

Laser Tattoo Removal, Precautions, and Unwanted Effects

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Abstract

Laser tattoo removal uses the physical properties of photoselective thermolysis in order to remove tattoo pigment. The technique has gradually improved over the years with the development of Q-switched lasers, with overall good results and a relatively low degree of adverse effects. However, lasers cannot always erase the unwanted tattoo completely, and there are still risks of unwanted effects such as scarring, pigment changes, ink darkening, and potential aggravation of latent skin conditions. This chapter will discuss the precautions that have to be taken and what pitfalls to avoid before starting the procedure of laser tattoo removal.

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Introduction

Tattoos have been part of human culture for thousands of years, with a wide range of patterns and symbolic values. Earlier in the history of mankind, tattooing was not as mainstream a feature as it has become today, with millions of people having tattoos or planning on getting one. The quest for expressing your individual identity seems to be central. However, many tattoo customers have regrets about their tattoo sooner or later in life, and this leads to an increasing world-

wide demand for effective and safe ways of tattoo removal [1].

Since 1993, at our hospital department, we have removed different kinds of tattoos, mainly with a quality-switched, or Q-switched (QS), pulsed laser. In order to qualify for our laser treatment regime, patients have to fulfil certain criteria since financing of the sessions is subsidised with public means. The tattoos removed have varied, including stigmatising symbols and patterns (fig. 1), tattoos associated with an earlier criminal life, and medical tattoos. Additionally, some patients, and especially women, have had tattoos forced upon them by a dominant partner. Cosmetic tattoos with extreme disfiguration have also been accepted for treatment. Furthermore, all patients with traumatic tattoos have been offered laser treatment, as well as those who have developed different allergic reactions to the tattoo ink.

Early Tattoo Removal and Non-Specific Wavelength Lasers

Over the years, different chemical abrasions and surgical techniques have been used for tattoo removal, but with many side effects, and especially scarring and pigment retention. Heating and



Fig. 1. Shamanistic tattoo for medical effect of goitre. Skin type V. Before and after several QS Nd:YAG laser 1,064 nm treatments. Postinflammatory hyperpigmentation to a certain degree on the neck where it was treated only 3 times. Photos: Dr A Troilius Rubin.

burning the skin in order to get rid of tattoo pigment have been used for centuries, including using fire, charcoal, and cigarettes. In the 1980s, removing tattoos in a more controlled manner, with heat, was tried with an infrared coagulator. Still, scarring was common due to the non-specific heat damage of dermal tissue [2]. Try-outs with lasers started, such as with argon lasers, but since the wavelengths were non-specific for the tattoo ink and instead largely absorbed by melanin and haemoglobin, the procedure often ended up with the same problem as earlier, causing scarring. Another alternative at this time was the carbon-dioxide laser (CO₂ laser), with vaporisation of the upper skin layers as its major mechanism in order to clear away the tattoo ink by transepidermal migration. However, there were great differences in depth during one and the same session, which often resulted in thick scarring and residual pigment [3].

Principles of Q-Switched Laser in Tattoo Removal

Anderson and Parrish's principle of selective photothermolysis in 1983 revolutionised the treatment of tattoos. They proposed that if a wavelength was well absorbed by the target and the pulse width was equal to or shorter than the tar-

get's thermal relaxation time, the heat generated from the laser would be confined to the target [4]. Considering that ink particles are very small and will hold heat in just a fraction of a second, one must use extremely short pulses. With the introduction of so-called QS lasers in the 1990s, with specific wavelengths that were well absorbed by ink particles and with a pulse duration of only nanoseconds, there was a golden standard for laser tattoo removal. Increasing evidence has also shown that there seems to be an important mechanism of photo-acoustic waves created by heat differences in the skin, contributing to the effect [5].

