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Nd:YAG Laser Tattoo Removal in Individuals With Skin Phototypes IV-VI: A Case Series

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Abstract

Introduction: Although tattoos are ancient and very popular among young people, it is also a reason for regret, and many people today have a desire to remove them. Among the possibilities for this, laser removal is the most successful procedure with the highest degree of pigment removal and the lowest risk of complications.

Methods: This study was recorded on three patients with tattoos, and only the black pigments were removed. None of the patients involved had a history of skin allergies, skin cancer, and/or keloid formation. Case 1 had a professional tattoo removed in the right calf region in two sessions. Case 2 had an amateur tattoo that was removed on the scalp in three sessions. Finally, Case 3 had two professional tattoos, which were removed from the face in a total of eleven sessions. The following equipment was used: Spectra XT Q-Switched Nd:YAG 1064 nm with a pulse width of 5 ns; Pico Ultra 300 Nd:YAG 1064 nm with a pulse width of 300 ps; and SoftLight Q-Switched Nd:YAG 1064 nm with a pulse width of 17 ns.

Results: In general, satisfactory results were obtained, but hypopigmentation was present in Cases 1 and 3. This was probably due to sun exposure at the laser removal site, the short interval between the sessions, and/or higher radiant exposure combined with a smaller spot size, respectively.

Conclusion: To achieve a successful tattoo removal in the higher phototypes and reduce unwanted effects, the professionals must know the best parameters to be used, as well as the adequate foundation on the individual characteristics of each patient and the tattoos. Furthermore, patient compliance with the pre/post session care and a suitable interval between the laser sessions are essential to avoid undesirable complications.

Keywords: Q-Switched laser; Nd:YAG laser; Laser tattoo removal; Tattoo removal.

Introduction

Tattoos are present on the skin in a large part of the population.[1,2] However, there is a significant percentage of regret and desire for the removal of the tattoo in individuals from several countries.[1,3,4] According to the American Society for Dermatologic Surgery, more than 160 000 tattoo removal procedures were performed in 2019 in the USA for a variety of reasons.[5]

Several techniques such as salabrasion, dermabrasion, electrocautery, cryosurgery, and chemical peeling have been developed to remove pigments from the skin since then, although they are accompanied by unsatisfactory results and adverse events, such as scar formation and skin dyspigmentation. Nowadays, tattoo removal with the Q-Switched Laser has become the method of choice, given the availability of different wavelengths, which allows for reaching the various pigments with a less risk of complications.[1,2,6]

The use of laser for tattoo removal is based on selective photothermolysis, which occurs from the absorption of energy that is emitted from the equipment to the ink that is present in the skin.[7] Additionally, light absorption may also generate any photoacoustic effect, whose mechanical stress might destroy the pigment particle.[1] In this way, the ink particles that are present within the lysosomes of the resident dermal cells are released into the extracellular space and phagocytosed, with the subsequent transfer through the lymphatic system and elimination.[1,4,8]

Although safe and effective, Nd:YAG laser tattoo removal in patients with ethnic skin, for instance, with Fitzpatrick skin phototypes from IV to VI, is still challenging since dyspigmentation and scarring are of greater risk. These effects may be due to existing biological characteristics in the darkly pigmented populations, namely an increased epidermal melanin content, especially enriched in DHI-eumelanin (black)[9] together with larger melanosomes that are more singly dispersed (non-aggregated) and widely distributed throughout the entire epidermis. Additionally, naturally more reactive fibroblasts due to genetic factors that are present in this type of population, favor the development of keloids and hypertrophic scars as a consequence of dermal injuries.[10,11] In addition, in

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patients with higher phototypes, it is common for results to take longer to appear, and they are often unsatisfactory, given that epidermal melanin acts as a competitor for the ink pigment that is present in the tattoo,[10] making these subjects more prone to hypopigmentation after the laser procedure.[1] Thus, this study aimed to describe and evaluate a case series, in which protocols were used to enable effective laser tattoo removal in patients with darker skin types.

