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Effective Tattoo Removal

Dr Zohaib Ullah discusses the challenges and limitations of treating tattoos with Q-switched laser technology

With the tattoo industry booming and sales worldwide reaching nearly $2 billion a year and climbing,[1] it is obvious that the market for the ever-increasing removal of such artwork is in high demand. Survey findings presented at the British Association of Dermatologists showed that around one-third of people regret their tattoos and a total of around 10% eventually do opt for tattoo removal.[2]

Given this, and the ever-evolving desire for speedy and painless results, the market for tattoo removal has come far from its true inception in the 1960s when laser usage became the norm. Prior to laser use, many different methods, including chemical peels, abrasion techniques with ablative treatments, excisions, microneedling and various other remedies were used, often with poor results, and high complication rates.[3] Due to these complications, the gold standard for tattoo removal has been Q-switched lasers.

To understand why lasers are able to help in tattoo removal, we must first understand how they work. For the purposes of this article, we will focus purely on Q-switched lasers and up-to-date methods, rather than historic usage of lasers, such as CO2 or argon-related. Although CO2 is still used today, for example in resurfacing treatments, it is not commonly in the scope for tattoo removal; CO2 took a back-seat due to the risks of unwanted complications, including post-inflammatory hyperpigmentation, burns and scarring, not to mention longer downtime.[4]

Q-switched lasers

Q-switched lasers emit nanosecond pulses with a high peak power. These pulses are calculated based on the thermal relaxation time of a pigment, thus leading to less surrounding tissue being traumatised by the resultant burst of energy itself. This allows the pigment to be broken down into smaller fragments, whereby the body's natural immune system can clear up the remaining pigment particles.[5] The range of Q-switched lasers are 532 nm (frequency doubled Nd:YAG), 694 nm (ruby laser), 755 nm (alexandrite) and the 1064 nm (Nd:YAG). The most efficient laser in tattoo removal in recent times is the 1064 nm (Nd:YAG), given its ability to switch between the 1064 nm and the 532 nm, thus covering the largest light spectrum for tattoo pigments.[6] This is demonstrated well in **Figure 1**. Although the other two wavelengths, 694 nm and 755 nm, have very good outcomes for specific colours in those ranges (**Figure 1**), having different laser devices for just one type of aesthetic treatment is not usually a viable business model. This would add to initial costs of supply vs. demand and they also have the highest risk of adverse events, when compared to the 1064 nm, such as pigment changes and or vascular/localised damage.[7] This is why the 1064 nm is a viable option as a single device, as it is able to cover the largest spectrum, with most tattoos being in the darker range, thus giving the best overall outcomes.

To understand how the tattoo is broken down, we must understand the theory of selective photothermolysis, which works on the basis that, in order to effectively treat tattoo pigment, the wavelength of light used must correspond to that which is maximally absorbed by that tattoo pigment.[8] This depends generally on a few factors. The colour of the laser light must penetrate the skin; it must be highly absorbed by the target chromophore, but less than the surrounding tissues; the time or pulse duration must be very short so that the heat is dissipated before the surrounding tissues are affected, and that sufficient energy can be sent down to ensure effective pigmentation fragmentation.[7] Several colours of laser light (quantified by light wavelengths) are used for tattoo removal (**Figure 1**). Subsequently, different lasers are better for different tattoo colours to a certain degree. The four types or lasers used interact very differently with pigment dependent on their parameters.[9]

Given the above, and looking at the light spectrum (**Figure 2**), it is easy to see why it is preferable to use Nd:YAG over the other choices, given its ability to target a larger area safely. If you follow the tattoo ink colour ranges at the bottom of **Figure 2**, and the corresponding level above, it shows that the

	532 nm Nd:YAG Frequency-doubled	694 nm Ruby	755 nm Alexandrite	1064 nm Nd:YAG
Light production	Green	Red	Red (weaker)	Near infrared light (not visible)
Best targeted pigment	Red/yellow/orange	Green and dark pigments	Green but less on dark pigments	Dark pigments
Melanin absorption	High	Very high	High	Poor
Pigmentation concerns	Pigmentation and vascular issues	Pigmentation issues	Low risk	Low risk

Figure 1: Table shows which lasers are most suited to tattoo colours[9]

