

Tattoo removal

Tattoo removal has been performed with various tools during the history of tattooing. While tattoos were once considered permanent, it is now possible to remove them with treatments, fully or partially.

Before the development of laser tattoo removal methods, common techniques included dermabrasion, TCA (Trichloroacetic acid, an acid that removes the top layers of skin, reaching as deep as the layer in which the tattoo ink resides), salabrasion (scrubbing the skin with salt), cryosurgery and excision which is sometimes still used along with skin grafts for larger tattoos. Some early forms of tattoo removal included the injection or application of wine, lime, garlic or pigeon excrement. Tattoo removal by laser was performed with continuous-wave lasers initially, and later with Q-switched lasers, which became commercially available in the early 1990s. Today, "laser tattoo removal" usually refers to the non-invasive removal of tattoo pigments using Q-switched lasers. Typically, black and darker-colored inks can be removed more completely.

Motives

A poll conducted in January 2012 by Harris Interactive reported that 1 in 7 (14%) of the 21% of American adults who have a tattoo regret getting one. The poll didn't report the reasons for these regrets, but a poll that was done 4 years prior reported that the most common reasons were "too young when I got the tattoo" (20%), "it's permanent" and "I'm marked for life" (19%), and "I just don't like it" (18%). An earlier poll showed that 19% of Britons with tattoos suffered regret, as did 11% of Italians with tattoos.^[1] Surveys of tattoo removal patients were done in 1996 and 2006 and provided more insight. Of those polled, the patients who regretted their tattoos typically obtained their tattoos in their late teens or early twenties, and were evenly distributed by gender. Among those seeking removals, more than half reported that they "suffered embarrassment". A new job, problems with clothes, and a significant life event were also commonly cited as motivations.^[2]

The choice to get a tattoo that is later regretted is related to the end-of-history illusion, in which teenagers and adults of all ages know that their tastes have changed regularly over the years before the current moment, but believe that their tastes will somehow not continue to grow and mature in the future. As a result, they wrongly believe that any tattoo that appeals to them today will always appeal to them in the future.

Methods

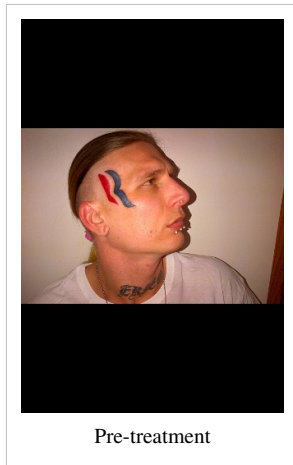
Laser removal

Tattoo removal is most commonly performed using lasers that break down the ink in the tattoo. The broken-down ink is then absorbed by the body, mimicking the natural fading that time or sun exposure would create. All tattoo pigments have specific light absorption spectra. A tattoo laser must be capable of emitting adequate energy within the given absorption spectrum of the pigment to provide an effective treatment. Certain tattoo pigments, such as yellows, greens and fluorescent inks are more challenging to treat than darker blacks and blues, because they have absorption spectra that fall outside or on the edge of the emission spectra available in the tattoo removal laser.

Widely considered the gold standard treatment modality to remove a tattoo, laser tattoo removal requires repeat visits. The newer Q-switched lasers are said by the National Institutes of Health to result in scarring only rarely and are usually used only after a topical anesthetic has been applied. Areas with thin skin will be more likely to scar than thicker-skinned areas. There are several types of Q-switched lasers, and each is effective at removing a different range of the color spectrum. Lasers developed after 2006 provide multiple wavelengths and can successfully treat a much broader range of tattoo pigments than previous Q-switched lasers.

