Tattoo Removal With an Electro-optic Q-Switched Nd:YAG Laser With Unique Pulse Dispersion

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The objective of this study was to evaluate the clinical effectiveness of an electro-optic Q-switched Nd:YAG laser with standard pulse and pulse dispersion options for the treatment of unwanted tattoos.

Statistics released in 2002 from the American Society of Dermatological Surgery suggested that 50% of individuals receiving tattoos at that time would want them removed in 5 years.[1] The growing demand for effective tattoo removal without scars, pigmentation issues, or textural changes has fueled the search for alternatives to dermabrasion, cryotherapy, surgical excision, CO_2 or argon laser treatment, and other superficial and nonspecific destructive methods of the past.[2] Studies with ruby lasers in the 1960s were early milestones in the use of light-based therapy for the clearance of tattoo ink. In the succeeding 30 years, the Q-switched ruby, Nd:YAG, and alexandrite lasers would all prove the usefulness of the theory of selective photothermolysis in this area. Advances in Q-switched laser technology continue to provide increasingly effective methods for tattoo removal, addressing the need for low-risk, practical solutions to the problems presented by unwanted professional, amateur, traumatic, and cosmetic tattoos.

Although the biological pathways are not always fully understood, practitioners generally acknowledge that in the treatment of tattoos, the following principles apply[2-4]: (1) amateur tattoos are easier to remove than professional ones; (2) distally located tattoos are harder to remove, theoretically due to lymphatic drainage; (3) older tattoos are easier to remove; (4) darker Fitzpatrick skin types have a greater risk for scarring and pigmentary changes during laser tattoo removal procedures.

Three types of Q-switched lasers (694-nm Q-switched ruby, 755-nm Q-switched alexandrite, and the 1064-nm Q-switched Nd:YAG) have been studied in the treatment of tattoos. Each wavelength has an affinity for selective absorption by certain ink colors, the most common colors being black (Q-switched ruby, Q-switched Nd:YAG, Q-switched alexandrite), blue-black (Q-switched ruby, Q-switched Nd:YAG), green (Q-switched ruby, Q-switched alexandrite), and blue (Q-switched alexandrite). Newer Q-switched ruby lasers with a shorter pulse duration (approximately 25 ns) and higher fluences (8–10 J/cm^2) have shown greater effectiveness in tattoo ink clearance, but with a drawback of more nonspecific tissue damage.[4] Long-lasting hypopigmentation and transient hyperpigmentation are common side effects of Q-switched ruby laser treatment. Hypopigmentation is also a common occurrence with the Q-switched alexandrite laser, affecting approximately 50% of patients.[4] The 1064-nm/frequency-doubled 532-nm Nd:YAG laser provides a deeper penetration into the skin and less interaction with melanin,[5] and the 532-nm wavelength has the added benefit of red ink clearance.[4] A 1996 study of the Q-switched Nd:YAG in tattoo removal from darker Fitzpatrick skin type VI provided

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evidence of the suitability of Nd:YAG therapy for patients at significant risk for keloid scarring or the unwanted destruction of natural pigment during tattoo removal.[6] With its lower risk for hypopigmentation and proven clearance record for the most common dark blue and black inks, the Q-switched Nd:YAG offers a clear advantage in the growing field of tattoo removal. The present study was performed with an electro-optic (EO) Q-switched Nd:YAG laser with a unique pulse dispersion (PTP) option.

METHODS

Subjects

Fourteen subjects (8 male, 6 female), with tattoos of 6×6 cm or smaller who were not contraindicated or previously proven to be resistant to Nd:YAG laser treatment were enrolled in this institutional review board–approved study at 3 sites. Subjects' ages ranged from 18 to 46. Tattoos were located mostly on the arm (54.5%), with the remainder located on the neck, ear, buttocks, toe, and back (9.1% for each location). Subjects who had received treatment for tattoo removal within 3 months or had used photosensitizing drugs within a time frame where those drugs might still be present in the system were excluded. All subjects gave informed consent for treatment and photographs.

Treatment Protocol

All treatments were performed with an EO Q-Switched Nd:YAG laser. Subjects in this prospective, randomized, split-treatment study received a total of 4 monthly laser treatments. The study was designed to evaluate the efficacy of the laser in removing tattoos and to compare clinical ink clearance and tolerability between the standard pulse (SP) and PTP modes of the laser. The entire tattoo was treated at each session; half of the tattoo received treatment with the SP mode and half of the tattoo received treatment with the PTP option. Subjects were randomized as to which half of the tattoo area would be treated with the PTP option, as well as to the order of treatment (left to right vs right to left).

