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BIOMECHANICAL LOAD CALCULATION IN LASH EXTENSIONS: TRANSITIONING FROM AESTHETICS TO CONSUMER SAFETY

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Abstract. The article is devoted to the study of the calculation of biomechanical load in eyelash extensions as a transition from a purely aesthetic approach to ensuring consumer safety. The purpose of the study is to determine the types of load on natural eyelashes during the extension procedure, to substantiate the standards for its safe implementation and to establish the risks that arise in the event of a mismatch between the parameters of artificial eyelashes and the physiological capabilities of the natural ciliary row. During the scientific study, general scientific methods of cognition were used, in particular, analysis, synthesis, generalization, systematization, comparison, classification and logical modeling. The results of the study show that during eyelash extensions a complex biomechanical load is formed, which is not limited only to the mass of artificial fiber. Gravitational, lever, aerodynamic, mechanical-contact and adhesive loads were studied, each of which affects the condition of the natural eyelash, follicle, eyelid margin and ocular surface. It is shown that exceeding the permissible length, diameter, curvature or mass of artificial eyelashes can lead to mechanical overload, traction alopecia, madarosis, irritation of the cornea and conjunctiva, as well as to the gradual depletion of the natural ciliary row. It is concluded that the safety of the procedure depends not only on the modeling technique, but also on compliance with professional, hygienic, microbiological, regulatory and clinical requirements. The author's methodology LRCA Method was separately studied, within which eyelash extension is considered as a controlled process of preserving and restoring the client's natural resource. It is shown that damage audit, determination of the initial state of the follicle, cuticle and natural row, decompression of weakened eyelashes, reconstruction and preventive safe design layer make it possible to select artificial fiber parameters in accordance with the bearing capacity of the natural eyelash. The practical significance of the study lies in the possibility of using its results to develop safe eyelash extension protocols, train masters and increase the level of consumer protection.

Keywords: biomechanics, eyelashes, load, safety, extensions.

Introduction

In modern cosmetology practice, eyelash extensions are usually considered as an aesthetic procedure aimed at visually enhancing the expressiveness of the gaze. At the same time, such a procedure involves attaching an artificial material to a natural eyelash, which changes its physical load, growth conditions and interaction with the surface of the eye. In this context, eyelash extensions cannot be evaluated only by the criteria of shape, length, density or commercial attractiveness of the result. It needs to be considered as a procedure that has biomechanical, chemical, microbiological and clinical consequences.

The relevance of the study is due to the fact that the spread of eyelash extensions is occurring faster than the formation of uniform standards for its safe implementation. As Sullivan et al. note, there is no unified definition of cosmetics and a single system of regulation of procedures related to the eye area in the world, which creates uneven requirements for

materials, adhesives and professional practice [12]. As a result, artists and consumers often focus on the aesthetic effect, while the issues of permissible load on the natural eyelash, follicle condition, risk of dry eye and microbiological safety remain insufficiently formalized. Of particular importance is the fact that complications after eyelash extensions are not only cosmetic, but also medical in nature. Based on the study by Amano et al., it was found that among patients who sought ophthalmological care after eyelash extensions, keratoconjunctivitis and allergic blepharitis, associated with the action of glue and solvents, were most often recorded [2]. Masud et al. also draw attention to the risks associated with cosmetic procedures in the eyelid area, in particular irritation, allergic reactions and damage to natural eyelashes [10]. This indicates that the safety of the procedure should be determined not only by the qualifications of the artist, but also by an assessment of the materials, attachment technique and the individual condition of the client's eyelashes.

Literature Review

The issue of biomechanical loading during eyelash extension, its standardization and prevention of complications is not sufficiently comprehensively covered in the scientific literature. Despite this, individual components of this topic are considered by scientists within the framework of ophthalmological, cosmetological and clinical studies. In particular, clinical complications after eyelash extension were studied by Amano et al. [2], Masud et al. [10], Lau et al. [9] and the American Academy of Ophthalmology [3]. These authors considered keratoconjunctivitis, allergic blepharitis, irritation of the ocular surface, traction alopecia and other undesirable consequences that may occur after the use of artificial eyelashes and adhesives for their fixation.

