

Article

Reconstruction of Scalp Defects with Rotational Flaps: Where Is the Limit?

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Abstract: Background/Objectives: Scalp defect reconstruction often poses a challenge due to the distinct anatomy and limited skin elasticity of the region. Rotational flaps, when properly planned, offer a superior and creative solution for effectively covering most scalp defects. The aim of this study is to present the indications, and versatile use of rotational flaps in scalp reconstructive surgery, guided by an algorithmic approach and exemplified by numerous clinical applications. Methods: An observational cohort study was conducted between 2019 and 2024. The study protocol adhered to the ethical guidelines of the Declaration of Helsinki, was approved by the local ethics committee, and followed the STROBE statement for cohort studies. Results: A total of 152 rotational flaps were performed in 138 patients to reconstruct scalp defects, mostly following skin cancer excision. The defect size ranged from 30 to 96 mm in largest diameter (mean diameter, 52.8 ± 8.8 mm). Postoperative complications occurred in 13 cases (9.4%), and 5 cases (3.6%) required further surgical treatment, due to wound healing problems and/or necrosis. Based on high VAS scores ($9.4 + 0.3$), the cosmetic outcomes were deemed satisfactory, with excellent color and texture matching. Conclusions: This study underscores the critical role of meticulous surgical planning and technique in achieving optimal outcomes in scalp reconstruction. By combining the principles of tissue biomechanics with the versatility of rotational flaps, surgeons can effectively address a wide range of defects, achieving both functional and esthetic excellence.



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Keywords: rotational flap; scalp; reconstruction; defect

1. Introduction

The reconstruction of scalp defects, commonly resulting from skin tumors, trauma, burns, and congenital anomalies, often presents a significant challenge for the plastic surgeon. Major issues arise due to the anatomical presence of the galea aponeurotica, which is the principal culprit of the marked skin inelasticity encountered in the region, particularly when compared to other anatomical sites [1]. The degree of skin tension renders the primary closure of even relatively small defects unattainable, despite excessive undermining maneuvers. Consequently, surgeons must explore alternative treatment options, including skin grafts, local and regional flaps, and free tissue transfer.

The goals of successful reconstruction dictate a satisfactory functional outcome by providing adequate skin coverage over exposed tissues, while also achieving optimal cosmesis. Moreover, great attention is essential to avoid hairline distortion or induced alopecia. Over the years, numerous efforts have been made to establish a comprehensible algorithm for scalp reconstruction, considering several key factors in its development [2–5]. Desai et al.

summarized the four most critical parameters described in the literature, including defect size, location, radiation history, and the potential for hairline distortion, which facilitate a consistent outcome [6].

Local flaps have been advocated for as an optimal reconstructive method for medium-sized scalp defects, yielding excellent outcomes, due to the use of “like with like” tissue, while reporting a remarkably low major complication rate of 3.4% [7]. Nonetheless, advancement and transposition flaps display limitations in scalp reconstruction and are primarily reserved for temporoparietal defects, on account of the anelasticity and the multidirectional tension lines created by the galea. Conversely, rotational flaps are not constrained by the local anatomy, provided that proper planning and adequate subgaleal undermining are performed, and thus sufficient rotation can be achieved to cover over adjacent defects, often in a highly innovative manner [8]. Their suitability for scalp reconstruction is unquestionable, since the convex surface of the scalp favors the curvilinear incisions necessary for raising these flaps [9,10].

The aim of this study is to present the indications, versatile use, and various applications of rotational flaps in scalp reconstruction, based on an algorithmic approach, thereby highlighting the true potential of this flap.

2. Materials and Methods

A retrospective observational cohort study was conducted in the Plastic Surgery Department of a tertiary university hospital between January 2019 and December 2024. The study protocol conformed to the ethical guidelines of the Declaration of Helsinki, was approved by the local ethical committee, as part of a larger research project (approval code: 17/22-9-21, s.10, approval date: 22 September 2021) and adhered to the STROBE statement for cohort studies. The patients were consecutively enrolled by one surgeon (K.S.) if reconstruction of scalp defects with a rotational flap was performed. Patients unable to undergo this operation, due to medical illness or with defects that exceeded the clinical applicability of this flap, were excluded from the study. Informed consent was obtained from all patients included in the study.

A prospectively maintained clinic database was used to collect demographics, as well as clinical and surgical parameters of the study population. Outcomes of interest included the defect size, total operation time, immediate and delayed complications, based on Clavien–Dindo classification, total length of stay, and patient satisfaction, measured by a 10-point visual analog scale (VAS), which was evaluated three months postoperatively.

Data were analyzed using SPSS (IBM SPSS Statistics for Macintosh, Version 28, Armonk, NY, USA). Descriptive statistics for continuous variables were expressed as means and standard deviations (SDs). Frequencies and percentages summarized dichotomous variables and categorical observations.

Surgical Technique

The rotational flap is designed, based on the actual defect size, location, and skin laxity. Firstly, the diameter of the defect is measured, and a flap with a diameter two- to three-fold the defect is drawn, adjacent to the defect. The curvilinear incision begins at the supero- or inferolateral defect margin in order to incorporate one of the main vessels of the scalp, thus either anteriorly (supratrochlear artery), laterally (superficial temporal artery), or posteriorly (occipital artery). The rotational arc is enhanced by designing the flap at a slightly greater height than a typical semicircular flap (Figure 1a). Typically, larger defects are preferred to be reconstructed, by designing two opposing rotational flaps in a yin-yang manner, based on the principles described above, and with careful attention to prevent any noticeable distortion of the hairline.

