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REVIEW

Scalp complications of craniofacial surgery: classification, prevention, and initial approach: an updated review

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Abstract

Background Scalp complications in craniofacial surgeries can increase morbidity and mortality. Given the inelastic characteristics of the scalp, these surgeries can be challenging, and multiple complications can arise. The literature on craniofacial surgery is extensive. However, few articles address scalp complications, associated factors, and prevention. This study aims to identify and classify scalp complications in craniofacial surgery and describe associated risk factors, general preventive measures, and an initial therapeutic approach.

Methods We conducted a literature search in PubMed, Scopus, Cochrane Library, and LILACS to review the scalp complications in craniofacial surgery. The studies selected included retrospective case series, narrative reviews, systematic reviews, and cadaveric anatomic studies. We completed the search with book chapters and specific topic reviews.

Results We screened a total of 124 sources and selected 35 items for inclusion in this review. Based on the updated review, we categorized scalp complications into wound defects, soft tissue contour irregularities, neurovascular defects, and infection. We discuss the main characteristics, risk factors, preventive measures, and initial management of these complications.

Conclusions For craniofacial surgery, understanding the surgical anatomy, identifying risk factors, adequate surgical planning, and interdisciplinary cooperation between neurosurgeons, plastic surgeons, and the interdisciplinary team are essential to prevent and treat scalp complications.

Level of evidence: Not ratable

Keywords Craniofacial surgery · Scalp · Complications · Risk mitigation · Dehiscence · Necrosis

Introduction

Due to the inelastic scalp characteristics, craniofacial surgeries and treatment of scalp defects are challenging to neurosurgeons and plastic surgeons [1]. Scalp complications, defined in this paper as surgical complications on the scalp after craniofacial approaches, can increase morbidity, mortality, and healthcare costs [2]. Several risk factors influence the appearance of these complications. Its prevention begins with a good review of the patient's medical history, continuing with proper surgical planning in which a complete understanding of the anatomy of the scalp, its layered structure, irrigation, and innervation is necessary.

The incidence of scalp complications varies widely depending on the type of surgery performed and the complication itself. For instance, wound defects can vary between 6–20% within the reviewed literature [1, 3–6]. Golas et al. performed a retrospective review of 64 patients who underwent craniofacial surgery, of which 16.7% required additional interventions for wound complications [3]. Additionally, Butenschoen et al. also performed a retrospective review on neurosurgical intervention and reconstructive surgery procedures in which scalp wound healing problems occurred in 12.8% [4]. On the other hand, complications like temporal hollowing (TH), specifically related to incisions

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and dissections that compromise the temporal area, for example, the pterional approach, can vary between 30 and 75% [7, 8].

The literature describing preventive measures for scalp complications in craniofacial surgery is scarce or usually not discussed in depth [4]. The published literature generally does not classify scalp complications considering particular features; moreover, authors mainly focus on small case series of specific defects or describe only one reconstructive approach to treat the scalp complication.

This updated review aims to describe the relevant anatomical aspects when surgically approaching the scalp in craniofacial surgery, identify and classify the main scalp complications of these procedures, understand how to prevent them, and describe the initial approach when they occur.

Methods

We conducted a literature search in four databases: PubMed, Scopus, Cochrane Library, and LILACS. We used the following mesh terms: "Scalp" AND "Craniofacial surgery" AND "Postoperative Complications." We included additional terms to enrich the research; "Risk Factors" OR "Surgical Wound Dehiscence" OR "Contour irregularities" OR "Neurovascular complications" OR "infection."

We screened 124 articles focused on the anatomy and structure of the scalp, craniofacial surgery principles, scalp complications, and risk mitigation. The final selection of papers was based on the researchers' discretion, yielding 35 scientific publications included in this review (Table 1 and Fig. 1).

A limitation of this study is that it is not a systematic review because of the researchers' subjective selection of the articles. Regardless, the goal is to provide an updated review of the current information available for scalp complications in craniofacial surgery and help surgeons reduce their incidence.

Table 1 Sources used for this review article

Type of source	Number
Retrospective case series	16
Book chapters	6
Narrative reviews	4
Specific topic reviews	4
Cadaveric anatomic studies	3
Systematic reviews	2
Total	**35**

Results

Surgical scalp anatomy

The scalp extends laterally from each frontal process of the zygoma and zygomatic arch and from the supraorbital margin to the superior nuchal line anteroposteriorly [9]. It is composed of five layers, easily remembered by the mnemonic: "SCALP," which represents the skin, connective tissue, aponeurotic galea, loose connective tissue (subgaleal fascia), and pericranium (Fig. 2).

The scalp is a highly vascular structure irrigated by internal and external carotid artery branches, leading to four vascular territories: anterior, lateral, posterolateral, and posterior (Fig. 3). Likewise, three divisions of the trigeminal nerve and two cervical nerves constitute the sensory innervation of the scalp (Fig. 3).

