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Features of the Selection of Gradient Coloring Techniques for Curly and Porous Hair

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Abstract: ***This article examines a methodological approach to selecting gradient coloring techniques that aim to preserve the structure and enhance the visual appearance of curly and porous hair. The relevance of the study is determined by the sustained increase in demand for ombré, balayage, and their hybrids, as well as by the specific structural features of curly and porous hair types that require individualized lightening protocols and post-procedure restoration. This work aims to develop an applied model that integrates diagnostic approaches to porosity and curl geometry with a comparative review of the leading gradient techniques, alongside protocols for restoring the cuticle to its optimal state. Novelty can be attributed to this study based on its integrated evaluation approach toward chemical and optical factors, the inclusion of metric classification in curl form, and virtual modeling of skin and hair shades, through which exactness in predicting pigment behavior, as well as attaining the visual characteristics of the gradient, is made possible. The analysis demonstrates that a safe tone lift for highly porous curls should not exceed two to three levels; this necessitates the use of cream oxidizers with bond-building systems and acidic toning products. The choice of ombré, balayage, shatush, or AirTouch technique is founded on a compromise between the desired level of expressiveness and the permissible degree of damage. Hair porosity, curl shape, client phototype, and readiness for post-procedure care emerge as key factors. The formulated recommendations for gentle cleansing, acidic sealing of the cuticle, and regular use of toning products ensure color longevity and hair health. This article will be of value to professional colorists, trichologists, and researchers in the field of cosmetology.***

Keywords: gradient coloring techniques, curly hair, hair porosity, porosity diagnostics, curl geometry

1. Introduction

Gradient coloring techniques, including ombré, balayage, and their modern hybrids, are no longer viewed as seasonal trends; they have become a component of sustained demand for both salon and at-home treatments. The Global Growth Insights report noted a 48% surge in interest in lightning transitions, with almost 55% of today's salon services involving pre-lightening. The global hair colorant market is projected to be worth USD 32 billion by 2025, according to Global Growth Insights (2025). This commercial dynamic is enforced by aesthetic preference: the revival of soft ombré, described as an optimized soft gradient in spring 2025 trend reviews, re-emphasizes low-maintenance colors, which are the express route for both cost-conscious clients and those desiring naturalness (Schneider, 2025).

However, the versatility of these techniques conceals their limited transferability to fibers with increased curl and porosity. Such hair types are characterized by a greater angular curvature of the shaft and a persistently raised cuticle layer, factors that facilitate dye penetration while simultaneously accelerating pigment washout. An experimental comparison of morphological changes during chemical bleaching has revealed a significant increase in porosity and micro-tortuosity, particularly when peroxide is employed (Saddiq, 2020). These findings necessitate an individualized selection of gradient protocols: the stylist must consider the safe limit of lightening, select oxidizers based on porosity, and plan for post-procedure infusion of cationic or direct dyes. The following sections of this article will sequentially examine diagnostic methodologies for such hair, conduct a comparative analysis of color-transition techniques and restoration protocols, and thereby formulate a practical model capable of ensuring a durable gradient without exacerbating curl fragility.

2. Materials and Methodology

The study was based on the analysis of 14 sources: the Global Growth Insights report (2025) on the rise in demand for gradient techniques and the spring trends review by Schneider (2025) regarding the return of ombré; laboratory investigations of hair porosity (Saddiq, 2020; Syed & Ayoub, 2002) and microstructural alterations under excessive bleaching (Kim et al., 2024); metric classification of curl form with consideration of angular curvature and Young's modulus (Gaines et al., 2023); virtual modeling of hair and skin shade combinations (Galliano et al., 2022); as well as market dynamics and consumer preference reports from Fact MR (2025) and DHR (2024), supplemented by professional reviews of coloring techniques (Cohen, 2024; Kelly, 2024; Xray Greyb, 2025).