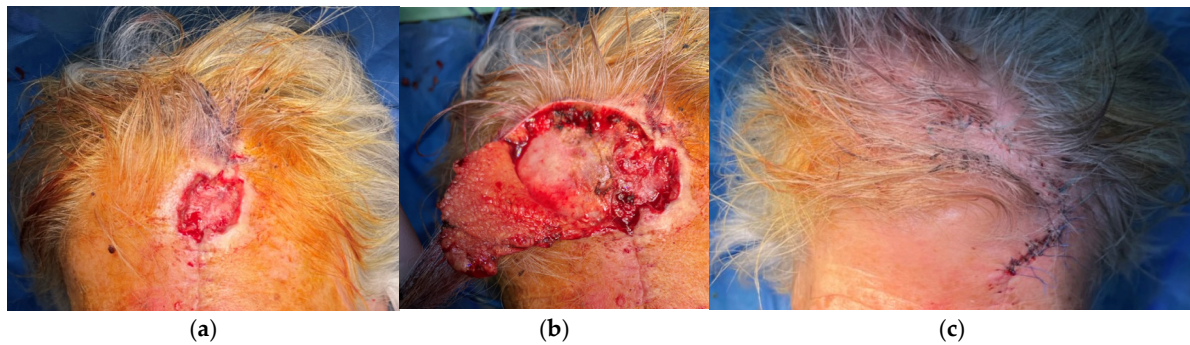


Figure 1. (a) A 30 mm defect of the frontoparietal area following postoperative wound dehiscence; (b) a rotational flap was elevated; (c) immediate defect reconstruction without any tension.

Local wide infiltration with an anesthetic solution, as previously described, is administered by the surgeon, before prepping, over the entire area to be dissected [11,12]. The patient's skin is cleansed and draped in a typical manner, and the operation is initiated nearly 30 min after the infiltration. Following skin incision, Raney clips are never placed along the wound margins to control the scalp bleeding. Instead, minimal bleeding, due to the local anesthesia mixture, is encountered from the subdermal vessels, which are cauterized before deepening the incision. The flap is meticulously elevated in the subgaleal plane, ensuring that the underlying pericranium remains intact. Once adequate mobilization is achieved, the flap is rotated into the surgical defect. If needed, a small “back-cut” is performed at the pivot point to enable sufficient flap rotation, while ensuring that potentially redundant tissue at the base of the pedicle is not removed, to prevent compromising flap viability. Galeal-relaxing incisions in a typical manner, vertical to the axis of rotation, and avoiding the more superficially running vessels, are rarely required. However, they can be performed in the case of excessive wound tension. In rare cases, a skin graft may be applied to the area of maximum tension, should the previously mentioned maneuvers be inefficient. This stepwise approach is followed in every case, which facilitates the defect closure without undue tension. A two-layer closure is performed using interrupted subdermal Vicryl 2-0 and 3-0 sutures, followed by Prolene 3-0 or 4-0 sutures in a continuous fashion. A standing cone at the base of the defect may need conservative trimming, which could risk compromising the pedicle base. However, the initial disfigurement of this skin surplus typically resolves over the following months. No-pressure dressing is applied, and the patient is instructed to keep their head raised, while the blood pressure is carefully regulated.

Regular follow-ups are scheduled within the first 14–20 days, per the surgeon's protocol, to ensure optimal healing through the early diagnosis and treatment of potential complications. Esthetic outcomes are evaluated during the 3- and 12- month visits.

3. Results

In the current study, 152 rotational flaps were performed in 138 patients, 110 males and 28 females. The mean patient age at the time of surgery was 75 years. The mean preoperative ASA classification was 2.7 ± 0.5 . The demographic and clinical characteristics of the study participants are presented in Table 1.

The rotational flaps were typically performed under local anesthesia (95.7%) to reconstruct scalp defects, primarily following skin cancer excision (81.8%). The defect size ranged from 30 to 96 mm in largest diameter (mean diameter, 52.8 ± 8.8 mm). Two opposing rotational flaps were used in 12 cases, while 2 flaps were used to concomitantly cover two distinct defects twice. One rotational flap successfully covered three concomitant scalp defects once. The additional use of a full-thickness skin graft was required in 10 cases (7.2%).

Most cases were completed in one hour, with the mean operative time being 83 ± 18 min. Table 2 depicts the surgical parameters recorded and the flaps' characteristics.

Table 1. Demographic characteristics.

Feature	Patients n (%)
Patients' gender	138
Male	110 (79.7%)
Female	28 (20.3%)
Patient's age at surgery (y)	
Range, Mean $\pm$ SD, Median	26–95, 75.4 ± 12.8 , 78
Indication for surgery	
BCC	34 (24.6%)
SCC	73 (52.9%)
MM	6 (4.3%)
Other skin tumor	4 (2.9%)
Defect	19 (13.8%)
Burn	2 (1.4%)
Comorbidities	
Hypertension	94 (68.1%)
Coronary disease	51 (37.0%)
Diabetes Mellitus	35 (25.4%)
Anticoagulation	48 (34.8%)
Smoking	
No	129 (93.5%)
Yes	9 (6.5%)

y: Year; n: number of cases; SD: standard deviation; BCC: basal skin cancer; SCC: squamous skin cancer; MM: malignant melanoma.

Table 2. Surgical parameters and flap characteristics.

	Patients n (%)
Anesthesia	
Local	132 (95.7%)
General	6 (4.3%)
Duration of surgery (h)	
<1	88 (63.8%)
1–2	48 (34.8%)
>2	2 (1.4%)
Use of skin graft	
No	128 (92.8%)
Yes	10 (7.2%)
Flaps/patient	
1	124 (89.9%)
2	14 (10.1%)
Defect diameter (mm)	
Range, Mean $\pm$ SD, Median	30–96, 52.8 ± 8.8 , 56
Length of stay (d)	
<1	103 (74.7%)
1	29 (21.0%)
2–7	6 (4.3%)
Follow Up (m)	
Range, Mean $\pm$ SD, Median	1–71, 27.2 ± 11.3 , 23

n: number of cases; h: hour; mm: millimeter; SD: standard deviation; d: days; m: months.

