THERAPEUTIC UPDATE

Using Lasers For Tattoo Removal

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An estimated 10% of the US population has at least one tattoo, with up to one fourth in those younger than 30 years of age. Yet more than half of all people with tattoos eventually regret having them and many want them removed.[1]

Tattoos are made up of small particles of pigment located in the dermis. The discovery of selective photothermolysis has facilitated the targeted destruction of tattoo pigment with only minimal damage to surrounding skin.[2]

There are three conditions that must be met for successful tattoo removal. First, the ink molecules must absorb the beam to convert a sufficient amount of light energy to heat. Transient skin whitening serves as an indicator of proper light absorption by the tattoo pigments. Second, the radiant exposure of the applied laser pulses must be high enough to generate a sufficiently high temperature increase in the ink particle. Third, the pulse duration must be very short (in the range of nanoseconds or picoseconds) due to the small size of the ink particles.[3]

Q-Switched Lasers

A special technique, known as "Q-switching" provides high intensity, ultra short pulse durations. Use of a quality-switched (QS) laser for tattoo removal (694 nm ruby) was first reported in 1965 by Leon Goldman.[4] But it was not until the theory of selective phototherymalysis was introduced in 1983 that QS lasers became the gold standard for modern day tattoo removal.[5] A Q-switched laser is necessary to achieve selective photothermalysis, as the exposure time in the nanosecond (10^{-9}) domain is less than half the thermal relaxation time of the target pigment.

A QS laser ensures that the thermal damage is confined to the target chromophore, resulting in photoacoustic destruction and minimizing damage to the surrounding skin from thermal diffusion. The four QS laser wavelengths are in the visible and infared spectrum, and include the 694 nm ruby, the 755 nm alexandrite, the 1064 nm Nd:YAG and the 532 nm KTP. If a tattoo is comprised of different colors, several wavelengths must be used to target the tattoo pigments, which have different absorption characteristics (see chart).[6] The lighter one's skin the more successful the procedure will be because the melanin in darker skin competes with the laser's beam of light, thus making the light less likely to reach the deeper level of pigment. The QS Nd: YAG is usually recommended when treating tattoos on Fitzpatrick type IV to VI patients, as the 1064 nm wavelength penetrates deeper and is minimally absorbed by epidermal melanin.

TABLE 1.

Q-switched Laser	Wavelength	Pulse Duration	Tattoo Colors
Ruby	694 nm	< 40 ns	black, blue, green
Alexandrite	755 nm	50 ns - 100 ns	black, blue, green
Nd:YAG	1064 nm	< 10 ns	black, blue
KTP	532 nm	< 10 ns	red, orange, yellow, brown

Immediately upon treatment, there is a photoacoustic effect, which creates a very superficial wound. It is not unusual for some of the tattoo pigment to come off with dressing changes. But the main fading of the tattoo color occurs as a delayed phenomenon weeks after treatment. It is the result of cellular mechanisms ie, phagocytosis by macrophages, which transport and dispose of the ink particles via the lymphatic system. Laser treatments are usually spaced 1 to 2 months apart. However, it may take up to three months for the full effect of a single treatment to be realized. The difficulty with tattoo removal is that it can take up to 10 to 15 treatment sessions to remove the unwanted pigment. A recent retrospective review of 238 patients who underwent an average of 3.57 treatments (ranging between 1 to 18 sessions) found that only 1.26% achieved total clearance of the tattoo defined as complete absence of pigment.[7] Many patients get discouraged and discontinue treatment due to the expense and/or prolonged treatment regimen. Even after a series of numerous treatments, in some cases, complete removal is still not possible.

The "R20" Protocol and "RO" Protocol

Laser tattoo removal is typically frustrating for patient and doctor alike since it can take numerous treatments at 1-2 month intervals. The limiting factor when treating a tattoo has been that white gas bubbles develop under the skin, which inhibits the laser from being effective. The visible transient whitening usually lasts approximately 20-30 minutes. It is due to rapid, localized heating causing gas and plasma formation and subsequent dermal vacuolization. Recently, physicians noted that after 20 minutes the bubbles were gone, allowing for another treatment. This waiting 20 minutes and repeating the treatment has become known as the R20 protocol, and it allows for four treatments in a single session spaced 20 minutes apart to allow whitening to fade.[9]

An innovative development called the RO protocol now essentially eliminates the 20-minute wait between treatments. By placing a topical perfluorodecalin (PFD) on the skin, the white gas bubbles are eliminated almost instantly, thereby allowing the four treatments to be performed in rapid succession. A recent study showed that this treatment was safe and effective and that the tattoos were removed faster than with the single treatment per session standard protocol.

The Picosecond Alexandrite Laser

An exciting new technology has recently come to the forefront. The first picosecond alexandrite laser (Picosure by Cynosure Inc.) is in the 10^{-12} domain. In theory, delivering a subnanonsecond pulse may more effectively confine the energy to the tattoo particle, causing increased photoacoustic breakup of the target. Potentially, this might allow for effective treatment utilizing lower fluencies, thereby resulting in less thermal damage to surrounding skin and less risk of scarring. In a recent study, 15 patients with darkly pigmented tattoos were treated with the picosecond alexandrite laser at sessions 6 weeks apart. Twelve of 15 patients completed the study. All 12 obtained greater than 75% clearance. Nine patients obtained greater than 75% clearance after having 2-4 treatments. The average number of treatment sessions needed to obtain greater than 75% clearance was 4.25. All 12 patients were satisfied or extremely satisfied with the treatment.[10]

Other Lasers and Light Sources

There are many articles in the literature which report scarring associated with tattoo removal when using intense pulsed light and long pulsed lasers without Q-switching (ie, the long pulsed Nd: YAG or long pulsed alexandrite).[11,12,13] This is because longer pulse durations exceed the thermal relaxation time of the tattoo pigment, causing excess heat conduction to the surrounding skin and subsequent scarring and pigmentary changes. These lasers are not suitable for safe destruction of tattoo pigment. Fractional CO_2 laser therapy immediately following Q-switched laser treatment has been reported to enhance the rate of pigment clearance when compared to Q-switched laser alone.[14] This may be due to ablation of superficial tattoo pigment and the induction of an immune response that facilitates removal of the tattoo particles. The fractional carbon dioxide lasers and fractional erbium:YAG lasers are useful to treat cosmetic tattoos. Q-switched lasers should not be used on permanent makeup tattoos composed of pink, tan, white, or yellow pigment. Use of a QS laser can lead to paradoxical darkening as the iron oxide pigment or titanium-dioxide pigment is reduced by the QS laser treatment.[15,16,17]

Conclusion

In the future, the increasing popularity of tattoos most certainly will give rise to an increase in requests for removal. Emerging technologies and innovative protocols will undoubtedly improved patient satisfaction and help us meet patient demand.

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