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Dual Lash Science: A Comparative Neuroaesthetic Analysis of Eyelash Extensions and Eyelash Lamination

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Abstract- Against the backdrop of the rapid, essentially exponential, expansion of the global segment of eyelash aesthetic interventions, a scientific and practical gap is widening between the pursuit of neuroaesthetically grounded ideals of attractiveness and the documented biochemical and toxicological constraints of prevailing technologies. This study aims to conduct an integrated comparative analysis of eyelash extension and lamination procedures from the standpoint of their influence on perceptual mechanisms and on the structural integrity of the keratin fiber, as well as to perform scientific validation of innovative, biocompatible approaches. The methodological basis includes a systematic review of the specialized literature, a comparative chemical-toxicological analysis, and a case study of the author's solutions. The data obtained indicate that traditional methods based on cyanoacrylate adhesives and thioglycolate-containing formulations are associated with substantial risks of sensitization, immunosuppressive effects, and persistent degradation of hair structure. In contrast, lamination systems based on cysteamine, a derivative of a natural amino acid, demonstrate comparable aesthetic outcomes with a markedly more favorable safety profile. In conclusion, it is asserted that overcoming the neuro-toxicological dissonance is achieved through a systemic approach that combines biocompatible chemical compositions, individualized clinical protocols, and stringent educational standards. The material presented in this article will be of interest to cosmetologists, dermatologists, chemical technologists, regulatory specialists in the cosmetics industry, and researchers in the fields of neuroaesthetics and perceptual psychology.

Keywords: neuroaesthetics, facial attractiveness,

eyelash lamination, eyelash extensions, keratin, cysteamine, thioglycolate, cyanoacrylate, cosmetic toxicology, dermatological safety

Introduction

The contemporary beauty sector exhibits sustained, near-exponential dynamics, especially in the niche of services that transform the appearance of eyelashes. According to analytical reviews, the aggregate size of the global market for eyelash extensions and lamination in 2024 was estimated at 1,94 billion USD, with a forecast increase to 3,26 billion USD by 2032; this corresponds to a compound annual growth rate (CAGR) of 6,7% [1]. Alternative estimates converge on this trajectory: 1,50 billion USD in 2024 with an expected expansion to 2,70 billion USD by 2032 (CAGR 7,79%) [2]. The key growth determinants are the intensifying media influence of social networks that construct aesthetic norms and the rise in consumer spending on cosmetology practices perceived as part of self-care routines and as instruments of self-presentation [2].

However, behind the economic expansion and broad popularity lies a fundamental collision: prevailing technological solutions carry substantial biochemical and toxicological risks. There emerges a tension between aesthetic motivation, rooted in neurobiological and evolutionary mechanisms, and the requirements of biological safety for the applied procedures [3]. Hence a pronounced research gap: there are no comprehensive interdisciplinary works that systematically connect the neurobiology of gaze attractiveness with molecular mechanisms of action, safety profiles, and long-term effects of contemporary eyelash interventions. Existing publications are generally fragmentary: some focus on narrowly specialized issues such as the toxicology of cyanoacrylate adhesive systems [4] or the psychophysics of lash length perception [6], while others remain purely applied and unsystematized, lacking a robust theoretical foundation.

The aim of the study is to perform a comparative neuroaesthetic, biochemical, and toxicological analysis of eyelash extension and lamination procedures to quantitatively assess their impact on perceptual parameters and the structural integrity of the eyelash shaft, as well as to provide scientific validation of innovative methods grounded in principles of biocompatibility.

The scientific novelty lies in the development of the integrative framework Dual Lash Science, which unites neuroaesthetics and biochemistry for a holistic evaluation of eyelash modification technologies, and in the formalization of the concept of neuro-toxicological dissonance as a key issue of the modern lash industry.

The author's hypothesis asserts that protocols based on biocompatible reagents (in particular, cysteamine) can provide a comparable or superior neuroaesthetic effect relative to traditional approaches (extensions using cyanoacrylates, lamination based on thioglycolates), while simultaneously substantially reducing the risk of disrupting keratin architecture and minimizing the toxicological and allergenic burden on peri-orbital tissues.

