Інформаційні технології

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INTEGRATION OF DIGITAL TECHNOLOGIES IN EYEBROW MORPHOLOGY ASSESSMENT AND CORRECTION PLANNING: A NEW ERA IN AESTHETIC MEDICINE

Summary. *The article explores the integration of digital technologies into the assessment of eyebrow morphology and the planning of their correction as a new stage in the development of aesthetic medicine. The aim of the study is to examine the impact of advanced technologies on the eyebrow correction process, taking into account facial morphology, which is understood as the analysis of facial shape, proportions, and symmetry in order to create a personalized image. The study employed general scientific methods of cognition: analysis, synthesis, comparison, modeling, systematization, and generalization. The findings indicate that the modern approach to eyebrow shaping is based on a combination of anatomical knowledge, age-related morphological features, innovative digital modeling, and standardized aesthetic parameters. The interdisciplinary nature of eyebrow morphology is emphasized, as it integrates anatomical, aesthetic, and anthropometric knowledge to enable precise analysis and correction of eyebrow shape while considering individual patient characteristics such as age, gender, ethnicity, and facial structure. It is noted that effective eyebrow shaping cannot be achieved without taking into account the facial morphotype and deep anatomical changes, especially in older patients. The study shows that digital technologies are actively being implemented in the field of eyebrow modeling and correction, with the most significant being: artificial intelligence (AI); augmented*

and virtual reality (AR/VR); 3D printing; 3D photogrammetry; CAD/CAM technologies. AI provides a personalized approach to analysis and modeling, while AR/VR allows real-time testing and visualization of different shape options. 3D printing is used for the creation of customized stencils or models, and 3D photogrammetry enables the acquisition of highly accurate facial parameters. CAD/CAM technologies ensure symmetry in both aesthetic and surgical procedures. The prospects for further development in this field are outlined: implementation of AI-based mobile applications for instant visualization of results; development of biometric models that consider age-related changes; AR technologies for dynamic eyebrow shape fitting; application of 3D scanners to monitor intervention effectiveness; and the use of virtual simulations as a communication tool between specialists and patients. The practical value of the study lies in the implementation of a personalized digital approach to eyebrow correction planning based on scientifically grounded morphological parameters.

Key words: *eyebrow morphology, digital technologies, artificial intelligence, aesthetic medicine, AR/VR.*

Introduction. Aesthetic medicine in the 21st century is increasingly influenced by digital technologies. Whereas eyebrow correction used to rely mostly on the specialist's visual perception and experience, the current focus has shifted toward precise shapes, visualizations, anatomical modeling, and predictive simulations. These advanced technologies contribute to the creation of so-called "beauty standards," which are shaped not only by fashion trends but also by scientific research in facial aesthetics.

Numerous researchers have explored various digital technologies used in aesthetic medicine. For example, Ali A., Zopf D., Green K., Green G., and Reighard C. demonstrated the use of computer modeling and 3D printing for developing anatomical models for surgical simulation. Although their study

mainly focuses on cleft lip surgery, the underlying methodological principles are highly applicable to cosmetic procedures such as eyebrow correction [2].

Augmented and virtual reality are also important technological tools in cosmetology, used not only in corrective treatments but also in facial plastic surgery. Chou D., Annadata V., Willson G., Gray M., and Rosenberg J. highlight how augmented reality enables the overlay of virtual models onto anatomical structures, providing specialists with necessary reference points when working with individual patients. These technologies also help reduce anxiety among both patients and professionals performing the procedures. This technological toolkit opens new possibilities for preoperative planning and aligning the visual outcome with patient expectations [3].

Artificial intelligence, one of the leading technologies of the last decade, has also found wide application in cosmetology. Duong T., Vu P.T.V., and Hung T. show that machine learning and deep neural networks allow the processing of large sets of medical images, which in turn supports the generation of personalized outcome predictions [4].

In aesthetic cosmetology, digital modeling outcomes can be applied to plan the shape and positioning of eyebrows while taking into account individual morphological features. This becomes especially critical in cases of noticeable facial asymmetry. Most modern standards and approaches to eyebrow correction are designed for symmetrical faces, so dealing with non-standard cases requires extensive experience and solid methodological training. In order to make asymmetry less noticeable, the specialist's work must be carefully planned, adhering to standards while accounting for the specific features of the face and the unique nature of the task.