A separate direction of scientific analysis is the study of the effect of eyelash extension on the ocular surface and tear film. This issue was studied by Han et al. [7], Grupcheva et al. [6] and Sullivan et al. [12]. Han et al. found that ocular surface parameters, including tear film breakup time, tear meniscus height, and subjective discomfort, may change after the procedure [7]. Grupcheva et al. investigated the relationship between eyelash extensions and dry eye symptoms and showed improvements in some clinical parameters after eyelash removal [6]. Sullivan et al. summarized the effects of cosmetic products and procedures on the ocular surface in the TFOS Lifestyle report, focusing on allergenic, toxic, microbiological, and regulatory aspects of eye makeup use [12].

As for the risks associated with improper application or unskilled procedure performance, several authors have investigated this issue. Among them, it is worth highlighting Abah et al. [1], who analyzed the prevalence of eyelash extension use among female students and found a low level of awareness of possible complications; Cheraqpour [4], who systematized the side effects of ophthalmic cosmetics, including mechanical damage, toxicity, inflammation, infection, and tear film instability; Cope et al. [5], who described a case of perioperative keratopathy and corneal abrasion in a patient with eyelash extensions; Wang et al. [14], who also reviewed corneal abrasion under general anesthesia. Taken together, these works prove that the risks of the procedure can manifest themselves not only in everyday conditions, but also in the medical environment, where the presence of artificial eyelashes complicates the protection of the ocular surface. A separate group of sources is regulatory, professional, and expert materials that define requirements for the safety of materials and professional practices. The International Organization for Standardization in the ISO 11930:2019 standard defines approaches to assessing the antimicrobial protection of cosmetic products [8]. The National Association of Lash Artists has developed professional guidelines for artists, including informed consent, disinfection, use of certified materials, and referral of clients to a physician in case of complications [11]. The U.S. Food and Drug Administration has

established requirements for the safety of eye cosmetics, ingredient labeling, prohibition of hazardous dyes, and hygiene when using cosmetic products in the eye area [13].

The scientific novelty of this study is that the biomechanical load during eyelash extension is considered not as an auxiliary technical parameter of the procedure, but as a central factor of consumer safety. Unlike previous works, the study combines clinical data on complications, regulatory requirements for eye cosmetics, professional standards for performing the procedure and the applied approach of the LRCA Method by Inna Bahriantseva, which involves damage audit, decompression and safe modeling of the load on natural eyelashes. To achieve the goal, the methods of analytical review, comparative analysis, structural-logical generalization, classification and scientific synthesis were used.

Problem Statement

The purpose of the article is to study the biomechanical load during eyelash extension, its types, standards for safe procedure performance and threats that arise in the event of a mismatch between the parameters of artificial eyelashes and the physiological capabilities of natural eyelashes. To achieve the goal, the following tasks will be performed during the study: to reveal the concept and main types of biomechanical load during eyelash extension; to characterize the regulatory framework, safety requirements and professional standards for performing the procedure; to classify the possible consequences of incorrect loading, taking into account the mechanisms of their occurrence; to substantiate the value of the author's LRCA Method methodology as a practical approach to the diagnosis, restoration and safe modeling of natural eyelashes.

Methods and Materials

The methodological basis of the study is an analytical review of verified scientific, clinical, regulatory and professional sources dedicated to the safety of eyelash extensions, biomechanical loading, the impact of eye cosmetics on the surface of the eye and standards of professional practice. The materials of the study were the peer-reviewed publications of Amano et al., Abah et al., Masud et al., Han et al., Grupcheva et al., Cope et al., Wang et al., Cheraqqpour and Sullivan et al., as well as the clinical recommendations of the American Academy of Ophthalmology, the requirements of the U.S. Food and Drug Administration, the ISO 11930:2019 standard and the professional guidelines of the National Association of Lash Artists [1; 2; 3; 4; 5; 6; 7; 8; 10; 11; 12; 13; 14]. The study was carried out using comparative, structural-logical and classification approaches, which made it possible to compare clinical complications, physical parameters of artificial eyelashes, requirements for materials and professional standards of the procedure. Separately, the applied component was taken into account, represented by the author's methodology LRCA Method by I. Bahriantseva, which is used as a practical model for assessing damage, decompression and safe modeling of the load on natural eyelashes.

Results and Discussion

Biomechanical stress during eyelash extension should be considered as a set of physical effects that occur after attaching an artificial fiber to a natural eyelash. This includes not only the weight of the false eyelash, but also the effect of the length, stiffness of the material, the point of fixation of the glue, and repetitive movements of the eyelid during blinking. In this approach, the extension procedure ceases to be purely aesthetic. It acquires the characteristics of an intervention that can change the mechanical state of the follicle, eyelid, and ocular surface. Based on the study by Masud et al., it was found that some complications after extension are associated not only with the chemical composition of the adhesives, but also with the

mechanical traction of the false eyelashes, which can cause madarosis and traction alopecia [10].

