



Fundamentals of Eyebrow Colorimetry: Color Theory, Practical Application, and Typical Errors with Atypical Consequences

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Abstract

The present methodology constitutes a systematized inquiry for scientifically substantiating and formalizing professional practices in eyebrow colorimetry. The work aims to close up the divide between the empirical techniques and foundational knowledge. This knowledge comes from the fields of colorimetry, trichology, and dermatology. For effectively managing non-standard cases like gray hair (canities), albinism, and residual permanent makeup, the primary objective is to present an algorithm throughout that minimizes the risks of undesirable chemical reactions and improves the accuracy and predictability of coloring outcomes. The methodology integrates classical color theory, adapts it to the specificity of oxidative dyes, along with analyses of the physiological characteristics of eyebrow hair and the peri-orbital skin. Large focus is given to fixing colorimetric errors plus their detection, while investigating results that go past mere visual issues, involving matters about dermatologic health. The practical value of this work lies in offering specialists a reproducible, scientifically grounded system that facilitates the standardization of service quality and enhances procedural safety. The methodology will be beneficial to practicing brow colorists and educators in eyebrow colorimetry, as well as to cosmetologists and trichologists, and to educational programs and dye manufacturers, for whom reproducibility, result predictability, and dermatologic safety are paramount.

Keywords: Eyebrow Colorimetry, Color Theory, CIE Lab, Shade Neutralization, Dermatologic Safety, Gray Hair (Canities), Permanent Makeup Correction.

INTRODUCTION

Eyebrow colorimetry, traditionally regarded as a branch of aesthetic cosmetology, has in recent years asserted itself as an autonomous discipline at the intersection of applied chemistry, dermatology, and trichology. The growing demand for eyebrow services and the emergence of new coloring technologies require specialists not only an artistic vision but also a deep understanding of the biochemical processes unfolding as dye interacts with hair and skin. The extant information base is often limited to superficial manufacturer instructions and basic coloristic rules borrowed from hairdressing, which fail to account for the unique features of this anatomical zone.

The central thesis of the present methodology is that achieving stable, predictable, and—most crucially—safe outcomes in eyebrow colorimetry is impossible without a multidisciplinary approach. The mere mixing of pigments without regard for hair structure, skin condition, dye chemical composition, and the dynamics of the oxidative

process inevitably leads to an increase in coloristic errors and, in some cases, to serious dermatologic sequelae.

Despite their apparent similarity, eyebrow coloring differs fundamentally from scalp hair coloring across a range of trichologic, dermatologic, and chemical parameters. Neglecting these differences is the root cause of many professional errors.

Eyebrow hair has a unique life cycle and structure. A key distinction lies in the duration of growth phases. Hair follicles of the eyebrows exhibit a markedly shorter anagen (growth) phase than scalp follicles, resulting in shorter hair length and more frequent replacement (Nguyen, 2014). This directly affects color fastness and the frequency of required procedures. Although the basic shaft architecture (cuticle, cortex, medulla) is common across hair types, eyebrows may demonstrate differences in diameter and porosity, which influence the rate and depth of pigment penetration (Pogrebnaya, 2024).

The peri-orbital skin is significantly thinner and more

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sensitive and possesses different pH and lipid-barrier characteristics compared with the scalp. In eyebrow coloring, the objective often includes tinting not only hair but also skin to create an impression of density. This necessitates understanding how dye interacts with the epidermis, the state of its lipid mantle, and pH level to ensure even staining and minimize irritation. Proximity to the ocular mucosa imposes stringent requirements on formulation safety and application technique, a factor less critical in scalp work (Teixeira et al., 2006).

While most permanent dyes for hair and eyebrows share

an oxidative mechanism, eyebrow formulations must be adapted. They are designed for shorter processing times, a gentler impact on delicate skin, and a minimized risk of allergies. Key components such as p-phenylenediamine (PPD) are potent allergens; their concentration and use in eyebrow products are strictly regulated (Brondeel et al., 2022). Noncompliance with protocols and the use of dyes not intended for eyebrows can lead to serious consequences, including chemical burns and severe contact dermatitis. Table 1 provides a comparative analysis of key differences between scalp hair coloring and eyebrow colorimetry.

Table 1. Comparative analysis of hair coloring characteristics on the head and eyebrows

Parameter	Scalp hair coloring	Eyebrow coloring
Procedure	Coloring of the hair on the head	Brow color/eyebrow colorist work
Trichology	Long anagen phase (years) — allows greater hair length	Short anagen phase (a few months) — limited hair length
Hair condition	Variable porosity; often damaged by styling	Generally, a less damaged structure, but may be coarse
Dermatology	Dense, relatively thick scalp skin	Thin, sensitive peri-orbital skin
Skin staining	Skin staining undesirable	Light skin staining is often part of the desired effect
Proximity to mucous membranes	Distant from mucous membranes	Immediately close to the eyes — higher safety requirements
Chemistry	Higher levels of alkaline agents, longer processing time	Balanced formulas with reduced alkalinity, shorter processing time
Dye range	Wide range of dyes, including high-ammonia products	Specialized dyes that have undergone ophthalmological safety assessment
Safety	Risk of contact dermatitis on the scalp and neck	High risk of dermatitis, chemical burns, and allergic blepharoconjunctivitis

The primary objective of this work is to present a systematic, scientifically grounded methodology that enables eyebrow colorists to transition from intuitive color selection to a controlled and predictable process. This methodology aims to reduce subjectivity and enhance safety standards across the industry.

