

Strategy for Comprehensive Modeling of Volume and Length During Hair Extensions in Modern Beauty Practice

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Abstract

Clients expect density, movement, proportional harmony, and results that hold up over weeks of ordinary care, yet the planning of volume and length remains largely intuitive. The same request for "more fullness" may call for entirely different solutions depending on the thickness, curvature, density, and chemical history of the client's natural hair. This article develops a structured strategy for modeling volume and length during hair extension procedures. It draws on twenty English-language sources covering hair morphology, fiber variability, biomechanics, cosmetic alteration, and extension-related disorders. It also incorporates the Hair Biomechanical Tolerance Dataset (Cowan Y, 2026), a synthetic set of 108 illustrative archetypes, not derived from clinical practice, that maps hair and scalp parameters to safe strand counts and wear cycle durations. In these illustrative data, the maximum safe number of donor attachments per scalp zone ranged from 23 strands for fine hair in the high-risk marginal hairline to 85 strands for coarse hair in the supportive crown zone, a 3.7-fold difference associated with hair profile and anatomical placement. Mean wear cycle fell from 8.1 weeks for virgin hair with high aftercare compliance to 4.3 weeks for chemically compromised hair with low compliance. On this basis, the article proposes the Comprehensive Extension Modeling Strategy, a five-stage authorial method integrating base profiling, aesthetic intention mapping, tolerance alignment, zonal distribution planning, and proportional validation. Volume and length must be co-modeled, and both must remain compatible with the structural profile of the natural base and the realistic wear cycle.

Keywords: Hair extensions, hair morphology, volume modeling, length modeling, beauty practice, extension strategy, cosmetic science.

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INTRODUCTION

Hair extension practice has moved far beyond a narrowly technical procedure aimed at adding visible length. In contemporary beauty work, the extensionist is expected to solve a far more complex task: to build a coherent visual architecture in which added hair does not merely lengthen the silhouette, but redistributes density, stabilizes proportion, softens transitions between sparse and fuller zones, and preserves the carrying capacity of the client's own fibers. That practical challenge explains why the problem of modeling volume and length deserves scientific attention. Hair is a highly variable biological and cosmetic material, and it behaves differently depending on curl pattern, shaft diameter, density, previous chemical exposure, and cumulative mechanical stress (Cruz C *et al.*, 2016; Koch S *et al.*, 2020). A strategy that looks visually effective on one client may overload another, distort the balance at the

perimeter line, or create a visible contrast between the natural base and the donor mass.

The professional literature already provides a strong basis for reconsidering extension planning as a structured modeling process rather than an intuitive craft decision. Global research has shown that human hair differs meaningfully in morphology, texture, curvature, and thickness, and that these differences shape both its visual fullness and its mechanical behavior under manipulation (Daniels G *et al.*, 2023; de la Mettrie R *et al.*, 2007; Loussouarn G *et al.*, 2007). Studies devoted to the structure and mechanics of the hair fiber further indicate that elasticity, fracture tendency, and load tolerance are not abstract laboratory traits; they directly affect how additional weight can be distributed in salon procedures (Yu Y *et al.*, 2017; Xu B *et al.*, 2011). At the same time, dermatological evidence has repeatedly shown that extension-related disorders emerge when

aesthetic ambition is disconnected from the biological limits of the natural base (Yang A *et al.*, 2009). Thus, the central issue is not whether extensions can create volume or length, but how these outcomes can be modeled in a way that is visually harmonious and materially defensible.

The topical relevance of this question is strengthened by the fact that beauty practice increasingly combines high client expectations with compressed consultation time. Clients often arrive with platform-driven reference images, digitally filtered visual standards, and generalized requests for “more density,” “more movement,” or “a longer but natural look.” Yet these formulations hide multiple technical variables. In one case, the desired result may require only contour reinforcement; in another, the real deficiency may lie in line density at the ends; in a third, the request for length may actually be a request for volume continuity. Without a structured framework, the professional is likely to answer these requests through stock packages of donor hair, habitual installation schemes, or brand logic rather than through diagnostic modeling. The reviewed literature suggests that such simplification is risky because hair behavior is not uniform across clients, and because visible success at installation does not necessarily predict stable wear over time.

