

Current Concepts in Laser Tattoo Removal

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Abstract and Introduction

Abstract

Today, more than 10% of the Western population has at least 1 tattoo, with prevalence of up to one-fourth in the cohort younger than 30 years of age. Many of these individuals come to regret their decision within months due to several reasons, often socially-related, and seek medical treatment. The discovery of selective photothermolysis has enabled the targeted destruction of tattoo pigments with only minimal damage to the surrounding tissue and limited risk of adverse effects, which contrasts previously used nonspecific methods. This treatment modality requires laser pulses of short durations (nanoseconds) and high intensities. However, the inappropriate use of laser parameters, such as inadequate pulse duration, can unnecessarily increase the incidence of permanent adverse effects. This article provides an overview of applicable laser systems and therapeutic strategies for optimized tattoo removal.

Introduction

Tattooing as a means of body art dates back to the early beginnings of modern civilization. In recent years, there has been a remarkable increase in the number of individuals seeking this permanent form of skin embellishment, especially in the population under 30 years of age.^[1] A study in 2004 reported a prevalence of 24% among college students in the US.^[2] The proliferating popularity of tattoos has correspondingly given rise to an increase in requests for their removal. The various motivating reasons behind tattoo regret include social stigmatization, familial pressure, a desire to improve career opportunities, and maturity-related factors. On average, tattoo removal is initiated after 14 years of remorse, but it can occur within months.^[2]

Tattoos consist of small particles of pigment situated in the dermis of the skin. These pigments are mainly found intracellularly, but small extracellular aggregates are also present, ranging in size from about 0.1–10 μm in interstitial space.^[3,4]

Not all tattoos are decorative. Certain events can lead to unintentional exogenous pigmentation (e.g., embedded gunpowder or dirt particles from the road following an accident) that can result in esthetically displeasing skin discolorations.

Mechanisms of Laser Tattoo Removal

With laser removal, tattoo pigment particles can be selectively destroyed without harming the surrounding tissue by means of selective photothermolysis.^[5] This requires the correct choice of laser parameters, including wavelength, radiant exposure, and pulse duration of the laser applied. Three main laser-induced mechanisms are involved in the targeted destruction of inoculated tattoo pigments. Firstly, the ink molecules must absorb the laser light in order to convert a sufficient amount of light energy to heat within the pigment particle. Usually, the type of tattoo pigment in the skin and its absorption spectrum is unknown to both the patient and physician. Transient skin whitening after laser treatment (lasting up to 30 minutes) can serve as an indicator of proper light absorption by the pigments. Secondly, the radiant exposure of the applied laser pulses must be high enough (approximately 107 W/cm^2) in order to generate a sufficiently high temperature increase in the color pigment particle. If treated properly, particles will reach very high absolute temperatures of several hundred degrees Celsius. Thirdly, the pulse duration must be in the range of nanoseconds (ns) due to the size of the tattoo pigment particles (a few microns).

Q-switched Lasers

High intensity, ultra-short pulse durations are provided only by a special laser technique known as "Q-switching". At present, there are 4 different types of Q-switched (Qs) lasers that are employed successfully in tattoo removal

(Table 1): 532 nm and 1064 nm Nd:YAG, alexandrite, and ruby.^[6] With appropriate use, the risk of scarring is less than 4.5% for all treatments.^[7,8] During the laser treatment of tattoos, energy impulses should be placed without considerable overlap in order to avoid additional thermal damage.

Table 1.

Q-switched Lasers	Wavelength	Radiant Exposure	Pulse Duration	Spot Sizes	Tattoo Colors
Alexandrite	755 nm	8 J/cm ²	50–100 ns	≤7 mm	Black, blue, green
Nd:YAG	532 nm	≤12 J/cm ²	≤10 ns	≤8 mm	Red
	1064 nm	≤12 J/cm ²	≤10 ns	≤8 mm	Black, blue
Ruby	694 nm	8–10 J/cm ²	≤40 ns	≤6 mm	Black, blue, green

Intense Pulsed Light Sources

Intense pulsed light (IPL) sources (lasers with millisecond pulses and low light intensities) are not suitable for tattoo removal. These devices normally have light intensities that are not sufficiently high enough to destroy the pigment particles, but rather simply heat the ink granules. This results in unspecific thermal damage to the adjacent tissue, which can cause significant scarring and pigmentary changes.^[9]

Tattoo Ink Colors and Skin Color

Black tattoo ink is most suitable for removal with any type of the aforementioned Qs lasers due to the color's broadband absorption, whereas laser destruction of other color pigments are met with varying degrees of efficacy owing to their light absorption occurring at different wavelengths. In general, bluish-black tattoos are more responsive than other colors to laser therapy and lighter inks tend to be resistant. In particular, purple, yellow, and green tones can be therapeutically challenging. Consequently, multicolor tattoos may require the use of 2 or more types of Qs devices in order to cover the spectrum of colors. Table 1 shows a list of suitable Qs lasers recommended for different tattoo colors.