Risk factors

Knowledge of a patient's risk factors is crucial for deciding the surgical approach and preventing scalp complications. These include age, underlying diseases such as diabetes mellitus, active smoking, previous surgical interventions, and exposure to radiation [9].

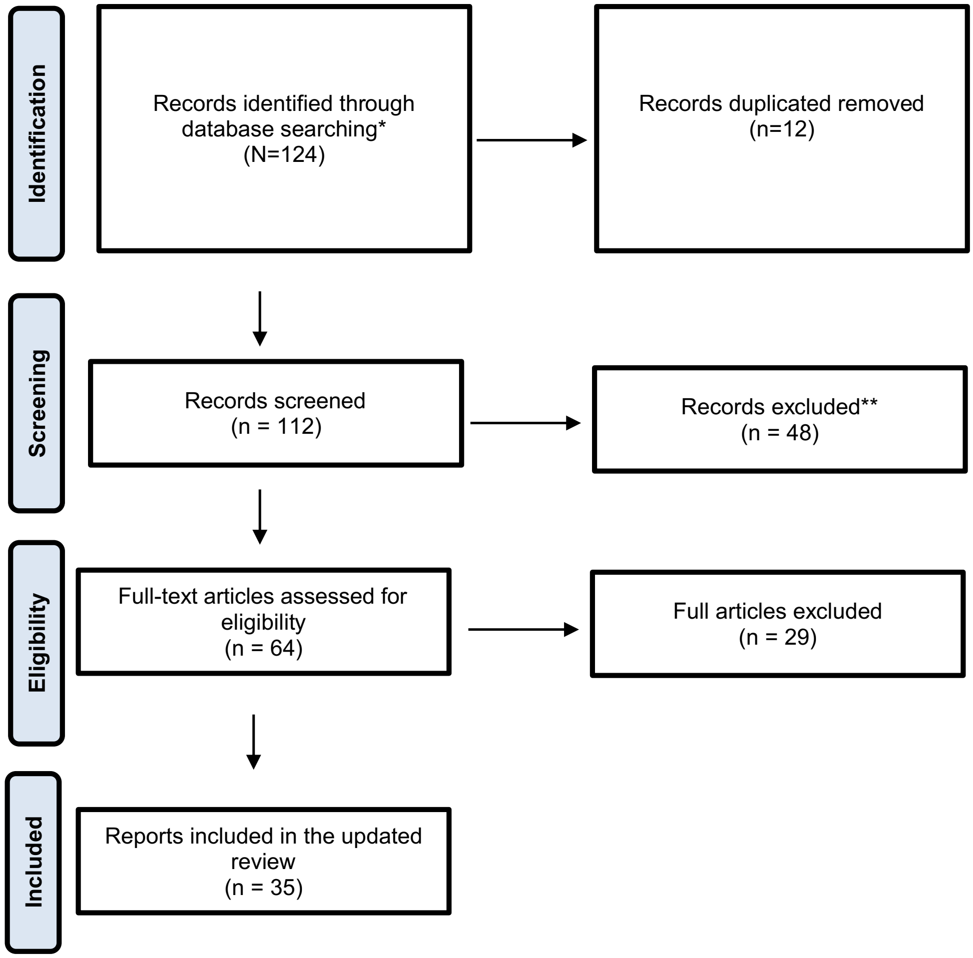
Tissues with radiation exposure are at risk of wound healing complications and infection [10]. Radiation causes DNA damage and produces free radicals that damage cell membranes and proteins [9]. In addition, it affects microcirculation and alters the repair functions of epithelial cells [11]. Therefore, it alters fibroblast proliferation and wound contraction, making wound healing more difficult and increasing the propensity for complications. Similarly, patients with altered irrigation of the scalp, such as disruption of the STA due to previous interventions, surgery, or embolization, have an increased risk for necrosis of the skin flap due to compromise of the vascular supply [9].

Reddy et al. conducted a retrospective analysis of the clinical outcomes in 180 cranioplasties between 1993 and 2010, considering all the risk factors [6]. Preoperative irradiation was the strongest predictor of any complication (odds ratio, OR: 6.21), followed by the presence of preoperative infection (OR: 2.22). Other risk factors associated with no significant increase in complications were smoking history and previous surgical interventions [6].

Planning and performing scalp incisions

It is essential to select the proper surgical incision to get the greatest exposure possible combined with the most reliable closure to prevent scalp complications, avoid

Fig. 1 Study selections



secondary interventions, and improve aesthetic results. The incisions should generally parallel the tension lines, also known as Langer lines [12]. These lines are parallel to the natural orientation of the fibers in the dermis and perpendicular to the underlying muscle fibers. They are directed anteroposteriorly in the vertex of the scalp and circumferentially in the temporal and posterior regions [9]. Incisions that follow the Langer lines facilitate healing and produce less scarring.