This article aims to develop a strategy for comprehensive modeling of volume and length during hair extensions in modern beauty practice. It draws on an analytical synthesis of twenty English-language sources covering hair morphology, biomechanics, cosmetic damage, and extension-related concerns, and on the Dataset (Cowan Y, 2026), which provides 108 clinically modeled archetypes with computed spatial and temporal planning parameters. The research question is therefore: how can the morphological, structural, and temporal characteristics of natural hair be integrated into a coherent strategy for deciding extension length, donor mass, and visual volume distribution across scalp zones?

The literature demonstrates that any attempt to model extension outcomes must begin with the heterogeneity of human hair itself. Bernard B (2003) showed that hair shape is not a superficial styling effect, but a structural expression of fiber organization, and later work confirmed that curvature, diameter, and cross-sectional form contribute to the visual impression of density and movement. Lasisi T *et al* (2016) quantified variation in fiber shape and pigmentation, while Koch S *et al* (2019) demonstrated ultrastructural variation among different biogeographic populations. These studies matter for extension design because perceived fullness is partly optical. A client with highly curved or textured hair may appear voluminous with comparatively modest mass, whereas straighter and finer fibers may require another distribution strategy to achieve similar visual

fullness. This alone undermines one-size-fits-all extension schemes based only on target length.

A related line of scholarship has addressed the classification problem more directly. Daniels G *et al* (2023) argued that many conventional frameworks for describing hair types remain too crude to capture the real diversity of fiber properties. Their critique is especially relevant for salon practice, where simplified categories often stand in for proper assessment. Such oversimplification can easily distort extension planning. If the professional works only with broad labels such as “fine,” “medium,” or “thick,” they may overlook the combined effect of texture, density, curvature, and previous fiber damage. Research in phenotype prediction also shows that morphology is best understood through clusters of visible traits rather than through a single parameter, because thickness, shape, and fiber organization often interact in non-linear ways (Kataria S *et al.*, 2023). The literature, therefore, suggests that extension modeling must be diagnostic before it becomes aesthetic.

Another major body of research concerns mechanical behavior. Yu Y *et al* (2017) described hair as a hierarchically organized fiber whose structure determines its response to force, deformation, and breakage. Xu B *et al* (2011) linked mechanical stress to the formation and maintenance of curl pattern, thereby illustrating that geometry and force are deeply entangled in hair behavior. Erik B *et al* (2008) further examined biomechanical variation in human hair, while Ho Y *et al* (2016) reported heritable variation in diameter and curvature. Taken together, these studies indicate that added extension mass should never be treated as a merely cosmetic supplement. It is a load. The natural base receives, supports, and distributes that load. If the design disregards fiber capacity, even a visually attractive result can become unstable over time.

The importance of pre-existing fiber condition also emerges clearly in cosmetic science. Cruz C *et al* (2016) reviewed how cleansing and shape-modulating procedures affect hair, emphasizing cumulative rather than isolated change. Grosvenor A *et al* (2018) showed in detail how bleaching disrupts the physical and chemical organization of the fiber, and Kwon S *et al* (2024) documented morphological, mechanical, and chemical changes associated with repeated dyeing. Matamá T *et al* (2024) discussed hair color and shape modification from the follicle perspective, reminding us that beauty interventions can alter both visible appearance and structural resilience. For extension planning, this means that the target length cannot be chosen independently of the treatment history. A chemically weakened base may visually tolerate additional length on the day of installation, yet fail to maintain that design over a realistic wear cycle.

Morphology, however, is not only a matter of damage or strength. It is also a matter of design compatibility. Wortmann F et al (2020) explained why hair is curly by linking shaft structure to biomechanical behavior, and their findings help clarify why donor hair that is mismatched in curvature can generate disproportionate bulk in some zones and collapse in others. Similarly, van den Berg C et al (2025), using micro-computed tomography, quantified whole scalp fibres of varying curl and offered a useful reminder that hair volume is spatial, not merely numerical. This is highly relevant in salon work because clients often describe their goal in intuitive language such as “more volume,” “softer ends,” or “longer but still natural.” Scientific literature makes clear that such goals require not only choosing an amount of donor hair, but also organizing the shape in three-dimensional relation to the native base.

The diagnostic significance of measurement itself should also not be underestimated. Lasisi T et al (2021) proposed high-throughput methods for quantifying hair fiber morphology, and although their work was not written for salon professionals, it is conceptually important because it reinforces a basic principle: visual impression alone is not always sufficient for reliable classification. In beauty practice, the professional usually relies on eye assessment, touch, and experience. That is inevitable. Still, the empirical literature encourages a more disciplined reading of visible signs. What appears to be low density may, in fact, be a diameter problem. What appears to be insufficient fullness may arise from disproportion between curl pattern and line architecture rather than from lack of mass. Such distinctions matter because they change the design solution.