The majority of patients (74.7%) were discharged directly or a few hours following the surgery, 21% stayed overnight due to older age and/or higher risk of complications, and only 4.3% (six cases) were hospitalized up to 1 week.

All patients were followed-up with on regular intervals until the stitches were removed, at 3, 6, and 12 months, and then once a year. Postoperative complications occurred in 13 cases (9.4%), with 5 cases (3.6%) requiring further surgical treatment due to wound healing problems and/or necrosis (Table 3).

Table 3. Postoperative complications overview.

	Patients n (%)
Clavien–Dindo classification	
0	120 (87.0%)
1–3	13 (9.4%)
3a	5 (3.6%)
3b–5	0 (0%)
Type of complications	
Infection	8 (5.8%)
Delayed wound healing	5 (3.6%)
Partial necrosis	5 (3.6%)

n: number of cases.

Therefore, grade 3a complications, based on the Clavien–Dindo classification, were recorded only in five cases, which were the highest-grade complications encountered in this cohort. All five cases were successfully treated by reelevating the same flap or using another rotational flap from the opposite side. Postoperative radiotherapy was administered in 12 cases (8.7%), based on the biopsy results and according to the NCCN guidelines, uneventfully.

Based on the high VAS scores (9.4 ± 0.3), the cosmetic outcomes were deemed satisfactory, demonstrating excellent color and texture match, with no distortion of the hairline or significant postoperative alopecia.

3.1. Cases

Several representative cases can be presented. We categorized the defect based on its largest diameter and the reconstructive approach chosen.

3.1.1. Scalp Defects up to 3 cm in Diameter

These cases are the most straightforward to perform. The rotational flap provides a defect closure without tension, completed quickly, and without the potential complications or limitations associated with smaller local flaps (i.e., Limberg flap) or attempting primary closure (Figures 1 and 2).

3.1.2. Scalp Defects 3 to 6 cm in Diameter

These cases are the most typical to perform. The rotational flap represents the gold standard for reconstructing such scalp defects, owing to its consistent reliability and safety. Based on the surgical principles outlined above, any such scalp defect can be effectively reconstructed (Figures 3 and 4).

3.1.3. Scalp Defects 6 to 9 cm in Diameter

These cases are the most advanced to perform. The rotational flap remains a viable option, provided that the surgical principles outlined above are adhered to and certain

decisions are made. Firstly, based on the defect's location and the patient's skin elasticity, either a large axially based rotational flap (Figures 5 and 6) or two opposing flaps (Figure 7) should be planned. If elevated tension is encountered during the flap elevation, a back-cut at the pivot point, galeal scoring, a skin graft, or any combination of these options, should be employed, always following this order.

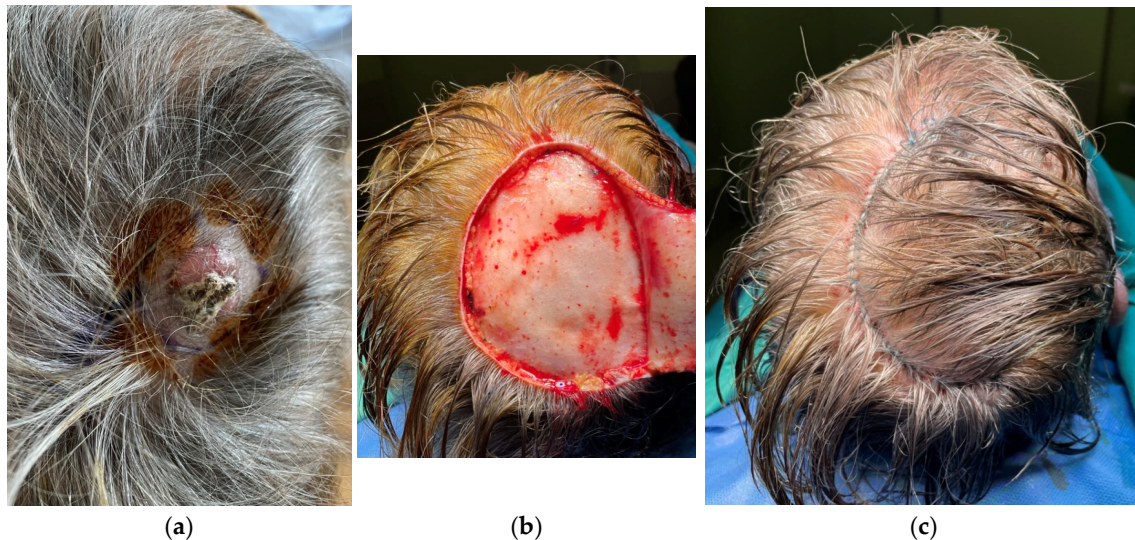


Figure 2. (a) A 30 mm SCC of the right temporoparietal area along with the excisional margins marked; (b) scalp defect and rotational flap elevation, based on the right superficial temporal artery; (c) immediate scalp reconstruction with an inconspicuous suture line.

