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COMBINED METHODS OF TATTOOS AND PERMANENT MAKEUP REMOVAL: LASER AND ADJUVANT TECHNOLOGIES

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Abstract
This paper analyzes modern methods of laser tattoo and permanent makeup removal, highlights the advantages of combined techniques, and discusses their practical application, as well as the risks and limitations. The focus is on individualizing the approach, selecting laser parameters, and adjuvant therapy strategies to maximize effectiveness and minimize complications.

Keywords: Laser tattoo removal, permanent makeup, Q- Switched laser, picosecond laser, fractional ablation, combination therapy, pigment complications.

Introduction

The scientific novelty of the article: a systematic analysis of combined methods of laser removal of tattoos and permanent makeup with an emphasis on fractional ablation and adjuvant technologies to increase efficiency and reduce complications.

As the prevalence of decorative tattoos and permanent makeup procedures increases, so does the need for high-quality removal. At the same time, the complexity of this task increases due to the variety of pigments used (including those containing metals and oxides), the depth of placement, the density of application, and the presence of scarring from previous procedures or ink application. These circumstances place increased demands on removal techniques and motivate the development of combined (adjuvant) approaches.

Early tattoo removal methods included surgical excision, dermabrasion, cryosurgery, and the use of acids/chemicals, but these carried a high risk of

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scarring and often produced unsatisfactory results. The rise of laser technology represented a major breakthrough: the use of the principle of selective photothermolysis. made it possible to destroy pigment particles with minimal damage to surrounding tissues. In the article " Lasers for tattoo removal: a review » it is noted that Q - Switched lasers are most frequently used (for example, Ruby 694 nm, Alexandrite 755 nm, Nd : YAG 1064 nm /532 nm) [1].
Modern research shows that picosecond lasers can provide shorter pulses and, consequently, an enhanced photoacoustic effect, which increases the efficiency of pigment removal, especially for "difficult" colours [2].
However, even with modern lasers, it is not always possible to achieve complete removal or avoid complications: especially in cases of multi-color tattoos, the presence of scars, metal oxide pigments, or after unsuccessful removal attempts. One scientific study found that, despite the advantage of picosecond lasers, there remains significant variability in outcomes and there is no single universal scheme [3]. In addition, the study " Pitfalls" in tattoo removal " emphasizes that the effectiveness of the achievement depends not only on the laser, but also on many factors: skin phototype , type and depth of pigmentation, previous procedures, correct choice of laser parameters and adequate preparation/care [4]. Thus, there is a need to systematize combined approaches, including, for example, fractional ablation, preparatory and stimulating post-procedure techniques, to optimize results and reduce risks. The aim of this study is to analyze modern laser techniques for tattoo and permanent makeup removal, with a particular emphasis on combined and adjuvant technologies.
Laser tattoo and permanent makeup removal is based on the fact that ink (pigments) in the skin absorb laser light of a specific wavelength, which then destroys the pigment particles and removes them from the tissue. One of the key concepts is the theory of selective photothermolysis: if the laser pulse duration is less than or equal to the thermal relaxation time (TRT), Relaxation Time (TRT) of the target chromophore (pigment), and if the wavelength is chosen correctly, it is possible to damage the pigment without significant damage to surrounding tissue. In the article " Laser" Treatment of Tattoos : Basic Principles » notes that

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despite the classical model of selective photothermolysis, in the case of tattoo pigments, nonlinear and acoustic effects are also involved [5].

The mechanisms of pigment destruction may be as follows:

1. Thermothermal (photothermal) destruction. When the laser pulse is absorbed by pigment particles, they heat up: if the pulse is short enough, the heat does not have time to dissipate in the tissue, and the particles heat up quickly and locally. This leads to their destruction or significantly facilitates their fragmentation [6].
2. Photoacoustic (photomechanical) destruction. At very short pulses (nanoseconds, picoseconds), rapid expansion and/or cavitation occurs around the pigment particle, which generates an acoustic wave or shock wave, mechanically breaking the particle. For example, for pulses of the order of 5-100 ns, explosive destruction of the pigment is observed with Q - switched lasers due to the photoacoustic effect [7].
3. Phagocytosis and removal. After the destruction of pigment particles (thermally or acoustically), small fragments remain. These fragments are captured by macrophages, transported to the lymphatic system, and gradually removed from the treatment area [7].