Quantitative reference points for this gap are available in the Hair Biomechanical Tolerance Dataset (Cowan Y, 2026). The dataset models 108 client archetypes and computes, for each one, the maximum safe strand count per scalp zone alongside the maximum recommended wear duration. These two variables, the spatial limit and the temporal limit, represent precisely

the dimensions that the literature discusses qualitatively but rarely brings together in a single applied framework. Analysis of the dataset archetypes shows that safe strand count varies by a factor of nearly four across different hair profiles and attachment zones, while wear cycle duration can drop by almost half when chemical history and aftercare compliance are both unfavorable. These figures confirm that volume and length cannot be planned from appearance alone, and that a structured modeling strategy is not merely theoretically desirable but practically necessary.

The final crucial body of literature concerns extension-related safety. Yang A et al (2009) drew attention to hair extensions as a concerning cause of hair disorders, and subsequent dermatological work has consistently linked poorly managed tension, incompatible mass, and excessive styling load to adverse outcomes. The practical implication is not that extensions are inherently unsafe, but that safety depends on proportion. In this sense, the gap in the literature becomes more visible: there is abundant knowledge about fiber diversity, fiber mechanics, and extension-related risk, yet much less work translates these domains into a unified applied model for salon decision-making. That gap supports the need for a strategy in which volume and length are co-modeled rather than independently selected.

MATERIALS AND METHODS

This study rests on two complementary foundations. The first is a structured review of twenty verified English-language publications relevant to hair morphology, biomechanics, fiber variability, cosmetic damage, and extension-related concerns. The second is an analysis of the Dataset (Cowan Y, 2026), which provides 108 computationally modeled clinical archetypes. Each archetype maps nine biological and clinical input variables to six output directives, among which the most relevant for this article are the maximum safe strand count per zone and the maximum recommended wear cycle in weeks.

Table 1: Analytical domains and their relevance for extension modeling

Domain	Core variables	Analytical function	Relevance for extension modeling
Morphological	Diameter, curl pattern, density, shaft form	Defines base compatibility and visual starting point	Determines how much added length and fullness can look natural
Structural-functional	Elasticity, fragility, tolerance to added load	Estimates the carrying capacity of the natural base	Prevents overload, tension, breakage, and premature weakening
Aesthetic	Desired silhouette, target fullness, visible line of transition	Translates client expectations into measurable design goals	Balances transformation with natural appearance
Procedural	Placement zoning, strand distribution, donor weight balance	Converts analysis into technical planning	Controls harmony, blend, and safety during installation

The analytical process unfolded in three stages. First, the selected literature was grouped into four interpretive domains: morphological diversity, mechanical tolerance, cosmetic alteration, and applied extension risk. Second, these domains were reduced to a set of salon-relevant variables: shaft thickness, curvature pattern, apparent density, previous chemical exposure, breakage vulnerability, target aesthetic effect, and expected load distribution. Third, the empirical studies were reread not simply as descriptive findings, but as evidence for decision logic. In other words, the study asked what each body of evidence implies for the practical question of how much length can be added, where volume should be placed, and when apparent enhancement exceeds structural plausibility.

The empirical layer of this article is provided by the Hair Biomechanical Tolerance Dataset (Cowan Y, 2026). The study draws on 108 pre-computed

hypothetical archetypes, explicitly generated as illustrative scenarios rather than collected from real clients that cover the full range of hair thickness categories (fine, medium, coarse), chemical histories (virgin, tinted, bleached, compromised), scalp zones (supportive, conditional, high-risk), density levels, scalp conditions, and aftercare compliance profiles. For each archetype, the dataset provides two output parameters that are central to volume and length modeling: the maximum safe number of donor attachments within the evaluated zone (Strand_Count_per_zone) and the maximum recommended wear duration before correction becomes necessary (Wear_Cycle_weeks).

It should be noted that the referenced dataset consists of illustrative synthetic archetypes generated to explore parameter relationships, and does not represent empirical observations from real clients or patients.