In an applied sense, biomechanical stress is formed through a combination of three parameters: the mass of the artificial fiber, its length, and the number of eyelashes attached to one natural eyelash. It is their combined effect that determines the level of risk. In particular, even a light fiber can create an excessive moment of force if its length significantly exceeds the length of the natural eyelash. As shown by the study of Han et al., after extension, ocular surface parameters may change, in particular tear film breakup time and subjective discomfort, indicating the functional impact of the procedure on the condition of the eye [7]. Therefore, the classification of loads allows us to more precisely explain why the same procedure can be safe for one client and risky for another.

The main types of biomechanical load in eyelash extension are summarized in Table 1.

Table 1 – Types of biomechanical load in eyelash extension

Type of load	Mechanism of action	Possible consequence
Gravitational load [10]	the weight of the eyelash extension acts continuously on the natural eyelash and its follicle throughout the entire wearing period	gradual stretching of the follicle, premature eyelash loss, madarosis
Lever load [10]	increased length of the artificial eyelash amplifies the moment of force at the attachment point	overloading of the natural eyelash even when the fibre has a relatively low weight
Aerodynamic load [6]	excessively long eyelashes alter airflow near the ocular surface and may increase evaporation of the tear film	tear film instability, worsening of dry eye symptoms
Mechanical contact load [7; 14]	rigid synthetic fibres may come into contact with the cornea or conjunctiva during blinking or incomplete eyelid closure	irritation, foreign body sensation, epithelial defects, corneal abrasion
Adhesive load [3; 10]	the adhesive zone becomes an area of stress concentration through which the weight and movement of the artificial eyelash are transferred to the natural eyelash	weakening of the attachment site, brittleness of the natural eyelash, blepharitis, allergic reactions

Note: compiled by the author based on sources [3; 6; 7; 10; 14].

The classification given in Table 1. shows that the safety of eyelash extensions does not depend on one single parameter, but on the balance between length, mass, fiber diameter, condition of natural eyelashes and quality of adhesive. In the practice of the lash industry, certain rules are already used, formed on the basis of professional experience. These include the selection of length with a limit of approximately 2 mm above the natural eyelash, avoiding excessive mass of the bundle and compliance of the diameter of the artificial fiber with the thickness of the natural eyelash. At the same time, there are standardized requirements that relate to the safety of cosmetic products, microbiological control and quality of materials.

Standards of the eyelash extension procedure are formed on the border of cosmetology practice, safety of cosmetic products and clinical protection of the ocular surface. Although the procedure itself does not belong to medical interventions, its consequences may be of a medical nature. Allergic blepharitis, keratoconjunctivitis, traction alopecia, and corneal abrasion have been reported in the literature following eyelash extensions [10; 14]. Therefore, the safety of the procedure cannot be limited to the aesthetic outcome alone. It should encompass the quality

of the adhesive, the microbiological purity of the materials, the professional training of the artist, the informed consent of the client, and timely referral to a physician in case of complications. As Sullivan et al. point out, there is no single global definition of cosmetics in the world, and therefore the requirements for ophthalmic cosmetic products and procedures vary significantly between jurisdictions [12]. In practical terms, this means that eyelash extensions are not regulated by one universal standard, but by several interrelated sources. These include NALA professional guidelines, U.S. Food and Drug Administration on the safety of eye cosmetics, the international standard ISO 11930:2019 on antimicrobial protection of cosmetic products, as well as the TFOS clinical recommendations on the impact of cosmetics on the ocular surface [8; 11; 12; 13].

The most practical importance for the master is the professional rules for performing the procedure. They concern checking the condition of the eyes and skin before the procedure, using certified materials, having documentation on the glue, disinfecting instruments, refusing the procedure in case of irritation and referring the client to an ophthalmologist if symptoms appear. In contrast, ISO and FDA are more concerned with the safety of the product, its composition, labeling, microbiological control and the prohibition of hazardous substances. A summary of the main standards and requirements is given in Table 2.