The research methodology involved a systematic review and comparative analysis of the selected publications. First, sources were classified by data type: laboratory studies of hair microstructure, virtual aesthetic modeling, market reports, and professional case studies. Second, each source was assessed based on the validity of its methods, sample size, and data currency, ensuring the high reproducibility of the conclusions. Third, qualitative content analysis was applied to compare the ombré, balayage, shatush, and AirTouch techniques. Parameters such as tone lift level, oxidizer concentration, structural load on curls, and home-care requirements were evaluated.

Market report data were aggregated to identify trends in technique popularity and service frequency, enabling assessment of each method's practical applicability across different levels of hair porosity. The theoretical findings were consolidated into a practical model in which parameters for selecting a gradient coloring technique are determined by

porosity, curl geometry, skin tone, and client readiness for post-procedure care.

3. Results and Discussion

It is impossible to evaluate the suitability of a gradient technique without understanding the internal fiber structure, since both porosity and curl form dictate how the chemical composition traverses the cuticle and how the final pigment is reflected on the surface. Cuticular scales function as valves, facilitating or impeding dye access to the cortex, and their relative orientation changes with the angular curvature of the shaft, an effect particularly pronounced in curly and porous hair types.

Porosity is defined as the hair's capacity to absorb and retain water and low-molecular-weight compounds, including dyes. Diagnostically, it is determined by a series of simple laboratory or at-home methods: methylene blue staining permits quantitative assessment of dye penetration, whereas the floating strand test provides qualitative confirmation by exploiting the density difference between air and the water-saturated strand, as shown in Figure 1 (Saddiq, 2020).

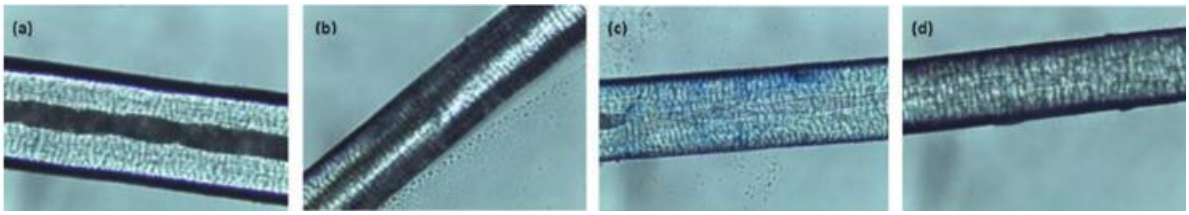

Figure 1: Grey unadulterated adult hair soaked in methylene blue (a) Untreated hair. (b) 3% hydrogen peroxide 10 mins (c) 3% H2O2 20 mins (d) 3% H2O2 30 mins (Saddiq, 2020)

High porosity also alters optical behavior: the interface between air and keratin becomes more diffusive, resulting in a decrease in light intensity within the color gradient. In practice, this manifests as a need for active acidic or protein sealing after coloring, to restore cuticle lipid density and minimize pigment diffusion during the first seven days, when the leakage rate is at its maximum. The geometric parameters of spiral pitch and diameter determine the type of curl. The modern metric system has expanded the traditional Andre Walker 1–4 scale with quantitative measures of curvature and Young's modulus, allowing for a more precise prediction of color behavior on the curl surface (Gaines et al., 2023). When moving from wavy type 2B to tight ringlet 4C, the number of micro-mirrors formed by the lateral edges of cuticle scales increases, so incident light is broken into a chain of points with an average spacing of 81-145 μm; the more of these discrete highlights, the more any sharp contrast is visually fragmented (McMullen & Jachowicz, 2004). A smooth gradient compensates for this effect by creating a continuous band of highlight instead of discrete points, which is especially noticeable on dark bases, where the ratio of diffuse to specular reflection is higher. Thus, porosity governs the chemical aspect of the process, determining depth and durability of dye penetration, whereas curl shape controls the optical element, influencing how the eye perceives the gradient.