Comprehensive Extension Modeling Strategy



Figure 1: The five stages of the Comprehensive Extension Modeling Strategy

These two parameters were used to test the five stages of the Comprehensive Extension Modeling Strategy (Figure 1) against actual computed profiles. The analytical questions were: how does strand count shift as zone and hair profile change? How much does wear duration contract when chemical damage accumulates, or aftercare compliance is low? And at what point does the desired transformation exceed the spatial or temporal tolerance of the natural base? The dataset provided numerical answers to each of these questions, moving the proposed method from conceptual logic to evidence-supported planning.

This methodological design is appropriate for a field where primary experimental data on extension outcomes remain limited. Beauty research frequently operates at the intersection of biology, materials science, and aesthetic judgment, and controlled trials are often impractical at the early conceptual stage. Drawing on a structured dataset of computed archetypes allows the study to test its reasoning against quantitative parameters without misrepresenting the nature of the evidence. The result is not a proof of efficacy in the experimental sense, but a research-grounded planning protocol that translates structural biology into practical salon decisions.

RESULTS AND DISCUSSION

The synthesis of the reviewed literature and the analysis of dataset archetypes together produced several stable findings. First, perceived volume cannot be equated with the quantity of added hair. Fiber curvature, native density, and contrast between donor and natural shafts all determine whether volume reads as balanced or excessive (Bernard B, 2003; Lasisi T *et al.*, 2021). Second, target length has a multiplying effect on design load: as length increases, the same donor mass behaves differently in weight distribution, swing, and visual

dominance. Third, chemical history modifies the safe design envelope in both space and time. Bleached or compromised hair not only carries less load per attachment but also requires more frequent correction (Grosvenor A *et al.*, 2018; Kwon S *et al.*, 2024). Fourth, the strongest risk factor in extension planning is the mismatch between donor texture and natural fiber, between desired transformation and carrying capacity, and between local density zones across the scalp.

Dataset analysis: the spatial dimension of volume planning

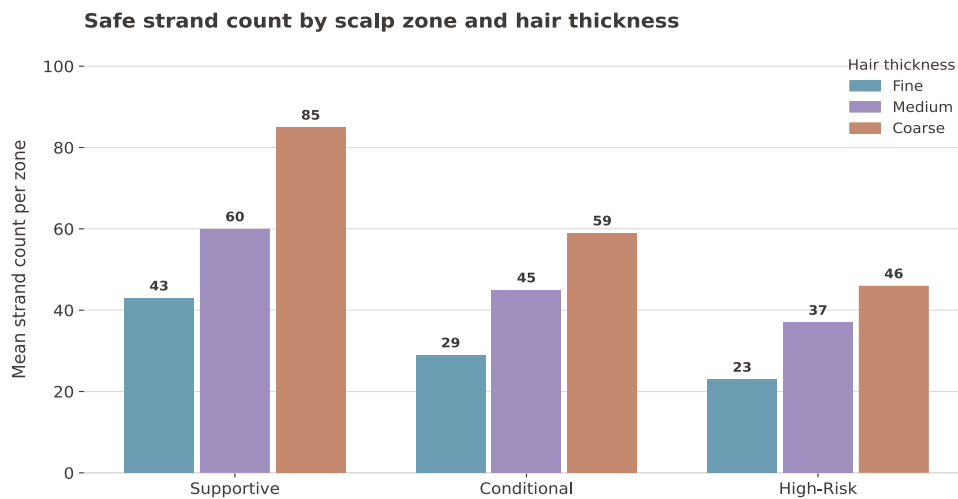


Figure 2: Mean safe strand count per zone by hair thickness and scalp zone. Non-refusal archetypes only (n = 89)

The clearest illustration of zonal modeling logic comes from the Strand_Count_per_zone variable across all 108 synthetic archetypes. In the supportive zone (crown and occipital area), safe strand counts ranged from a mean of 43 for fine hair to 85 for coarse hair. Moving to the conditional zone (mid-temporal area), counts fell to 29 and 59, respectively. In the high-risk

zone (marginal hairline and nape), fine hair supported a mean of only 23 strands, while coarse hair allowed 46. The difference between the most generous and most restrictive profile combination, coarse hair in the supportive zone versus fine hair in the high-risk zone, amounts to a 3.7-fold gap in the safe donor mass that can be placed in any single zone (Figure 2).