Other considerations are critical in the planning of the incision. The area and route of the main arteries supplying the scalp, especially the STA and occipital arteries, are essential to avoid inadequate tissue perfusion [13]. When possible, incisions in line with the main arteries' trajectories offer increased vascularization and many options for repair if a wound breakdown happens [10]. Previous neurosurgical interventions may have compromised the tissular blood supply; therefore, surgeons must evaluate any previous defects found on the scalp when planning the incision [14].

The coronal incision, which generates a bicoronal flap, is often used due to its excellent exposure and good cosmetic results. This incision exposes the superior nasal, orbital, ethmoidal region, superior-lateral-medial orbital walls, temporomandibular joint, and zygomatic arch [15]. It can be done from ear to ear in a linear or zigzag pattern; usually, the last option is better in terms of cosmetic results [9]. It can be extended preauricular, retroauricular, and inferiorly and laterally to expose the zygomatic arch and temporomandibular joints [15]. To preserve the facial nerve and avoid damage, the incision must be made through the superficial layer of the temporal fascia or dissected against the temporal fascia. In addition, it is necessary to dissect the subfascial fat plane down to the region of the zygomatic arch [9].

Although this incision requires more time to close because of its extension, it maintains all units of the forehead resulting in better aesthetic results, especially when done behind the vertex [9]. An incision must be made in the periosteum to expose the skull, although it is always ideal for preserving this layer. In the lateral region of the scalp, the temporalis muscle covers the skull. Elevating the temporalis muscle with the scalp flap can protect the facial nerve, preventing inferior retraction and nerve damage [9].

Suboccipital incisions grant appropriate access to the posterior fossa. It can be made along the midline, preserving

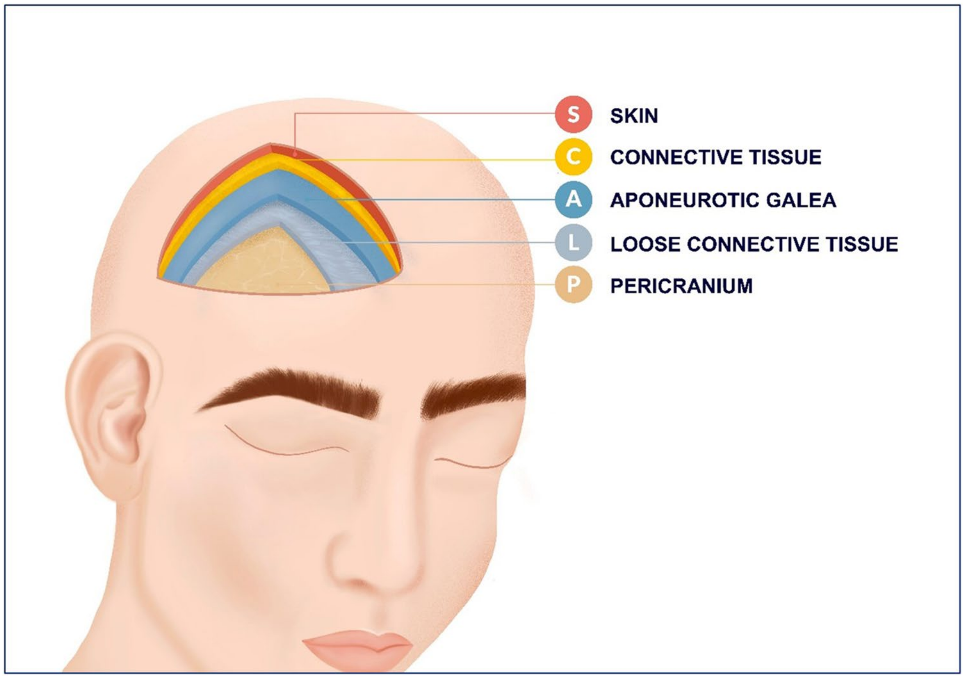


Fig. 2 Layers of the scalp. Source: author's work using Adobe Illustrator™, based on the literature review