In the SP mode, treatment parameters were set at 1064 nm, with a pulse frequency of 10 Hz, fluences of 3.2 to 3.6 J/cm^2, with a 6-mm spot size, and 2 to 3 passes for dark ink colors (blue, black). For light ink colors (red, green, sky blue), investigators had the option of using either 1064-nm or 532-nm wavelengths, with or without 650-nm and 585-nm wavelengths. In the PTP mode, the spot size was increased to 8 mm, with all other treatment parameters identical to the SP mode. Investigators were allowed to use injectable or topical anesthesia for the entire treatment area. After laser treatment, a dressing and antibacterial ointment was applied. Subjects were provided with verbal and written posttreatment skin care instructions to gently clean the skin with warm water and a mild cleanser a maximum of 2 to 3 times daily. Subjects were advised to apply a thin layer of antibacterial ointment to the treated area after each cleansing. Although showers were allowed on the day after the treatment, subjects were advised not to scrub the area, and if a scab should form, it should not be picked, scratched, or removed prematurely.

Standardized photographs were taken at baseline and at 30 days following the final laser session. Subjects and investigators who were blinded to the randomization assignment and were not involved in the performance of the laser treatments were asked to assess the percentage of improvement according to the following scale: 0%=no improvement; 1% to 25%=poor improvement; 26% to 50%=fair improvement; 51% to 75%=good improvement; 76% to 99%=excellent improvement; and 100%=clear (no visible ink). Subjects reported on the tolerability of the SP and PTP modes of treatment. Stinging/burning sensations were recorded on a 4-point scale: 0=none; 1=mild; 2=moderate; and 3=severe. After each half of the treatment was performed, blinded investigators were asked to record the effects of the treatment with regard to any erythema, scaling, dryness, edema, or blistering. These effects of treatment were judged on a 5-point scale: 0=none; 1=minor; 2=mild; 3=moderate; and 4=severe. These assessments were recorded independently of adverse/unanticipated device events.

RESULTS

Fourteen subjects received an initial treatment. Eleven subjects completed the study with 4 monthly treatments and were evaluated at 30 days following the final laser session. Tattoos were composed of greater than 50% black and dark blue ink. Seven of the tattoos were professional, and one tattoo was amateur. One site with 3 subjects did not classify the tattoos. Blinded investigators and subjects completed percentage of improvement questionnaires.

Investigator-Rated Percentage of Improvement

Table 1 shows the percentage of improvement scores recorded by the blinded investigators for 11 subjects. On the SP-treated side of the tattoo, 4 subjects (36.4%) received excellent ink clearance of greater than 76%; 4 subjects (36.4%) received good results of at least 51% improvement; 2 subjects (18%) showed fair improvement of at least a 26% reduction in the appearance of tattoo ink; and one subject (9.1%) showed a poor improvement of less than 25%. On the PTP-treated side, investigators rated 3 subjects (27.3%) as having achieved good

TABLE 1

Investigator Improvement Scores at 1 Month

	No Improvement	Poor Improvement	Fair Improvement	Good Improvement	Excellent Improvement	Clear
PTP	1	1	6	3	0	0
SP	0	1	2	4	4	0

Abbreviations: PTP, pulse dispersion; SP, standard pulse.

TABLE 2

Subject Improvement Scores at 1 Month

	No Improvement	Poor Improvement	Fair Improvement	Good Improvement	Excellent Improvement	Clear
PTP	0	3	5	2	1	0
SP	0	0	3	6	2	0

Abbreviations: PTP, pulse dispersion; SP, standard pulse.

TABLE 3

Tolerability

	During Treatment				Posttreatment			
	None	Mild	Moderate	Severe	None	Mild	Moderate	Severe
PTP	1	5	4	4	11	2	1	0
SP	1	4	7	2	11	2	1	0

Abbreviations: PTP, pulse dispersion; SP, standard pulse.

improvement of 51% to 75%, and 6 subjects (54.5%) with a fair improvement rating of 26% to 50%. The investigators rated one subject (9.1%) as receiving a poor improvement score of less than 25%, and one patient (9.1%) with no improvement on the PTP-treated side.