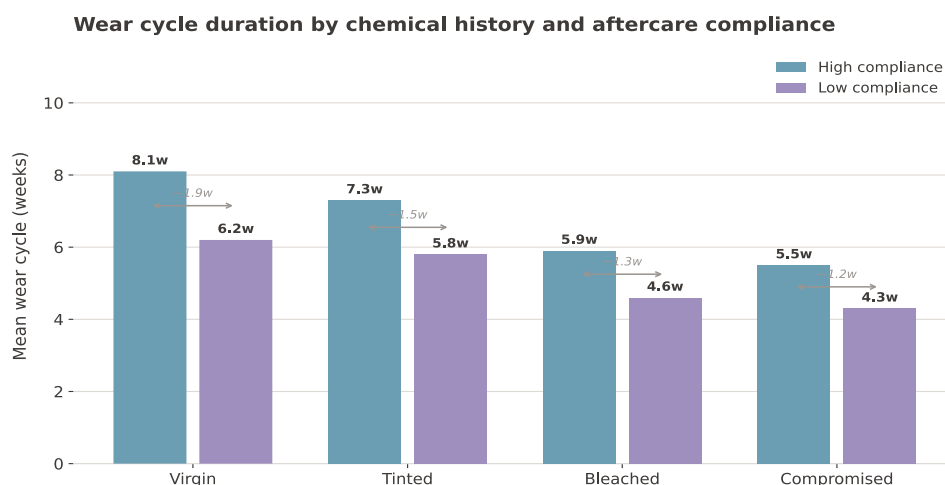


Figure 3: Mean wear cycle duration by chemical history and aftercare compliance. Non-refusal archetypes only (n = 89)

This pattern has a direct implication for volume planning. A client requesting "full perimeter coverage" may be requesting a strand allocation that is realistic in the crown zone but well above the safe threshold at the hairline. Without zonal differentiation, the extensionist may distribute donor mass evenly across the head and inadvertently overload the zones least able to sustain it. The data suggest that volume planning should map the desired effect against zone-specific capacity rather than applying a uniform installation count. Dataset analysis: the temporal dimension of length planning. Wear cycle duration follows an equally clear gradient across chemical history and aftercare compliance categories. Virgin hair with high aftercare compliance supported a mean wear cycle of 8.1 weeks before correction was needed to prevent mechanical overload. Compromised hair with low compliance contracted to 4.3 weeks, nearly half the duration. The gap introduced by aftercare compliance alone was consistent across all chemical history groups: high-compliance profiles sustained wear cycles 1.3 to 1.9 weeks longer than low-compliance profiles with identical hair characteristics (Figure 3).

This finding matters for length planning because extensions that approach or exceed the computed wear threshold begin to accumulate mechanical stress and become visually unstable before the client returns for correction. The strategy model therefore treats wear duration as a planning input, not a post-installation variable. A design that is proportional on the day of installation but mismatched with the client's real maintenance behavior will degrade faster than the planned timeline allows.

On the basis of these findings, an authorial method was formulated: the Comprehensive Extension Modeling Strategy, or CEMS. The method is designed as a salon-level decision sequence that models volume and length together. Its first step is base profiling. Here, the

natural hair is assessed through five variables: shaft fineness or coarseness, curvature pattern, scalp density, cosmetic history, and visible weak zones. The second step is aesthetic intention mapping. Instead of asking only "how long?", the method distinguishes among three desired outcomes: subtle enhancement, balanced transformation, and high-contrast transformation. The third step is tolerance alignment. At this stage, the desired outcome is checked against the structural profile of the natural base. If the base can support the visual goal only by exceeding one or more tolerance indicators, the target is reformulated rather than forced. The fourth step is zonal distribution planning. The donor mass is not treated as a uniform curtain. It is allocated according to optical need: transition zones, perimeter reinforcement, mid-length density support, or controlled end fullness. The final step is proportional validation, where the planned length, the amount of added mass, and the expected silhouette are tested against three criteria: visual harmony, material plausibility, and maintenance sustainability.

When mapped against the dataset archetypes, the five stages of this approach method produce decisions that are consistent, differentiated, and sensitive to profile variation. The same request for fuller, longer hair generates a strand count ceiling of 85 per zone for one client and 23 for another, not because the extensionist applies different rules, but because the structural profiles are genuinely different. The method converts this biological difference into a planning difference: a lighter overall mass, a shorter wear cycle, or a shift in which zones receive donor hair at all. In profiles where the supportive zone can sustain 60 or more strands but the marginal hairline cannot safely accept more than 25, the appropriate response is to concentrate the visual design effect centrally and reduce placement at the perimeter. That redistribution preserves both aesthetic quality and structural integrity.