The amount of energy (fluence/joules/cm²) is determined prior to each treatment as well as the spot size and treatment speed (Hz/hertz). To mitigate pain the preferred method is simply to cool the area during treatment with a

medical-grade chiller/cooler and to use a topical anesthetic. During the treatment process the laser beam passes harmlessly through the skin, targeting only the ink resting in a liquid state within. While it is possible to see immediate results, in most cases the fading occurs gradually over the 7–8 week healing period between treatments.^[3]



Mechanism of laser action

Experimental observations of the effects of short-pulsed lasers on tattoos were first reported in the late 1960s.^[4] In 1979 an argon laser was used for tattoo removal in 28 patients, with limited success. In 1978 a carbon dioxide was also used, but generally caused scarring after treatments.^[5]

In the early 1980s a new clinical study began in Canniesburn Hospital's Burns and Plastic Surgery Unit, in Glasgow, Scotland, into the effects of Q-switched ruby laser energy on blue/black tattoos.^[6] Further studies into other tattoo colours were then carried out with various degrees of success.^[7]

It was not until the late 1980s that Q-switched lasers became commercially practical with the first marketed laser coming from Dermalase Limited, Glasgow. One of the first American published articles describing laser tattoo removal was authored by a group at Massachusetts General Hospital in 1990.^[8]

Tattoos consist of thousands of particles of tattoo pigment suspended in the skin.^[9] While normal human growth and healing processes will remove small foreign particles from the skin, tattoo pigment particles are permanent because they are too big to be removed. Laser treatment causes tattoo pigment particles to heat up and fragment into smaller pieces. These smaller pieces are then removed by normal body processes.

Laser tattoo removal is a successful application of the theory of selective photothermolysis (SPTL).^[10] However, unlike treatments for blood vessels or hair the mechanism required to shatter tattoo particles uses the photomechanical effect. In this situation the energy is absorbed by the ink particles in a very short time, typically nanoseconds. The surface temperature of the ink particles can rise to thousands of degrees but this energy profile rapidly collapses into a shock wave. This shock wave then propagates throughout the local tissue (the dermis) causing brittle structures to fragment. Hence tissues are largely unaffected since they simply vibrate as the shock wave passes. For laser tattoo removal the selective destruction of tattoo pigments depends on four factors:

- The color of the light must penetrate sufficiently deep into the skin to reach the tattoo pigment.
- The color of the laser light must be more highly absorbed by the tattoo pigment than the surrounding skin. Different tattoo pigments therefore require different laser colors. For example, red light is highly absorbed by green tattoo pigments.
- The time duration (pulse duration) of the laser energy must be very short, so that the tattoo pigment is heated to fragmentation temperature before its heat can dissipate to the surrounding skin. Otherwise, heating of the surrounding tissue can cause burns or scars. For laser tattoo removal, this duration should be on the order of nanoseconds.

- Sufficient energy must be delivered during each laser pulse to heat the pigment to fragmentation. If the energy is too low, pigment will not fragment and no removal will take place.

Q-switched lasers are the only commercially available devices that can meet these requirements.^[11]

Although they occur infrequently, mucosal tattoos can be successfully treated with Q-switched lasers as well.^[12]

A novel method for laser tattoo removal using a fractionated CO₂ or Erbium:YAG laser, alone or in combination with Q-switched lasers, was reported by Ibrahimi and coworkers from the Wellman Center of Photomedicine at the Massachusetts General Hospital. This new approach to laser tattoo removal may afford the ability to remove colors such as yellow and white, which have proven to be resistant to traditional Q-switched laser therapy.

Laser parameters that affect results

Several colors of laser light (measured as wavelengths of laser energy) are used for tattoo removal, from visible light to near-infrared radiation. Different lasers are better for different tattoo colors. Consequently, multi-color tattoo removal almost always requires the use of two or more laser wavelengths. Tattoo removal lasers are usually identified by the lasing medium used to create the wavelength (measured in nanometers (nm)):