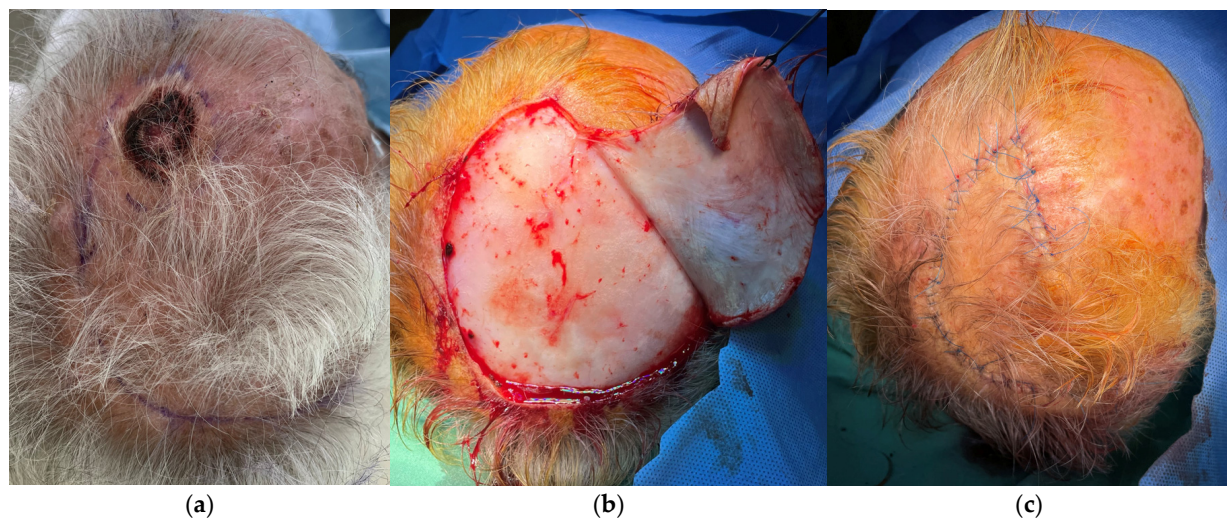


Figure 3. (a) A 45 mm × 35 mm SCC of the left parietal area along with the margins marked; (b) the rotational flap was elevated by dissecting below the galea, based on the parietal branch of the right superficial temporal artery; (c) the immediate postoperative result.

In the event of wound dehiscence or flap necrosis, a rotational flap can be considered the primary option for reconstructing the secondary defects (Figure 8). Finally, more than one rotational flap can be used concurrently to address scalp defects when multiple tumors are diagnosed. This is not uncommon in older men with alopecia or immunodeficient patients, where the proper planning of axial rotational flaps, incorporating multiple vessels into the pedicle, offers a reliable reconstructive solution (Figure 9).

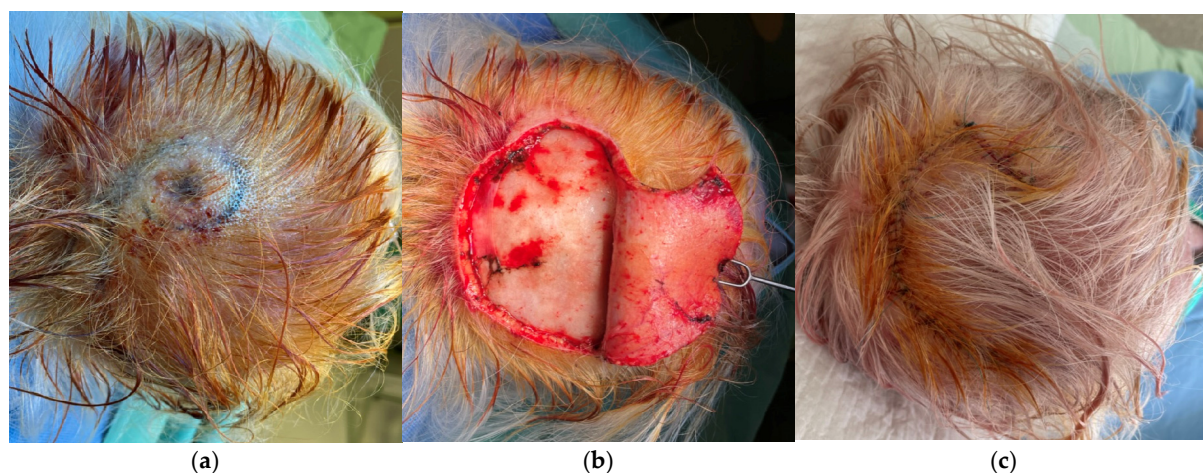


Figure 4. (a) A 50 mm × 40 mm marked excision for an SCC of the left parietal area; (b) the rotational flap was elevated, including the galea, based on the parietal branch of the right superficial temporal artery; (c) the immediate postoperative result.

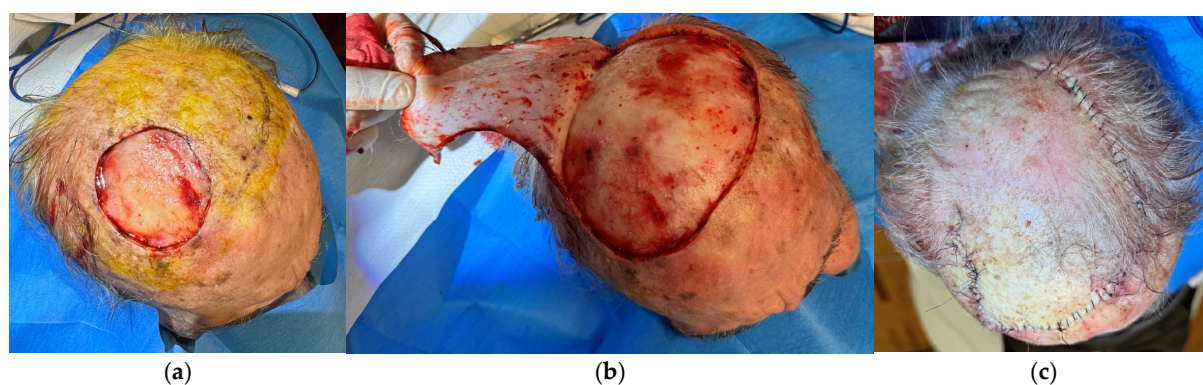


Figure 5. (a) A right frontoparietal defect, measuring 85 mm × 75 mm, postoncological excision; (b) the rotational flap was designed along the anterior hairline, and elevated based on the right occipital artery; (c) the immediate postoperative result.