Materials and methods

The present study relies on an interdisciplinary methodological configuration that ensures a comprehensive analysis of the stated problem. The research is built on a combination of several complementary approaches.

A systematic literature review established the theoretical and empirical foundation of the study. The search and analytical selection of sources were conducted in leading academic databases — Scopus, Web of Science, PubMed, and Google Scholar — using relevant key queries: neuroaesthetics, facial attractiveness, keratin biochemistry, cysteamine, thioglycolate, cyanoacrylate toxicology, dermatological risks of lash procedures. The inclusion criteria stipulated strict thematic relevance, publication in peer-reviewed outlets, and a time restriction: not older than five years as of the date of the study.

Comparative analysis was employed as the principal method of juxtaposition for technologies of eyelash modification. The comparison encompassed the chemical protocols of procedures, molecular mechanisms of action of active components, toxicological and dermatological safety profiles, as well as long-term effects on the keratin architecture of eyelashes.

Content analysis was used to examine authoritative non-academic sources. In particular, industry reports of leading research agencies (Fortune Business Insights, Maximize Market Research, Verified Market Research) were reviewed to assess market dynamics, volumes, and consumer preferences. Additionally, safety standards established by relevant professional associations,

including The National Association of Lash Artists (NALA), were analyzed.

Case study. Authorial developments — the lamination formula H-Lashes Powder, the diagnostic methodology Dual Lash Balance, and the educational program Clean Reputation — are presented as an applied case of implementing a scientifically grounded, systemic approach to ensuring safety and efficacy in the lash industry.

Results and discussion

The human inclination to modify and accentuate the eyelashes is not limited to the fashion trends of recent decades; it is rooted in evolutionarily and neurobiologically determined motives. The assessment of facial attractiveness is closely coupled with an implicit appraisal of the biological suitability of a potential partner, where a set of morphological features function as indicators of health, youth, and reproductive potential [7, 9]. Within this system of perceptual markers, the eyelashes framing the eyes—the central zone of social and affective signal decoding—serve as a significant amplifier of these indicators.

One of the main principles underlying the preference for long and dark eyelashes is neoteny, that is, the preservation of juvenile traits in the adult phenotype [11, 21]. Typical neotenic facial constants include large eyes, a high forehead, a small nose, and full lips, which automatically activate caregiving patterns and are associated with youth and somatic well-being. Long, dense, and richly pigmented eyelashes visually increase the apparent size of the eyes, thereby strengthening the neotenic signal [20, 22]. Accordingly, practices of cosmetic enhancement of the eyelashes effectively exploit this innate perceptual mechanism. At the same time, the dependence of the effect on length is not linear: an inverted U-shaped function has been empirically described, in which the highest attractiveness rating is achieved at a length approximately equal to one third of the eye's transverse diameter [6]. Excessively long and excessively short eyelashes are systematically perceived as less attractive, likely because extreme values of the trait are interpreted as potential markers of health impairments or genetic deviations.

On the neurobiological level, the aesthetic evaluation of the face relies on selective neural circuits of the reward system. fMRI data indicate that encountering an attractive face enhances activation of the medial orbitofrontal cortex (mOFC), the nucleus accumbens, and the ventral striatum [9]. In parallel, the fusiform gyrus—the region specialized for face processing (fusiform face area, FFA)—exhibits an automatic response to cues of beauty that does not require voluntary control, indicating a basic, prereflective nature of such evaluation [9].

The principal perceptual mechanism is visual contrast. The enhancement of eyelash parameters—length, density, curvature, and pigment saturation—increases facial contrast in the periorbital zone. Increased contrast between diagnostic features (eyes, lips) and the background of the skin is a sexually dimorphic indicator: on average it is higher in women and consistently correlates with markers of youth, femininity, and somatic well-being. Accordingly, decorative cosmetics (mascara, eyeliner) and their semi-permanent analogues (extensions, lamination) act by modulating this natural contrast, visually shifting perception toward greater femininity and youth [15, 19].