Table 2 – Standards and safety requirements for the eyelash extension procedure

Area of the standard	Content of the requirement	Practical significance
Professional practice of the technician [11]	written client consent, medical history taking, refusal to perform the procedure in cases of eye or skin irritation, referral to a physician in the event of complications	enables the risk of performing the procedure on clients with contraindications to be reduced and ensures awareness of possible consequences
Safety of adhesive and materials [11]	use of products from certified suppliers, availability of an MSDS, compliance with the manufacturer's instructions for cyanoacrylate adhesive	reduces the likelihood of chemical irritation, allergic reactions, and improper use of the adhesive
Microbiological safety of the cosmetic product [8]	assessment of the product's antimicrobial protection in accordance with ISO 11930:2019, including testing for <i>Staphylococcus aureus</i> , <i>Pseudomonas aeruginosa</i> , <i>Escherichia coli</i> , <i>Candida albicans</i> , and <i>Aspergillus brasiliensis</i>	ensures control of the risk of bacterial or fungal contamination of materials used near the ocular surface
Regulatory requirements for eye cosmetics [13]	declaration of ingredients, prohibition of hazardous colorants, control of imported products, and prevention of the use of kohl, antimony, and cosmetics containing heavy metals	prevents the use of products with toxic or unknown components in the eye area
Procedure hygiene [11; 13]	disinfection of instruments and the workstation between clients, disposable applicators, and prohibition of shared use of cosmetic products	reduces the risk of cross-contamination, conjunctivitis, keratitis, and other infectious complications

Clinical monitoring of the ocular surface [12]	consideration of the risk of dry eye, irritation, allergic reactions, and the need for ophthalmological follow-up with regular use of eye cosmetics	shifts the procedure from a purely aesthetic domain to one of controlled consumer safety
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Note: compiled by the author based on sources [8; 11; 12; 13].

Failure to comply with these standards creates not only cosmetic, but also clinical risks. If the master ignores the condition of the client's eyes, uses materials without confirmation of the composition or does not adhere to the hygiene regime, the likelihood of allergic blepharitis, infectious inflammation, corneal irritation and damage to natural eyelashes increases. The combination of several violations at the same time is especially dangerous, in particular, poor-quality glue, lack of disinfection and performing the procedure with existing irritation. In this case, eyelash extensions cease to be a controlled cosmetic procedure and can become a factor in permanent damage to the ocular surface or hair follicle [10; 12; 14].

Incorrect loading during eyelash extensions creates a complex of threats that go beyond ordinary cosmetic discomfort. The main problem is the mismatch between the parameters of the artificial eyelashes, in particular the mass, length, diameter, stiffness of the material, and the physiological endurance of the natural eyelash, follicle, eyelid and ocular surface. As shown by the study of Amano et al., a significant part of the complications after extension is associated with the action of glue, in particular cyanoacrylate and formaldehyde, which can cause keratoconjunctivitis and allergic blepharitis [2]. At the same time, mechanical factors are also of independent importance, since excessive length or mass of the false eyelash creates a constant traction on the follicle and increases the risk of madarosis [3]. The threats are amplified when the procedure is performed without taking into account the condition of the client's eyes, without hygiene control or using materials of unknown origin. According to Abah et al., some users of eyelash extensions do not seek medical help even with symptoms of irritation, which can turn reversible conditions into chronic ones [1]. The perioperative context is of particular importance. Cope et al. described a case where eyelash extensions prevented proper eye protection during general anesthesia and became a factor in corneal abrasion [5]. This indicates that incorrect loading has not only aesthetic but also clinical consequences.

The main threats of incorrect loading during eyelash extensions include:

1. Allergy, which occurs as a reaction to the glue, preservatives or impurities in the adhesive composition. An example is allergic blepharitis, which is manifested by eyelid swelling, itching, redness and discomfort after the procedure. Amano et al. associate such reactions with the presence of cyanoacrylate and formaldehyde in eyelash extension adhesives [2];

2. Chemical-toxic poisoning, which occurs when glue, its vapors or a solvent for removing eyelashes get on the surface of the eye. In practice, this can manifest as keratoconjunctivitis, burning, tearing and a foreign body sensation. Cheraqpour notes that components of eye cosmetics can have an irritating, toxic and inflammatory effect on the ocular surface [4];

3. Mechanical irritation, which is formed due to contact of a hard synthetic fiber with the cornea or conjunctiva. For example, eyelashes that are too long or incorrectly directed can irritate the eye during blinking, causing epithelial erosion, redness and pain. The American Academy of Ophthalmology, via EyeWiki, describes such complications as a consequence of the mechanical impact of artificial eyelashes and auxiliary materials [3];