To achieve this aim, the following objectives were defined:

1. To formalize the author’s shade-selection algorithm based on a comprehensive analysis of individual client features (skin, hair, eyes) and to justify each stage in terms of colorimetry and physiology.
2. To develop and describe scientifically substantiated protocols for non-standard and complex cases, including the coloring of gray and depigmented hair, as well as permanent makeup correction.
3. To create a clear diagnostic and remediation system for colorimetric errors based on color laws and to analyze potential adverse consequences, including delayed dermatologic reactions.

AUTHOR’S SHADE-SELECTION ALGORITHM BASED ON A SYSTEMS ANALYSIS OF COLOR TYPE

Success in eyebrow colorimetry depends less on the manual dexterity of color mixing than on the practitioner’s capacity

to perform rigorous diagnostics and to predict the trajectory of chemical interactions on an individual biological substrate. This paradigm foregrounds algorithmic methods that render unarticulated intuition into choices that are formally structured and amenable to analytical evaluation. To truly grasp hair as well as skin, professionals have to diagnose beyond simply superficial hue. Properties like hair porosity and strand thickness also must be measured because each property affects oxidizer penetration and pigment displacement in chromatic interactions. By codifying these variables, the proposed system recommends concrete, parameterized options (selecting bases, adding corrective pigments, concentrating oxidizers, exposing materials, along with pretreating and post-treating adjuncts) through suggesting heuristics, thereby reducing undesirable tones plus damaging substrates.

The algorithm operates as a stepwise workflow, beginning with systematic data collection — standardized photography, client history documentation, and tactile/visual quality assessment — followed by objective scoring of parameters. Next, profiles are classified by risk and desired outcomes are specified, constrained by client preferences and safety considerations. The appropriate formula is then selected and chromatic shifts are simulated, with expected values and uncertainty ranges clearly shown and informed consent

documented. Finally, the procedure is executed with staged monitoring and in-process adjustments, followed by neutralization and provision of post-procedure aftercare. Crucially, the protocol incorporates standardized patch testing with visual reference libraries and rule-based corrective heuristics. Violet toners, for example, work to counteract a pronounced yellow bias. They also reduce exposure time if delicate cuticles and high oxidizer concentrations indicate the risk of over-processing. Rules that are predictive and based on usage get refined as feedback formalized captures deviations.

Adoption of this methodology improves reproducibility and reduces adverse outcomes by easing training for novices, thereby promoting transparent client communication. Framing eyebrow colorimetry as a diagnostic-predictive discipline aligns practice with contemporary expectations for evidence-based, risk-aware aesthetic interventions and creates a scalable foundation for continual improvement through documented outcomes and iterative model refinement.

Foundational Principles of Color Theory in Cosmetic Science

Professional discourse on color must transcend colloquial descriptors (warm, cool) and adopt a standardized descriptive system. Color perception is a complex process comprising three elements: the light source, the object with which light interacts, and the observer (human eye or instrument) (Dobos, n.d.). In scientific and industrial colorimetry, the CIE $L^*a^*b^*$ three-dimensional color space, developed by the International Commission on Illumination (CIE), is employed for objective color measurement, as shown in Figure 1. This system describes any color via three numeric coordinates, thereby eliminating perceptual subjectivity.

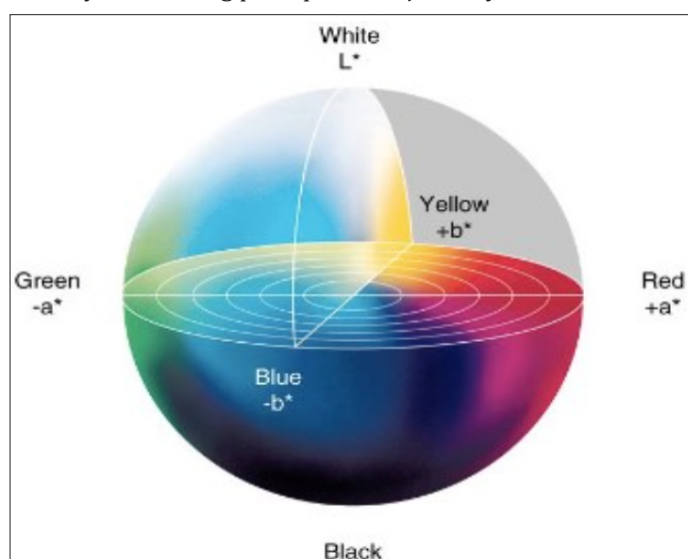


Fig. 1. Representation of the three axes of the CIE Lab* color space (Dobos, n.d.)