Based on this, a conceptual model of the neuroaesthetic action of eyelash modification is formed (Fig. 1), describing the cascade from the physical intervention to the final judgment of attractiveness.

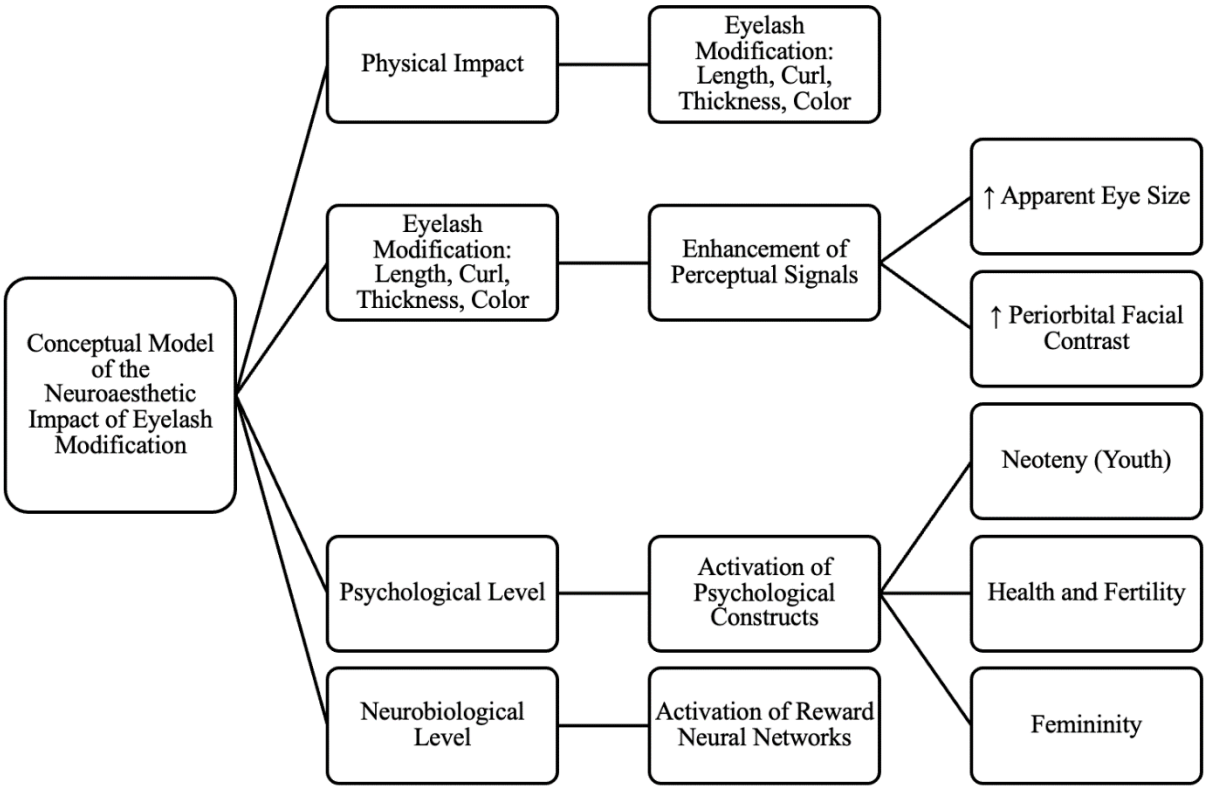

Fig.1. Conceptual model of the neuroaesthetic impact of eyelash modification (compiled by the author on the basis of [6, 15, 19]).

The presence of a powerful, evolutionarily entrenched mechanism prescribing the perception of accentuated eyelashes as a sign of attractiveness is at odds with the practices of the modern cosmetic industry. The most common ways to achieve this visual standard, as will be shown below, are associated with substantial health hazards. A phenomenon of neurotoxicological dissonance arises: an internal conflict between a deeply rooted, neurobiologically supported drive toward an aesthetic ideal and the potential or actual physiological harm accompanying the means of its attainment. The intensity of this drive, repeatedly amplified by marketing stimuli and sociocultural prescriptions [1], explains consumers' willingness to accept high risks. This dissonance constitutes a key challenge for the industry and underscores the exceptional importance of innovations aimed at overcoming it.