The selection of a specific gradient methodology begins with calculating the maximum safe tone lift, as the damage extent depends directly on peroxide concentration and the number of lightning cycles. A 2024 electron microscopy study showed that three consecutive exposures to a 6% H_2O_2 blend result in almost complete cuticle delamination and the formation of longitudinal cracks in the cortex; in other words, exceeding a three-level lift for porous curls sharply increases the breakage risk (Kim et al., 2024). In practice, this means the stylist should limit the lift to two, at most three tones, use cream lighteners with bond-building systems, and maintain the processing temperature without external heat.

The following parameter is transition contrast, which determines correction frequency. Market analysis of lightening colorants reveals a steady 6% annual growth in the balayage segment, as consumers seek low-maintenance color and a natural fade-out, rather than sharp ombré contrast. This trend is reflected in Fig. 2 (Fact MR, 2025).

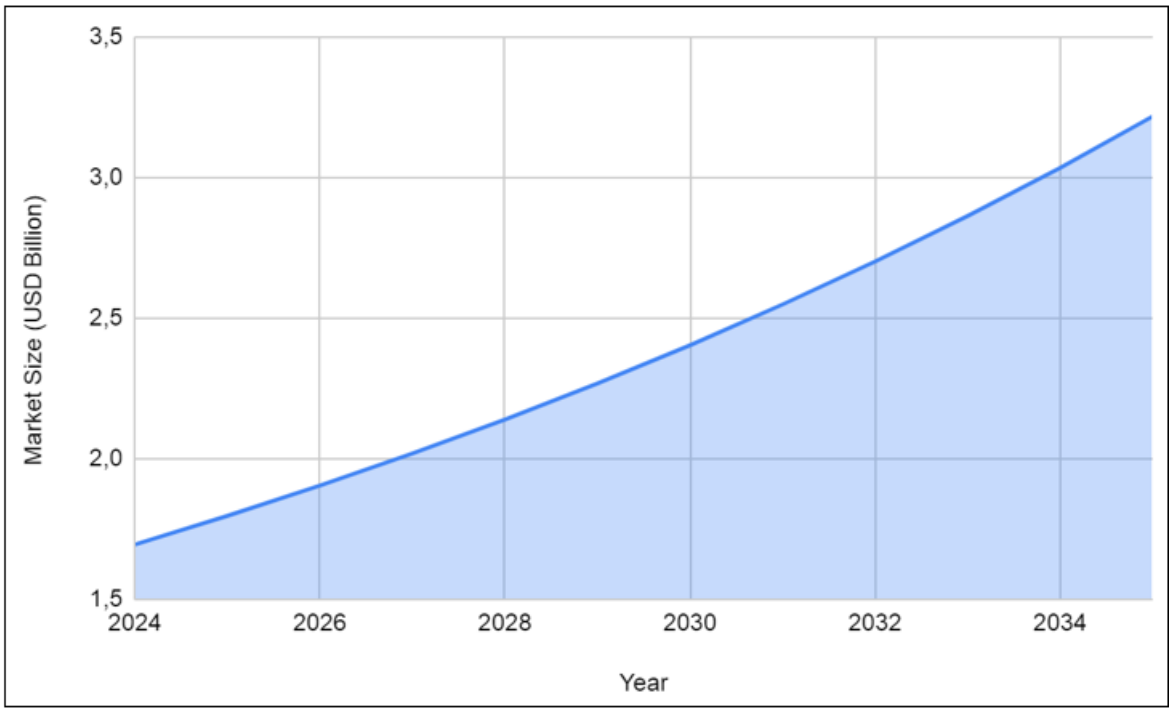

Figure 2: The global balayage lightener market (Fact MR, 2025)

For curly textures, soft blending is also essential: the numerous micro-mirrors on the shaft curve fragment any abrupt block of color, so a moderate gradient appears visually cleaner and maintains harmony longer.