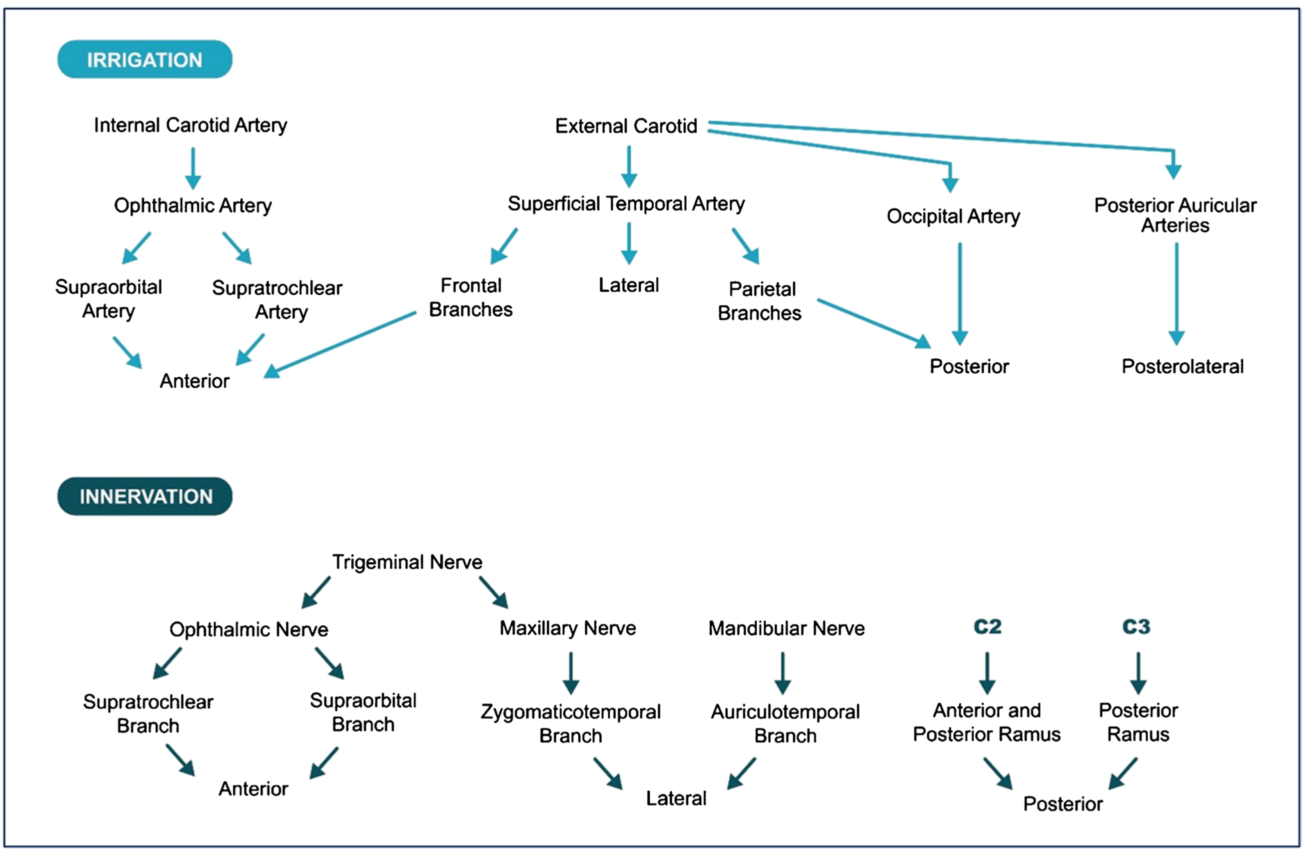


Fig. 3 Irrigation and innervation of the scalp. Source: author's work using Adobe Illustrator™, based on the literature review

the occipital arteries. In addition, this approach offers better wound closure and healing since the raphe between the bellies of the occipital muscle is avascular [9].

The subtemporal approach utilizes a C-shaped incision or horseshoe shape, usually above the zygomatic arch, 1 cm anterior to the tragus, extended posteriorly around the ear up to the superior temporal line, which then follows the horseshoe anteriorly to the hairline [16]. The resultant flap's irrigation is based on the STA and the posterior auricular artery to a lesser extent. Preserving these arteries is vital when making the incision to secure a rich vascular supply to the flap [9].

Surgical closure

Ineffective suturing can lead to galeal dehiscence, eventually causing wound infection and dehiscence [13]. One of the most fundamental factors is to achieve a tension-free closure and, at the same time, adequate coverage of the soft tissue. Helpful techniques include simple layered closure, tissue expansion with flap closure, skin grafts, local flaps, and free tissue transfer [3].

Interdisciplinary dialogue and planning of the closure between neurosurgeons and plastic surgeons can reduce the incidence of scalp complications. Anticipation and coordination are critical for the primary closure to prevent future injuries or complications of the scalp and even more for second or repeated surgeries [3].

In a retrospective study, Golas et al. included 64 patients who underwent 84 procedures (craniotomy, craniectomy, or other neurosurgical scalp incision closure) in a single institution between 2006 and 2013. Among them, 16.7% required other plastic surgery interventions for wound complications. When plastic surgery closures were done with no previous complications, the rate fell to 11.8% [3].

Classification and initial approach to scalp complications

Despite preventive efforts, various scalp complications can arise. We summarize the most important findings during the literature review in Table 2 regarding the different types of scalp complications and their risk factors. Note that there are limited studies of craniofacial surgeries regarding scalp complications. Since complications vary significantly depending on the surgery performed, comparing studies is difficult. Additionally, the table did not include studies that did not contribute to the scalp complication incidence, categorization, or risk factors.