- Q-switched Frequency-doubled Nd:Yag: 532 nm. This laser creates a green light which is highly absorbed by red and orange targets. Useful primarily for red and orange tattoo pigments, this wavelength is also highly absorbed by melanin (the chemical which gives skin color or tan) which makes the laser wavelength effective for age spot or sun spot removal.
- Q-switched Ruby: 694 nm. This laser creates a red light which is highly absorbed by green and dark tattoo pigments. Because it is more highly absorbed by melanin this laser may produce undesirable side effects such as pigmentary changes for patients of all but white skin.^[13]
- Q-switched Alexandrite: 755 nm. The weakest of all the q-switched devices and somewhat similar to the Ruby laser in that the Alexandrite creates a red light which is highly absorbed by green and dark tattoo pigments. However, the alexandrite laser color is slightly less absorbed by melanin, so this laser has a slightly lower incidence of unwanted pigmentary changes than a ruby laser.^[14] This laser works well on green tattoos but because of its weaker peak power it works only moderately well on black and blue ink. It does not work at all on red, orange, brown, etc.
- Q-switched Nd:YAG: 1064 nm. This laser creates a near-infrared light (invisible to humans) which is poorly absorbed by melanin, making this the only laser suitable for darker skin. This laser wavelength is also absorbed by all dark tattoo pigments and is the safest wavelength to use on the tissue due to the low melanin absorption and low hemoglobin absorption. This is the wavelength of choice for tattoo removal in darker skin types.
- Dye modules are available for some lasers to convert 532 nm to 650 nm or 585 nm light which allows one laser system to safely and effectively treat multi-color tattoo inks. The role of dye lasers in tattoo removal is discussed in detail in the literature.^[15]

Pulsewidth or pulse duration is a critical laser parameter. All Q-switched lasers have appropriate pulse durations for tattoo removal. However, lasers with a shorter pulses have a safer and more efficient removal method because the peak power of the pulse is greater.

Spot size, or the width of the laser beam, affects treatment. Light is optically scattered in the skin, like automobile headlights in fog. Larger spot sizes slightly increase the effective penetration depth of the laser light, thus enabling more effective targeting of deeper tattoo pigments. Larger spot sizes also help make treatments faster.

Fluence or energy level is another important consideration. Fluence is measured in joules per square centimeter (J/cm²). It is important to get treated at high enough settings to fragment tattoo particles.

Repetition rate helps make treatments faster but is not associated with any treatment effect.

Number of laser tattoo removal treatment sessions needed

Complete laser tattoo removal requires numerous treatment sessions, typically spaced at least seven weeks apart. Treating more frequently than seven weeks increases the risk of adverse effects and does not necessarily increase the rate of ink absorption. Anecdotal reports of treatments sessions at four weeks leads to more scarring and dischromia and can be a source of liability for clinicians. At each session, some but not all of the tattoo pigment particles are effectively fragmented, and the body removes the smallest fragments over the course of several weeks. The result is that the tattoo is lightened over time. Remaining large particles of tattoo pigment are then targeted at subsequent treatment sessions, causing further lightening. The number of sessions and spacing between treatments depends on various parameters, including the area of the body treated and skin color. Tattoos located on the extremities, such as the ankle, generally take longest. As tattoos fade clinicians may recommend that patients wait many months between treatments to facilitate ink resolution and minimize unwanted side effects.

The amount of time required for the removal of a tattoo and the success of the removal varies with each individual. Factors influencing this include: skin type, location, color, amount of ink, scarring or tissue change, and layering. In the past health care providers would simply guess on the number of treatments a patient needed which was rather frustrating to patients. A predictive scale, the "Kirby-Desai Scale", was developed by Dr. Will Kirby and Dr. Alpesh Desai, dermatologists with specialization in tattoo removal techniques, to assess the potential success and number of treatments necessary for laser tattoo removal, provided the medical practitioner is using a quality-switched Nd:YAG (neodymium-doped yttrium aluminum garnet) laser incorporating selective photothermolysis with six weeks between treatments.

The Kirby-Desai Scale assigns numerical values to six parameters: skin type, location, color, amount of ink, scarring or tissue change, and layering. Parameter scores are then added to yield a combined score that will show the estimated number of treatments needed for successful tattoo removal. Experts recommend that the Kirby-Desai scale be used by all laser practitioners prior to starting tattoo removal treatment to help determine the number of treatments required for tattoo removal and as a predictor of the success of the laser tattoo removal treatments.^[16] Prior to 2009, clinicians had no scientific basis by which to estimate the number of treatments needed to remove a tattoo and the use of this scale is now standard practice in laser tattoo removal.