The most common colour of a tattoo is black, and following that are blue, green, red, yellow, and orange. All of these colours have different wavelength absorption, ranging from about 420 to 800 nm (table 1). A suitable laser with a specific wavelength is chosen according to this principle (table 2). However, nowadays, especially in professional tattoos, there is a wide range of colour mixes, making it sometimes a challenge to foresee the pigment reaction to a chosen laser wavelength. This problem is particularly seen in so-called cover-up tattoos placed on an earlier tattoo.

If the right wavelength and adjustable parameters such as spot size and fluence are chosen, the heat accumulation in the target colour will result in fragmentation of the ink, with the surrounding

Table 1. Absorption spectrum of the different tattoo pigment colours, measured in nanometres

Colour	Maximum absorption, nm
Black	600–800*
Blue-green	656–808
Permanent green	570–800
Red-violet	500–570
Orange	420–540
Yellow	470–485

* Black absorbs over the entire spectrum, with no specific peak (adapted from Verhaeghe 2010 [6]).

Table 2. QS lasers with their specific wavelengths and colour targets

Wavelength, nm	Laser	Colours
532	Nd:YAG laser	Red, orange, (brown, yellow)
694	Ruby laser	Black, blue, green, (purple, brown)
755	Alexandrite laser	Black, blue, green, (brown)
1,064	Nd:YAG laser	Black, blue, (brown)

The colours in brackets indicate some but less satisfactory absorption than for the other chromophores (adapted from Verhaeghe 2010 [6] and Karsai and Raulin 2011 [21]).

tissue spared [6]. Immediately after the laser treatment, an expected whitening of the skin will be seen, and this is usually a sign of good light absorption by the ink. The reaction represents dermal and epidermal vacuolisation due to localised steam formation and is often accompanied by normal pinpoint bleeding to a moderate degree, as a sign of slight epidermal disruption. The skin will heal within the next 2–7 days. In order to avoid bacterial infection, we recommend application of antiseptic ointment or dressing during this period. In the weeks following the laser procedure, there will be a gradual clearing of the tattoo

pigment by immune cells, such as macrophages and lymphocytes, via the lymph nodes. However, where the ink goes after the lymph nodes is not yet established, which means that a full comprehension of all immunological pathways involved is still lacking. Therefore, there have been questions about the safety of the ink particles regarding their potential toxicity, both before and after laser treatment, and their allergenic and carcinogenic properties [7, 8]. These fears have made a few physicians quit removing tattoos with lasers.

Initial Consultation

The patient should be thoroughly informed about what laser treatment of a tattoo actually comprises. There is a common misconception among the public that it is easy to remove a tattoo. Multiple laser treatments are always required, and many times, it is not possible to remove the tattoo completely, especially for multilayered, re-tattooed ones. It is important that the patient receives information on this concept and that an estimation of the number of laser sessions needed is made at the initial consultation. Otherwise, there will be a risk of poor treatment adherence, with the patient underestimating the effort and time required to clear a tattoo. In 2009, the Kirby-Desai scale was presented as a practical tool for assessing the number of laser sessions needed. In short, a darker skin type; dense tattoo ink; professional, complex tattoos with many colours; and distal tattoos on the extremities will require many laser treatments [9]. In some cases, up to 20 sessions or more are needed. Amateur tattoos are usually easier to remove, with fewer numbers of treatments, because of the irregularity of the depths of the pigment and the lower amount of pigment used.

In a substantial percentage of patients, there will be some residual pigment resisting further laser removal, depending on the factors mentioned above. It might be tempting to be more aggressive in treatment parameters or to use shorter treatment

intervals, but since tattoo ink is cleared by dermal macrophage cells several weeks after each laser procedure, it is of utmost importance that there is a treatment interval of at least 6–8 weeks. Shorter treatment intervals have been reported to interfere with immune cell activity and may even increase the risk of scarring and ink retention [10]. If the tattoo has many features that will make full clearance impossible, it may be wiser to discourage the patient from any laser treatment at all. In order to avoid disagreement over the result or other issues, photos should be taken before starting the laser sessions and also during the treatment period.