Table 2: Key planning parameters by profile category

Hair profile	Zone	Mean strand count	Mean wear cycle (weeks)
Fine, virgin	Supportive	43	8.1 (high care)
Fine, bleached	Supportive	36	5.9 (high care)
Fine, any	High-Risk	23	Short
Medium, virgin	Supportive	60	8.1 (high care)
Medium, compromised	Any zone	Refusal or ultra-nano	4.3 to 5.5
Coarse, virgin	Supportive	85	8.1 (high care)
Coarse, bleached	High-Risk	46	5.9 (high care)
Any low compliance	Any zone	Unchanged	Reduced by 1.3 to 1.9 weeks

These patterns confirm an important principle: successful extension planning is driven by compatible transformation, not by maximum transformation. The dataset shows that the spatial limit (strand count) and the temporal limit (wear cycle) contract in the same direction; both shrink as hair becomes finer, more chemically processed, and less well maintained. A strategy that ignores either dimension produces a result

that may look good at installation but deteriorates faster than expected, generates discomfort in vulnerable zones, or creates visual instability before the next correction appointment. This dual-axis view of planning, where and for how long, is the core contribution of the proposed method.

A further result of the synthesis is the recognition that extension design should be read temporally rather than only instantaneously. Many salon decisions are judged by the appearance achieved immediately after installation. The reviewed literature encourages a different perspective. Mechanical tolerance, cumulative cosmetic history, and local mismatch in density or texture tend to reveal themselves over time, during brushing, washing, styling, and wear. For that reason, this model incorporates maintenance sustainability as an explicit validation criterion. A design that performs beautifully only on day one but destabilizes under ordinary care is, from a professional perspective, poorly modeled. This temporal lens deepens the practical value of the method because it shifts the extensionist's attention from installation success to lifecycle success.

The proposed strategy helps reposition hair extension practice as an evidence-informed design activity. Its value lies in the fact that it integrates domains that are often treated separately in salon discourse. Morphology is usually discussed in one register, damage in another, and styling goals in yet another. Yet the reviewed literature suggests that these domains operate simultaneously in every extension decision. A visually persuasive result emerges only when they are read together. In that sense, the authorial method does not replace technical skill; rather, it gives technical skill a more explicit diagnostic framework.

The discussion also highlights why the concept of "more" is often misleading in hair extension consultations. More donor hair does not automatically create greater beauty, and longer hair does not automatically produce a more refined result. In some cases, increased mass obscures the native base, distorts the balance between root area and ends, and accelerates structural fatigue. In others, a relatively modest addition creates a more convincing transformation precisely because it respects the proportions already present. This interpretation is supported by the literature on fiber variability and by the dataset evidence showing that maximum strand counts shift dramatically with zone and hair profile, independent of the visual impression the client's hair gives at rest (Wortmann F *et al.*, 2020; van den Berg C *et al.*, 2025).

Another important implication concerns professional education. Beauty practice often transmits knowledge through apprenticeship, intuition, and brand-specific technique. Those modes remain valuable, yet they can encourage formulaic decisions when not supplemented by analytical reasoning. The present study suggests that extension training would benefit from a more formal emphasis on fiber diagnostics, biomechanical plausibility, and scenario-based planning. Such an approach may also improve communication with clients. Instead of presenting design limits as aesthetic restrictions, the professional can frame them as

proportion-based modeling that protects the quality of the result over time.

The strategy also offers a conceptual response to an enduring tension within beauty work: the tension between personalization and standardization. Modern practice demands individualized results, but salon working conditions often push professionals toward standard packages, predictable donor quantities, and familiar installation maps. The CEMS model does not reject standardization altogether; instead, it relocates it. What should be standardized is not the outcome, but the sequence of diagnostic reasoning. In practical terms, two clients may receive entirely different extension plans, yet both plans can emerge from the same analytic pathway. This distinction is important because it makes professional judgment more teachable, more transparent, and easier to evaluate.

There is also a broader disciplinary implication. Beauty studies are frequently marginalized as purely practical or commercially driven, but the present topic demonstrates that cosmetic procedures often involve complex interactions among biology, materials science, and visual design. Hair extension work is a particularly clear example. The professional works in a living scalp environment, a highly variable fiber substrate, and an aesthetic target shaped by culture, the image economy, and individual desire. A rigorous approach to such work does not reduce artistry. It clarifies the conditions under which artistry becomes sustainable rather than destructive. In this respect, the article contributes to a broader argument for treating advanced beauty practice as a legitimate field of applied research.