Certain colours have proved more difficult to remove than others. In particular, green ink has always posed a problem. The reason for this is due to the molecular size of the green ink particles being significantly smaller than other colours.^[17] Consequently green ink tattoos require higher power densities than are achievable with Q-switched lasers; such lasers need to output energy in picosecond pulsewidths. Clinical studies with picosecond Nd:YAG lasers have proven more successful with green, and other coloured, inks.,^{[18][19]}

A study referred to as the R20 method showed that four passes with the laser, twenty minutes apart, caused more breaking up of the ink than the conventional method. In this limited study performed in Greece it was reported that this technique created no more scarring or adverse effects than traditional methods and it removed more ink than a single pass. However, this study was performed on a very small patient population (12 patients total) using the weakest of the QS lasers, the 755 nm Alexandrite laser. One of the main problems with this study, in addition to the



Post-procedure result (first session)

limited number of patient participants, was the fact that more than half of the 18 tattoos were not professional and amateur tattoos are always easier to remove. Proof of concept studies are underway but many laser experts advise against the R20 method using the more modern and powerful tattoo removal lasers available at most offices as an increase in adverse side effects including scarring and dyschromia are likely. Patients should inquire about the laser being used if the R20 treatment method is offered by a facility as it is usually only offered by clinics that are using the weak 755 nm Alexandrite as opposed to the more powerful and versatile devices that are more commonly used. Moreover, dermatologists offering the R20 method should inform patients that it is not a gold standard treatment method.

Factors contributing to the success of laser tattoo removal

Multiple factors contribute to the success of laser tattoo removal, one of which is a patient's own immune system. The Kirby-Desai scale parameters qualify the factors that can dictate tattoo removal success. Moreover, treatment on some patients with immune system problems are contraindicated.^[20]

Pain management during treatment

Laser tattoo removal can be uncomfortable but is very tolerable in most cases. The pain is often described to be similar to that of hot oil on the skin, or a "slap" from an elastic band. Depending on the patient's pain threshold, and while some patients may forgo anesthesia altogether, most patients will require some form of local anesthesia. Pre-treatment might include the application of an anesthetic cream under occlusion for 45 to 90 minutes prior to the laser treatment session. In very rare cases, if complete anesthesia is necessary, it can be administered locally by injections of 1% to 2% lidocaine with epinephrine. Anecdotal reports, however, have noted that patients receiving anesthesia by local injection may require additional treatment as the injection causes mechanical edema, a spreading out of the tattoo ink. This makes it more difficult for the laser light to act on specific ink particles, so experts in the laser tattoo removal field caution against injecting anesthetic, as these injections may also increase the risk of scarring and/or additional treatment.

Post-treatment considerations

Immediately after laser treatment, a slightly elevated, white discoloration with or without the presence of punctuate bleeding is often observed. This white color change is thought to be the result of rapid, heat-formed steam or gas, causing dermal and epidermal vacuolization. Pinpoint bleeding represents vascular injury from photoacoustic waves created by the laser's interaction with tattoo pigment. Minimal edema and erythema of adjacent normal skin usually resolve within 24 hours. Subsequently, a crust appears over the entire tattoo, which sloughs off at approximately 14 days post-treatment. As noted above, some tattoo pigment may be found within this crust. Post-operative wound care consists of simple wound care and a non-occlusive dressing. Since the application of laser light is sterile there is no need for topical antibiotics. Moreover, topical antibiotic ointments can cause allergic reactions and should be avoided. Fading of the tattoo will be noted over the next eight weeks and re-treatment energy levels can be tailored depending on the clinical response observed.^[1]

Side effects and complications

About half of the patients treated with Q-switched lasers for tattoo removal will show some transient changes in the normal skin pigmentation. These changes usually resolve in 6 to 12 months but may rarely be permanent.^[21]

Hyperpigmentation is related to the patient's skin tone, with skin types IV, V and VI more prone regardless of the wavelength used. Twice daily treatment with hydroquinones and broad-spectrum sunscreens usually resolves the hyperpigmentation within a few months, although, in some patients, resolution can be prolonged.

Transient textural changes are occasionally noted but often resolve within a few months; however, permanent textural changes and scarring very rarely occur. If a patient is prone to pigmentary or textural changes, longer treatment intervals are recommended. Additionally, if a blister or crust forms following treatment, it is imperative

that the patient does not manipulate this secondary skin change. Early removal of a blister or crust increases the chances of developing a scar. Additionally, patients with a history of hypertrophic or keloidal scarring need to be warned of their increased risk of scarring.