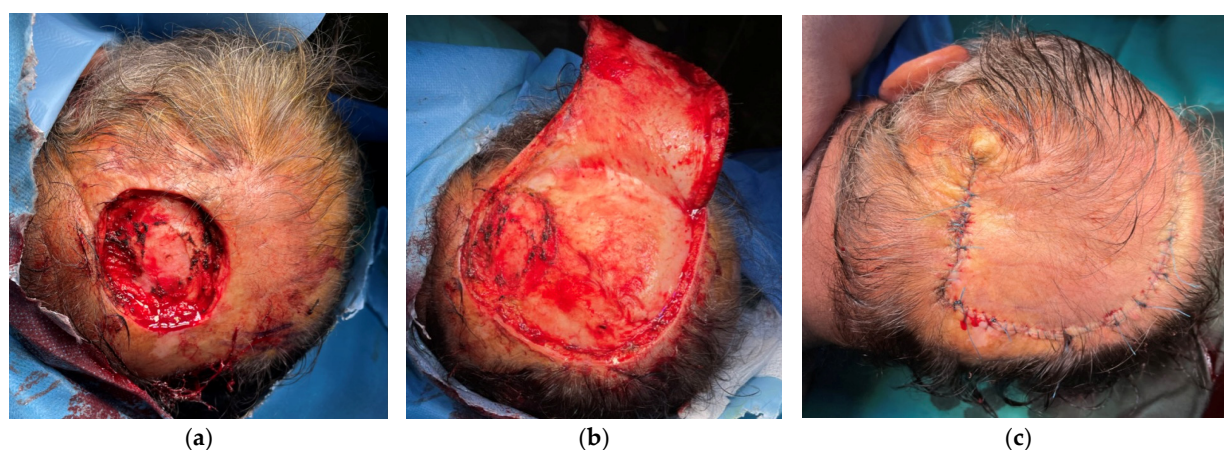


Figure 6. (a) An occipital scalp defect, measuring 80 mm × 65 mm following the excision of an SCC; (b) the rotational flap was elevated based on the parietal branch of the left superficial temporal artery; (c) the immediate postoperative result.

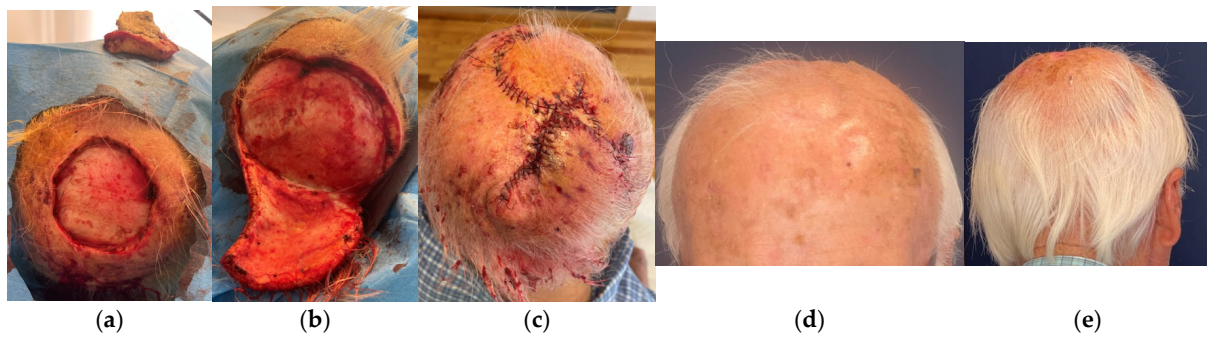


Figure 7. (a) A parietal scalp defect, measuring 85 mm $\times$ 70 mm, following the excision of an SCC; (b) two opposing rotational flaps were elevated based on the occipital artery (posterior flap) and the supratrochlear artery (anterior flap); (c) the immediate postoperative result; (d,e) the 3-month result from anterior and posterior aspects.

