Other

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INVESTIGATION OF OPTIMAL HARDWARE PARAMETERS AND NEEDLE CONFIGURATIONS IN ORDER TO MINIMIZE MICROTRAUMA TO THE SKIN DURING PERMANENT MAKEUP

Summary. *Permanent makeup is one of the most sought-after cosmetic procedures. However, despite its popularity, there is a problem of skin microtrauma, which can occur due to incorrect choice of device and needle parameters. In this article, we will look at the key factors affecting the safety and effectiveness of permanent makeup. These factors include the diameter and configuration of the needles, the length of their tips, as well as the depth and rate of penetration of the pigment. Assessing the effect of these parameters on the skin and ways to optimize them will help minimize tissue damage and improve the safety of procedures. The article will provide recommendations for improving permanent makeup technologies, including the use of more accurate devices, optimizing needles, and developing better pigments.*

Key words: *permanent makeup, skin microtrauma, optimization of devices, needle configuration, pigmentation, safety, cosmetology.*

Relevance of the study. Permanent makeup is one of the most sought-after cosmetic procedures, which is gaining more and more popularity among clients every year. However, despite the high demand, the problems associated with microtrauma of the skin during the application of permanent makeup remain unresolved. Microtrauma, which can lead to irritation, inflammation, and even

damage to the skin, remains a serious challenge for both specialists and clients. Therefore, optimizing the parameters of the device and needle configuration becomes the most important task, the solution of which directly affects the safety of the procedure and the quality of the result.

The inability or low efficiency of optimizing these parameters can lead to an increased risk of skin damage, which, in turn, reduces the credibility of this service. In addition, insufficient attention to setting up equipment and tools can cause increased pain sensitivity, a prolonged recovery period, and even complications.

Thus, optimizing the parameters of devices and needle configurations to reduce skin microtrauma during permanent makeup is an important area for the development of cosmetology technologies and improving the safety and quality of procedures. Developing effective and safe methods to optimize this process will help strengthen customer trust and improve the reputation of the industry as a whole.

The purpose of the study. The purpose of this study is to identify the key factors influencing skin damage during permanent makeup and to develop recommendations for their elimination. This will make the procedure safer and better.

Materials and research methods. In the course of the study, we examined various types of permanent makeup devices and needles, as well as studied information from scientific and professional sources on how these factors affect skin microtrauma.

We conducted a comparative analysis of the characteristics of the equipment and needles, as well as studied existing technologies and recommendations for their use in cosmetology.

The results of the study. Permanent makeup (PM) is a cosmetic procedure in which a coloring pigment is injected into the upper layers of the skin. Its purpose is to create a lasting decorative effect, as well as to adjust the shape and

color of eyebrows, lips or eyes. PM is often confused with tattooing, but these procedures vary in the depth of pigment injection and the materials used. In PM, the paint is located closer to the surface of the skin, which allows it to fade gradually over time. This, in turn, reduces the risk of noticeable scarring, unlike a classic tattoo [2].

During the procedure, an apparatus is used that, like a fountain pen, writes on the skin, repeatedly piercing it and injecting pigment into the dermis. Electric devices for permanent makeup can be of two types: rotary and induction (coil). They differ in the principle of needle movement, stability, and vibration level, which, in turn, affects the depth of dye injection and, as a result, the degree of skin injury.

Micropigmentation offers a variety of techniques to achieve the desired result. The classic hardware method allows a specialist to precisely control the depth and density of pigment application, which makes it preferable for most areas of the face. Manual techniques such as microblading are performed without the use of a machine, using a fine needle and a manipulator. However, this method can be more traumatic due to the high mechanical stress on the tissues [3].

The coloring pigments used in permanent makeup have a unique shape that ensures their stability and durability, while reducing the risk of tissue reactions. Unlike traditional tattoo dyes, these pigments and their formulations are created specifically for cosmetic purposes. They provide a natural visual effect and gradually disappear without causing serious complications.

One of the key factors influencing the technique and safety of the permanent makeup procedure is the anatomical features of the skin. The skin consists of two layers: the epidermis and the dermis. The pigment should be injected primarily into the papillary layer of the dermis, which is located approximately 1.0 - 2.0 mm below the surface of the skin. This allows the paint to last long enough without causing severe injury to the tissues. If the penetration depth is lower, the pigment will be removed along with the natural renewal of the

epidermis. If it is larger, there is a risk of vascular damage, increased bleeding, scarring or "spill" of paint in deeper layers.