Presentation of the Cases

This case series reports on three clinical cases of patients with Fitzpatrick phototypes between IV and VI, who sought a laser removal service because they were dissatisfied and regretful about instigating their tattoos. These patients were informed about the interest of the researchers to publish the information regarding their treatments, and they signed a consent form, which was approved by the Ethics Committee of Nove de Julho University, Brazil, No. 5.598.427. All of the participants also filled and signed the image use permission term.

All of the removed figures contained black ink pigment, and the patients that were involved in this study had no history of skin allergies, skin cancer, and/or keloid formation. All of the patients that have been described received asepsis with 70% ethanol, followed by 2% lidocaine, plus epinephrine 5 mcg/mL injections at the treatment site. All of these patients received skin cooling when using a cold air device (SIBERIAN-FIT®, VYDENCE Medical, São Carlos, Brazil) during the laser application. The devices used in this study were SOFTLIGHT® Q-Switched Nd:YAG 1064nm ThermoLase with a 17 ns pulse width, SPECTRA XT™ Q-Switched Nd:YAG 1064nm Lutronic with a 5ns pulse width, and PICO ULTRA® 300 Nd:YAG 1064 nm with a 300 ps pulse width, and their details are presented in Table 1. The interval between the sessions, the equipment models, and the parameters that were used for cases 1, 2, and 3 are shown in Tables 2, 3, and 4, respectively.

Table 1. Laser System Parameters

	SoftLight	Spectra XT	Pico Ultra 300
System type	Nd:YAG	Nd:YAG	Nd:YAG
Wavelength (nm)	1064	1064 (532, 585, and 650)	1064
Pulse width (ps)	17000	5000	300
Spot size range (mm)	4-7	2-10	2-10
Energy range (mJ)		100-1150	100-500
Radiant exposure range (J/cm^2)	2-9	0.13-38	0.13-16.7
Repetition rate range (Hz)	1-10	1-10	1-10

Table 2. Treatment Protocol for the Tattoo Removal in Case 1

Session	Date (M/D/Y)	Equipment	Repetition Rate (Hz)	Spot Diameter at Tissue (mm)	Radiant Exposure (J/cm^2)
1st	3/28/2020	SoftLight	5	6.8	2.0
2nd	12/4/2021	SoftLight	5	6	2.8

Table 3. Treatment Protocol for the Tattoo Removal in Case 2

Session	Session (M/D/Y)	Equipment	Repetition Rate (Hz)	Spot Diameter at Tissue (mm)	Radiant Exposure (J/cm^2)
1st	10/06/2017	SoftLight	10	5	1.6
2nd	03/03/2018	SoftLight	10	5	2.1
3rd	06/08/2019	SoftLight	10	5	2.6

Table 4. Treatment Protocol for the Tattoo Removal in Case 3

Session	Session (M/D/Y)	Equipment	Repetition Rate (Hz)	Spot Diameter at Tissue (mm)	Radiant Exposure (J/cm^2)
1st	7/24/2020	Spectra XT	5	5	5.2
2nd	9/23/2020	Spectra XT	5	4	6.8
3rd	2/22/2021	Pico Ultra 300	2	5	1.7
4th	4/19/2021	SoftLight	2	5	1.8
5th	6/11/2021	SoftLight	2	5	2.1
6th	9/23/2021	SoftLight	2	5	2.8
7th	10/27/2021	SoftLight	2	5	2.8
8th	11/22/2021	SoftLight	2	5	3.2
9th	1/13/2022	Spectra XT	4	5	9.2
10th	2/21/2022	Spectra XT	2	4	9.4
11th	4/7/2022	Spectra XT	2	3	13

* Spectra XT Q-Switched Nd:YAG 1064 nm, 5 ns pulse width; Pico Ultra 300 Nd:YAG 1064 nm, 300 ps pulse width; and SoftLight Q-Switched Nd:YAG 1064nm, 17 ns pulse width.

