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RESEARCH ARTICLE

THE USE OF Q-SWITCHED ND:YAG WITH *755nm* AND *1064nm* FOR TATTOO REMOVAL

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Abstract

High-power lasers have been frequently used to remove tattoo pigments. According to reports in the literature, the most used types of lasers for this purpose are Alexandrite and Nd:Yag. As an innovation, this study aimed to investigate the action of the Q-Switched Nd:Yag laser at two different wavelengths (755 nm and 1064 nm) for tattoo removal. A case study was carried out, in which the patient was selected according to the predetermined inclusion and exclusion criteria. The region was then examined and the treatment protocol was initiated. For this study, the Syrius Yag equipment, developed and manufactured by the Brazilian medical equipment industry - IBRAMED, was used. Three treatment sessions were performed with an interval of 45 days between them. In the first two sessions, the wavelength of 1064 nm, 200 mJ, 7 Hz with the spot set at 9 mm and 300 mJ, 7 Hz with the spot set at 8 mm respectively were used. The results demonstrated lightening of the tattoo throughout the treated area, quantified by scale at up to 75%, which indicates the effectiveness of the treatment in removing pigments present in the skin. In addition, the patient reported satisfaction with the treatment in only three sessions and no adverse events were recorded during the entire investigation period. In conclusion, the study demonstrates that the protocol using Q-switched laser at the wavelengths used is safe and effective for removing skin pigments, further reinforcing that the 755 nm fractional tip can significantly contribute to the removal of smaller and more superficial pigments.

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Introduction:-

Tattoos and permanent make-up have become common procedures over the last few decades due to a large population. Tattoos are created by inserting pigments into the skin, which remain in the dermis layer, and can be classified into five categories: professional, amateur, cosmetic, traumatic and medical. The most common are professional tattoos, produced by the vibration of a needle capable of injecting pigments of different colors into the skin, which are resistant and permanent, unlike the pigments used in amateur tattoos, which do not have the right quality for optimal permanence.

On the other hand, despite the spread of tattoos in the population, technologies and/or clinical strategies for their removal have become challenges in the biotechnological sphere, since in the past surgical procedures or dermabrasion were used to remove unwanted pigments, which resulted in significant tissue changes, such as scarring. The different types of pigments, their chemical composition and quality, the different colors, the possible mixing of colors, as well as the patient's skin type and immune system, and how long these pigments remain in the tissue must all be taken into account when assessing proper removal. This has led to the search for the use of photobiomodulation as a therapeutic resource in tattoo removal (Wenzel, Landthaler, Baumler, 2009).

Laser equipment has been used to remove tattoos since the late 1970s and has come to the fore in recent years due to its high effectiveness and low incidence of side effects (Kirby et al., 2009). In this sense, the Q-Switched laser has become an interesting treatment strategy, as it is non-ablative and operates by emitting short pulses of optical radiation in nanoseconds (Hruza et al. 1991; Leuenberger et al. 1999). It is known that laser light is by definition collimated, coherent and monochromatic, and therefore each wavelength is capable of interacting with the target tissue through the absorption of light by chromophores, which in this case promote the effect of selective photothermolysis (Bäumler and Weiß 2019; "Anderson, Parrish - 1981 - The Optics of Human Skin.Pdf," n.d.).

The 1064 nm wavelength has been reported to be effective in removing blue and black pigments in common tattoos, and it is also capable of interacting with red and brown pigments in cosmetic tattoos, including permanent make-up (Lin et al. 2009). It also has the advantage of being applied to larger phototypes, since the light effectively penetrates the dermis with less absorption in the epidermis. As a result, the Q-switched laser is currently considered the gold standard for tattoo removal and cosmetic micropigmentation. However, despite the vast literature demonstrating the use of lasers in tattoo removal, with technological evolution, new laser types are appearing on the market, such as 755 nm Q-switched lasers with fractional emission. Therefore, its therapeutic performance and clinical results are essential to validate its use in tattoo removal. This case study proposes to investigate the application of the Q-switched 1064 nm laser and the 755 nm laser in the removal of colored tattoos in order to establish the best protocol and parameterization to be used (Leuenberger et al., 1994; (Fitzpatrick and Goldman, n.d.)