Below is Table 1, which describes the main characteristics of the needles used in permanent makeup and their effect on the skin treatment process.

Table 1

The main parameters of needles used in permanent makeup

Needle Parameter	Description	Effects on skin and injury
Diameter (mm)	Needle thickness size	Thinner needles (0.18–0.25 mm) allow you to make a less noticeable incision and work more accurately, but they require some experience. At the same time, thicker needles (>0.30 mm) provide faster pigment injection and make the procedure more comfortable for the skin.
Configuration (grouping)	The location of the needles in the cartridge	Narrow configurations provide high detail, while wide ones provide uniform filling, but can increase overall injury.
Length of the point	Needle cone length	The long pointed cone causes less injury, but the pigment is injected more slowly. The short cone allows the pigment to be injected faster, but at the same time increases the risk of damage.
Needle position (central/eccentric)	Displacement of the needle inside the cartridge	The centered position usually ensures uniform feeding, while the eccentric position provides additional flexibility in operation, but requires careful control to minimize damage.

Source: author's development based on [5]

After analyzing the main characteristics of the needles, such as diameter, configuration, length of the tip, and location in the cartridge, it is important to move on to a deeper understanding of their interaction with the skin during puncture. This will help to link the choice of needle and operating modes of the device with the biomechanics of the puncture, the depth of pigment injection and, as a result, reduce the risk of microtrauma and ensure a more stable result. The following figure shows a diagram of needle penetration through the epidermis

into the dermis and shows the relationship between penetration depth and pigment retention.