Based on the Kirby-Desai scale (KDS), the number of sessions needed for tattoo removal was estimated for each patient.[12,13] This scale attributes points to the characteristics, such as the Fitzpatrick skin type, location of the tattoo, color, amount of ink, scarring, and layering of the tattoos, together with cumulative points, correlated to the estimated number of sessions. During the description of the cases, after the presentation of the parameter, the number between the parentheses was the points that were attributed to it on this aforementioned scale.

Patient 1 was a 28 years old female presenting Fitzpatrick skin type VI (6 points KDS). Her tattoo contained black ink (1 point KDS), was performed by a professional and presented complex design (3 points KDS). It measured 22 per 10 cm on the right leg in the calf region (4 points). No scars or layering were present (0 points). Only two sessions were held, starting in March 2020, with a 21-month interval between them (Figure 1).

Patient 2 was a 28 years old male with Fitzpatrick skin type IV (4 points KDS). His tattoo was black (1 point), amateur and simple (1 point), performed on the head in the scalp region (1 point KDS) 1 year and a half before starting the removal. No scars or layering were present (0 points). A total of three sessions were held from October 2017 to November 2019 – 25 months (Figure 2), which resulted in an average of almost one session each for eight months, with five months being the smallest interval between the sessions and fifteen months being the highest.

Patient 3 was a 19 years old male, presenting Fitzpatrick skin type V (5 points KDS). He had two black tattoos (1 point KDS) on the face (1 point KDS) performed by a professional and presenting simple design (2 points). No scars or layering were present (0 points). He underwent the removal of the two tattoos, one on each side of the face (a rose on the right side of the face and an A on the left side of the face). A total of eleven sessions were held, which started in July 2020 and ended in April 2022– 21 months (Figure 3). The average interval between the sessions was almost one session every two months, with one month being the smallest interval between the sessions and five months being the highest. When considering the region of the tattoos being removed, this patient was deeply anxious regarding the treatment evolution, and even with the warnings regarding the interval between the sessions, he took the risk and asked for monthly sessions.

An independent investigator, unfamiliar with the

Figure 1. Patient 1 - Professional Tattoo (A) Before the 1st Session, (B) 4 Months After the 1st Session, (C) Before the 2nd Session With the Laser Treatment, 20 Months After the 1st Session, and (D) Six Months After the 2nd Session.

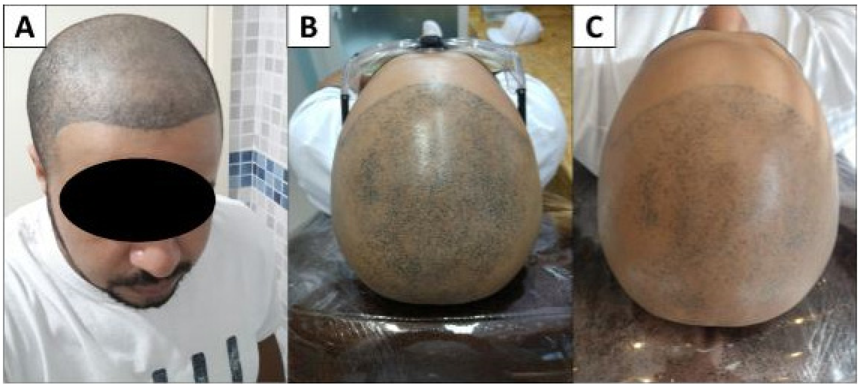

Figure 2. Patient 2 - Amateur Tattoo (A) Before, (B) After a Session, 5 Months After the First Session, and (C) 15 Months After the 2nd Session.