Subject-Rated Percentage of Improvement

Eleven subjects rated their perception of the percentage of improvement after 4 treatments. Results are shown in Table 2. On the SP-treated side of the tattoo, 2 subjects (18.2%) reported that they had received excellent improvement of 76% to 99%; 6 subjects (54%) reported good results, with an improvement of 51% to 75%; and 3 subjects (27.3%) noted fair improvement of 26% to 50%. On the PTP-treated side, one subject (9.1%) reported excellent improvement of 76% to 99%; 2 subjects (18.2%) rated good improvement of 51% to 75%; and 5 subjects (45.5%) assessed fair improvement of 26% to 50%. Three subjects (27.3%) reported poor improvement of less than 25% on the PTP-treated side.

Treatment Tolerability

Subject tolerability of the treatment is shown in Table 3. Subjects rated any stinging/burning sensations both during and immediately after laser treatments on each side of the tattoo. Ratings are included for subjects who did not complete the study. During treatment, over half of the subjects (SP side: n=9, 64%; PTP side: n=8, 57%) reported moderate to severe discomfort. Immediately posttreatment, 11 subjects (78%) reported no discomfort, regardless of pulse modality.

Effects of Treatment

After laser treatment to each side of the tattoo, investigators rated the severity of expected treatment effects (erythema, scaling/drying, edema) on a 5-point scale as follows: 0=none; 1=minor; 2=mild; 3=moderate; and 4=severe. Fifty-eight expected treatment effects were assessed during 4 treatment sessions. The most prevalent effect was erythema (n=26; 44.8%), with an average severity score of 1.29. Twenty-four instances of edema were also reported (n=58; 41.4%), with an average severity score of 1.18. The investigators documented 8 cases of scaling/dryness, and all incidences were rated as minor. During the assessment of the second treatment, more instances of edema were reported on the PTP-treated side (PTP=5, SP=3), whereas a higher number of cases of erythema were reported on the SP-treated side (SP=5, PTP=3). For all other treatments, reports of expected effects of treatment were equal between the PTP-treated and SP-treated sides.

Adverse Events

Subjects did not report any downtime after laser treatments. There were no unanticipated device effects or adverse events of any kind during the study.

DISCUSSION

An EO Q-switched laser is able to achieve a shorter output pulse by storing energy between pulses. This trial was originally designed to study the differences between the SP mode and the unique PTP option of the EO Q-switched laser. While in SP mode, the EO Q-switched laser system is identical in strength and function to its predecessor, the MedLite C_6, which has a proven track record of success in the removal of common dark blue and black tattoo inks. Results from a recent retrospective study by Karsai et al[7] suggest that the flat top beam profile of the MedLite C_6 is uniquely effective in clearing tattoos which was proven resistant to previous Nd:YAG therapy. Utilizing larger spot sizes (3 mm, 4 mm, 6 mm) and a mean energy of 4.8 (SD, 1.3 J/cm^2), tattoos in the Karsai et al[7] study were treated 5 times with the MedLite C_6 at 4-week intervals. The investigators report the clearance rate as follows: 33% of subjects had results in the category of 0% to 25% clearance; 16.7% had clearance in the range of 26% to 50%; 16.7% of subjects had clearance as 51% to 75%; 30.5% of subjects achieved 76% to 95% clearance; and 2.8% of subjects had 96% to 100% clearance. Karsai et al[7] postulate that improved clearance of previously resistant tattoos is probably attributable to the larger spot size and a larger energy fluence in the deeper layers of the dermis, resulting in less treatment sessions and less potential for tissue reaction.[7] This study achieved 66.7% of patients with a clearance rate of greater than 25%. In our study of nonresistant tattoos, with a treatment algorithm involving a larger spot size in the PTP mode, but a lower fluence of 3.2 to 3.6 J/cm^2 and one less treatment, investigators reported a clearance rate of greater than 25% for 90.8% of patients on the SP-treated side, and 81.8% on the PTP-treated side. Subject ratings for the SP side of the tattoo were even higher. At the one-month follow-up visit, 99.7% of subjects assessed their percentage of improvement as greater than 25%. On the PTP-treated side, 72.8% of subjects rated their improvement as greater than 25% at one month following the final treatment.