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In patients with darker skin types (Fitzpatrick IV-VI) the Qs 1064 nm Nd:YAG-laser should be favored due to deeper penetration and less melanin absorption, and hence, reduced risk of potential side-effects, such as depigmentation and scarring.^[10,11]

Nonetheless, test treatments should always be performed because of the possibility of permanent unwanted pigmentary changes from light to dark colors in multicolored tattoos and skin areas with permanent makeup (e.g., laser-induced allergic reactions from red ink, brown tones turn to black, and flesh tones or white turn to black or dark green). This effect is caused by the reduction of iron-containing pigments (used in certain cosmetic applications, such as permanent makeup) to iron-oxide. Titanium dioxide, a white pigment that is widely used to lighten or brighten two-thirds of all tattoo colors,^[12] can also darken following irradiation with Qs laser energy.

Treatment Effects

Frequently, lightening of the tattoo can be immediately noticeable after laser treatment. This effect has also been demonstrated in experimental studies. Dozier et al. showed that there is no considerable difference in the level of

lightening, irrespective of whether the treatment was performed in vivo (tattoos on animals) or ex vivo (harvested human skin).^[13] Elaborate publications using histopathologic and electron-microscopic examinations of laser treated tattooed skin showed that after absorption into the intracellular pigment molecule, the energy of the ultrashort laser pulse is converted to heat, leading to a reduction in both pigment size and density, as well as triggering molecular structural changes.^[14,15] This rapid localized heating causes gas and plasma formation and subsequent dermal vacuolization, leading to the visible transient whitening of the skin after therapy.

The delayed onset of tattoo color fading (often weeks after treatment) is the result of cellular mechanisms (phagocytation by macrophages), which transport and dispose the ink particles via the lymphatic system and reorganize the remaining pigment granules. About 4 weeks after laser-assisted treatment the remaining particles can again be encapsulated intracellularly within dermal phagocytic cells (macrophages), contributing to further lightening.^[8,13]

Due to the described mechanisms of delayed tattoo lightening, retreatment should not be performed at intervals shorter than 1 month. Based on the author's experience, spacing treatment sessions at intervals between 6 weeks to 2 months apart have generated optimal outcomes.

In general, professional tattoos require more treatment sessions than amateur tattoos, which is attributable to the higher density of ink pigments used and deeper skin placement. Normally, irrespective of the chosen Qs laser system, several (up to 10 or more) treatment sessions are needed for complete tattoo removal.

Patient Expectations

It is advisable to counsel patients on expected treatment outcomes, and that often times a complete clearance of the tattoo color pigments cannot be achieved by laser therapy. Side-effects are generally few, but they commonly include transient hypopigmentation both during and after treatment, and patients must be informed prior to commencing treatment.

Laser Tattoo Removal Post-treatment

Under normal circumstances, specific post-operative care is not needed. As with other laser treatments, in order to reduce the risk of side-effects, some safety precautions should be taken, namely the avoidance of sun exposure before and 6 weeks after treatment, and the use of topical antimicrobial agents in case of blistering and crusting. Some authors recommend an immediate application of topical antibacterial ointment following the laser therapy session as part of routine post-operative care to reduce the risk of superinfection that can cause scarring.^[6]

Ho et al. conducted a study involving 120 Chinese patients with Fitzpatrick skin types III-V who received laser tattoo treatment.^[16] Patients experienced significantly lower scarring rates when applications of a heparin and allantoin based gel was used twice daily between laser treatments. Resultantly, study findings included a recommendation that this precautionary post-operative measure be considered for patients with darker skin types.

Conclusion

Tattoo removal should only be performed with Q-switched lasers (i.e., alexandrite, ruby, and 532 nm or 1064 nm Nd:YAG). In order to destroy the pigment particles while minimizing the risk of side-effects to the skin, strict adherence to the rules of selective photothermolysis is strongly advisable. IPL sources; long pulse-duration pulsed dye lasers; and Nd:YAG, alexandrite, or ruby devices without Q-switching that are also used in other indications of laser therapy (e.g. hair removal), are not suitable for tattoo pigment destruction. When considering their demonstrated safety and efficacy profiles, Q-switched lasers represent the favored therapeutic modality for successful tattoo removal.

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