The CIE $L^*a^*b^*$ system is a mathematical model encompassing all colors visible to humans. It has three axes:

- L^* (Lightness): Represents color lightness, ranging from 0 (absolute black) to 100 (absolute white). In eyebrow colorimetry, this axis corresponds to depth or level.
- a^* (Red–Green Axis): Positions color from green (negative values) to red (positive values). This axis correlates directly with warmth or coolness. Reddish, coppery shades exhibit high positive a^* , whereas ashy, olive tones show negative a^* .
- b^* (Yellow–Blue Axis): Positions color from blue (negative values) to yellow (positive values). This axis helps determine dye undertone (e.g., golden or ashy).

This system enables the objective quantification of any color and is a standard in cosmetic science for the quality control of pigments and finished products.

Using this system foregrounds three fundamental color attributes:

1. Hue: The primary quality enabling us to distinguish red, yellow, green, blue, etc.
2. Value (Lightness/Depth): How light or dark a color is; corresponds to L^* .
3. Chroma (Saturation/Intensity): The purity or vividness of a color; highly saturated colors are bright and pure, whereas low-saturation colors are muted and grayish.

Mastery of these attributes allows the specialist to analyze both the client's baseline parameters and dye characteristics—and, crucially, the coloring outcome.

Deconstruction of the Author's Four-Stage Algorithm

The proposed algorithm consists of a sequence of analytical steps, each scientifically justified and designed to gather data for an informed coloristic decision, as illustrated in Figure 2.

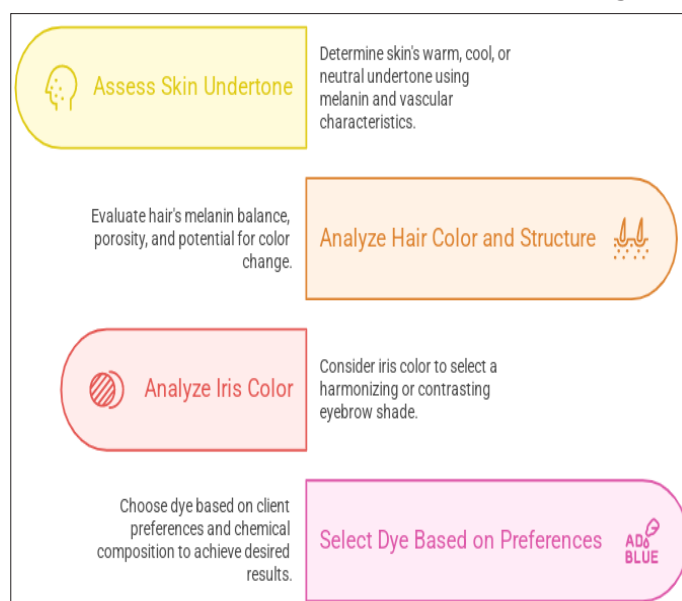


Fig. 2. The proposed algorithm for eyebrow color selection process

Stage 1: Assessing Skin Undertone (warm, cool, neutral)

This stage is pivotal for predicting the final result, as the eyebrow color is perceived inseparably from skin color. The predominant melanin type and vascular characteristics determine skin undertone. Scientifically, this is not merely an aesthetic appraisal. Dye applied to skin (as often occurs in eyebrow tinting) mixes with intrinsic pigment, creating a new composite color. For instance, a cool ashy dye on skin with a warm, yellowish undertone (high b* axis value) may ultimately yield an undesirable greenish cast. To standardize assessment, one can employ the Fitzpatrick phototype scale, which, though designed to classify UV response, often correlates with general color type. Moreover, skin condition, its pH, and the integrity of the lipid barrier affect pigment adhesion to the epidermis and staining uniformity.

Stage 2: Analyzing Natural Hair Color and Structure

This stage involves assessing the balance of two melanin types within the hair shaft: eumelanin (responsible for black–brown shades) and pheomelanin (responsible for red–yellow shades) (Cosmetic Science, 2024). Tone level (lightness) is determined by overall melanin concentration, while hue reflects the eumelanin–pheomelanin ratio. Even in the darkest hair, pheomelanin is present and, upon lightening or during oxidative dye processing, may surface as an undesirable warm background. A critical parameter is hair porosity—the capacity to absorb and retain moisture and, by extension, dye. High-porosity hair absorbs pigment rapidly and may over-darken; low-porosity glassy hair (often gray) requires more intensive chemical action to open the cuticle (Pogrebnaya, 2024).