In 1995, Levine and Geronemus[8] completed the first comparison study between the Q-switched ruby laser and the Q-switched Nd:YAG laser in the treatment of tattoos. Forty-eight professional and amateur tattoos were divided in half; one side of the tattoo was treated with each laser. Although the ruby laser proved to be superior in removing black and green tattoo ink, it was also found to have a higher incidence of hypopigmentation. The Nd:YAG laser in this study tended to produce more textural changes. A later study by Leuenberger et al[9] simultaneously compared 3 Q-switched lasers (ruby, Nd:YAG, alexandrite) for tattoo ink removal, and their results confirmed the fact that whereas the Q-switched ruby laser had the highest clearance rate for blue-black tattoo ink, it also had the highest incidence of long-lasting hypopigmentation.[9] In their discussion of the results of this study, the investigators also stated their belief that the final outcome in tattoo clearing (in favor of the Q-switched ruby laser) was influenced by the larger spot size. The Q-switched ruby laser in this study operated with a 5-mm spot size, whereas the Q-switched Nd:YAG and the Q-switched alexandrite utilized a 3-mm spot size. Results from the current study of the 6-mm and 8-mm spot sizes of the EO Q-switched laser add evidence to this argument that a larger spot size is beneficial for tattoo removal. It is also worth noting that Leuenberger et al[9] had 3 cases of hyperpigmentation (7%) with the Nd:YAG laser utilized in their study.

Prinz and colleagues[2] performed a retrospective analysis on tattoos treated with a single Q-switched laser system at 755 nm, 1064 nm, and 532 nm. Subjects received up to 15 laser treatments with either the 1064-nm wavelength (pulse duration 5–7 ns; spot size 3 mm; maximum energy density 5 J/cm^2); the 532-nm wavelength (pulse duration 5–7 ns; spot size 3 mm; maximum energy density 2.6 J/cm^2); 755-nm wavelength (pulse duration 100 ns; spot size 3–4 mm; maximum energy density 5 J/cm^2); or the variable pulse 532-nm wavelength (pulse duration 10–15 ns; spot size 3 mm; energy density 10–16 J/cm^2). The investigators state that the 532 nm was used for areas of erythema and telangiectasia in the tattoos. The average interval between treatments was 2.6 months. Their results were analyzed by type of tattoo (professional, amateur, cosmetic, accidental). However, with the exception of a few illustrative cases, the percentages of ink clearance were not linked to specific wavelengths. With this combination laser, 14 patients (19%) in the retrospective study achieved a complete response of greater than 95% lightening; 23 patients (31%) achieved a 76% to 95% lightening; 21 patients (28%) achieved a 51% to 75% lightening response; and 16 patients (22%) showed a response of 50% or less. The large patient population, multiple treatment algorithms, and significantly higher number of possible treatment sessions in the Prinz et al[2] retrospective analysis make comparison difficult. However, it should be noted that the retrospective trial detailed previously recorded 78% of patients with an improvement of 51% or greater. Despite the differences in study design, our study showed a similar 72.8% of investigator ratings with the same level of improvement. There were a small number of treatment-related adverse events in the Prinz study reported here, but there were no cases of postinflammatory hyperpigmentation or scarring in the EO Q-switched laser trial.

Although the novel PTP option on the EO Q-switched laser did not prove superior to the SP mode in this trial, it is a compelling fact that 72.8% of subjects and 81.8% of investigators assessed the ink clearance rate as greater than 25% on the PTP-treated side. In addition, contemporary study results of the PTP option for nonablative skin rejuvenation, collagen formation, and hair removal have shown a clear advantage for this mode of treatment. More than 60% of subjects in a recent study of photoaged skin (J. Garden, unpublished data, December 2008) reported considerably less discomfort during treatment in the PTP mode, as well as an increased number of excellent subject improvement ratings for the clinical signs of photodamaged skin and a high level of patient satisfaction. A contemporary histological study by Berlin et al[10] of the PTP mode further supplied evidence of new collagen formation by electron microscopy.

CONCLUSION

Laser therapy for tattoo removal is a complicated but growing field. The increased number of tattoos in recent years is linked to a greater diversity of inks with varying compositions, colors, and depth of implantation, requiring sophisticated methods for treatment. Results of the present study suggest that the EO Q-switched Nd:YAG provides reliable tattoo removal results with a small number of treatment sessions and a low risk for side effects.

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