Considering the growing number of women seeking eyebrow correction every year, this topic is gaining particular relevance. The practical significance of the study is further emphasized by the large number of specialists on the market who lack the proper experience and are not always capable of making the right

decisions in atypical situations. In such cases, digital technologies empower professionals to act with greater confidence, ultimately reducing dissatisfaction among clients.

The integration of digital technologies into the assessment of eyebrow morphology and the planning of corrections is well covered in international academic literature. However, domestic studies are absent from the reference list, highlighting the dominance of foreign scientific perspectives in this field. This underscores the need to adapt and analyze international experience to develop national practices.

The study by K. Gomes et al. [7] emphasizes the importance of virtual planning in addressing facial asymmetry, which is crucial for eyebrow modeling. The work of W. Hashimoto and S. Kaneda [8] presents a personalized mobile app for facial aesthetic evaluation, which can also be applied to eyebrow morphology assessment. Research by S.-H. Kwon and colleagues [9] demonstrates how 3D photogrammetry can be used to analyze age-related changes, a relevant factor in eyebrow correction planning. M. R. Markiewicz and R. B. Bell [10] provide a broad overview of 3D tools in facial plastic surgery, establishing a methodological foundation for digital planning.

An especially innovative contribution is the study by E. Nguyen and S. Htin [12], which introduces a regression-based algorithm for automated facial beauty optimization, opening the door to automated eyebrow shape analysis and design. E. Palermo et al. [13] illustrate a 3D approach to patient aesthetic evaluation, while J. Sainthillier and colleagues [14] explore the role of digital photography in dermatology, which remains a cornerstone in morphological analysis.

Despite the substantial volume of literature on this topic, there is a lack of systematized material directly focused on the subject of this study. Therefore, using various scientific cognition methods, the available information has been analyzed, grouped, and systematized in light of the research theme.

The purpose of this article is to examine the impact of advanced technologies on the eyebrow correction process, taking into account facial morphology, which is understood as the analysis of shape, proportions, and symmetry to create a personalized appearance. The article discusses key innovations such as artificial intelligence for brow mapping; augmented reality for virtual try-on; 3D printing of stencils; and robotic follicle transplantation, all of which are transforming traditional beauty procedures. Special attention is given to the analysis of practical case studies involving the use of these technologies in leading studios and companies, along with an evaluation of future developments toward even greater personalization, precision, and user convenience.

Research results. The shape of the eyebrows is not only an aesthetic feature but also an anatomical structure that directly influences the perception of age, emotional expression, and overall facial symmetry. It forms a key part of the upper third of the face and has a complex structure that includes muscles, fat compartments, ligaments, and skin. This is why understanding eyebrow morphology requires both a cosmetic and anatomical perspective.

Certain standards for eyebrow shaping have developed not only under the influence of fashion but also through numerous anthropometric studies. By analyzing differences between the faces of beauty pageant contestants and average young women, Kwon S.-H. and colleagues identified patterns that align with the general concept of harmonious features: a higher arch, a defined lateral peak, and symmetrical positioning in relation to the glabella and orbital axis [9].

The key morphological principles are systematized in Table 1.

Table 1

Basic principles of eyebrow morphology in aesthetic medicine

№	Morphological parameter	Criterion or rule	Comment
1	Starting point of the brow	Vertically from the medial canthus or the wing of the	Responsible for the openness of the gaze; defines visual balance

		nose through the inner corner of the eye	between the brows and the interocular distance
2	Brow peak or arch	Above the line drawn from the wing of the nose through the center of the pupil	Creates expressiveness and affects the impression of emotions (surprise, youthfulness, fatigue)
3	Brow tail (end point)	On the line from the wing of the nose through the lateral edge of the eye	Should not fall below the starting point of the brow to avoid a "sad" facial expression
4	Arch angle	Ideally: the arch rises 10–25° relative to the horizontal	An exaggerated angle appears artificial; absence of an angle indicates age-related changes
5	Brow thickness	Thickest in the medial part, gradually thinning toward the tail	Must be balanced with other facial features; overly thin brows signal aging, overly thick – vulgarity
6	Symmetry	Mirror reflection, while accounting for natural facial asymmetry	Perfect symmetry is not the goal; visual harmony is what matters
7	Distance from the eyes	The space between brows and eyes should maintain an open gaze without overhang	Especially relevant in age-related upper eyelid ptosis
8	Consistency with face shape	Brow shape should match the overall geometry of the face: oval, round, triangular, etc.	Helps visually balance facial proportions

Note: systematized by the author based on the study by Palermo E., Anzai A., Jacomo A. [13]