Stage 3: Analyzing Iris Color

This step introduces an element of aesthetic harmonization grounded in classical color theory. The goal is to select an eyebrow shade that either harmonizes with the eye color or creates a complementary contrast to accentuate it. For blue eyes (cool spectrum), soft browns with neutral or cool undertones often avoid dissonance; for brown eyes with golden flecks (warm spectrum), brows with a subtle caramel or nut nuance are congenial.

Stage 4: Selecting the Dye about Client Preferences and Chemical Composition

At this final stage, the compiled analytical information is translated into a concrete chemical formula. This requires deep knowledge of the dye palette in use. One must understand not merely the nominal shade (light brown) but its base—the undertone embedded by the manufacturer. Light brown, for example, may have green, red, or violet bases. Base selection is governed by the need to neutralize expected lightning backgrounds or the client’s skin undertone. The practice of adding a neutralizer to the dye operationalizes this principle: a small, pre-emptive admixture of a complementary color is introduced to suppress the predictable unwanted hue that may emerge during oxidation. Table 2 summarizes key components of oxidative dyes to clarify the chemical foundations.

Table 2. Key chemical components in oxidative dyes for eyebrows and their functions (Brondeel et al., 2022; Cosmetic Science, 2024)

Component	Chemical class	Function	Potential risks
p-Phenylenediamine (PPD)	Aromatic amine	Precursor (primary intermediate); forms the basis of dark color	Highly allergenic; can cause severe allergic contact dermatitis (ACD)
Resorcinol	Phenol	Color modifier (coupler); reacts with precursors to create shades	Allergen: may cause skin irritation
Ammonia / Ethanolamine	Alkaline agent	Opens the hair cuticle to allow dye penetration; creates an alkaline environment for the reaction	Respiratory and skin irritation; damage to hair structure
Hydrogen peroxide (H ₂ O ₂)	Oxidant	Oxidizes precursors to polymerize into colored molecules; lightens natural melanin	Chemical burns at high concentrations; drying of hair and skin

The Adapted Color Wheel and Principles of Neutralization

The classical Itten's color wheel, as shown in Figure 3, underpins the understanding of color relations.

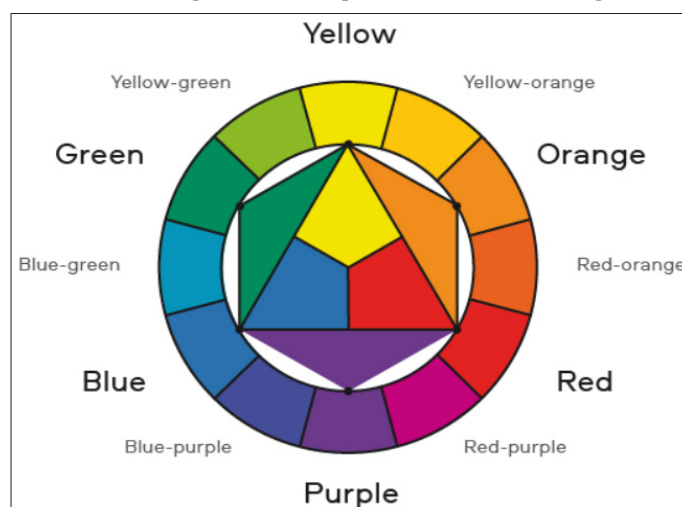


Fig. 3. Itten's colour wheel (Sargsyan, 2020)

In eyebrow practice, the adapted colour wheel should be regarded not as a static taxonomy but as a dynamic, predictive model that integrates chemical reaction dynamics and hair-specific variables to forecast resultant hues. Oxidative colouring is the in-situ synthesis of chromophores within the hair shaft via oxidative chemistry, rather than the mere application of preformed pigment. This process proceeds via the reaction of colorless precursors (e.g., PPD) and color modifiers (couplers, e.g., resorcinol) in an alkaline medium in the presence of an oxidant (Al-Enezi & Aldawsari, 2022). The final color depends not only on tube-mixing proportions but also on the interaction of this reaction with the hair's native pigment (especially pheomelanin, which confers warmth) and the skin undertone.

Thus, the adapted color wheel becomes a predictive instrument. It accounts for, for example, the fact that when tinting dark blond hair to an ashy shade, the oxidant will lighten native pheomelanin, creating a yellow-orange background. To neutralize this background, the dye must initially include blue-violet (complementary to yellow-orange) pigment. Figure 2 illustrates this principle.