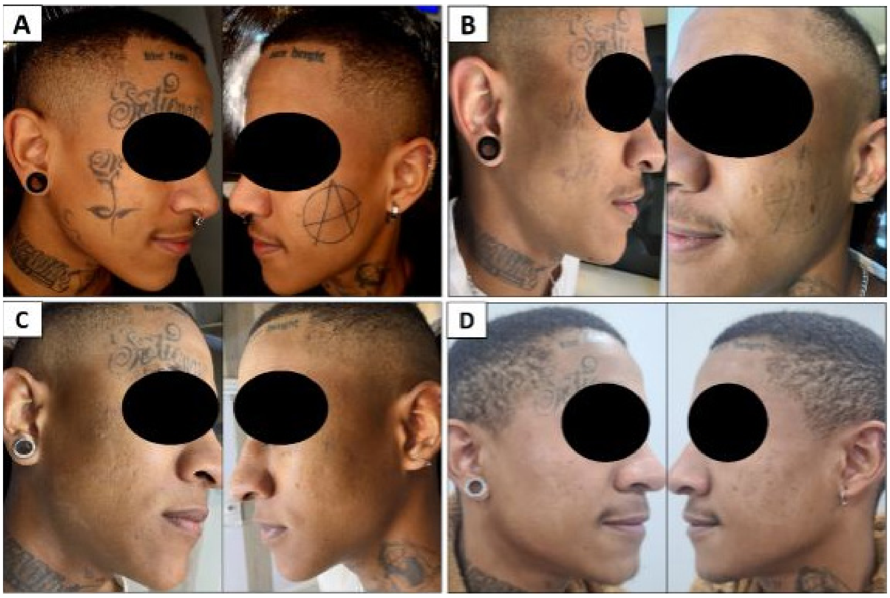

Figure 3. Patient 3 - Professional Tattoo (A) Before, (B) After Six Sessions, 165 Days Interval From the Beginning, (C) Results After the 11th Laser Treatment Session (an 18-Month Interval From the Beginning), and (D) Two Months After the 11th Session of the Laser Treatment (a 20-Month Interval From the Beginning).

subjects or the tattoos and not involved with the treatments, performed the assessment and the classification of tattoo ink lightness (TIL) from the serial digital photographs as presented in this study. The TIL was obtained based on the percentage of improvement in the photographs and described as 1: poor/minimal (<25%), 2: mild/moderate (25-50%), 3: good (51-75%), 4: excellent (76-95%), and 5: clear (>96%). The adverse events resulting from the laser procedure were also evaluated. These results are shown in Table 5.

Discussion

The Nd:YAG laser for tattoo removal is considered very versatile since 1064 nm is effective for dark pigments such as black and blue while using the KTP 532 nm red, orange, and yellow dyes are more prompt to respond.[1] When considering individuals with darker skin types, short wavelengths are not recommended. Longer wavelengths have the potential to penetrate more deeply, reaching the dermis and acting on the dark pigments, while preserving the melanocytes and keratinocytes in the epidermis,[1,11] together with a lower risk of adverse events such as hypopigmentation.[2,14] In general, the 1064 nm Q-switched Nd:YAG laser is safe for darker skin types,[8] and this was the choice for treating the listed cases.

In addition to the wavelength, other parameters such as radiant exposure, spot size, pulse width, the interval between the sessions, and the number of sessions are all important factors for a better tattoo removal result. Radiant exposure, measured in J/cm^2, is the energy that is delivered to the tissue's superficial area. When starting the treatment, the lowest radiant exposure that can induce a whitening response was used to protect the epidermis, minimizing any laser-induced dyschromia.[9] The whitening of the tattoo occurs due to the rapid heating of the pigment, which leads to the formation of gas or plasma, and that results in dermal vacuoles. This effect disappears only a few hours later. When high radiant exposure is used, the excess energy absorbed by the epidermis can result in blistering, peeling, and an increased chance of scarring.[11] The radiant exposure can be increased in later sessions as the ink density decreases.[1] A 7-11 J/cm^2 radiant exposure range is considered optimal for ink fragmentation[15]; however, in ethnic skin patients, smaller values should be considered. In this study, for patients 1 and 2, SoftLight was the equipment used, and the radiant exposure was used in the range between 1.6 to 3 J/cm^2, being smaller at the first session, and then it gradually increased.