For an accurate assessment of the risks associated with eyelash modification, it is necessary to consider effects at the molecular level. Eyelashes, like hair, consist predominantly of α-keratin, a fibrillar protein whose mechanical strength and elasticity are determined by disulfide bridges between cysteine residues in polypeptide chains [13]. These bonds maintain the natural curvature and structural integrity of the hair shaft. Extension and lamination procedures act on eyelashes by fundamentally different routes, yet in both cases potential risks are present.

The extension procedure entails attaching synthetic fibers to natural eyelashes using specialized adhesive compositions. As the chemical basis of the overwhelming majority of such adhesives, cyanoacrylates are used, predominantly ethyl 2-cyanoacrylate [5]. Despite the technological efficiency of this class of monomers, their toxicological profile raises substantial concerns.

The most typical and well-documented adverse outcome is allergic blepharitis: according to systematic reviews it accounts for up to 79% of all reported adverse effects [17]. The key initiator of sensitization is considered to be formaldehyde, a recognized allergen and carcinogen, released during the polymerization of cyanoacrylates; its concentrations in a number of adhesives may exceed regulated safe levels. In addition to blepharitis, cases of contact dermatitis, keratoconjunctivitis, and conjunctival erosion are repeatedly recorded [10, 12].

Emerging observations indicate that cyanoacrylate formulations exhibit not only local irritant but also

immunosuppressive effects. A study of the cytokine profile of tear fluid demonstrated that one month of using a polyacrylate adhesive is accompanied by a statistically significant decrease in the level of interleukin-6 (IL-6), a key proinflammatory mediator critically important for anti-infective defense [4]. Attenuation of the local immune response thus potentially increases ocular susceptibility to bacterial and viral agents.

Vapors of cyanoacrylates belong to volatile organic compounds and pose a significant hazard to professionals working with them: they are associated with the development of occupational asthma and rhinitis, which necessitates stringent air quality control in workplaces [5].

Eyelash lamination represents a controlled restructuring of the geometry of the native hairs through targeted chemical modification of the keratin framework. Technologically, the procedure reduces to two interrelated stages: in the first stage a reductive cleavage of disulfide bridges is induced, and in the second an oxidative fixation of the newly specified configuration is carried out.

In the classical paradigm (thioglycolates), derivatives of thioglycolic acid are traditionally used as the reducing system [14]. Their active form, the thiolate ion, is generated under strongly alkaline pH conditions, which increases nucleophilicity and facilitates attack at the keratin disulfide bond [16]. Although this approach ensures high efficiency of reformation, its aggressiveness is biochemically determined: elevated pH and the reactivity of thioglycolates are associated with irreversible disruption of cuticle integrity, fiber dehydration, increased porosity, and brittleness. Under extreme conditions, even partial hydrolytic destruction of peptide bonds in the keratin polypeptide chain is possible [14]. The final oxidative step, necessary to stabilize the shape, can further exacerbate damage by provoking protein fragmentation and irreversible loss of cystine with the formation of cysteic acid [16].

A contemporary alternative (case study H-Lashes Powder based on cysteamine) relies on the use of cysteamine, an aminothiol derived from the natural amino acid cysteine. This agent retains reducing potential but implements it through a milder thiol–disulfide exchange mechanism effective at substantially gentler, near-neutral pH values [14]. This allows plastic reshaping of form while better preserving the architecture and elastic properties of the keratin matrix. From a safety standpoint, cysteamine is widely used in topical dermatology for the treatment of melasma and is characterized by a favorable tolerability profile; at the same time, like any chemically active compound, it does not eliminate risks: with regular and prolonged professional contact, technicians may develop contact sensitization [18]. This underscores the fundamental importance of strict adherence to safety protocols and the use of personal protective equipment.