The starting hair shade and client phototype define the palette boundaries. Virtual modeling of hair and skin correspondence, conducted in 2022 on a sample of women from diverse ethnic groups, confirmed that the highest aesthetic ratings are achieved for combinations where hair color differs from skin tone by one to two lightness steps, but remains within the same warm-cool plane, as shown in Fig. 3 (Galliano et al., 2022). Practically, this means that for phototypes I–II it is safer to choose cool sandy and ash gradients, and for IV–V caramel and copper ones, with the base pigment allowed to show through the lightened layer to enhance optical depth.

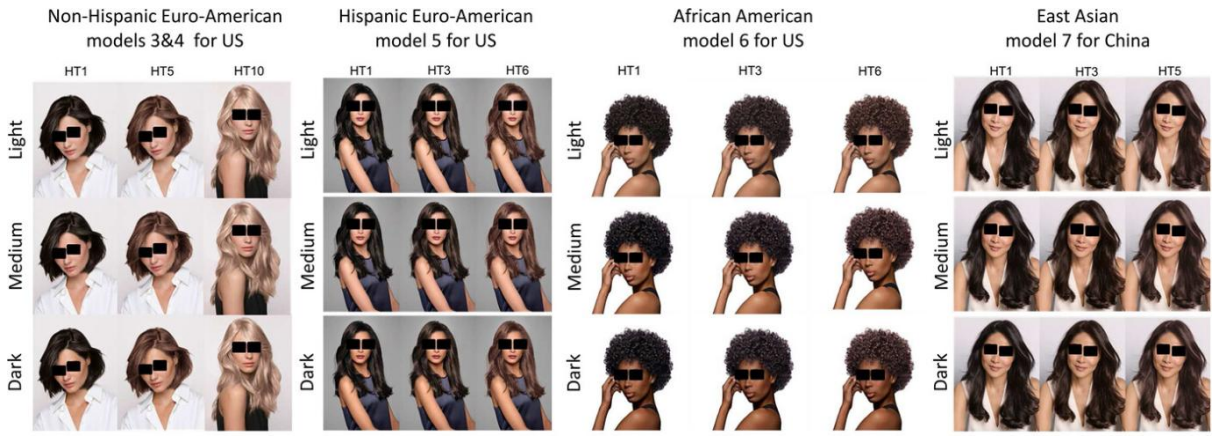

Figure 3: Examples of some virtual images obtained by merging different skin and hair tones in the five groups (Galliano et al., 2022)

The final criterion is the client's readiness for at-home care. The DataHorizon report records that 62% of consumers who attempted to perform coloring at home remained dissatisfied with the result, and 38% subsequently sought professional correction, underscoring the importance of regular toning and the use of sulfate-free products after a complex gradient (DHR, 2024). Suppose the client is unwilling to refresh pigment every six to eight weeks. In that case, it is advisable to leave the natural root zone and use a gentle, freehand balayage technique, thereby minimizing the need for frequent salon visits.

Thus, controlled tone lift, soft visual contrast, precise alignment with the client's phototype, and a realistic at-home care regimen form an interconnected system that enables the selection of a gradient technique, which preserves curl structure while delivering a stable, predictable result.

Ombré produces the most legible gradient: a darkened root transitions smoothly into a lighter length, visually amplifying curl volume, yet the durability of this effect is constrained by the lightening limit at the ends. Contemporary guidelines specify that in current variants, contrast is reduced and lift is

limited to two to three levels, which has renewed the technique's popularity as a touch-and-forget solution; notable 2023 examples demonstrated a soft rather than a dip-dye outcome. Nevertheless, even a single bleaching of ends with 6 – 12 % H_2O_2 can reduce fiber strength by nearly 50 % and increase surface roughness by 30 %, which for highly porous curls means accelerated pigment loss and greater breakage risk (Xray Greyb, 2025).