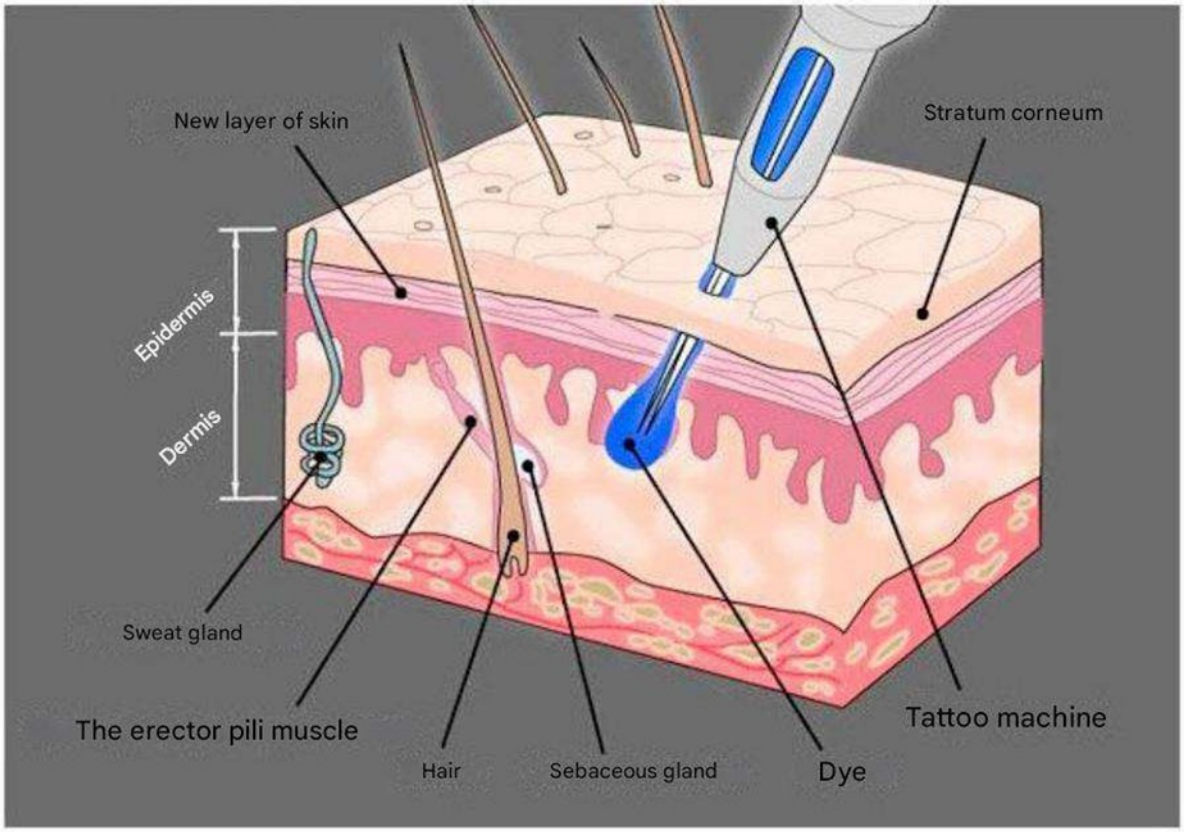

Fig. 1. Diagram of needle penetration through the epidermis into the dermis and the relationship of depth with pigment retention [1]

Permanent makeup, like any other cosmetic procedure involving the mechanical action of needles on the skin, inevitably leads to microtrauma. However, proper selection of the parameters of the device and needles, as well as proper working technique, can minimize this microtrauma, reduce inflammatory reactions and speed up the healing process. Modern permanent makeup machines, equipped with functions for adjusting the frequency of strokes, the amplitude of the needle stroke and depth control, significantly increase the safety and accuracy of the procedure compared to traditional methods.

Permanent makeup machines are special electrical devices that serve for the controlled and repeated injection of pigment into the upper layers of the skin. The design and performance characteristics of these devices directly affect the

puncture depth, the uniformity of pigment distribution, and the level of skin microtrauma. Rotary machines, known as pen-formats, are currently the most popular. This is confirmed by the technical descriptions of manufacturers and professional distributors. These devices are compact, have a low vibration level and can be precisely adjusted for operating parameters, which is especially important when working with sensitive areas of the face.

The main characteristics of permanent makeup devices include the length of the needle stroke, the speed of its reciprocating motion, the stability of the engine and the mechanism for adjusting the needle departure. The length of the needle stroke affects the amplitude of its movement and is directly related to the nature of the effect on the tissue. The technical documentation and training materials indicate that devices with a shorter stroke length provide a softer and more controlled penetration. In turn, increasing the stroke length allows you to increase the intensity of the pigment supply, but requires more careful control of the technique to avoid excessive injury to the skin.

An equally important aspect is the stability of the motor and the uniformity of needle movement. Modern machines are equipped with precise electric motors that maintain a constant needle speed, even if the resistance of the tissues changes. This avoids sudden changes in the depth of the puncture, which can lead to damage to the vessels of the dermis and increase the inflammatory response. Professional reviews note that reducing vibration and backlash in the needle node is one of the key factors that increase the safety of the procedure.

The needle departure adjustment system plays a key role in the permanent makeup process by setting the initial penetration depth relative to the skin surface. In pen-type devices, adjustment is usually carried out by turning the cartridge holder, which allows you to set the reach in the range from fractions of a millimeter to several millimeters. However, the actual penetration depth is determined not only by the set value, but also by a combination of other parameters such as stroke length, operating speed, and skin tissue resistance. That

is why the professional literature focuses on the need for comprehensive device configuration, taking into account the anatomical features of the treated area.

Table 2 shows the main characteristics of permanent makeup devices, which are mentioned in open technical specifications and professional sources.

Table 2

The main parameters of permanent makeup devices

Device Parameter	Characteristic	Effect on skin microtrauma
Needle stroke length, mm	Usually in the range of 2.5-4.0 mm	With deeper penetration, the puncture force increases and the risk of injury in the event of a violation of the technique.
Needle operation speed	Depends on the motor and the supply voltage	Uneven speed can lead to uneven tissue damage.
Adjusting the needle departure	Mechanical or combined	It allows you to control the depth of penetration and reduces the risk of skin damage.
Vibration level	Design characteristics of the device	Increased vibration leads to an increase in the area of microtrauma.
Type of drive	Rotary	Allows the needle to move more smoothly and precisely.

Source: author's development

Needle configuration plays a key role in the permanent makeup process, as it directly affects the quality and safety of the procedure. Permanent makeup needles differ in several important ways: shape, thickness, length, as well as the number of needles in the cartridge. There are, for example, single-needle, double-needle, and polyhedral configurations. All these parameters are crucial for minimizing skin microtrauma. Improper needle selection can lead to excessive tissue damage, inflammation, or even scarring [4].