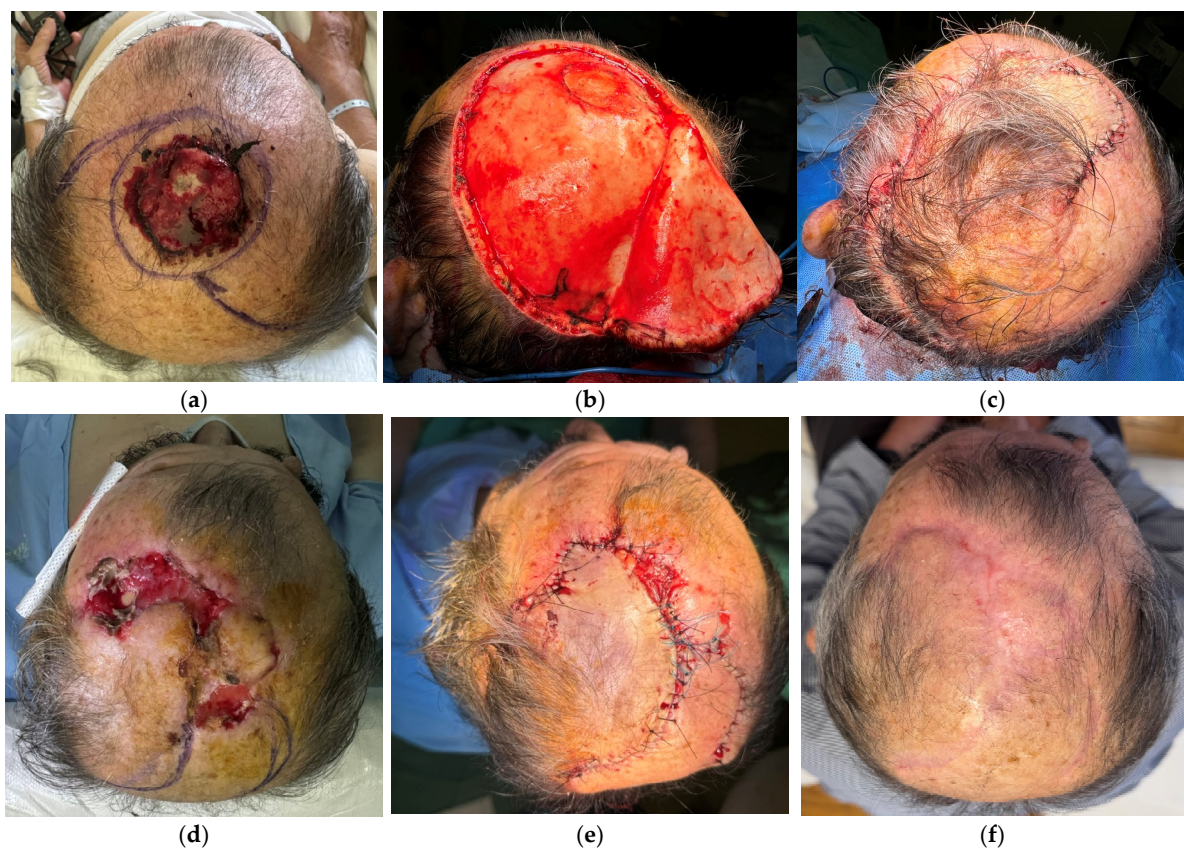


Figure 8. (a) A 75 mm $\times$ 70 mm marked excision for an SCC of the central parietal area. Two opposing rotational flaps were designed. (b) One large rotational flap, based on the right superficial temporal artery, was elevated and chosen for reconstruction. (c) The immediate postoperative result. (d) Two full-thickness postoperative defects at 1 month, following an infection and then wound dehiscence. A rotational flap for each defect was designed, with an axis directly opposite to the initial flap. (e) The immediate result following surgical debridement and repair of the defects. (f) The 3-month result, with complete healing and acceptable contouring of the scalp, despite the three scars from the rotational flaps.

An algorithm outlining the use of rotational flaps for scalp defects, along with the available maneuvers, is depicted in Figure 10.

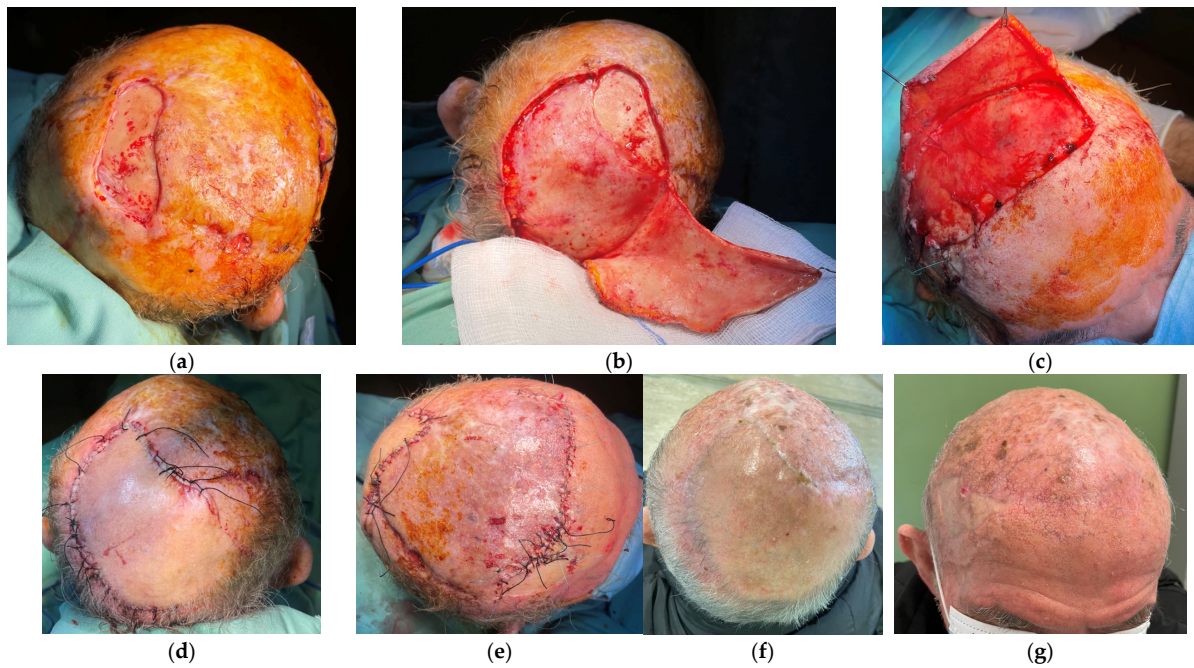


Figure 9. (a) Two scalp defects, located on the posterior vertex and the right frontotemporal area; (b) a large rotational flap, based on the parietal branch of the right superficial temporal artery, was elevated to reconstruct the posterior defect; (c) a second rotational flap, elevated along the hairline, was based on the frontal branch of the right superficial temporal artery; (d) the immediate postoperative result for the posterior defect; (e) the immediate result for the anterior defect; (f,g) the 3-month result, with complete healing and acceptable contouring of the scalp.