It is worth noting that eyebrow morphology is significantly influenced by age, gender, and ethnicity. As Palermo E. and colleagues emphasize, aging leads to volume loss in the upper third of the face, reduced skin elasticity, and changes in the density of fibrous structures – creating new challenges for aesthetic medicine specialists. Particular attention must be paid to the area where the brow anchors to the bony base, which loses tone due to resorption of the frontal and zygomatic bones [13]. Additionally, Kwon S.-H. et al. point out that aging results in volume reduction in the supraorbital area due to lipoatrophy, along with caudal displacement of the temporal fat compartments. This contributes to brow ptosis, loss of definition, and structural support [9]. At the same time, facial bone contours of the orbit gradually expand, leading to soft tissue ptosis, including the

lateral part of the brow. Therefore, in mature patients, eyebrow correction should consider both surface and deep anatomical changes.

Eyebrow design should rely not only on the specialist's intuition but also on a systematic anatomical analysis.

In modern aesthetic medicine, there is a clear trend toward integrating advanced digital technologies into the practice of modeling and correcting eyebrow morphology. One of the most essential technologies is computer-aided design (CAD) combined with 3D printing. In the study by Ali A. et al., the creation of physical models for surgical simulation based on individual patient data was demonstrated, enabling highly accurate visualization of how procedures affect the spatial architecture of tissues [2].

Another important area involves augmented reality (AR) and virtual reality (VR), which, according to Chou D. et al. [3], are actively used to overlay virtual models onto real anatomical areas, allowing real-time evaluation of potential eyebrow correction outcomes. AR also serves as a navigation system, while VR is used to train professionals and reduce patient anxiety [3]. One example of advanced integration is the work of ModiFace – a leader in AR for the beauty industry. Its technology enables users to virtually "try on" different eyebrow products in real time, selecting the most suitable option using live images or video [11].

Artificial intelligence (AI) and deep learning (DL) technologies have opened new possibilities for individualized planning. Duong T., Vu P.T.V., and Hung T. have shown that AI algorithms can be used to create personalized correction models, taking into account both anatomical parameters and the patient's aesthetic preferences. These simulations significantly improve pre-procedural communication and help establish realistic expectations [4]. Studios such as Brow De Art Studio use AI systems to scan the face, analyze proportions, and automatically generate the most harmonious, symmetrical, and personalized

brow shape. This greatly increases accuracy and eliminates the need for manual measurements, resulting in a more natural and balanced appearance [15].

A key technique in morphological analysis is 3D photogrammetry, which, according to Kwon S.-H. et al., allows for facial anatomy reconstruction with up to 1 mm accuracy, capturing dynamic age-related changes in the upper third of the face, including the brow area. This is especially relevant for planning procedures with consideration for age-related norms [9]. An example of innovation is the 3D shu:brow solution developed by L'Oréal and shu uemura. This technology combines high-resolution 3D printing (up to 1200 dpi) with ModiFace's AR facial recognition system, enabling users to create ideal 3D brows at home with personalized recommendations based on facial shape [1]. Another common practice is the use of 3D stencil models for brows, available on specialized platforms such as Yeggi. These models can be downloaded and printed at home, allowing precise brow shaping for makeup or microblading tailored to individual features [6].

Another example is the use of CAD/CAM technologies in surgery, described by Markiewicz M.R. and Bell R.B., which enable virtual modeling of a symmetrical supraorbital structure through mirrored analysis of the healthy side. This is especially useful for correcting asymmetric brows [10].

In cases where physical brow reconstruction is required, robotic systems such as ARTAS Robotic-Assisted FUE are employed. These systems enable precise follicular unit extraction without creating a linear scar, which is particularly important for eyebrow transplantation after injuries or scarring. The technology ensures a short healing period and high-quality results [5].

The key digital technologies used in eyebrow morphology analysis and correction planning are summarized in Table 2.

Table 2

Digital technologies used in morphological analysis and eyebrow correction planning

№	Technology	Description
1	Computer-aided design (CAD) and 3D printing	Creation of precise 3D anatomical models based on individual patient data for simulating eyebrow procedures [2]
2	Augmented reality (AR) and virtual reality (VR)	Overlaying virtual eyebrow models onto the real face for visualization and shape adaptation, as well as simulation-based training [3]
3	Artificial intelligence and deep learning (AI/DL)	Automated analysis of eyebrow morphology considering aesthetic patterns and modeling the desired outcome [4]
4	3D photogrammetry	Accurate registration of age-related and structural changes in the upper third of the face for personalized planning [9]
5	Digital navigation (CAD/CAM)	Virtual creation of symmetrical supraorbital models for precise surgical or cosmetic interventions [10]

Note: systematized by the author based on sources [2, 3, 4, 9, 10]

The application of modern digital technologies in eyebrow morphology enables a high degree of individualization, precision, and predictability in aesthetic procedures. Their implementation not only expands the professional toolkit but also enhances communication with patients, particularly in cases involving complex anatomical or age-related variations.