Regarding the spot size, the smaller spots are usually

Table 5. Tattoo Ink Bleaching and the Identified Adverse Events

Patient ID	Number of Predicted	Number of Sessions	TIL (Before vs. After)	Adverse Effects		
	Sessions			Hypopigmentation/ Hyperpigmentation	Textural Changes	Scarring
1	14	2	4	Trace present	Absent	Absent
2	7	3	3	Absent	Absent	Absent
3	9	11	5	Present	Absent	Absent

TIL: tattoo ink lightness. The classification was realized based on the percentage of improvement in the photographs and described as 1: poor/minimal (<25%), 2: mild/moderate (25-50%), 3: good (51-75%), 4: excellent (76-95%), and 5: clear (>96%).

used with higher radiant exposure in the patients with low skin phototypes (Fitzpatrick phototypes I to III), while in the patients with darker skin (phototypes IV to VI), the treatment, in general, starts with low radiant exposure and a larger spot size.[1] When considering that there is a reduction in the depth of light penetration as the skin color becomes darker, the reduction of the spot size makes the energy delivery more superficial with a greater scattering degree, making it necessary to increase the radiant exposure so that there is a balance in the energy delivery and the removal of the remaining ink.[1] Therefore, in the cases presented, an increase in radiant exposures was used during the sessions and was associated with the reduction of the spot size, which occurred according to the degree of remaining pigment. It is important to note that for case 1, which presented a higher skin phototype (VI), higher spot sizes were used (6.8-6), but for case 2 (phototype IV), a spot size of 5 mm was used. On the other hand, smaller radiant exposures were used in case 2 in comparison with case 1, which resulted in the worst clearance/removal (TIL 3 versus TIL 4 – Table 5). Hence, those patients presenting higher skin phototypes need higher spot sizes and lower radiant exposures.

Additionally, the pulse width is a parameter, and this influences the results since it interferes with the extension of the photoacoustic and photothermal effects. Depending upon the particle size of the ink used, the specific thermal relaxation time (TRT) and the inertial confinement time will necessarily be used. When the pulse width is larger than the TRT, this can cause thermal damage to the surrounding tissue, reducing the bleaching effect and increasing the unwanted effects on the tissue. Smaller pulse widths might be necessary for treated tattoos since the particle size gets smaller.

When considering the devices that were used in this report, SoftLight presented the largest pulse width (17 ns), followed by Spectra XT (5 ns), and finally Pico Ultra (300 ps). At the beginning of cases 1 and 2, SoftLight was the only equipment available at the clinics, so it inevitably was the choice for these treatments. For the treatment of patient 3, the first two sessions were performed with Spectra XT since it was mentioned that the black ink pigments of TRT were around 10 ns; thus, the pulse width used was smaller than that for the TRT. With tattoo bleaching, a smaller pulse width was used with Pico Ultra. When using Pico Ultra, some technical issues were observed regarding the maintenance of the device. The treatment was then reinitiated using SoftLight when considering the low radiant exposure. Gradually, the radiant exposure was increased up to 3.2. The treatment was again changed to a smaller pulse width with Spectra XT, gradually increasing the radiant exposure and reducing the spot size.

Tattoo removal is a treatment that greatly involves the patient's emotional/psychological state. The regret or dissatisfaction with the tattoo might affect self-esteem, confidence, and both social and professional relationships. Accordingly, it is important to manage the patient´s anxiety and his/her expectation regarding the treatment. In case 3, it was possible to verify that after 11 sessions, there was slight hypopigmentation at the removal sites (see Table 5), which does not have an exact mechanism described but might be associated with cellular damage by shock waves, as well as the physical effects that are induced by thermal expansion and/or the extreme thermal gradients within the melanocytes.[14] Hypopigmentation is considered a common adverse effect, where the number of sessions is considered a risk factor,[16] reaching 8.1% and 2.7% when using the 1064 nm nanosecond laser and the 1064 nm picosecond laser, respectively.[15] In addition, the patient in question requested a greater number of sessions during the initially combined treatment period, causing a reduction in the interval between the sessions, and insisted even after the professional alerted the patient about the possible risk of hypopigmentation. In the most recent photo that was obtained after the 11th session, it was possible to verify that despite having improved, the observed hypopigmentation was still considerable. In the other cases, there was a longer interval between the sessions, and any pigmentation changes were not observed. Furthermore, the patient's immune response was essential for the success of laser tattoo removal since, after the ink fragmentation, the tissue response directs the phagocytosis and the removal from the skin.