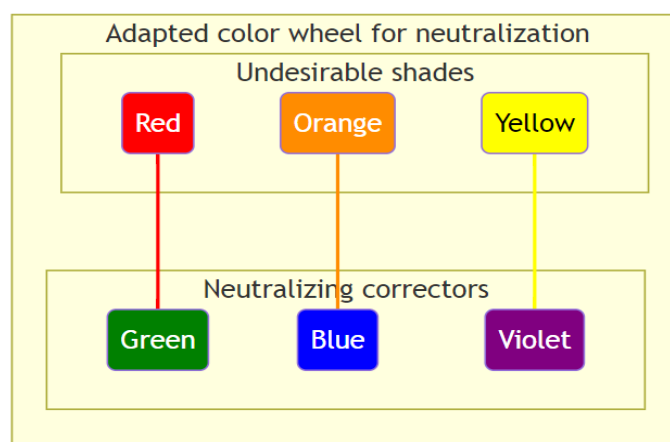


Fig. 2. Adapted color wheel demonstrating the main pairs of complementary colors for neutralizing unwanted shades in eyebrow coloring

For instance, to correct a reddish cast (Red), a corrector based on green pigment (Green) is used.

This approach, rooted in the law of color whereby complementary hues neutralize each other upon mixing, is fundamental both to initial formula selection and to subsequent error correction. It transforms coloring from guesswork into a controlled chemical process with a predictable optical outcome.

PRACTICAL SOLUTIONS FOR NON-STANDARD CLINICAL AND AESTHETIC CASES

Standard coloring protocols are effective for most clients; however, professional acumen is demonstrated in the ability to handle complex and atypical scenarios. Such situations require not only technique adaptation but also a profound understanding of the biological and chemical idiosyncrasies of each case.

Coloring Gray Eyebrows (Canities)

Gray hair (canities) is not merely an absence of color but the culmination of complex biological processes. With age or under the influence of stress and oxidative shock, the population of melanocyte stem cells in the follicular bulge region is depleted (Herdiana, 2025). Melanin synthesis ceases, and hair grows depigmented. Concomitant structural changes often occur: gray hair becomes stiffer; its cuticle denser and less permeable to chemicals—professionally termed glassy. Accumulation of hydrogen peroxide (H_2O_2) within the follicle also contributes to inactivation of tyrosinase, the key enzyme of melanogenesis (Herdiana, 2025).

Standard gray eyebrow coloring often yields a dull, translucent color that fades rapidly. A protocol incorporating a warm pigment into the dye mix is a modification of the classical hairdressing techniques of pre-pigmentation or filling. This method addresses two problems:

1. Recreating the lightning background: Natural hair always contains warm pheomelanin. Gray hair lacks this background. Introducing warm (golden or copper) pigment at the first stage or within the central mix imitates this native background, enabling the subsequent cool or neutral shade to deposit more densely and read as natural rather than gray or green.
2. Improving adhesion: Warm-shade dye molecules may have sizes and structures favoring better anchoring to keratin in glassy hair, creating a base for subsequent pigment layers. Effective penetration into such hair requires dyes with sufficient alkaline agent (e.g., ammonia) to adequately loosen the dense cuticle. Table 3 presents comparative protocols for different hair types.

Table 3. Comparative analysis of coloring protocols for different types of eyebrow hair (compiled by the author based on Pogrebnaya, 2024)

Stage / Step	Normal hair	Porous hair	Gray / Glassy hair
Preparation	Standard cleansing	Cleansing + use of a primer to even out structure	Cleansing + possible use of a special cuticle-opening agent
Formula	Standard dye: oxidant ratio	Reduce processing time or lower % oxidant; add conditioning/care components	Use a pre-pigmentation technique (add warm pigment); use oxidant no less than 3%
Processing time	According to instructions (typically 5–15 minutes)	Shortened, with continuous visual monitoring	Extended — up to 15–20 minutes to ensure pigment penetration
Finishing / Aftercare	Color stabilizer and routine aftercare	Intensive aftercare to close the cuticle and retain pigment	Intensive aftercare: recommend using oils to maintain elasticity

Working with Clients with Albinism

Albinism comprises a group of hereditary disorders characterized by the complete or partial absence of melanin in skin, hair, and eyes. Such clients' skin is susceptible to ultraviolet radiation and predisposed to sunburn and neoplasia. Ocular findings frequently include photophobia, nystagmus, and reduced visual acuity (Federico & Krishnamurthy, 2023). Any cosmetic procedure in the peri-orbital zone therefore, requires maximal caution and deliberation.

The cardinal principle is *primum non nocere*. The aim of coloring is not to achieve a vivid hue but to create a barely perceptible shadow that lends expressiveness without disrupting native harmony or creating health risks. The use of very delicate shades having a cool base is almost diffused coupled with optimal. Such delicacy is achieved by the dye's strong dilution or minimal processing time, thereby reducing potentially irritating chemicals' concentration on sensitive skin. People do prefer cool tones such as ashy and grayish since they want to avoid warm undertones such as red and orange. Warm undertones are going to appear as deeply unnatural for skin that is very light with pink or with bluish undertones. As an alternative, permanent makeup (cosmetic tattooing) may be considered, but only after dermatologic consultation, using hypoallergenic pigments and a specialist experienced with such cases.