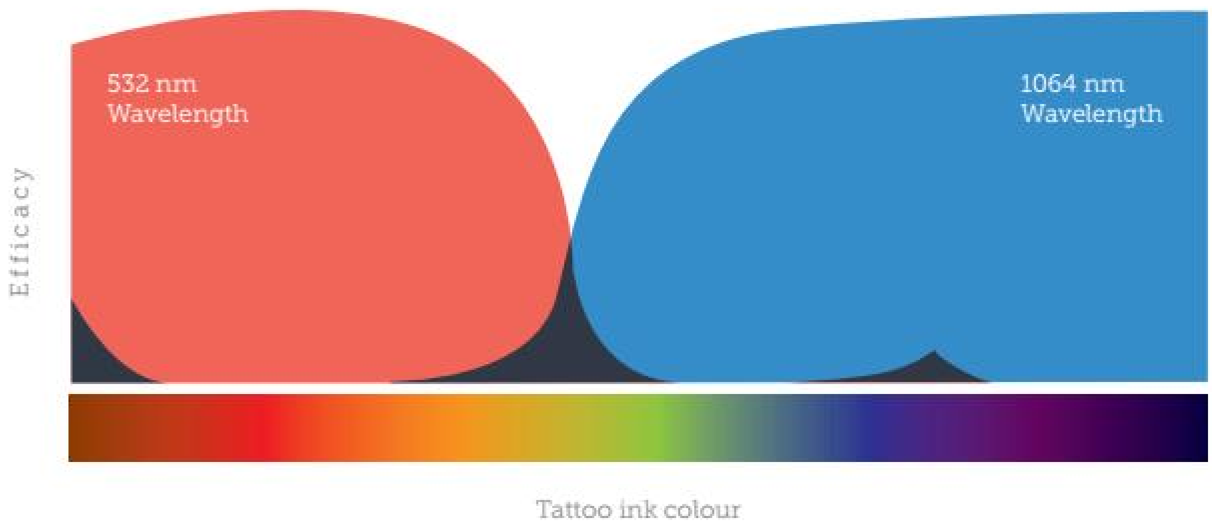

Figure 2: Efficacy of Nd: YAG laser wavelengths, defined by clearance of tattoo ink.[10]

level of efficacy remains high, apart from the very white-based colours.

Pulse width/duration (total time of laser beam activation) is also a critical laser parameter as well as spot size/width of the laser beam. Light disperses once in the skin, hence the larger the spot sizes, the increased effective penetration depth of the laser light, enabling more effective targeting of deeper tattoo pigments. Larger spot sizes also help make treatments faster; this also works the other way – when more superficial pigments need targeting, then a smaller spot size would help. Fluence (energy density) is another important consideration as this dictates how well the fragmentation will occur.[7]

Black ink has shown to be the easiest to work with when it comes to tattoo removal. This, with the combination of a lighter skin type, is the ideal environment for tattoo removal.[11] Conversely, white ink has the lowest absorption over the visible light spectrum and hence is hardest to remove. Given this, whites/yellow and flesh tone colours are typically the most difficult to remove.[12] It is also worth noting that white and lighter inks have a tendency to darken post-laser irradiation, but this is usually transient.[13] This was demonstrated in one study via an electron microscope, which showed post-irradiation white tattoo particles were still a mixture of large and small particles, whereas the black particles showed overall reduction in number and size, as well as some that were non-existent after treatment.[14] There is also Level 1 evidence to suggest that Nd:YAG lasers treat the most common colour, black, with excellent results.[15] Bright colours are harder to deal with in the 1064 nm spectrum, but higher doses and repeated treatment is very well tolerated in this case.[15]

Complications

There are a number of factors that determine how many treatments will be needed and the level of success one might experience. Age of the tattoo, skill of the tattooist, ink density and amount, colour and even where the tattoo is located on the body, all play an important role in how many treatments will be needed for complete removal. Nevertheless, complications and side effects can result from laser treatment and include scarring, hypopigmentation, hyperpigmentation, partial removal, infection, bleeding and tattoo ink darkening.

> Some tattoo pigments contain metals that could theoretically break down into toxic chemicals when exposed to lights

Although minimised in the advent of Q-switched lasers, complications can still occur at a rate of around 5%.[16] Immediate complications include pain, blisters, crusting and pinpoint haemorrhage. These are more common in darker skins, using a higher fluence[17] and can be easily minimised if topical anaesthetic is applied earlier or, in the case of crusting, blisters or infection, topical preparations to help soothe and treat.