The optimal number of sessions varies on a case-by-case basis, but typically, 4-6 sessions were required for amateur tattoo removal and 15-20 sessions, if not more, for professional tattoos.[17] When considering the KDS, 14, 7, and 9 sessions would be necessary for the tattoo clearance for patients 1, 2, and 3, respectively (Table 5). Very good results were obtained since TIL 4 (excellent) was obtained for case 1 after 2 sessions (12 sessions less than predicted), and TIL 3 (good) was achieved for case 2 after 3 laser sessions (4 sessions less than estimated), while TIL 5 (clear) was achieved for case 3 with 11 sessions (2 sessions more than estimated). Both Cases 1 and 2 could exhibit better results (TIL 5), with some additional sessions. It was important to keep in mind that a 'not so good' response in the lower limb tattoos might occur when compared with other locations, and this fact is documented.[17] This problem is possibly related to the transport of the particles resulting from the photo-pyrolysis and the photoacoustic breakdown via the lymphatic system,[18] which has a smaller number of lymph nodes in the lower extremities,[19] making it difficult to eliminate the pigment residues from the tattoo.

From the results presented, it can be observed that case 1 was the one that presented the best result with the smallest number of sessions, demonstrating, once again, the importance of using low radiant exposures, high spot sizes, and having an adequate interval between the sessions for the decomposition of the pigments and the removal of the residues that are generated via phagocytosis, especially in those patients prone to pigmentary and textural changes, in which longer treatment intervals might be useful.[13] It was also important to note that during the laser tattoo removal process, the patient should be instructed to avoid sun exposure, as well as using sunscreen during the treatment, to reduce the risk of complications.[7,13] In case 1, the patient, after the second session, did not show any signs of hypopigmentation, but in the most recent photo, the patient presented this complaint significantly after the skin tanning, which is also considered a risk factor for this adverse effect.[20] Last but not least, the use of cooling devices was also included since they increase comfort during the laser application, with decreased damage to the surrounding tissue.

Despite the anxiety and the expectation on the part of the patients to have the tattoo removed in the shortest possible time, this laser application when conducted several times on the same tattoo can result in fibrosis and visible textural changes, which reduce the response for the subsequent treatments.[13] A minimum time of a month is required between the sessions for optimal ink removal and wound healing,[1] as well as for the immunological breakdown process of the pigments, which leads to the continuous whitening of the tattoo, even after several weeks of treatment.[17] The findings of this study suggest that longer intervals between the sessions might lead to more favorable results.

Conclusion

The successful laser tattoo removal, with low or absent adverse effects on ethnic skin, is related to a good evaluation of the patient (for instance, Fitzpatrick's phototype, immunosuppression, the use of medications such as oral steroids, and whether the skin is tanned), and the tattoo to be removed (color, density of the ink, region of the body, and the age of the tattoo). Regarding this analysis, the success of the clearance/removal is defined by the treatment protocol that was used when considering the laser parameters such as wavelength, pulse width, radiant exposure, spot size, the number of sessions, and the interval between them. In this work, the researchers noted that for the black tattoos in ethnic skin, the 1064 nm with a 17 ns pulse width was effective (as did the smaller ones) using radiant exposures from 2 J/cm^2, with higher spot sizes (5-6.8 mm) and interval between the sessions longer than 2 months. The compliance of the patient to avoid sun exposure and to use sunscreen was essential to reduce the side effects that are related to dyschromia.

Conflict of Interests

The authors declare no conflict of interest.

Ethical Considerations

This case series report was evaluated by the Research Ethics Committee from the Universidade Nove de Julho, Brazil, and approved by No. 5,495,933 on June 28, 2022. Informed consent was obtained from all of the human adult participants.

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