In the near future, eyebrow morphology is expected to become one of the most dynamic areas for the use of digital technologies in aesthetic medicine. What makes it unique is that even minor changes in eyebrow shape, position, or symmetry can significantly affect overall facial perception. For this reason, technologies that provide micro-anatomical accuracy, a high level of personalization, and evidence-based approaches are becoming increasingly important.

One of the leading directions in development is the integration of artificial intelligence with visual modeling technologies. Based on deep learning algorithms, systems are already being developed that can recognize complex

patterns of attractiveness and automatically generate personalized recommendations for eyebrow shape and position according to facial morphotype, cranial anatomy, and even ethnic features [4, 10]. In the future, such systems may be integrated directly into mobile applications, allowing for real-time pre-evaluation and visualization of results on a smartphone screen.

Another promising direction is the use of augmented reality (AR) for dynamic pre-procedural testing. For example, when a patient wears AR glasses or activates a smartphone camera, the system instantly overlays virtual brows with various shapes, arches, or heights onto the real face. This makes it possible not only to visualize potential outcomes but also to collect subjective client feedback before the procedure, increasing their involvement in the planning process [3].

The use of 3D photogrammetry is also expected to expand in the daily practice of cosmetologists and brow artists. Instead of relying on subjective assessments of symmetry, specialists will be able to use portable 3D scanners or even smartphones with appropriate apps to accurately measure parameters of the brow region. This will allow for dynamic monitoring of post-procedural changes, assessment of the effectiveness of injections or skincare products, and documentation of the entire correction process [10].

Another area of development involves biometric modeling based on age and gender morphology. It is known that aging causes a complex restructuring of facial anatomy, including the brow region: lipoatrophy, fat pad displacement, bone remodeling, and more [8]. In the future, large biobanks of age-specific 3D facial models may be created, allowing systems to automatically suggest eyebrow shapes that appear "younger" while remaining anatomically and age-appropriate.

Special attention should be given to ethical and communicative aspects. By using virtual simulations based on real images of the patient, specialists will be able to have clearer, evidence-based discussions with clients about expected

outcomes, demonstrate options, and set realistic expectations. This will reduce the risk of dissatisfaction and build trust in the patient-practitioner relationship.

Therefore, the future of eyebrow morphology lies in the synthesis of aesthetics, engineering precision, and neural network analytics. The introduction of digital technologies is not only transforming the tools available to professionals but also redefining the approach to aesthetic procedures – from an art form to a scientifically grounded, personalized model of action.

Conclusions. The modern approach to working with eyebrow shape is based on the synthesis of anatomical knowledge, age-related morphology, digital modeling, and standardized aesthetic parameters. Eyebrow morphology is an interdisciplinary field that combines anatomical, aesthetic, and anthropometric knowledge for the accurate analysis and correction of eyebrow shape, considering age, gender, ethnicity, and individual facial structure. Modeling in this context requires precise analysis of facial morphotype and an understanding of deep anatomical changes, particularly in older patients.

The field of eyebrow modeling and correction is increasingly integrating innovative digital technologies. The most significant among them include: artificial intelligence (AI) for personalized analysis and modeling; augmented and virtual reality (AR/VR) for real-time visualization and shape testing; 3D printing for creating customized stencils or anatomical models; 3D photogrammetry for highly accurate structural measurements; and CAD/CAM technologies for symmetrical surgical or aesthetic interventions. These solutions are already being used in both clinical and cosmetic practice, including studios such as Brow De Art Studio and technologies from companies like L'Oréal, ModiFace, and Bauman Medical.

The future of eyebrow morphology opens new directions: from AI-based mobile apps for instant result visualization to the creation of biometric models that account for age-related changes and offer evidence-based recommendations. AR technologies will enable dynamic shape "try-ons", 3D scanners will ensure

precise monitoring of intervention effectiveness, and virtual simulations will serve as tools for ethical communication between specialists and patients.

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