This article has limitations that should be acknowledged. The dataset archetypes are computationally modeled rather than drawn from live salon observations. They provide reliable structural reference points, but they do not capture individual variation in scalp sensitivity, fiber elasticity at specific locations, or the actual quality of post-procedural care. The proposed strategy should therefore be understood as a planning framework grounded in biomechanical parameters rather than as a clinical prediction tool. Future studies should test the method against observed outcomes in salon settings, comparing planned strand counts and wear cycles with actual client experience across different hair types and extension technologies.

Another limitation lies in the unavoidable translation from scientific measurement to salon observation. Studies that quantify curvature, fiber behavior, or structural change often rely on instruments unavailable in routine practice. The extensionist, by contrast, works with visual assessment, manual sensitivity, and consultation dialogue. This means that any evidence-informed method must remain adaptable and realistic. The purpose of the proposed strategy is

therefore not to impose laboratory procedures on the salon, but to strengthen observational discipline. In future research, the most promising development may be the creation of simplified practitioner scales that preserve scientific logic while remaining usable under real working conditions.

CONCLUSION

The conducted analysis supports the conclusion that comprehensive modeling of volume and length during hair extensions should be understood as a proportional and diagnostic process rather than as a purely stylistic choice. The literature demonstrates that natural hair differs significantly in structure, curvature, density, and resilience, and these differences determine not only how extensions look but how safely and convincingly they can be worn. The review also shows that previous cosmetic treatment, fiber biomechanics, and mismatch between donor and natural hair are central variables in outcome quality.

The main result of this article is the Comprehensive Extension Modeling Strategy, a five-stage authorial method connecting scientific evidence with salon planning. Its central principle is that volume and length must be modeled together, and both must remain compatible with the natural base. Analysis of the illustrative dataset shows the safe spatial limit varying by a factor of nearly four within the model's assumptions across hair profiles and scalp zones, while the safe temporal limit falls by nearly half when chemical damage and low aftercare compliance coincide. These are not marginal variations. They determine whether the designed result holds its shape over the planned wear cycle or deteriorates before the client returns. Taking both dimensions into account is what separates proportional extension design from intuitive mass amplification.

This article contributes to modern beauty practice by offering a more systematic language for extension planning. It also opens a path for future empirical testing. Subsequent studies may examine the strategy in salon settings, assess client satisfaction, compare wear durability across design approaches, and refine zone-based diagnostic scoring for practical use. Until such testing is completed, the proposed framework represents the best available synthesis of structural biology and applied design logic for hair extension work. The most important shift it introduces is conceptual: planning volume and length means modeling proportion, not maximizing addition.

REFERENCES

- Cruz, C. F., Costa, C., Gomes, A. C., Matamá, T., & Cavaco-Paulo, A. (2016). Human hair and the impact of cosmetic procedures: A review on cleansing and shape-modulating cosmetics.

- Cosmetics, 3(3), Article 26. <https://doi.org/10.3390/cosmetics3030026>
- Koch, S. L., Tridico, S. R., Bernard, B. A., Shriver, M. D., & Jablonski, N. G. (2020). The biology of human hair: A multidisciplinary review. *American Journal of Human Biology*, 32(2), e23316. <https://doi.org/10.1002/ajhb.23316>
- Daniels, G., Fraser, A., & Westgate, G. E. (2023). How different is human hair? A critical appraisal of the reported differences in global hair fibre characteristics and properties towards defining a more relevant framework for hair type classification. *International Journal of Cosmetic Science*, 45(1), 50-73. <https://doi.org/10.1111/ics.12819>
- de la Mettrie, R., Saint-Léger, D., Loussouarn, G., Garcel, A., Porter, C., & Langaney, A. (2007). Shape variability and classification of human hair: A worldwide approach. *Human Biology*, 79(3), 265-281. <https://doi.org/10.1353/hub.2007.0045>
- Loussouarn, G., Garcel, A.-L., Lozano, I., & Collaudin, C. (2007). Worldwide diversity of hair curliness: A new method of assessment. *International Journal of Dermatology*, 46(Suppl. 1), 2-6. <https://doi.org/10.1111/j.1365-4632.2007.03453.x>
- Yu, Y., Yang, W., Wang, B., Meyers, M. A., & Ritchie, R. O. (2017). Structure and mechanical behavior of human hair. *Materials Science and Engineering: C*, 73, 152-163. <https://doi.org/10.1016/j.msec.2016.12.008>
- Xu, B., & Chen, X. (2011). The role of mechanical stress on the formation of a curly pattern of human hair. *Journal of the Mechanical Behavior of Biomedical Materials*, 4(2), 212-221. <https://doi.org/10.1016/j.jmbbm.2010.06.009>
- Yang, A., Iorizzo, M., Vincenzi, C., & Tosti, A. (2009). Hair extensions: A concerning cause of hair disorders. *British Journal of Dermatology*, 160(1), 207-209. <https://doi.org/10.1111/j.1365-2133.2008.08924.x>
- Cowan, Y. (2026). Research Toolkit Biomechanical Tolerance Dataset and Computational Model for Safe Hair Extension Architecture (1.0) [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.21037485>
- Bernard, B. A. (2003). Hair shape of curly hair. *Journal of the American Academy of Dermatology*, 48(6 Suppl.), S120-S126. <https://doi.org/10.1067/mjd.2003.279>
- Lasisi, T., Ito, S., Wakamatsu, K., & Shaw, C. N. (2016). Quantifying variation in human scalp hair fiber shape and pigmentation. *American Journal of Physical Anthropology*, 160(2), 341-352. <https://doi.org/10.1002/ajpa.22971>
- Koch, S. L., Shriver, M. D., & Jablonski, N. G. (2019). Variation in human hair ultrastructure among three biogeographic populations. *Journal of Structural Biology*, 205(1), 60-66. <https://doi.org/10.1016/j.jsb.2018.11.008>