The most common complication is pigmentation issues, either hypopigmentation or hyperpigmentation. These occur four to six weeks after laser treatment and most of them are transient.[18] However, longer lasting changes can occur, especially in darker or tanned skin, with up to 20% reported in those with darker skins.[18] There are also Level 2 studies that suggest Nd:YAG is far superior in terms of not only outcomes, but also in reduction of complications such as hypopigmentation, which is much more common when using ruby and alexandrite lasers.[19] There is some Level 3 evidence to even suggest a complication rate nearing 10% in patients when using ruby.[20]

Local allergic reactions, particularly to the red and yellow pigment, can occur in the form of pruritic papules, nodules or scaly plaques.[21] Systemic reactions rarely occur, but have been reported.[21] These local reactions may be early or delayed after several months or even years following tattoo removal.[22]

It is sometimes difficult to remove the tattoo in the first place, especially those with multi-layered or multi-coloured tattoos. This can sometimes leave a residual ink print, which can look like faded tattoos, which may also become unsightly. Alongside this, the skin texture can be affected, worsening this appearance. Also, newer inks have now begun to contain titanium, and with its highly reflective properties, can be hard to remove given the lasers being unable to fully penetrate them.[20]

Scarring is now less common given the introduction of 1064 Nd:YAG lasers, but is still a possibility if others are used at high fluences and with darker skins. In one such large level 2 study, adverse effects were observed in only 6.2% of patients with hyperpigmentation being the most common issue.[23]

It is thus important that the laser in question should be chosen according to the colour of the tattoo pigment and the patient's skin type. Generally, Q-switched 1064 nm Nd:YAG laser is safer in darker Fitzpatrick skin types, V-VI. The spot size, the fluence and the pulse duration are important and should be

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> Topical imiquimod is also another favourable option, with effects of tattoo removal destruction almost twice as improved

carefully selected. Some tattoo pigments contain metals that could theoretically break down into toxic chemicals when exposed to light.[24] These are usually found from tattoos that have been done abroad, in unsafe environments or unregulated parlours. Although this has not yet been shown in vivo, it has been demonstrated in laboratory tests.[24] 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.[25,26]

Combatting complications

These tattoo treatment limitations have led to some prevailing techniques to try to combat them and have shown some good progress. The 'multi-pass' technique (essentially overlapping an already treated area on the same sitting) has been found to be of good use,[27] with Level 3 evidence suggesting that even by the introduction of increased passing over in the same session (around three to four, rather than the conventional one pass) helps to remove tattoos in a smaller number of sessions in total.[27] Although there was an increased chance of epidermal injury, there were no adverse events or scarring. Dispersion of the tattoo inks was also much higher than via the conventional one pass method.[27] Added to this, there is also some Level 2 evidence to suggest that the multi-pass technique, combined with topical agents, can improve immediate outcomes, more specifically related to the whitening effect made after the initial pass (multiple or single, the whitening effect is spontaneous after the first pass). A study by Reddy *et al.* evaluated the safety and efficacy of topical perfluorodecalin in facilitating rapid effective multiple-pass tattoo removal, and found it to be as equally effective as treatment without the topical agent.[28] Topical imiquimod is also another favourable option, with effects of tattoo removal destruction almost twice as improved, and with no adverse reactions, according to one study.[29]
Also, there is the obvious fact that some wavelengths cannot be reached by the current lasers on the market. These are usually related to the lower spectrum and thus harder to treat. Picosecond lasers – as assumed by the name – may well help in this field and the future for tattoo removal.[30] They work by delivering pulsed energy in picoseconds, which is faster than the traditional nanosecond. This means that higher energy can be delivered, in a shorter period of time, resulting in maximal pigmentation removal and minimal damage to surrounding tissues.[31] In my opinion, this would mean that removal would be faster, safer and above all much more directed and colour-friendly than ever before.

Conclusion

Laser tattoo removal has come a long way since its inception in the 19th century, and continues to evolve. Although complications are becoming less frequent, with better controlled systems, it is likely to improve further with the first advent of the picosecond lasers. With this in mind, the only limitations continue to be the light spectrum in which to target different pigment colours, especially the white and lighter colours. With the tattoo industry itself booming, the ever more fluorescent/glitter and otherwise metallic-based pigments will be the next type of pigment removal that will need to be investigated.

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