The effectiveness of laser tattoo and permanent makeup removal is determined by many factors:

1. Laser wavelength: Different ink colors absorb different wavelengths. For example, black and dark blue inks absorb 1064 nm , red and orange inks absorb 532 nm , and so on.
2. Pulse duration. The shorter the pulse (especially picoseconds), the more effective the pigment destruction and the less thermal damage to surrounding tissue. For example, simulations show that the optimal pulse duration is ~10-100 ps for pigment fragmentation with minimal fluence.
3. Fluence (energy per area) and spot size: high energy density and appropriate spot size help to achieve the desired penetration depth and pigment fragmentation.
4. The depth and concentration of the pigment. The deeper and denser the pigment, the more difficult it is to remove.

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5. Ink type and pigment composition: Some pigments contain metals or oxides that may absorb the laser less effectively or form permanent fragments.

Table 1 - The main mechanisms of pigment destruction during laser removal and key influencing factors

Mechanism / factor	Description	Practical significance
Selective photothermolysis	Laser pulse is smaller than the TRT of the target chromophore → minimal damage to surrounding tissues.	Requires correct selection of pulse duration and wavelength.
Photoacoustic destruction	Very short pulse → acoustic/ cavitation wave → destruction of pigment particle.	Particularly effective for dense/deep and difficult to remove pigments.
Fragmentation + phagocytosis	The broken particles are captured by macrophages and removed lymphatically .	After the procedure, an interval for immune clearance is required.
Laser wavelength	Different colors absorb different waves.	Selecting the right wavelength for the pigment color is key.
Pulse duration	The shorter, the less heat damage.	Picosecond lasers are preferred.
Depth of occurrence / density	Deep or dense pigment is more difficult to remove.	More sessions and/or a combination approach may be required.
Ink composition	Metals/oxides may change behavior when exposed to laser radiation.	An ink assessment and possible adjustment of strategy is required.

Modern research demonstrates the advantages of picosecond lasers: they provide shorter pulses and an enhanced photoacoustic effect than traditional Q- switched (nanosecond) lasers, resulting in more efficient pigment fragmentation with less thermal damage. One study noted that, despite technological advances, challenges remain: some pigments are difficult to remove due to their composition or depth, requiring more precise parameter adjustment and individualized therapy [5].
Understanding the mechanisms of laser pigment removal, photothermal, photoacoustic and subsequent phagocytosis, as well as factors influencing

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effectiveness (wavelength, pulse duration, pigment composition, etc.) allows for a more informed selection of a therapeutic strategy.

Despite significant advances in laser pigment removal, standard techniques (such as using only a QS or picosecond laser) often face challenges: dense or deep pigment deposits, the presence of scar tissue, the use of metal oxide dyes, and the limited ability of tissue to remove pigment fragments. In such cases, combined and adjuvant approaches become relevant because they allow:

- create additional channels for the exit of pigment fragments (for example, through fractional ablation);
- improve the penetration and effectiveness of laser treatment by preparing the skin or using methods that stimulate tissue remodeling ;
- reduce the number of sessions and reduce side effects with the right combination of techniques (for example, fractional + laser).

The main directions of combined and adjuvant methods include:

1. Fractional ablative skin preparation. The use of lasers that create microablation (e.g., Er : YAG , CO_2) to create microchannels through which pigment fragments are more easily removed and/or to improve the structural condition of the dermis. Thus, in an experimental model, removal of a cosmetic tattoo was performed using CO_2 fractional ablation and showed good results [8].
2. Combination of fractional ablation and then laser pigment removal: For example, a study compared the combination method (fractional 1064 nm picosecond + conventional 1064 nm picosecond) and the conventional method alone; the combination side showed better results [9].
3. Use of adjuvant technologies to stimulate healing and tissue remodeling : For example, the use of platelet-rich plasma (PRP) after ablative procedures to improve skin quality and reduce the risk of complications [10].
4. Use of additional optical or "support" agents: One example is a study with 15 combinations of lasers and a patch agent (perfluorodecalin) for tattoo removal, in which the combinations were found to be more effective [11].