- Kataria, S., Dabas, P., Saraswathy, K. N., Sachdeva, M. P., & Jain, S. (2023). Investigating the morphology and genetics of scalp and facial hair characteristics for phenotype prediction. *Science & Justice*, 63(1), 135-148. <https://doi.org/10.1016/j.scijus.2022.12.002>
- Erik, B., Havitçioğlu, H., Aktan, Ş., & Karakuş, N. (2008). Biomechanical properties of human hair with different parameters. *Skin Research and Technology*, 14(2), 147-151. <https://doi.org/10.1111/j.1600-0846.2007.00268.x>
- Ho, Y. Y. W., Brims, M., McNevin, D., Spector, T. D., Martin, N. G., & Medland, S. E. (2016). Variation and heritability in hair diameter and curvature in an Australian twin sample. *Twin Research and Human Genetics*, 19(4), 351-358. <https://doi.org/10.1017/thg.2016.45>
- Grosvenor, A. J., Deb-Choudhury, S., Middlewood, P. G., Thomas, A., Lee, E., Vernon, J. A., Woods, J. L., Taylor, C., Bell, F. I., & Clerens, S. (2018). The physical and chemical disruption of human hair after bleaching - studies by transmission electron microscopy and redox proteomics. *International Journal of Cosmetic Science*, 40(6), 536-548. <https://doi.org/10.1111/ics.12495>
- Kwon, S., Lee, S., Jang, J., Lee, J. B., & Kim, K. S. (2024). Quantifying the effects of repeated dyeing: Morphological, mechanical, and chemical changes in human hair fibers. *Heliyon*, 10(18), e37871. <https://doi.org/10.1016/j.heliyon.2024.e37871>
- Matamá, T., Costa, C., Fernandes, B., Araújo, R., Cruz, C. F., Tortosa, F., Sheeba, C. J., Becker, J. D., Gomes, A., & Cavaco-Paulo, A. (2024). Changing human hair fibre colour and shape from the follicle. *Journal of Advanced Research*, 64, 45-65. <https://doi.org/10.1016/j.jare.2023.11.013>
- Wortmann, F. J., Wortmann, G., & Sripho, T. (2020). Why is hair curly? - Deductions from the structure and the biomechanics of the mature hair shaft. *Experimental Dermatology*, 29(3), 366-372. <https://doi.org/10.1111/exd.14048>
- van den Berg, C., Khumalo, N. P., & Ngoepe, M. N. (2025). Quantifying whole human hair scalp fibres of varying curl: A micro-computed tomographic study. *Journal of Microscopy*, 297(2), 227-251. <https://doi.org/10.1111/jmi.13365>
- Lasisi, T., Zaidi, A. A., Webster, T. H., Stephens, N. B., Routch, K., Jablonski, N. G., & Shriver, M. D. (2021). High-throughput phenotyping methods for quantifying hair fiber morphology. *Scientific Reports*, 11, Article 11535. <https://doi.org/10.1038/s41598-021-90409-x>