A comparison of key parameters of the indicated techniques is summarized in Table 1.

Table 1. Comparative characteristics of eyelash modification methods (compiled by the author on the basis of [4]).

Parameter	Eyelash extensions	Lamination (Thioglycolate)	Lamination (Cysteamine, H-Lashes Powder case)
Main active substance	Cyanoacrylate adhesive	Thioglycolic acid/salts	Cysteamine / Cysteamine hydrochloride
Mechanism of action	Adhesion of synthetic fiber	Chemical reduction of disulfide bonds (aggressive)	Chemical reduction of disulfide bonds (gentle)
Effect on eyelash structure	Mechanical load, risk of breakage	High risk of damage, dehydration, protein fragmentation	Minimal damage, preservation of elasticity and keratin structure

Key toxicological risks	Formaldehyde release, immunosuppression (↓IL-6), cytotoxicity	Chemical burn, severe irritation of skin and mucosa	Contact sensitization potential (mainly in technicians)
Key dermatological risks	Allergic blepharitis (79%), contact dermatitis	Contact dermatitis, irritation	Moderate irritation when the protocol is not followed
Occupational risks	Respiratory sensitization (asthma, rhinitis)	Contact dermatitis	Contact dermatitis

Relative frequency of adverse events characteristic of the specified methods is visualized in Figure 2.

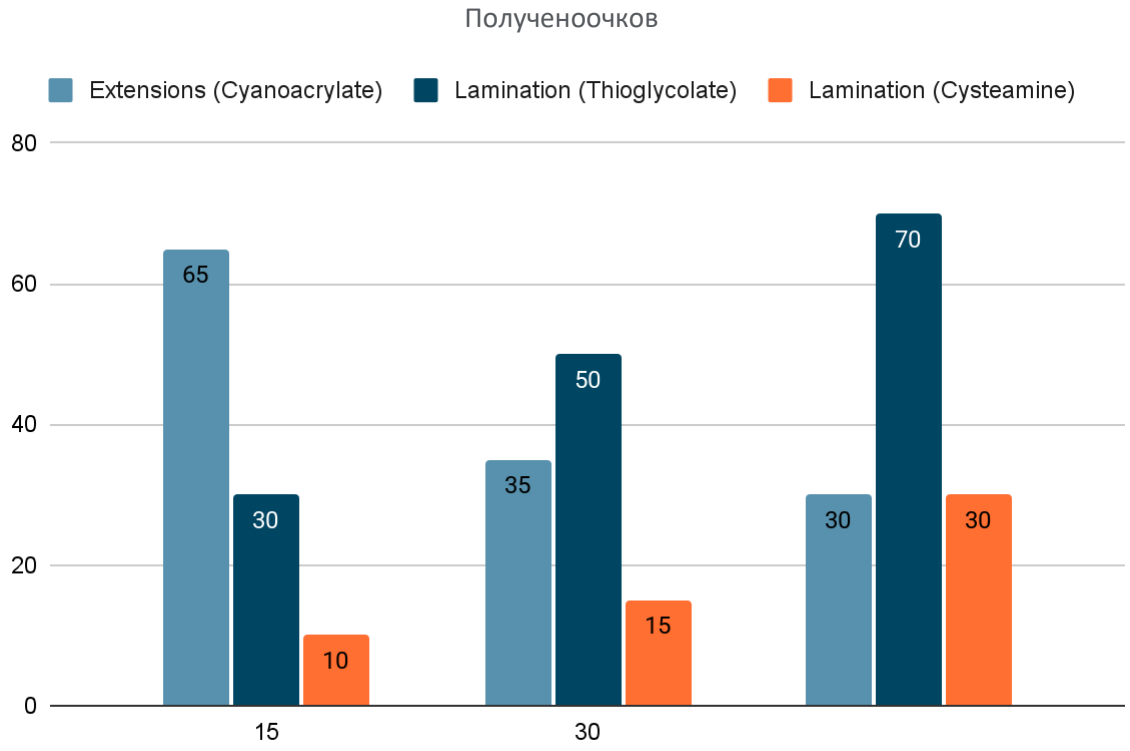

Fig.2. Comparative analysis of the risks of eyelash modification procedures (compiled based on [14, 17]).