Medical Evaluation

Because of the theoretical systemic spread of fragmented ink particles after laser treatment, we never treat pregnant or lactating women. Additionally, patients with severe diabetes are discouraged from QS laser treatment due to their diminished wound healing and higher risk of complicated infections. With regard to the safety of personnel, human immunodeficiency virus or hepatitis could be a risk factor. However, to our knowledge, no cases of patient-laser surgeon transmission have yet been reported. Furthermore, some medications might interfere with a successful result, such as retinoids, which are reported to increase the potential for scarring in some cases, although other reports do not fully support this [11]. Earlier gold injections against arthritis can result in hyperpigmentation (chrysiasis), even if the gold was given years ago [12]. It is also of value to know if the patient has any allergies, considering that it sometimes will be necessary to orally or topically treat the patient with medication. Questioning about earlier scarring is important since this can reveal whether the patient has a tendency to form hypertrophic scars or keloids. If an increased risk of scarring is suspected, information should be given, and as a precaution, a corticosteroid ointment and silicon dressing could be applied after each laser procedure.

General Precautions

Even though the rates of adverse effects are low with QS lasers, there are still some general risks that have to be considered before starting laser treatment. For example, a laser machine is not safe to use if the treating personnel does not have the proper education and experience. Even if photoselective thermolysis is the goal of tattoo removal, the wrong choice of wavelength, fluence, or pulse width will not reach this goal and will instead cause dermal damage and long-term side effects. Parameter settings that work well and safely in one patient might be wrong in another due to differences in skin texture and pigmentation. There are also risks of treating a tattoo with too many pulses on a single occasion since it can lead to a too-intense tissue reaction. In one rare case, this reaction led to a compartment syndrome of the forearm. For this reason, newer methods (such as the R20 method) that comprise multiple passes on the same occasion for better tattoo clearing should, according to our opinion, perhaps not be performed at distal parts of extremities [13, 14]. Even in the hands of an experienced laser surgeon, it is sometimes best to perform treatment first on a small test surface, especially if there are uncertainties about the right choice of wavelength and the response of the ink particles.

Dermatological Assessment

There is a necessity of having professional skills in the medical field since there are dermatological reactions, nevi, and tumours found within a tattoo in some cases. This needs to be evaluated before treatment. For example, psoriasis, lichen, and vitiligo can be exacerbated by tattooing (Koebner phenomenon) and potentially also by the procedure of lasing. Other histological reactions in tattoos might be reactions to the pigment itself, and these can be granulomatous or lichenoid, and

sometimes even pseudolymphomas might develop [15]. All of this can be a diagnostic challenge. Additionally, different tumours can occur within a tattoo, such as basalioma, squamous cell carcinoma, and malignant melanoma. Whether this is a coincidence or actually caused by the tattoo is not established. A general rule is to never put a tattoo over a pigmented lesion and, before tattoo removal, to always excise a nevus or tumour in order to acquire a histopathological diagnosis [16, 17]. Finally, infectious complications should be avoided, and if there are signs of an active skin infection, whether bacterial or viral, laser treatment should be postponed and the infection treated. Additionally, if the tattoo is near an area with inactive intermittent herpes infection, e.g. the mouth, one should consider herpes prophylaxis in order to avoid reactivation.

Scarring

The risk of developing scars from laser tattoo removal is generally reported to be low, or just a few percent [18]. However, using too-high energy fluence and a too-large spot size increases the risk of deeper thermal injury, with potential scarring as a consequence. If exaggerated inflammation post-laser is noticed, a cooling device can be used, together with the application of a potent corticosteroid ointment. In a reported series of treatment-resistant tattoos, as many as 18.8–25% developed scarring, probably due to more intense treatment [16]. If there is a need to penetrate deeper, a larger spot size should be tried first, instead of increasing the fluence, in order to get less light scattering in the skin and hence less damage [19]. However, there are risks even with this strategy. Although the right parameters might be used, with an adequate tissue reaction, it is well established that with multiple laser sessions, the risk of fibrosis as well as hypopigmentation or postinflammatory hyperpigmentation will gradually increase [10].