Based on the review of the scientific literature, we classified the scalp complications in craniofacial surgery into four categories, shown in Table 3: intrinsic wound defects, soft tissue contour irregularities (STCI), neurovascular defects, and infection. Below, we discuss the clinical presentation, relevant risk factors, and general preventive measures for the main complication in each category.

Wound defects

Wound dehiscence is the most studied complication in this category. Other complications classified as wound defects (Table 3) are reported in some studies without describing their incidence or relevant risk factors. The incidence of dehiscence can vary between 1 and 10% after primary closure [1, 6, 11, 17, 19, 24]. In addition, this number can increase to 30% in secondary surgeries and revisions after the first intervention, highlighting the importance of adequate closure in primary surgery to avoid future interventions [17].

Wound dehiscence is more common in thinner parts of the scalp than in thicker areas [1, 5]. Multiple conditions favor a thinning of the layers of the scalp, such as older age, female sex, nutrition, endocrine disorders, previous interventions, infections, and chronic wounds [1, 9]. Janus et al. studied 139 scalp reconstructions which highlighted that immunosuppressed patients, preoperative radiation, and poorly controlled diabetes mellitus (HbA1c > 8%) were risk factors for wound complications [19]. Accordingly, Bahrami et al. showed that patients with cachexia and poor nutrition had more wound rate complications.

Radiation is a significant risk factor since it affects the normal healing wound mechanisms [6, 19]. When designing a flap on irradiated tissue or older adults, using a conservative flap length and not passing the midline with the extension of the flap is recommended [9]. When possible, using pericranium flaps helps preserve the deeper tissue's integrity, giving more consistent results of fine line scars and fewer wound complications (Fig. 4) [25].

The appropriate flap and the suture technique used for closure are also crucial. Hyeon Jang et al. performed a retrospective review of 94 patients who underwent scalp reconstructive surgery in which local flaps had less risk of complications [1]. Knowing that tension must be avoided for scalp closure, rotational flaps are often the best alternative due to their great adaptation to skin expansion and remobilization [26]. In addition, they can easily adapt to the shape of the head, even more so if performed with a large rotation arc and with galeotomies to increase the perimeter of coverage. Sutures must have a minimum separation of 1 cm and be perpendicular to the axis of traction of the flap [26].

To prevent wound defects, "T-incisions" should be avoided because flap tissues are more vulnerable when located next to the intersection point [3]. In addition, since the scalp contains hair, it is recommended to make a slightly angled incision parallel to the hair angulation. This technique will protect the hair follicles and avoid cicatricial

Table 2 Types of scalp complications, risk factors, and other significant findings within the reviewed literature

Author	Study scope	Complication	Comment/risk factors
Hyeon Uk Jang, Young Woong Choi (2020) [1]	RS of 94 patients who underwent scalp reconstructive surgery	Hematoma: 15.9% Skin necrosis: 9.6% Flap necrosis: 3.1% Skin necrosis 2.1% Dehiscence: 2.1% Infection: 2.1% Flap congestion: 1%	RF: thinner scalp Local flaps had less risk of complications
Kitiporn s, NasaengAkharatham-machote (2021) [7]	RS of 72 patients who underwent pterional craniotomy	**Suprafascial dissection** -FP*: 20.5% -TH: 36% **Interfascial dissection** -FP*: 5.6% -TH 72%%	Interfascial dissection and retaining the muscle cuff are risk factors for temporal hollowing
Tamir Shay, Micah Belzberg (2020) [17]	RS of 506 cranioplasties	Dehiscence Infection Hematoma CFL	Primary surgery complications 9% Secondary surgery complications 32%
Andrea Moreira-Gonzalez Ian T. Jackson (2003) [18]	A RS of 312 cranioplasties	Complication rate: 23.6% Infection 7.3% Exposure of material: 4% Hematoma 4%	RF-post tumor: 31.3% RF: temporal site: 32.4% Primary surgery complications: 8.7% Secondary surgery complications (revision): 14.7%
Sashank Reddy, SaamiKhalifian, (2014) [6]	RS of 195 cranioplasties	Infection: 15.9% Material exposure: 11.2% Dehiscence 4.6% Flap necrosis 5.54% CFS leak 3.58%	RF: Preoperative radiation (OR 6.21) RF: Preoperative infection OR (2.22)
Jeffrey R. Janus, Brandon W. Peck (2014) [19]	RS of 139 scalp reconstruction after oncologic resection	Complication rate 10.8% Delayed healing: 5% Dehiscence: 1.4% Flap necrosis 0.7% Hematoma 0.7% Surgical site infection 0.7%	RF: defect diameter, immunosuppressed patients, preoperative radiotherapy, and poorly controlled diabetes mellitus (HbA1c > 8%)
Ellie Broughton, Louis Pobereskin (2012) [20]	RS of 87 cranioplasties	Complication rate 30% Infections: 10.3% Extradural hemorrhages: 5.7%	No risk factors motioned
Mario Zanaty Nohra Chalouhi (2012) [21]	RS of 348 cranioplasty	Rate of complication 31.3% Infection 26.4%	RF for infection: Bilateral convexity cranioplasty
Victor Chang Paul Hartzfeld (2009) [22]	RS of 212 cranial repairs	Complication rate: 34% Infection 7%	RF: more than 40 years
Kaveh Barami Rui Fernandes (2010) [11]	RS of 64 craniotomies for tumor resection	Wound dehiscence 7.8%	RF: radiation injury RF: cachexia, and poor nutrition
Jeffrey A. Fialkov, Chantal Holy (2001) [23]	RS of 349 craniofacial reconstructive procedures	8.2% infection	No risk factors mentioned
Jaewoo Chung Seungjoo Lee (2020) [5]	RS of 427 cerebral revascularizations	Wound complications 6.6% Infection: 1.1%	RF: diabetes mellitus RF: thin scalp
Damir B. Matic Sharon Kim (2008) [8]	PRC of 27 patients (54 sides) requiring coronal flap elevation	**TH:** suprafascial 54%, subfascial 76%, deep dissection 71%	Less TH in suprafascial dissection RF: postoperative weight loss