The transition from thioglycolates to cysteamine is not a simple substitution of reagents, but a shift in the research lens within cosmetic chemistry. It is a transformation from the stance of maximum efficacy at any cost to the concept of biocompatible efficacy, or Gentle Chemistry. This evolution resonates with a broader shift in cosmetology and consumer practices toward clean, mindful, and safe beauty. The cysteamine-based product H-Lashes Powder serves as a functional implementation of this doctrine, aligning aesthetic goals with the preservation of the biological integrity of the eyelash fiber.

Analytical assessment indicates the systemic nature of risks in the lash industry. The ultimate safety and predictability of outcomes are determined not only by the molecular profile of the products used, but equally by the regulations governing their application, the qualifications of the specialist, adherence to hygiene standards, and the individual characteristics of the client. It follows that effective risk management is possible only within a holistic, multilevel model.

The author's solutions presented in this case study illustrate precisely such an integrative logic.

Method Dual Lash Balance. This diagnostic system, which evaluates symmetry, growth vector, and density of natural eyelashes, materializes the principle of optimality identified in neuroaesthetics research. It has been shown that perceived attractiveness of eyelash length follows an inverted U-shaped dependence [6].

Dual Lash Balance allows practitioners to abandon templated schemes and, based on personalized diagnostics, adjust parameters—curl, length, and density—so as to achieve a visually harmonious result without overloading natural eyelashes and with minimization of mechanical damage.

Educational program Clean Reputation. This course addresses systemic risks of a non-molecular nature—procedural and hygienic. By including step-by-step preparation of the workspace, disinfection and sterilization protocols, and standards for organizing the treatment room, the program fosters a robust culture of safety. Its goal is to reduce the likelihood of cross-contamination and to prevent occupational diseases among technicians (contact dermatitis, respiratory sensitization), widely described in the specialized literature [5].

The institutionalization of safety standards serves as a defining driver of the professionalization of the sector. NALA accreditation (The National Association of Lash Artists), obtained by the author and his educational courses, functions as an external expert review confirming compliance with international requirements. Thus, the discourse on safety is transferred from the space of subjective marketing formulations into the field of objectified, verifiable criteria of quality, professional ethics, and pedagogical soundness.

The necessity of such a systemic approach is particularly evident in current market conditions. Accelerated expansion of the segment (Fig. 3) simultaneously opens a window of opportunity for technological innovations and generates new zones of vulnerability. On the one hand, increased demand catalyzes the development of safer formulas and procedures. On the other hand, it attracts substantial flows of low-skilled practitioners and uncertified, potentially hazardous products to the market, which collectively increases the frequency of complications and inflicts reputational damage on the entire industry [8].