Dyspigmentation

Hyper- and hypopigmentation as adverse effects of laser tattoo removal are more common than scarring [20]. Hyperpigmentation might follow inflammation or numerous laser treatments. It is more common in darker skin with more melanin and can often develop even after an adequate laser reaction. Hyperpigmentation can often be managed with longer intervals, letting the pigment gradually fade. It can often be a benefit to prescribe a bleaching agent, such as hydroquinone 2–4%. In all cases, ultra-violet exposure should be avoided. The risk of hypopigmentation will increase not only with too-high fluences and subsequent inflammation but also if shorter wavelengths are used since this means potential competing absorption by the melanosomes in the basal layer of the epidermis. Consequently, in order to avoid hypopigmentation in dark-skinned patients, longer wavelengths and lower fluences are preferable. If hypopigmentation is seen, longer treatment intervals would be of value so that the skin and its melanosomes have time to recover. Most of the time, loss of pigment is transient, but it may persist for several months or years. However, some authors report permanent loss of melanin pigment in up to 10% of all cases [21].

Ink Retention and Paradoxical Ink Darkening

Black and blue pigments are often the easiest tattoo pigments to remove, while moderate success is seen with green. A poorer outcome is specifically seen with white, purple, turquoise, yellow, orange, and flesh-toned colours. Sometimes, instead of a QS laser, a pulsed dye laser (510 nm) can be used to treat pigment on the red-yellow spectrum, with good results described; however, it is not the first-line choice since its pulse duration is considerably longer [21, 22].

Paradoxical ink darkening might occur after QS laser treatment, especially in tattoos containing



Fig. 2. Paradoxical ink darkening to the left. Treated successfully with QS Nd:YAG laser 1,064 nm to the right. Photos: Dr A Troilius Rubin.

titanium dioxide, such as white ink, which is often used to add brilliance to other tattoo inks. Ink darkening might also develop due to the ferric oxide in flesh-toned cosmetic tattoos, often used as permanent make-up. The mechanism is probably due to a chemical reduction of the pigment with the laser light [23]. A trial session would be valuable in such cases since this ink darkening may be irreversible. After the immediate whitening is gone, about 10–20 min post-treatment, an evaluation of a possible colour change can be made. Even if a chemical reduction does occur, according to our experience and other reports, switching to a QS laser with an appropriate wavelength will often remove the darkened pigment (fig. 2) [24, 25]. Some authors suggest using a CO₂ laser in treating flesh-toned cosmetic tattoos or altered ink as a good alternative, taking advantage of the mechanism of transepidermal pigment migration [26]. In some cosmetic tattoos, such as permanent eyeliner, it is quite common to see fanning of the ink downwards, into the lower eyelid. This is usually easy to remove with a QS laser and does not need more than 1–2 treatments.

Traumatic Tattoos

Traumatic tattoos are the result of accidents in which pigmented particles get embedded in the skin. These can arise from abrasive damage, e.g.

asphalt from a bicycle accident, or a penetrating force, such as a graphite pencil. Unfortunately, a quite common cause of traumatic tattoos is explosions from fireworks and gun powder (fig. 3). This situation constitutes a specific risk since the material can explode during laser treatment and create pitted scars in the skin of the patient [27]. Therefore, these cases should always be treated with caution. Success in clearing the traumatic tattoo will depend on the depth and on the particle size. Deeply embedded material may not be erased completely, and the patient should be informed of this. Harder materials, e.g. asphalt and car paint, will need more treatments, while softer materials, e.g. dirt and mascara, need less [28]. If the particles are too large, the laser will not be sufficient to target them with its short pulses. In such situations, an ablative laser, such as an Erbium:YAG or CO₂ laser, could be beneficial [29].