RS, retrospective study; *RF*, risk factor; *PRC*, prospective randomized control trial; *FP**, frontalis paralysis; *paralysis was transient. No permanent paralysis was found. *TH*, temporal hollowing; *OR*, odds ratio; *CFL*, cerebrospinal fluid leak.

Table 3 Classification of scalp complications of craniofacial surgery. Source: own work, based on literature review

Wound defects	Soft tissue contour irregularities (STCI)	Neurovascular complications	Infections
Dehiscence	Soft tissue temporal hollowing	Flap necrosis	Hardware exposure
Ulcer	Soft tissue hollowing in other areas	Free flap failure	Flap infection
Scar abnormalities	Scalp thinning or atrophy	Sensory defects	Flap osteomyelitis
Delayed wound healing		Facial nerve weakness	Wound infections due to dead space
Cerebrospinal fluid leak		Intraoperative bleeding	
Residual alopecia		Postoperative bleeding	
		Hematoma	

Fig. 4 Case of a patient with a history of radiotherapy who had wound dehiscence in scalp closure (**1**). A scalp flap was designed in a secondary intervention (**2**), but it reappeared due to peripheral vasculature damage (**4**). Another scalp flap was made in a third intervention, adding a pericranium flap, highlighting the importance of preserving the pericranium (**5**)

alopecia. Toothed forceps are ideal for reducing crushed skin injuries [9].

Soft tissue contour irregularities (STCI)

Multiple STCI can arise after craniofacial surgeries. Contour irregularities usually originate in bony defects after the removal of a bone flap in primary surgery or as a complication [26]. However, this article highlights soft tissue defects, specifically temporal hollowing (TH) [27]. Similar defects can occur, including soft tissue hollowing in other areas and scalp thinning or atrophy, especially overlying a cranioplasty [28]. STCI arises from factors that alter the integrity of the structure of the scalp layers. These factors include ischemia, denervation, muscle atrophy or injury, and inadequate repositioning or resuspension of a muscle [27].

One of the most relevant and prevalent complications in craniofacial procedures involving the pterional region is TH, which can reach an incidence between 30 and 75%, depending on the series [29]. These deformities are diagnosed on physical examination after surgery by identifying a concave contour defect in the lateral facial area and the temporal fossa [29]. The etiology of the TH is generally associated with ischemia-induced tissue atrophy of the temporal muscle or denervation. However, a defect of one of the components of the adjacent structures, like the fat pad, subcutaneous tissue, or temporal bone, can contribute to the deformity [27].

An adequate presurgical state of the patient is necessary to reduce all the scalp complications, but specifically for the TH. A timely nutritional state is of utmost importance [8]. Weight loss favors a decrease in the superficial temporal fat pad, thus increasing the incidence of this contour complication [8]. Matic et al. performed a prospective study on patients requiring coronal flap elevation, highlighting operative weight loss as a risk factor for TH.

Planning of the incision and surgical technique is also crucial. The suprafascial dissection reduces the possibility of TH [8]. This technique also ensures adequate protection of TBFN and causes minimal damage to the superficial temporal fat pad [8]. Therefore, this technique prevents the risk of nerve damage and provides a safer surgical technique to protect the adjoining structures. Sriamornrattanakul performed a retrospective study of 72 pterional craniotomies in which he used two approaches: the suprafascial dissection with a TH rate of 36% and the interfascial dissection with a TH of 72%.