Correction of Residual Permanent Makeup

Unlike oxidative dyes, which generate color via chemical reaction, permanent makeup pigments are inert mineral or organic compounds mechanically deposited into the dermis. Common constituents include iron oxides (for brown, red, and yellow shades), titanium dioxide (for lightening and flesh tones), and carbon black for black. Over time, under UV exposure and metabolic processes, these pigments may degrade and clear unevenly. In a brown pigment composed of black, red, and yellow iron oxides, for instance, the black component may degrade faster, leaving an undesirable red–orange residue.

The author's method is an optical neutralization technique rather than physical pigment removal. Its essence lies in overlaying the faded tattoo with a new layer of pigment of the complementary (opposite) color. For example, to neutralize a red residue, a pigment with an olive (green) base is used. The blending of the two colors within the skin yields an optically neutral gray-brown perceived tone, serving as a base for the subsequent application of the desired eyebrow color.

This approach offers a gentler and often safer alternative to laser or chemical removal. Aggressive removal methods carry inherent risks. Laser removal, based on selective photothermolysis (pigment destruction by light pulse), may provoke paradoxical darkening, when titanium-dioxide- or iron-oxide-based pigments irreversibly shift to black or gray under laser exposure (Tijpt et al., 2023). Chemical removers (acidic or alkaline) extrude pigment outward but are traumatic, with scarring risk.

The correction by overpainting method circumvents these risks by neither destroying nor extracting the old pigment, but altering its optical perception. It is therefore a method of choice for faded permanent makeup correction—especially when titanium dioxide is suspected or the client has sensitive skin. Table 4 compares correction methods.

Table 4. Comparison of methods for correcting residual permanent makeup

Method	Mechanism of action	Advantages	Disadvantages & risks
Correction by overpainting (proprietary technique)	Optical neutralization by introducing a complementary pigment	Minimal trauma; no risk of paradoxical darkening; allows simultaneous correction of color and shape	Ineffective on very dense/dark pigment; requires a highly skilled colorist
Laser removal	Selective photothermolysis — laser energy breaks down pigment particles	Highly effective for dark pigments; minimal damage to surrounding skin	Risk of paradoxical darkening of light pigments; possible hypo-/hyperpigmentation; painful; expensive; requires multiple sessions
Chemical removal (remover)	Chemical extraction of pigment from the skin surface followed by exfoliation	Effective for all colors, including those not responsive to lasers (e.g., white, beige)	Highly traumatic; long healing period; risk of scarring and allergic reactions

A SYSTEM FOR CORRECTING COLORIMETRIC ERRORS AND AN ANALYSIS OF THEIR CONSEQUENCES

Even with meticulous adherence to the algorithm, the probability of a colorimetric error cannot be reduced to zero due to the diversity of individual reactions. The key is that the specialist possesses a clear diagnostic and remediation system and understands the potential long-term consequences of improper actions.

Algorithm for Diagnosing Colorimetric Errors

Effective correction begins with precise diagnosis. The author's approach can be formalized using the objective CIE L*a*b* coordinate system. Any coloristic error can be described as a deviation along one or more axes:

1. Error along L* (Lightness): The result is too dark or too light.
 - o Cause (too dark): Misjudged hair porosity, excessive processing time, initial shade too dark.
 - o Cause (too light): Insufficient processing time, oxidant percentage too low, low porosity (glassy hair).
2. Error along a* (Red–Green): The result is excessively warm (red, coppery) or excessively cool (greenish, murky).
 - o Cause (too warm): Underestimation of the warm lightning background (pheomelanin) in natural hair; use of a warm-base dye on warm skin.
 - o Cause (too cool): Use of an ashy dye on olive-undertone skin; over-neutralization of warm pigment.
3. Error along b* (Yellow–Blue): An undesirable undertone appears (e.g., dirty yellow or ashy blue).
 - o Cause (yellow): Insufficient neutralization during coloring to cool blond tones.
 - o Cause (blue/ashy): Use of a cool dye on a very light or gray base without adding a warm corrector.

Figure 3 presents an algorithm that systematizes decision-making in correction.