Allergic Reactions

If the patient has an allergy to the tattoo, this will appear as a typical allergic dermatitis or as either a granulomatous or a lichenoid reaction within specific colour areas [15]. In our experience, most common is an allergic reaction to red pigment, but an allergy to all sorts of colours can develop,



Fig. 3. Traumatic tattoo due to gun powder. Six sessions of QS Nd:YAG laser 1,064 nm. Photos: Dr A Troilius Rubin.



Fig. 4. Allergic reaction to red tattoo ink probably induced by the laser after two sessions of QS Nd:YAG laser 532 nm. Photos: Dr A Troilius Rubin.

with the least common being to black. Sometimes, it takes a long time, up to a year or so, to develop an allergy. This is due to chemical changes in the ink over time, with sunlight being an important factor. Laser treatment itself can also, in rare cases, induce allergy to the fragmented ink (fig. 4) [30, 31]. As mentioned earlier, after QS laser treatment, tattoo ink is cleared by cells that transport the ink fragments via the lymphatic system. Consequently, there is a potential risk of a systemic reaction to the ink particles after laser treatment, especially if there has been a local allergic reaction. Being prepared for such a reaction is therefore essential. The reports on clinical reactions following laser treatment have so far been mainly composed of mild or moderate allergic dermatitis, although generalised reactions have

also been described in some published cases [32]. To avoid a systemic reaction, some laser surgeons recommend a CO₂ or Erbium:YAG laser instead of, or before, QS laser treatment [33]. However, in our department, we have successfully treated at least ten patients with a localised allergic reaction to tattoo ink with a QS Nd:YAG laser. Several patients received intralesional corticosteroids or were prescribed daily application of a potent corticosteroid ointment in order to suppress most of the localised allergic reaction 1–2 months before laser treatment. At the time of treatment, all patients received an oral antihistamine one hour before laser treatment and were also kept under close surveillance during and 4 hours after the session. So far, there have not been any systemic allergic reactions during or after the procedure.

Newer Treatments and Future

Today, there are already promising studies and ongoing usage of the next generation of QS lasers, using pulses in the range of picoseconds, which are reported to create even better results in clearing a tattoo. This is attributed to the shortening of the pulse, matching the thermal relaxation time of the tattoo ink better and generating more effective photo-acoustic waves [5, 34]. However, these new machines are currently very costly, and it is too early to tell if they are worthwhile for their improved capacity for clearing tattoo ink. Hence, more studies are needed.

Newer techniques are combinations of already-known modalities, such as pretreating the skin with a fractional CO₂ laser or an Erbium:YAG laser and then directly treating the tattoo with a QS laser [35]. Another combination is the fractional QS laser (which is also new) with a QS laser with a full beam [5, 36]. Furthermore, in order to lessen the degree of scattering and to increase the penetration of light, it is possible to use diascopy (compression of the skin with a glass plate) during the QS laser session. In our experience, this seems to lead to a better effect of clearing deeper pigment. There are also reports on transdermal application of glycerol for the same effect [37].

For the future, one of the most important things is the development of safer tattoo pigment. Considering the large number of tattooed people who want to remove a tattoo, it would be so much easier if the pigment were made of non-toxic, biodegradable particles. However, this means that a tattoo will not 'be for life' and will therefore lose its symbolic value for many tattoo admirers. Should permanent ink be the overall choice of the tattoo community, it would be of great advantage if this ink had well-known absorption wavelengths, thereby making it easier to remove with a QS laser. Five years ago, a new tattoo ink was marketed in the United States, designed as microbeads of polymethylmethacrylate containing bioresorbable ink with specific laser wavelengths (InfinitInk; Freedom, Inc., N.J., USA). We will hopefully see more of this and of such initiatives in the future. In the meantime, the next important step is the development of lasers. For example, it would be of help to have lasers that can emit a large variety of wavelengths for treating all of the different ink colours that exist today while, at the same time, being able to penetrate deeper. Even if we do achieve all of the above improvements that are wished for, it would be very favourable if the public were given better information on the limitations of laser tattoo removal before getting a tattoo.

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