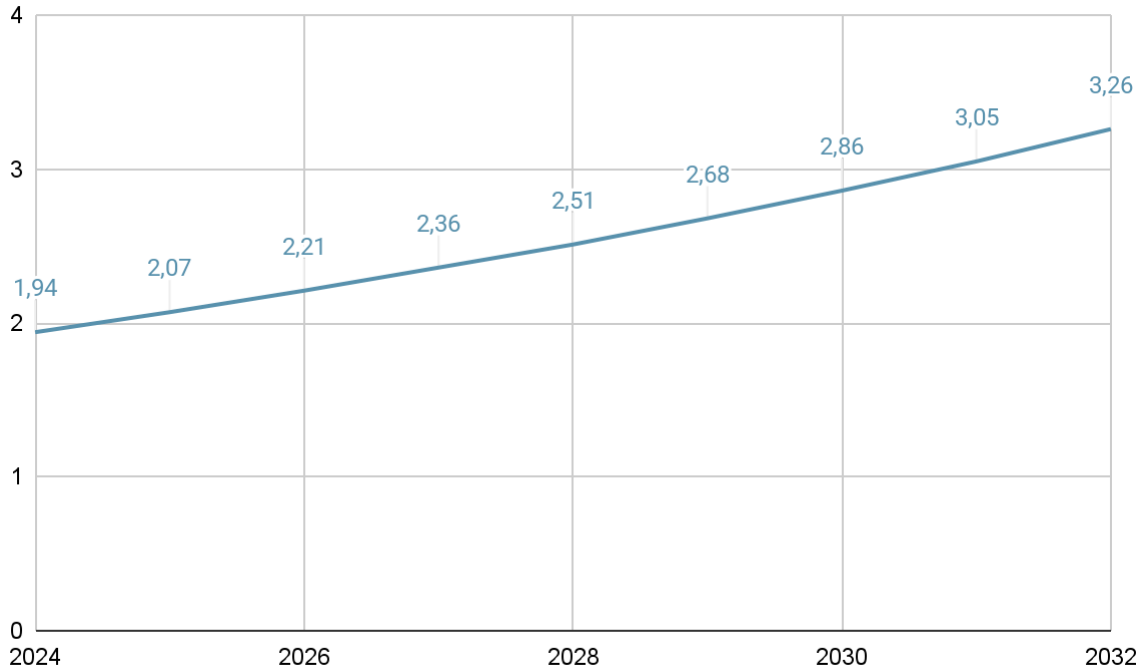

Fig. 3. Global market volume (USD billion) for eyelash modification services (2024–2032) (compiled by the author on the basis of [1, 8]).

Under current conditions, a holistic, systematically designed safety framework functions not only as an ethical and legal imperative but also as a strategic factor of competitiveness. It integrates three mutually complementary levels of protection: biochemical — the use of the biocompatible product H-Lashes Powder based on cysteamine; biomechanical/diagnostic — personalized adjustment of load and parameters according to the Dual Lash Balance method; procedural/educational — strict regulation of hygiene, sterilization, and staff training within the Clean Reputation program and NALA standards. Taken

together, such a multi-level architecture forms a coherent philosophy of safety that goes beyond a simple product offering and is aimed at sustainable and responsible development of the entire industry.

Conclusion

The conducted interdisciplinary study led to a number of fundamental results. First of all, it was established that the motivation for aesthetic eyelash modification is rooted in neuroaesthetic and evolutionary determinants: the basic mechanisms of perceiving youthfulness, vitality, and pronounced femininity rely on reading neotenic signals and enhancing visual contrast. Next, a critical analysis of prevailing technological solutions — eyelash extensions using cyanoacrylate adhesive systems and classical lamination based on thioglycolates — revealed a pronounced neurotoxicological dissonance. Achieving the target aesthetic effect through these procedures is associated with documented risks: allergic blepharitis, local immunosuppression, contact dermatitis, and persistent disruptions of the keratin architecture of the eyelashes.

The study also showed that overcoming this dissonance is possible through a transition to innovative solutions built on the principles of biocompatibility. As a case, it was demonstrated that a cysteamine-based formula, belonging to mild chemical agents, provides an aesthetic outcome comparable to the baseline methods while substantially reducing the hazard profile for the health of both the client and the specialist.

Thus, the author's hypothesis received full confirmation. Methods that employ cysteamine and are supplemented with a systemic protocol of individual diagnostics (Dual Lash Balance) in combination with a sanitation discipline regulation (Clean Reputation) make it possible to align aesthetic objectives with biological safety.

The practical significance of the work lies in forming a scientifically grounded platform for a conscious migration of practicing specialists to less risky technologies, in creating incentives for manufacturers to develop new biocompatible compositions, and in providing regulators with an evidence-based foundation for revising and tightening safety standards in the eyelash enhancement industry.

Prospects for further research include launching long-term comparative clinical studies to quantitatively assess the impact of lamination variants on the morphological characteristics and strength properties of eyelashes using electron microscopy and tensiometry. Additionally, large-scale epidemiological studies are required to accurately estimate the prevalence of occupational pathologies among practitioners depending on the technological approaches used and to substantiate preventive strategies.

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