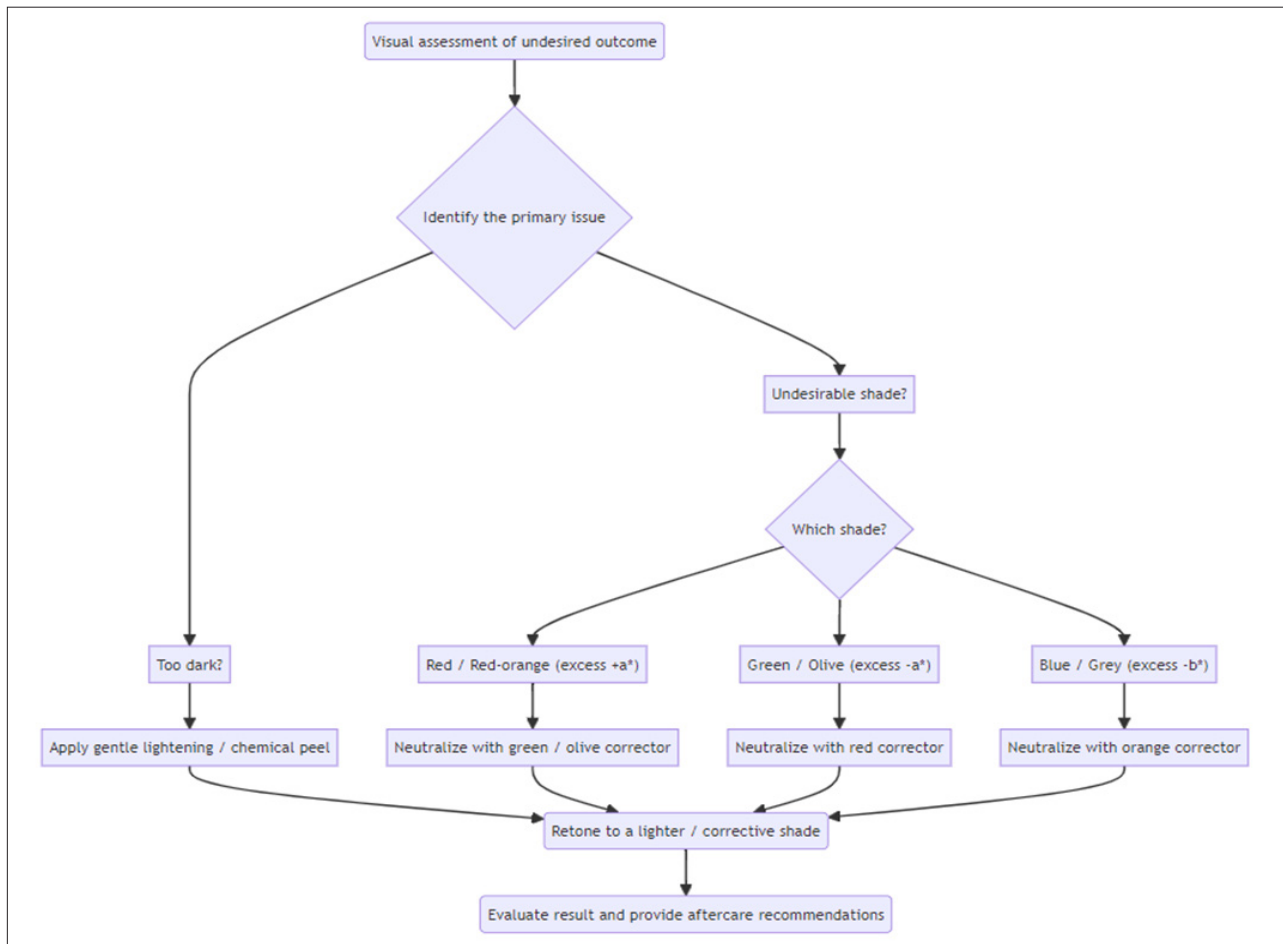


Fig. 3. Algorithm for diagnosing and correcting unwanted eyebrow shades

Methods of Chemical and Optical Correction

After diagnosis, the specialist selects the appropriate correction method, which may be chemical (color change) or optical (neutralization). If the result is too dark, especially if the error is noticed immediately after the procedure, partial pigment removal may be possible. The proprietary lightning or light peeling method may involve the fact that someone uses those special removers. These compounds when applied to skin rely on weak acids like glycolic acid or saline solutions for pulling pigment from the top epidermis layers. You may use light bleaching also. This method can be used for light bleaching. Hair gently has from 1 to 2 levels of tone removed with persulfate-based bleaching compounds (Cosmetic Science, 2024). This method requires special care to avoid damaging the hair and creating an unwanted lightning background.

Neutralization of the unwanted shade is the primary correction method, based on the use of complementary colors. The procedure involves re-coloring the hair using a dye containing the necessary neutralizing pigment. For example, to neutralize red/orange eyebrows, a dye with a distinct green/olive base is used. To neutralize blue/ash eyebrows, a dye with an orange/copper corrector is used. This process is a direct practical application of color theory and is widely used in both hair coloring and permanent makeup correction.

Atypical Consequences: From Dermatitis to Paradoxical Darkening

The typical consequence of a coloristic error is client dissatisfaction. Yet a cascade of incorrect actions may conceal atypical, delayed, and significantly more serious health consequences for skin and hair.

The gravest risk involves sensitization to p-phenylenediamine (PPD) (Teixeira et al., 2006). Every coloring—especially a corrective procedure—constitutes an additional antigenic burden to the skin. Studies show that PPD can disrupt the skin barrier (notably reducing expression of tight junction proteins such as claudins and occludin) even in individuals without clinical allergy (Meisser et al., 2020). Thus, each subsequent procedure—particularly on skin irritated by a failed coloring—increases allergen penetration risk and the likelihood of a complete allergic reaction. ACD to PPD can manifest as marked edema, erythema, oozing, vesiculation, and crusting in the peri-orbital zone, necessitating substantial medical intervention (McLean, 2025). Attempts to rapidly rectify an overly dark result using aggressive lighteners, misproportioned mixtures, or excessive processing times may lead to chemical burns of the thin eyelid skin.