Balayage addresses the same aesthetic goal selectively: the colorist applies lightener with a brush only to the upper layers of the hair and more often employs low peroxide percentages, so bleached sections are distributed more sparsely. At the same time, undamaged dark strands retain their elasticity. Professional reviews describe the technique as more natural and long-lasting: gentle blending allows for wear of up to six months without a visible regrowth line, and localized application reduces the total number of damaged fibers, which is especially important for curls prone to fissures along bends (Cohen, 2024). Its limitation remains high labour intensity and the need for precise brush-stroke thickness matched to curl diameter; otherwise, highlights may vanish in bulk or, conversely, desiccate fine sections along the entire length.

Therefore, the choice between ombré and balayage is based on a compromise between the desired gradient expressiveness and the acceptable lightening level: the former yields a more evident chiaroscuro pattern but demands strict damage control. At the same time, the latter reduces the chemical load at the expense of longer styling time.

Shatush relies on pre-teasing the strand at the root, after which the lightener is brushed only over the remaining tail, so that the boundary between dark and light areas blurs, resembling natural sun-fading. This pigment distribution is particularly advantageous for curls: the spiral divides light into numerous micro-mirrors, and a sparse network of highlights accentuates volume without distinct bands. However, mechanical teasing increases the number of bristle-cuticle contacts, so the risk of micro-cracks and short breaks rises. Hence, for porous hair, it is advisable to reduce teasing density, use brushes with rounded bristles, and incorporate bond-builders, which, according to comparative assessments of porosity and strength, restore ten to twelve percent of tensile elongation per care cycle (Syed & Ayoub, 2002).

In AirTouch, airflow from the dryer functions as a separator, displacing shorter, more porous fibers and leaving only the dense, long strands in the section to receive the lightener. By this selection, the average proportion of treated fibers falls to forty percent of the total mass, automatically reducing chemical load and speeding drying time, while the visual highlight area is preserved or even enhanced due to curls lifting as a result of density differences between lightened and unlightened zones; this effect was demonstrated in the Hair Visual Show 2024 training series, where curl volume increased by an average of 8 % after styling (Kelly, 2024).

Comparing both methods, Shatush wins in terms of tool simplicity and warm-cool palette versatility, whereas AirTouch demands higher skill and specialized equipment but delivers a structural volume bonus and minimizes damage through selective lightning. Against the previously outlined criteria, this means that for highly porous, breakage-prone curls, the preference shifts to AirTouch if the client is prepared for a longer procedure. Meanwhile, shatush remains justified for rapid tonal correction, provided that mechanical load is strictly controlled and cuticle sealing with acidic protectors is followed.

Preparation of porous curls for lightening always begins with balancing their moisture-lipid levels. Thus, on clean, slightly damp strands, an acidic primer containing amino acids and cationic polymers is applied. It partially fills micropores and reduces alkaline capillary uptake, thereby enabling more uniform lightener action without cuticle swelling. After a short moisture-based dwell time, the optimal moment for the chemical phase is determined, since over-hydrated curls absorb the reactive too rapidly.

The Lightener application on curls adheres to the rule of minimal mechanical stress: broad spirals are treated with flat strokes over the curl's surface, while fine coils are divided into micro-sections and wrapped with product without straightening the shape, thereby preserving natural resilience and preventing kinks after rinsing. In the root zone, the mixture is placed at a distance approximately equal to one curl diameter so that the root shadow remains soft and the stretch achieves optical depth.

The previously established lightning limit guides oxidizer selection: if the structure is already porous, a low peroxide concentration is used with an extended exposure time, simultaneously adding a bond builder based on dicarboxylic acids or hydroxypropyl sulfonate, which creates additional salt bridges within keratin and reduces cortex mass loss. During mixing, it is essential to maintain formula viscosity so that it does not run down the helical walls of the hair and form uneven patches.