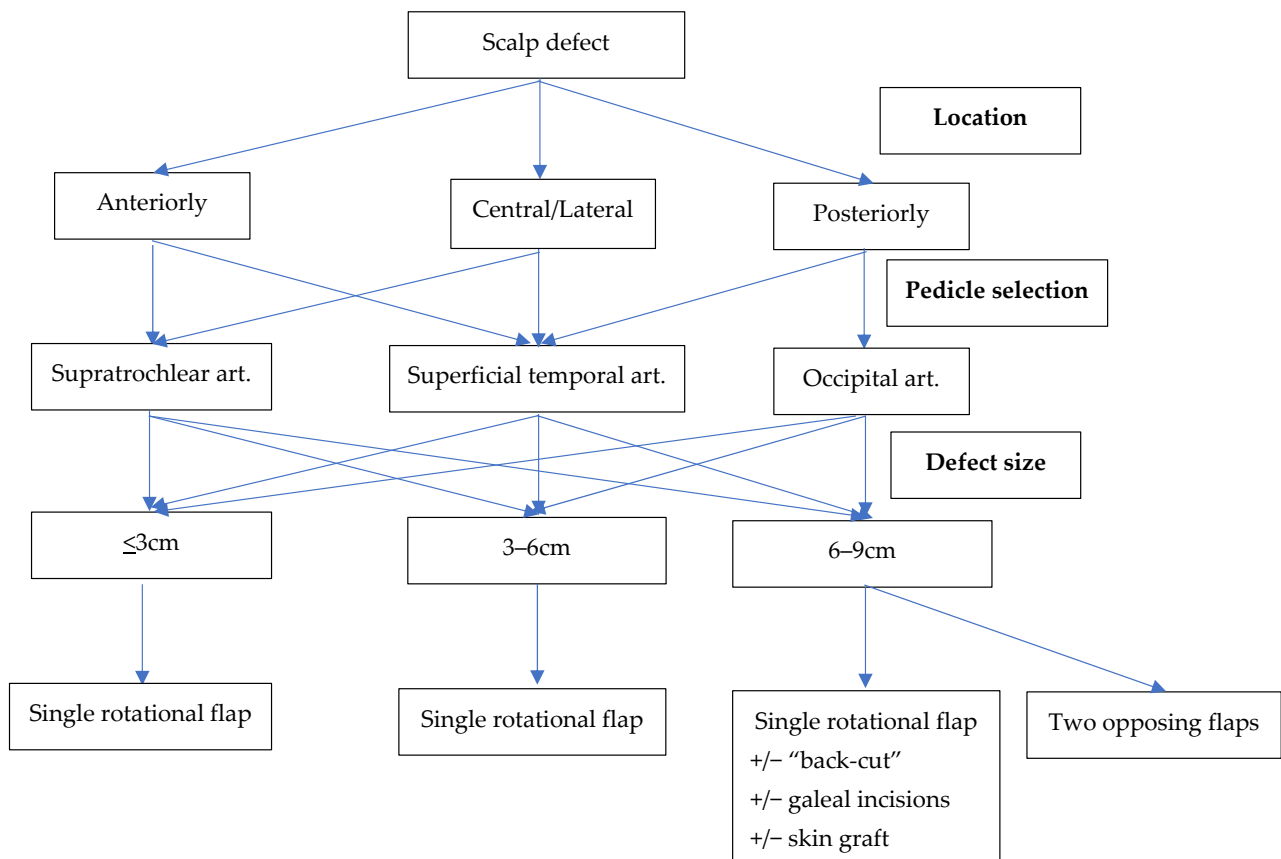


Figure 10. An algorithm for appropriate rotational flap selection, based on defect characteristics, for the reconstruction of scalp defects.

4. Discussion

Evidently, rotational flaps represent a highly versatile tool in the reconstructive surgeon's arsenal, demonstrating exceptional efficiency across a variety of defects regardless of location [9,13,14]. Unlike advancement and transpositional flaps, which are constrained by limitations in scalp reconstruction, rotational flaps are not subject to these constraints.

Updated reconstructive algorithms indicate that local flaps are ideal reconstructive options for addressing scalp defects ranging from 3 to 8 cm in diameter. For defects exceeding this size, free tissue transfer should be considered the preferred option [6]. However, studies by Newman et al. and Mehrara et al. have pushed the boundaries of rotational flaps, reporting stable closure for defects up to 150 cm², with major complication rates of less than 4% [7,15]. A commonly used technique to accomplish such a task is the elevation of double opposing rotational flaps, arranged in a yin-yang fashion, which helps distribute tension more evenly across the suture line and recruits skin from two directions. Alternatively, single large rotational flaps with a wide base can be designed, sometimes requiring an arc of incision up to six times the diameter of the defect [16]. Extensive subgaleal undermining is typically required, with additional galeal scoring performed parallel to the scalp to protect the blood vessels proving to be effective in relieving wound tension by up to 40% [17]. The single-stage closure of these massive skin defects may necessitate the use of these flaps in tandem with split-thickness skin grafts [18]. Surgeons should be cautious though when planning large flaps to ensure the inclusion of a major arterial vessel, like the occipital or superficial temporal arteries depending on the defect's location, to avoid jeopardizing perfusion. Notably, large defects mandate the creation of Burrow's triangle to facilitate rotation and prevent standing cone deformities. While dog ears can be excised, the best approach for smaller ones (≤ 8 mm) is to position them posteriorly, as they typically flatten over time, thus avoiding additional incisions which could compromise the flap's blood supply [19].

The unique trait of the rotational flap technique is that the reconstructive surgeon is only bound by their own creativity. Over the years, the application of these flaps has been marked by a growing level of experimentation, evident in the dynamic sprout of new modifications and proposed design alterations to accommodate various defects [9,10,20]. For instance, a popular variation is the "pinwheel flap", which consists of 4 L-shaped flaps designed at equal distances along the vertical and horizontal axes, making it particularly useful on the vertex area [21]. The "pinwheel" design can also be adjusted to resemble an "italic S", a modification that has been reported in the literature [22]. Both variations obviate the need for long incisions and share many similarities with the Orticochea flap, originally described for the reconstruction of large-diameter scalp defects [23]. Advances in tissue engineering have escalated the use of tissue expanders to promote skin expansion through mechanical creep, thereby increasing skin availability on the scalp and enabling reconstruction with rotational flaps at a later stage [24]. However, this method is not suitable for defects resulting from malignancies, which require direct reconstruction and potentially additional adjuvant treatments. Of interest is the fact that patients may present with multiple concurrent scalp lesions. These defects can be effectively reconstructed using a single, well-designed rotational flap or two separate flaps, depending on the defects' size [25].