Eyebrow hair has a limited resilience reserve. The color—lighten—recolor cycle commonly used in corrections is an extreme chemical load. Alkaline agents, as well as oxidants, degrade cuticular lipids and damage cortical protein bonds, which then increases porosity along with brittleness and thus ultimately causes hair loss (Pogrebnaya, 2024).

So the first color error begins a hazard chain. A wrong color choice can lead to the worst, most uncommon outcomes soon. Rather, the correction process precipitates from iatrogenic effects. This reframing fundamentally highlights the importance of primary diagnostics: accurate first-pass color selection serves not only as an aesthetic objective but also as a keystone of safety protocols, as it prevents repeated chemical exposure and its associated dermatologic and trichologic risks. Principal risks are summarized in Table 5.

Table 5. Principal risks and atypical consequences in eyebrow coloring

Risk	Manifestation	Cause	Prevention
Allergic contact dermatitis	Swelling, redness, itching, vesicles	Sensitization to PPD and other dye components	Mandatory patch test 48 hours before the procedure; minimize dye contact with the skin
Chemical burn	Redness, pain, blistering, crusting	Use of too high a % oxidant; exceeding processing time; contact of the product with mucous membranes	Strictly follow the manufacturer's instructions; use protective barrier cream around the application area
Structural hair damage	Dryness, brittleness, thinning, hair loss	Excessive chemical exposure, especially during lightning and repeated corrections	Accurate color selection on the first attempt; include conditioning/repairing ingredients; respect intervals between procedures
Infectious complications	Folliculitis, blepharitis	Failure to follow aseptic/antiseptic procedures; use of non-sterile instruments	Use disposable materials where possible; disinfect instruments and workspace

Thus, a single erroneous color choice can precipitate a cascade of corrective interventions that increase antigenic load and the risk of sensitization to p-phenylenediamine (PPD), compromise epidermal barrier function, and precipitate allergic contact dermatitis. Aggressive lightening procedures and exceeding oxidant concentrations/times may cause chemical burns to peri-ocular skin, while repeated lightening–recoloring cycles degrade the hair cuticle and cortex, increasing porosity, brittleness, and hair loss. Consequently, rigorous primary assessment and accurate first-pass color selection are essential, along with routine 48-hour patch testing, minimizing dye–skin contact, strict adherence to manufacturers’ instructions, using barrier creams and restorative agents, and maintaining aseptic technique to reduce the need for hazardous repeat procedures.

CONCLUSION

The presented methodology systematizes the eyebrow colorimetry process, elevating it from intuitive art to an applied scientific discipline. It is established that achieving stable, aesthetically satisfactory, and safe results requires a comprehensive approach integrating knowledge from colorimetry, oxidative dye chemistry, trichology, and dermatology.

Key conclusions are as follows. Algorithmization underpins predictability. The proposed four-stage algorithm (skin, hair, iris analysis, and formula selection) enables systematic data

collection for an evidence-based color decision, minimizing randomness. Color theory is a useful instrument. Through adaptation of the classical color wheel and employment of standardized descriptive systems (such as CIE L*a*b*) comes precise diagnosis of baseline parameters, accurate prediction of chemical reaction outcomes, and effective neutralization of undesirable shades. Safety emerges from precision. The accuracy in the process for initial shade selection establishes a direct link for dermatologic risk reduction. The most severe of atypical consequences like allergic contact dermatitis along with structural hair damage often stem not from that primary error but from procedures which correct in aggressive and repeated ways. Thus, precise colorimetry is not only an aesthetic imperative but a preventive measure for client health. Non-standard cases demand foundational knowledge. Effective protocols for gray hair coloring, work with clients with albinism, and permanent makeup correction rest on a deep understanding of the biochemical and physiological specifics of each condition rather than on universal templates.

The practical value of this methodology lies in providing specialists and educational institutions with a structured, reproducible, scientifically supported system of work. It can act on a basis because it standardizes service quality within the industry, also for advanced curricula with professional upskilling. If the outlined principles are implemented, that will elevate aesthetic outcomes, but more importantly, elevate safety standards for clients.

Vectors such as several span prospects in future development. First, designers have to design technological solutions that are accessible for objective diagnostics, such as portable colorimeters. Specialists may use spectrophotometry mobile apps because such solutions help them to determine hair and skin color precisely. Second, the ongoing search for and creation of less allergenic dye systems remains relevant—for example, PPD-free oxidative dyes with comparable fastness and palette, or improved natural pigments. Finally, further interdisciplinary study of the long-term impact of regular coloring procedures on hair follicles and peri-orbital skin is necessary to develop even safer and more effective protocols.

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