al. and Mateev et al., who also reported trauma as a dominant etiological factor among young, working individuals [55,56]. The higher number of cases in the 11–40-year age group (68%) reflects occupational hazards and greater risk of road traffic accidents in this demographic.

Table 8: Distribution of flaps/procedures according to aetiology of defect.

Aetiology	Trans- position Flap	Rotational flap	Bipedicled flap	Double opposing Rotational	STG	Primary closure
Direct Trauma	7	-	-	-	1	3
Post Decompressive surgery (Exposed bone/ implant)	2	1	-	-	-	1
Electrical injuries	2	-	-	-	1	-
Avulsion injuries	-	-	-	-	2	1
Benign Lesions	-	-	-	1	1	1
Burns	-	-	-	-	1	-
Total	11	1	0	1	6	6

Table 9: Distribution of procedure performed and incidence of complications post flap/ procedure in management of scalp & forehead defects.

Methods	No. of Patients (n = 25)	Observed Complications
Transposition Flap	11 (44%)	Partial flap necrosis (2), Flap retraction (2), Donor site infection (1)
Split-Thickness Skin Graft (STSG)	6 (24%)	Graft loss (1)
Rotational Flap	1 (4%)	None
Double Opposing Rotational Flap	1 (4%)	None
Primary Closure	6 (24%)	None
Total	25	6 cases with complications; no mortality reported

Table 10: Distribution of cases according to the duration of post-operative hospital stay.

Post-operative days	Flap	STG	Primary closure
0-15	5	3	5
16-30	8	2	1
31-45	-	-	-
45-60	-	1	-

While many studies have reported a strong male predominance in scalp defect cases [55,56], our study observed an almost equal gender distribution, with a male-to-female ratio of 1.08:1. This deviation may be attributable to the increasing involvement of women in agricultural and industrial activities, particularly in rural settings. Avulsion injuries, observed exclusively in female patients in this study, have previously been associated with entanglement of long hair in rotary machinery [57].

Electrical injuries, although representing a smaller portion of the study population (12%), were notably severe. All affected patients were young males, with defects often involving full-thickness scalp loss and exposed calvarium, consistent with the previous study done by Adamo et al., who reported the reconstructive complexity and high morbidity associated with high-voltage electrical injuries of the scalp [58].

The predominance of defects found in the frontal and parietal regions in the current study aligns with the previous reports, suggests vulnerability due to anatomical exposure and thinner soft tissue coverage [59]. Calvarial bone exposure was noted in 32% of cases. In such cases, reliable coverage becomes paramount, as skin grafting alone is insufficient on bare bone without pericranial support. In these cases, outer table burring or vascularised flap coverage is often required to facilitate successful reconstruction [36,37].

Transposition flaps were preferred in moderate (5–25 cm^2) to large defects (>25 cm^2), offering a reliable option with acceptable aesthetic outcomes. This preference aligns with findings by Mario Iger et al. and Abdul Memon et al [55,60]. Local flaps were favoured due to their reliability, vascular safety, and technical simplicity, particularly in resource-limited settings. These findings are in agreement with prior work done by Orticochea [43] and Zayakova et al [42]. Skin grafting was effective in cases without pericranial compromise, although aesthetic outcomes and durability were suboptimal compared to local flaps. However, a 20% complication rate was observed in flap reconstructions, including partial necrosis, flap retraction, and donor site infection, consistent with reports by Abhyankar et al [46].

Split-thickness skin grafts were used primarily when the pericranium was intact. Though technically straightforward, they are associated with cosmetic limitations such as alopecia and poor contour match [35]. Additionally, graft take is unpredictable in irradiated or poorly vascularised beds [39,49], and long-term stability may be compromised.

Postoperative complication rates in this study were comparable to those reported in the literature [60-62], with 18.1% necrosis rate of transposition flaps, slightly higher than some previous studies, but manageable with conservative treatment or secondary procedures. Hospital stays varied according to the procedure type, with primary closure associated with the shortest duration and flap or graft cases requiring longer admissions. Institutional policies, including extended inpatient care under public healthcare schemes, likely contributed to the observed lengths of stay - an issue also reported by Bhaskaranand and Parikh [63].

This study highlights the importance of individualised reconstruction planning, defect characteristics, patient comorbidities, and regional resources. However, several limitations must be acknowledged. The relatively smaller sample size limited the generalisability of the findings. The study was conducted at a single tertiary care centre, potentially introducing referral bias and limiting the representation of cases from primary and secondary healthcare settings. Additionally, the absence of a control group limits the comparative evaluation of the efficacy of the reconstructive techniques.

Conclusion

Scalp and forehead defects present diverse reconstructive challenges. Local transpositional flaps remain the cornerstone of management in most cases, offering reliable coverage with acceptable complication rates. While outcomes were largely favourable, proper patient selection, refinement of techniques and careful postoperative monitoring remain essential for optimal results. Multidisciplinary collaboration and advancements in microsurgical techniques may further augment reconstructive outcomes in complex cases. Future multicentric studies with larger sample sizes and objective outcome measures including patient satisfaction and aesthetic scoring are recommended for further validation and refinement of reconstructive protocols for the complex scalp and forehead defects.

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