One of the key factors to consider is the shape of the needle. Needles can have different configurations: straight, curved or angled. Straight needles are usually used for contouring, as they create a clear line that minimizes blurring of

the pigment. Curved and angled needles, in turn, are used in milder techniques such as shading, where a more gentle effect on the skin is required. Studies have shown that needles with angular and curved configurations exert less pressure on tissues, which in turn reduces skin injury and minimizes the risk of complications. This is because these needles evenly distribute the pigment without hitting the same spot, which makes the procedure less painful and safer.

Table 3 clearly shows the effect of the needle shape on the pigmentation process.

Table 3

The effect of needle shape on pigmentation process

Needle Shape	Type of exposure	Effect on skin microtrauma
Straight needle	Precise line, contours	High accuracy, but there is a risk of skin damage due to high pressure at one point.
Curved Needle	Soft shading	The pressure on the skin will be less, the pigment will be distributed more evenly, and the risk of injury will be lower.
The angular needle	Small details, shading	Promotes uniform application of paint with minimal injury to the skin. Perfect for shading.

Source: author's development

The number of needles in the cartridge also has a significant impact on the level of microtrauma. The needles arranged in groups in the cartridge ensure an even distribution of pressure on the skin, which avoids the concentration of force in one area and, as a result, reduces tissue damage. For example, multifaceted configurations containing 3 to 9 needles in a cartridge can have a softer and uniform effect on the skin when performing shading techniques. However, an increase in the number of needles can lead to a decrease in accuracy when working with small parts. Therefore, when choosing the needle configuration, it

is important to take into account both the general operating requirements and the specific accuracy requirements.

In addition to the thickness and number of needles, it is also important to pay attention to their length. The length of the needles directly affects the depth of pigment penetration into the skin. Standard permanent makeup needles have a length of 1.5 to 2.0 mm, which allows the pigment to be placed in the papillary layer of the dermis. However, if the depth of pigment injection is not adjusted properly, for example, due to incorrect needle insertion, this can lead to various undesirable consequences. The pigment can be injected too deeply, which can cause its migration or unnatural color shades, or too superficially, which will lead to rapid disappearance.

To improve the technology of permanent makeup, we can offer several recommendations:

1. Optimization of devices. Development and implementation of more precise and adjustable devices that will control the speed and amplitude of needle movement. This will minimize skin damage and ensure a more even distribution of pigment.

2. Improving needle configuration. Creation of needles with improved characteristics that will minimally injure tissues, while ensuring high-quality pigment application. For example, using more flexible and coordinated needles will allow for a uniform effect on the skin.

3. The use of innovative pigments. The development of pigments with a longer color retention period, which will not have a negative effect on the skin. In addition, the creation of pigments adapted to different skin types will achieve a more natural result.

4. Specialist training. Professional development of artisans through specialized courses and master classes is not only an opportunity to master new technologies, but also a guarantee of the safety of procedures.

5. Quality and safety control. The introduction of safety standards and certification for equipment and materials used in permanent makeup is not just a formality, but also a way to ensure that clients can safely perform procedures with minimal risk to their skin health.

6. Innovative techniques. Research and implementation of new methods, such as digital technologies and computer modeling, can improve the accuracy of pigment application and minimize skin microtrauma, which in turn contributes to a more natural result.

Conclusions. Permanent makeup is rapidly gaining popularity among clients, however, despite this, issues related to microtrauma to the skin remain important for both specialists and clients. The study found that the main factors determining the level of injury are the technical characteristics of the devices and the shape of the needles. These parameters have a direct effect on the depth of penetration of the pigment, the uniformity of its distribution and, as a result, on the degree of tissue damage.

Optimizing these factors is key to reducing skin microtrauma, improving the safety of procedures, and improving their results. The development of permanent makeup technologies, including the creation of more precise and adjustable devices, improved needle configuration and the introduction of innovative pigments, helps reduce risks and strengthen customer confidence.

The implementation of the proposed recommendations will make permanent makeup procedures safer and more effective, providing high-quality skin care and increasing the professionalism of the artisans. Thus, further research and development in this area will be aimed at further improving permanent makeup technology and ensuring a high level of safety in cosmetology practice.

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