Local allergic responses to many tattoo pigments have been reported, and allergic reactions to tattoo pigment after Q-switched laser treatment are also possible. Rarely, when yellow cadmium sulfide is used to "brighten" the red or yellow portion of a tattoo, a photoallergic reaction may occur. The reaction is also common with red ink, which may contain cinnabar (mercuric sulphide). Erythema, pruritus, and even inflamed nodules, verrucose papules, or granulomas may present. The reaction will be confined to the site of the red/yellow ink. Treatment consists of strict sunlight avoidance, sunscreen, interlesional steroid injections, or in some cases, surgical removal. Unlike the destructive modalities described, Q-switched lasers mobilize the ink and may generate a systemic allergic response. Oral antihistamines and anti-inflammatory steroids have been used to treat allergic reactions to tattoo ink.

Studies of various tattoo pigments have shown that a number of pigments (most containing iron oxide or titanium dioxide) change color when irradiated with Q-switched laser energy. Some tattoo colors including flesh tones, light red, white, peach and light brown containing pigments as well as some green and blue tattoo pigments, changed to black when irradiated with Q-switched laser pulses. The resulting gray-black color may require more treatments to remove. If tattoo darkening does occur, after 8 weeks the newly darkened tattoo can be treated as if it were black pigment.^[22]

Very rarely, non Q-switched laser treatments, like CO₂ or Argon lasers, which are very rarely offered these days, can rupture blood vessels and aerosolizes tissue requiring a plastic shield or a cone device to protect the laser operator from tissue and blood contact. Protective eye-wear may be worn if the laser operator choose to do so.

With the mechanical or salabrasion method of tattoo removal, the incidence of scarring, pigmentary alteration (hyper- and hypopigmentation), and ink retention are extremely high.^[23]

The use of Q-switched lasers could very rarely produce the development of large bulla. However, if patients follow post care directions to elevate, rest, and apply intermittent icing, it should minimize the chances of bulla and other adverse effects. In addition, health care practitioners should contemplate the use of a cooling device during the tattoo removal procedure. While the infrequent bulla development is a possible side effect of Q-switched laser tattoo removal, if treated appropriately and quickly by the health care practitioner, it is unlikely that long term consequences would ensue.^[24]

Risks

Although laser treatment is well known and often used to remove tattoos, unwanted side effects of laser tattoo removal include the possibility of discoloration of the skin such as hypopigmentation (white spots, more common in darker skin) and hyperpigmentation (dark spots) as well as textural changes - these changes are usually not permanent when the Nd:YAG is used but it is much more likely with the use of the 755 nm Alexandrite and the R20 method.... Very rarely, burns may result in scarring but this usually only occurs when patients don't care for the treated area properly. Rarely, "paradoxical darkening" of a tattoo may occur, when a treated tattoo becomes darker instead of lighter. This seems to occur more often with flesh tones, pink, and cosmetic make-up tattoos.^{[25][26]}

Some tattoo pigments contain metals that could theoretically break down into toxic chemicals in the body when exposed to light. This has not yet been reported in vivo but has been shown in laboratory tests. Laser removal of traumatic tattoos may similarly be complicated depending on the substance of the pigmenting material. In one reported instance, the use of a laser resulted in the ignition of embedded particles of firework debris.^[27]

Replacement strategy

Some wearers decide to cover an unwanted tattoo with a new tattoo. This is commonly known as a cover-up. An artfully done cover-up may render the old tattoo completely invisible, though this will depend largely on the size, style, colors and techniques used on the old tattoo and the skill of the tattoo artist. Covering up a previous tattoo necessitates darker tones in the new tattoo to effectively hide the older, unwanted piece. Many tattoos are too bright to cover up and in those cases patients may receive laser tattoo removal to lighten the existing ink to make themselves better candidates for a cover up tattoo.

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External links

- How Tattoo Removal Works (<http://health.howstuffworks.com/skin-care/beauty/skin-and-lifestyle/tattoo-removal.htm>)
- The Tattoo Removal Directory (<http://www.tattooremovaldirectory.com/>)

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