After achieving the desired underlying tone, the hair is rinsed and proceeds to acidic toning, where demi-permanent dyes with a pH close to physiological or direct pigments in a cream matrix are applied. Acidic media neutralize residual alkali, close cuticle scales, and simultaneously deposit color, which anchors in partially denatured proteins. Alkaline dyes are avoided, as they would reopen the cuticle and negate the effect of bond-builder additives.

Cuticle locking is completed by applying a low-pH mask with high ceramide concentrations, which form a hydrophobic barrier and fix the pigment. Additionally, a serum containing light oil esters is used, which polymerizes under the warmth of the palms to impart the specular reflection required for gradient depth.

Result longevity depends on home care, based on gentle sulfate-free cleansing. Co-wash or low-poo formulas remove impurities with anionic surfactants of plant origin, without stripping direct pigments. Hydrating masks are applied every few days, combining protein hydrolysates to fill microcracks and mid-molecular-weight oils that can penetrate the cortex and restore elasticity.

To maintain shade, toning conditioners or low-concentration direct pigments in a home format are recommended, as they

gently compensate for wash-out without creating visible bands. Before any heat exposure—whether from a diffuser or curling iron—a heat-protectant cream containing silicates or polymers is continually applied, forming a thin film that reduces keratin degradation. Finally, regular polishing and gentle trimming of the ends preserve the gradient geometry: the removal of dry, split areas prevents capillary moisture from wicking up the shaft, keeping the color transition sharp and even throughout the curl.

Thus, given the complexity of chemical and optical factor interactions when working with curly and porous hair, informed selection of a gradient technique requires an integrated approach: preliminary diagnostics of porosity and curl form determine the permissible tone-lift level and lightener application format; transition contrast control guarantees visual integrity; and a well-designed post-procedure care regimen preserves structure and color fastness. Limiting lightning to two to three levels, employing bond-building systems, and acidic toning minimizes damage, while precise shade selection based on the client's phototype enhances gradient depth. Combined with regular home care, these measures achieve a long-lasting natural result, maintaining curl elasticity and health.

4. Conclusion

This study's findings indicate that the structural features of curly and porous hair necessitate a differentiated approach to selecting gradient coloring techniques. Diagnostics of porosity and curl geometry enable the determination of the maximum safe tone lift—limited to two or three lightning levels—to reduce the risk of breakage and excessive cuticle opening. The use of cream lighteners with bond-building systems and process-temperature control, without additional heat, contributes to fiber integrity. Meanwhile, an acidic toning and subsequent cuticle sealing protocol restores the lipid layer and minimizes pigment wash-out during the critical first seven days.

Choice of a specific gradient coloring technique is based on a compromise between visual preferences and the hair's physical resilience. Ombré and shatush methods create more legible, softly graduated color stretches but require strict control of contrast density and mechanical stress during application. Balayage offers an extended invisible regrowth zone and minimizes overall chemical impact, yet it requires a more complex stroke technique and matching strand thickness to achieve the desired curl diameter. AirTouch offers a structural volume benefit and selective lightening—treating fewer fibers—which is especially beneficial for high-porosity hair, but demands specialized equipment and advanced skill.

A key component of the comprehensive model remains individualized color correlation: selecting a shade within one warm-cool plane and one to two lightness steps lighter than the client's skin ensures harmony and deep optical depth of the gradient. Phototype considerations guide palette formation, transitioning from cool, sandy, and ash tones for types I–II to caramel and copper for types IV–V, with the base pigment serving as the optical foundation for gradient fixation.

An indispensable element of long-term procedural success is a well-designed post-procedure care scheme. Recommendations for regular use of sulfate-free gentle shampoos, acidic and protein-sealing products, toning conditioners, and heat-protectant products support the maintenance of curl elasticity and color intensity. The combination of expert technique selection, strict adherence to a safe tone-lift limit, precise phototype alignment, and thoughtful home care produces a durable natural gradient that preserves the health and aesthetic appeal of curly, porous hair.

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