In some craniofacial surgeries, the temporal muscle is completely separated from the temporal crest. If the resuspension of this muscle is not adequate, it will posteriorly descend together with the adjoining fat pad, generating contour irregularities [29]. In addition, the detachment of the temporal muscle of the superior temporal line without cutting the fascia and its reinsertion to the bone favors the protection of the structures, reducing the possibility of contour defects [27].

Initiating the dissection of the temporal muscle 2 cm below the temporal crest is ideal for preserving the insertion point [23]. Also, when there is not enough tissue for muscle reinsertion (not enough temporalis fascia or muscle cuff), securing an edge of the muscle flap to the calvarium using titanium mesh and screws is recommended. These will favor the adequate repositioning of the muscle and adjacent structures, avoiding STCI [29].

Neurovascular complications

In craniofacial surgery, neurovascular complications are uncommon, but their effect can lead to permanent damage or the need for re-interventions. Appropriate incision selection, adequate closure, and suturing techniques can prevent bleeding problems.

Flap necrosis incidence varies between 0.7 and 5.5% within the reviewed literature. Vascular suffering leads to flap necrosis, either venous or arterial, being the former the most common [26]. Since the scalp veins are not always adjacent to the arteries, inadequate flap designs, including an insufficient skin pedicle, can evolve into distal necrosis, especially in the temporal region. It is crucial to ensure adequate venous drainage by the dermal and subdermal plexuses [26].

A flap kept under traction for a long time or prolongedly folded to expose the surgical field poses a particular risk for neurovascular compromise. Periodic unfolding and traction release during lengthy procedures can help mitigate this risk. Excessive tension generally causes altered arterial supply, leading to flap necrosis in scalp closure [26]. Galeotomies, skin grafts, and back cuts help mitigate the scalp's immobility. Distal necrosis can occur even with little stress at the scalp closure, so a suture under tension is not acceptable [26].

Before using a flap in the temporal and frontal region of the scalp, it is vital to check the temporal pulse. Its absence is a contraindication for flap extension in this region [30]. Increasing the width of the pedicle can also be a good technique since it increases both collateral circulation and venous drainage. The recommended scalp flap length/width ratio is 3:1 [30]. Remobilization of affected flaps can cause extended necrosis, especially in flaps that do not have flexibility or are previously affected by radiation, vascular alterations, or previous interventions. In these cases, a safe solution is to use a skin graft applied after multiple calvarium perforations or after removing the external table [26].

When a free flap is necessary for large, subtotal, or total scalp defects, vascular complications can be more challenging to address. In this case, bleeding and other vessel abnormalities can lead to thrombosis events resulting in flap failure. In the anastomosis of free flaps, bleeding can occur in any region with decreased vessel apposition [31].

The leading causes of thrombosis in free flaps are extrinsic vessel compression and bleeding. In the anastomosis regions where bleeding is likely, platelet aggregation in the defect to stop the bleeding can lead to a thrombotic event [31]. On the other hand, bleeding in small artery branches can result in the formation of a hematoma which, if it accumulates adjacent to a pedicle, generates an environment that favors vasospasm [31]. Compression of vessels and pedicles can also be caused by close contact with adjoining structures such as the skull. Therefore, a softer contact between structures is desirable to avoid this compression. A recommended technique is padding these areas with soft tissue placement [31].

Preserving the galeal flap is also recommended, especially between the parietal and frontal branches of the STA, since it functions as a revascularization bed for the scalp and helps minimize dead space under the scalp flap [5].

Nervous complications in craniofacial surgery are caused by direct damage to the nerve. Therefore, the prevention of these complications lies in the proper planning of the incision and the surgical technique for adequate protection of the nerves, especially and, more importantly, the motor nerves. For instance, in temporoparietal approaches, the suprafascial dissection lateral to the temporal line protects the TBFN [8].

Although suprafascial dissection is safe, it limits the exposure of the pterional region, and surgical approaches to increase exposure in the frontotemporal area can lead to damage in TBFN, causing paralysis of the orbicularis, frontalis, and corrugator supercilli muscles [32].

Two techniques allow better exposure and nerve protection: subpericraneal dissection and interfascial or subfascial dissection [7]. The scalp is divided along the temporal lines into medial and lateral regions in these techniques. The facial nerve runs in the medial region's loose areolar layer, so a subpericraneal dissection is recommended [32]. Likewise, in the lateral region (associated with the temporal muscle), the facial nerve lies in the loose areolar layer between the temporal fascia and the galea. In this sense, an interfacial or subfascial dissection help to protect against nerve damage while generating adequate exposure [7, 32].