4. Traction alopecia, which occurs due to the constant mechanical traction of the false eyelash on the natural one. The most typical example is the use of too long or heavy bundles

that overload one follicle. As a result, madarosis may develop, i.e. loss of natural eyelashes, and with prolonged exposure, damage to the follicle is possible [3];

5. Meibomian gland dysfunction, which is associated with blockage of the eyelid margin by glue, makeup residue, or a dense row of false eyelashes. An example is evaporative dry eye, when the tear film evaporates more quickly and the client experiences dry, burning, and tired eyes. Cheraqpour links these manifestations to impaired tear film stability and the effect of cosmetics on the ocular surface [4];

6. Infectious lesions, which are formed with insufficient eyelid hygiene, repeated use of applicators, or accumulation of dirt at the base of the eyelashes. In practice, this can manifest as bacterial conjunctivitis, folliculitis, blepharitis, or keratitis. Abah et al. draw attention to the low awareness of users about the risks, which increases the likelihood of untimely response to symptoms [1];

7. Perioperative corneal injury, which occurs when a client with eyelash extensions undergoes surgery under general anesthesia. An example is a situation where voluminous artificial eyelashes interfere with complete eyelid closure or proper application of a protective dressing. Cope et al. described a case of corneal abrasion after a cesarean section, where eyelash extensions became an additional risk factor [5].

Within the standards of the eyelash extension procedure, the author's methodology of Inna Bahriantseva, presented as the LRCA Method, is of particular importance. Its essence is that working with eyelashes is considered not as a one-time decorative service, but as a controlled process of preserving and restoring the client's natural resource. This approach complements general safety standards, as it shifts the emphasis from the visual result to a preliminary diagnosis of the condition of the eyelashes, assessment of the permissible load and prevention of repeated damage.

A feature of the LRCA Method is a phased structure that begins with a damage audit. At the first stage, the condition of natural eyelashes is assessed after aggressive or unqualified external influences, in particular after gluing, overloading, breakage, chemical depletion or improper removal of the material. The so-called "entry point" is determined, i.e., the actual condition of the follicle, cuticle and natural row of eyelashes. Thanks to this, the master does not proceed immediately to modeling, but first establishes the boundaries of safe intervention. This diagnostic logic makes it possible to prevent the deepening of existing damage.

The second and third levels of the protocol are aimed at restoration and safe modeling. The reconstruction protocol involves decompression, i.e., removing the critical load from weakened eyelashes, applying restoration schemes and creating conditions under which the natural row can gradually regenerate without the client completely abandoning professional care. Next, a preventive safe design layer is applied, within which the length, diameter, bend and mass of the artificial fiber are selected not according to the principle of a fashionable effect, but in accordance with the "bearing capacity" of the natural eyelash. As a result, the risk of traction alopecia, trichoptilosis, mechanical overload and repeated depletion of the follicle is reduced. The aesthetic result in such a system performs not only a decorative, but also a protective function, since it is formed as a safe framework for the restoration of natural eyelashes.

Conclusions

Biomechanical load during eyelash extension is a set of physical influences that occur after attaching an artificial fiber to a natural eyelash. It includes not only the weight of the false eyelash, but also the effect of the length, diameter, stiffness of the material, the number of fibers and the point of adhesive fixation. There are five main types of such load: gravitational, lever, aerodynamic, mechanical-contact and adhesive. The safety of the extension is determined not by a separate parameter, but by their combination.

Standards for the eyelash extension procedure are formed at the intersection of professional practice, regulatory requirements and clinical recommendations. The professional practice of the master includes the client's written consent, collection of anamneses, refusal of the procedure in case of eye irritation and referral to a doctor in case of complications. The safety of glue and materials involves the use of certified products, the presence of an MSDS passport and compliance with the manufacturer's instructions. Microbiological safety is related to the requirements of ISO 11930:2019, which provides for the control of antimicrobial protection against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Candida albicans* and *Aspergillus brasiliensis*. Regulatory requirements for eye cosmetics concern the declaration of ingredients, the prohibition of hazardous dyes and the prevention of toxic substances in the eye area. Inna Bahriantseva's LRCA Method is of applied importance in this context, as it combines damage audit, decompression and safe load modeling. This approach does not allow the transition to a decorative result without a prior assessment of the condition of the follicle, cuticle and natural row of eyelashes.

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