The employment of rotational flaps, and local flaps in general, is linked to superior esthetic outcomes on the scalp, considering that the defects are reconstructed using "like with like" tissues. Skin grafts or free tissue transfer cannot match the color and texture as effectively as local flaps, often leaving patients dissatisfied with the results. Of paramount importance is the fact that wound closure is carried out with hair-bearing skin, greatly enhancing cosmetic outcomes. Skin incisions made parallel to the direction of hair follicle

and minimizing tension along the suture line can help prevent alopecia and ensure subtle scar concealment. Vigilance is essential though when rotating the flap to avoid distorting the existing hairline. Furthermore, local flap procedures are technically straightforward and can be completed in a single stage, administering solely tumescent anesthesia, which is a valuable perk for patients with multiple comorbidities, who cannot undergo prolonged surgery or general anesthesia [26]. These procedures require minimal postoperative wound care, and shorter hospital stays have been reported, a finding also supported by the present study [27]. Their robust blood supply also makes local flaps excellent options for challenging wound environments, such as irradiated or inflamed tissues [6,28]. Rotational flaps on the scalp also offer a reliable solution in the context of burns and electrical injuries, where tissue necrosis and the exposure of vital structures necessitate prompt and durable coverage [8,29,30]. In these cases, where excessive scar formation and contracture can severely impact both function and esthetics, rotational flaps provide stable closure with pliable, well-vascularized tissue, minimizing the risk of secondary deformities. The already mentioned geometric adaptability of these flaps allows for strategic planning that maximizes tissue recruitment while preserving local vascular integrity, an essential factor in such wounds with potentially compromised perfusion. This, in turn, promotes superior healing outcomes, even in these unstable or evolving injury patterns [29,30]. For instance, another remarkable example of the versatility of rotational flaps is the two-layered rotational flap used for the reconstruction of the inherently complex cochlear explantation wounds. This technique involves first preparing a muscle flap from the temporoparietal region to cover the wound, followed by a second layer consisting of skin with subcutaneous tissue mobilized from the occipital region to fully close the defect [31]. Another combined approach involves the reconstruction of a large external auditory canal defect using a temporalis myofascial sling, along with a typical rotational flap to address the extended skin and soft tissue defect in the postauricular area [32].

This study presented an algorithmic approach for the reliable and efficient reconstruction of scalp defects of various sizes using rotational flaps, displaying the vast armamentarium of options available to the surgeon. The proposed algorithm broadens the understanding and highlights the optimal treatment path, primarily guided by the unique characteristics of each defect. The surgical planning and approach, illustrated through numerous cases, are intended to inspire fellow surgeons to further explore the use of these flaps, ultimately leading to outstanding outcomes that benefit patients.

The potential complications of the rotational flap have been well documented in previous studies [5,7]. Proper planning, adequate surgical technique, meticulous hemostasis and blood pressure control contribute to low rates of hematoma and necrosis. Avoiding excessive tension is the most important principle in mitigating the risk of delayed wound healing and potential flap necrosis. Similarly, thoughtful planning and minimizing flap tension are crucial in preventing hairline distortion. Therefore, the presented algorithm enables reliable reconstruction, as exemplified by the low complication rates and high patient satisfaction.

Limitations of this study include the single-surgeon experience, which may introduce observer and selection biases. However, a large homogenous sample was analyzed based on data from a prospectively maintained database. The sample size was sufficient to describe the flap indications, with a focus on the technical aspects that hold clinical significance. The study outcomes corroborate the evidence from previous research and emphasize the safety, reliability, and performance of this flap.

Future advancements in early skin cancer detection, management, and monitoring hold great promise for improving patient outcomes and expanding surgical possibilities [33]. The optimization of the flap design through computational modeling and a deeper

understanding of scalp biomechanics could enhance precision and minimize tension-related complications. Integrating emerging technologies, such as 3D imaging and robotic assistance, may further refine preoperative planning and intraoperative execution. Additionally, innovative strategies to reduce complications, including the use of advanced suturing materials, and pharmacological interventions to enhance flap viability, warrant exploration. Long-term, high-quality studies assessing the durability, esthetic outcomes, and patient satisfaction of rotational flaps will provide invaluable insights into their long-term efficacy. The application of regenerative medicine, such as stem cell therapy or growth factors, may further improve vascularization and healing. Expanding the indications for rotational flaps, particularly in complex cases involving extensive defects, alongside personalized medicine approaches, offers opportunities to tailor procedures to meet individual patient needs. Finally, the development of standardized training protocols and the dissemination of educational resources could empower surgeons to adopt best practices globally. These areas of focus highlight the potential for continuous innovation, ultimately leading to better outcomes, and setting new standards in scalp reconstruction.

5. Conclusions

In conclusion, rotational flaps are an incredibly versatile option for scalp reconstruction, able to empower the surgeon's creative skill and offer innovative solutions. Our study showed successful wound closure in all treated patients, with a low rate of minor complications in line with the existing medical literature. Beyond the undebatable functional outcomes, patients enjoyed exceptional cosmetic results, with a quick recovery and a short healing phase, as reflected in the high VAS scores.

This study underscores the crucial role of meticulous surgical planning and technique in achieving optimal outcomes in scalp reconstruction. By combining principles of tissue biomechanics with the versatility of rotational flaps, surgeons can address a broad range of defects with both functional and esthetic excellence. The findings contribute to the growing body of evidence supporting rotational flaps as a reliable and adaptable option in reconstructive surgery. As surgical techniques continue to evolve, future research should focus on refining these approaches, incorporating technological advancements, and exploring patient-centered strategies to further improve outcomes. Ultimately, this work aims to inspire continued innovation in the field, advancing both clinical practice and patient care.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

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