The suprafascial dissection is better in preventing TH but increases the risk for nerve damage than the intrafascial or subfascial dissection because the plane is closer to the TBFN [7]. The main goal of the surgery needs to be established, and different techniques need to be studied for the necessary exposure to prevent neurovascular complications and reduce the incidence of secondary reconstruction, which can lead to more complications, often worse than the previous defects [17].

Infections

Surgical site infections risk factors can be divided into factors intrinsically related to the type of surgery performed and those related to the patient. The first category includes surgical time, the extension of the tissue exposure, the use of foreign material, and the type of surgery. On the other hand, the patient's risk factors include comorbidities like diabetes mellitus, age, previous surgeries, radiotherapy, previous infections, and functional status [33, 34].

The incidence of infection is highly variable and depends strongly on the type of surgery performed. For instance, in non-traumatic scalp reconstructive surgeries, cranioplasties, and craniotomies ranged between 0.7 and 10% [1, 5, 18–20, 22, 23]. However, this number reaches a value between 15–26% in craniofacial surgeries performed by a traumatic cause [6, 21]. Additionally, infections increase morbidity [3]. Fialkov et al. conducted a retrospective review of 349 craniofacial skeletal procedures performed from 1996 to 1999, in which 38% of patients who had postoperative infections required a secondary procedure [23]. Infections eventually lead to increased health care costs and the risk of other defects, usually of greater complexity.

Preventive measures to reduce the onset of the infection begin long before the day of surgery. The necessary steps must be ensured for adequate control of comorbidities and modifiable risk factors, ultimately generating the best health status for the patient [33]. Preoperative measures are also crucial, including proper handwashing, chlorhexidine, or other alcohol-based solutions for skin preparation, draping the scalp, using sterile gloves, changing them every 2 h, and before contact with any implantable material [33]. Regarding showering with antiseptic solutions and shaving the scalp before surgery, the evidence on infection prevention is inconclusive. Several studies describe a possible increase in infections when shaving due to epidermal injury [33].

The use of prophylactic antibiotics is one of the most important measures. A single dose of 2 g of intravenous cefazolin is recommended 60 min before the first incision [24]. If the surgery compromises the paranasal sinuses, amoxicillin/clavulanate is recommended. In patients allergic to penicillin, a single dose of vancomycin of 1 g should be applied [24].

Finally, proper care of the scalp wounds with wound dressings is necessary to prevent postoperative infection. Continuing with prophylactic antibiotics for more than 24 h is discouraged, although some studies suggested the effectiveness of this measure, especially for clean-contaminated or contaminated wounds [33]. Preventing other scalp complications like wound dehiscence indirectly prevents future infection. Indeed, the most important measure to prevent infections and re-interventions is carefully planning and conducting primary surgery [17].

Conclusions

This updated research led to a comprehensive review of scalp complications in craniofacial surgery, including a summary of important literature and a novel objective classification of the main complications. Thorough knowledge of the scalp anatomy, identifying patients' risk factors and controlling their modifiable variables, adequate surgical planning, and neat surgical techniques are crucial in primary prevention.

The best opportunity for surgeons to reduce the appearance of scalp complications is a successful primary surgery since it prevents future interventions, which dramatically increase the risk of complications. Secondary procedures can lead to more complex defects than the initial ones, generating increased health costs, hospital stays, and patient morbidity and mortality.

Finally, the appearance of one complication may be closely related to additional ones. For instance, wound defects such as dehiscence favor the appearance of infection. Likewise, neurovascular alterations can generate the appearance of necrosis or even STCI, such as TH. In other words, the more complications we can avoid, the less the risk that additional defects will appear.

Integral evaluation of individual cases by the interdisciplinary team is vital in preventing, diagnosing, and approaching scalp complications for patients who undergo craniofacial surgery.

Abbreviations *OR*: Odds ratio; *SCALP*: Five layers of the scalp: skin, connective tissue, aponeurotic galea, loose connective tissue, and pericranium; *SMAS*: Superficial musculoaponeurotic system; *STA*: Superficial temporal artery; *STCI*: Soft tissue contour irregularity; *STF*: Superficial temporal fascia; *TBFN*: Temporal branch of the facial nerve; *TH*: Temporal hollowing

Author contribution SPG participated in the study design, investigation procedures, figure conceptualization, formal analysis, writing the

original draft, review, and editing. VGO and ZTS participated in the results' formal analysis and the manuscript's review and editing. KAG participated in study design, supervised the investigation, methodology, formal analysis, and validation procedures, wrote the original draft, and led the manuscript's review and editing.

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Declarations

Ethics approval Not applicable.

Consent to participate Patients and caregivers signed a consent form authorizing the publication of unidentified clinical pictures. This format is available at the Editor's request.

Competing interests Santiago Pedroza Gómez, Viviana Gómez Ortega, Zulma Tovar-Spinoza, and Kemel A. Ghotme declare no competing interests.

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