In 2022, a study of 19 tattoos in 11 patients was published: the combination of fractional 1064 nm picosecond laser and conventional 1064 nm picosecond laser showed >50% clearance in 84.6% of tattoos, while the conventional method alone

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showed >50% clearance in 69.2% [9]. In a series of 10 patients/13 tattoos, the Frac - Tat® (microdrilling + Q - Switched) method showed an average clearance of up to 97% after a median number of sessions of 4.85, which was approximately 40% fewer sessions than would be calculated using the standard Kirby - Desai scale [7]. A study on combination therapy (fractional CO 2 + nanosecond Q -1064 nm laser) for traumatic tattoos noted not only pigment removal but also improvement in scar skin texture [12].

Table 2 - Methods of combined and adjuvant removal of tattoos/permanent makeup

Method	**Mechanism of action**	**Clinical data and features**
Fractional ablative laser preparation (Er:YAG , CO_2)	Creation of microablation /channels → improved pigment yield and penetration	EP -animal study: CO_2AFR treatment of white/dense tattoo gave good results.
Combination of fractional priming and subsequent laser removal	Priming : removal of part of the pigment + creation of a channel → laser: fragmentation mainly	2022 -study: combination group 84.6% clearance vs 69.2% in monotherapy .
Micro -drilling + multi-pass QS -laser (e.g. Frac -Tat ® method)	Ablative tissue fragmentation + deep pigment fragmentation, improving skin texture	Average clearance up to 97% in ~4.85 sessions; fewer sessions.
Combination of laser removal + stimulation of healing (eg PRP)	Acceleration of remodeling , improvement of skin structure, reduction of complications	Research on PRP + fractional CO_2 in scar therapy is promising; direct data specifically for tattoos is still limited.
Use of additional agents + laser (eg PFD -patch + laser)	Improving the laser effect by reducing the scattering layer and improving pigment removal	A study with 15 combinations found that the best combination was picosecond lasers + fractional CO_2 without a patch .

Therefore, combined and adjuvant techniques for tattoo and permanent makeup removal represent a logical and justified extension of traditional laser approaches. Clinical studies demonstrate that the addition of fractional ablation, skin preparation, stimulation of healing, or a combination of different laser types can improve removal results, reduce the number of sessions, and improve skin quality in the treatment area.

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For successful tattoo and permanent makeup removal using combined techniques, it's important to consider the patient's individual characteristics, pigmentation characteristics, and skin condition. Based on a literature review, we've developed key recommendations and a procedure planning algorithm.
Practical recommendations:

1. Patient and tattoo assessment:
- determine the type and depth of pigment, color, application density;
- assess the skin phototype, the presence of scars and textural disorders;
- take into account previous removal attempts and possible complications.

2. Selection of laser technique and parameters:
- select the wavelength and pulse duration taking into account the color and composition of the pigment;
- determine the fluence and spot size for optimal depth of exposure;
- in complex or scarred areas, consider fractional ablation or other adjuvant methods.

3. Scheduling sessions and intervals:
- the interval between sessions should ensure the removal of destroyed pigment particles and skin restoration (usually 4–8 weeks);
- monitor the skin condition after each session and adjust parameters if necessary.

4. Post-procedure care:
- provide hydration and protection of the treated area from sun exposure;
- if necessary, use methods to stimulate healing and skin remodeling ;
- inform the patient about possible reactions: redness, swelling, short-term darkening of the pigment.

Combined approach algorithm:
Initial assessment → 2. Selection of laser and wavelength → 3. Consideration of combination methods (fraction, skin preparation, stimulation) → 4. Planning the

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number of sessions and intervals → 5. Monitoring results and adjusting parameters → 6. Aftercare and evaluation of the final result
This approach ensures individualization of therapy, increases the effectiveness of removal, minimizes complications and allows for better aesthetic results.
Thus, combined approaches to tattoo and permanent makeup removal, including laser treatment (QS, picosecond) and adjuvant methods (fractional ablation, skin preparation, and healing stimulation), represent a promising approach, especially for complex clinical cases. The choice of technique should be individualized, taking into account the patient's characteristics, tattoo/makeup, skin condition, and the desired outcome. In personalized therapy, it is important to balance efficacy and safety.

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