Technological Evolution

Laser technology began with Albert Einstein's discovery in 1917. Huge efforts were then made to understand how this light interacts with tissue. The findings indicated that the penetration of this type of light is directly related to the wavelength and the target chromophore. When the parameters are adjusted appropriately to the therapeutic need, excellent results are achieved (Goldman et al., n.d.; Reid et al. 1983).

In the case of high-powered laser equipment, it is classified into two distinct categories according to its interaction with biological tissue: ablative, or those that promote thermal damage to the tissue, and non-ablative, which only induce tissue changes, without significant damage and long recovery periods. Records of lasers used to remove tattoos began in 1960 with the creation of Maiman's Ruby laser, which was later validated by Goldman, who described its selective mechanism for destroying possible targets. These discoveries led in the following years to the creation of the Q-switched Nd:Yag laser, with Anderson and Parrish describing the mechanism of selective photothermolysis and its ability to destroy specific targets in the skin.

The theory of photothermolysis predicts the rapid heating of the target chromophore, respecting its thermal relaxation, i.e. the time needed for the target to reduce its heat by 50% (Anderson1983) This time is generally related to the size of the target, with smaller targets being able to heat up more quickly, and therefore extremely short pulse durations are needed to achieve them, as shown by the switched Nd:Yag laser, which operates in nanoseconds. In addition, its precision is essential for protecting the surrounding tissues. Considering the tissue, the main chromophores involved are melanin, oxyhemoglobin, water and exogenous pigments, which is why it is an effective method not only for tattoo removal, but it can also interact in clinical cases of melasma, onychomycosis, telangectasia and even photoaging, depending on the choice of wavelength and parameterization (Watanabe 2008).

Specifically for tattoo removal, the literature presents the 532 nm and 1064 nm wavelengths as the gold standard, as they are capable of interacting with reddish and black pigments. In addition, there are reports on the interaction of the 755 nm alexandrite laser wavelength with the same pigment coloration, showing good results. However, there

are no reports of the use of this wavelength, 755 nm, in the Nd:Yag laser. This emerges as a novelty in the biotechnology field, and is supported by taking into account the same action mechanism and its depth of action, adding properties due to its ability to fractionate the shots, which can mediate particles present on the tissue surface and which have a smaller scale, in addition to pigments in the colors blue, purple and green (Zelickson et al. 1994).
In a brief evaluation of the performance of both wavelengths, 755 nm and 1064 nm of the Q-switched Nd:Yag laser, in tattoo removal, the main differences are in the tissue depth reached, with the shorter wavelength being relatively more superficial, and the ability of 755 nm to fragment pigments into different colors. In terms of interaction with dark pigments, both works effectively, since they have a high affinity with hemoglobin and melanin. Considering these characteristics, clinically the advantage is to use the 1064 nm wavelength to remove the tattoo color and when the pigments are more fragmented, to use the 755 nm wavelength. Having both wavelengths in the equipment for a more effective therapeutic strategy when targeting pigment removal involving tattoos and micropigmentation.

Methods

Subjects Selection
The subject was selected by means of a previous anamnesis that identified their classification according to the inclusion criteria. Exclusion criteria included alterations to the subcutaneous tissue, including wounds and peeling, decompensated diabetes, coagulation problems, active infections or dermatitis, cancer and autoimmune diseases, pregnant or lactating patients and those who did not agree to sign the informed consent form for this study.
Protocol
For this study, we used the *Syrius Yag* equipment, developed and manufactured by the Brazilian Medical Equipment Industry - IBRAMED. Three treatment sessions were used in the clinical protocol. Before all treatment sessions, a test shot was taken at a single point to assess the formation of frost in the tissue. The proper formation of the frost reflects the energy to be used. In this case study, the first session was conducted using the 1064 nm wavelength with 200 mJ, 7 Hz with the spot set at 9 mm. In the second session, still using 1064 nm, after the test shot, the possibility of increasing the energy was verified, and so the equipment was set at 300 mJ, 7 Hz with the spot set at 8 mm. The third session was conducted with a wavelength of 755 nm, 300 mJ, 7 Hz. The sessions were held 45 days apart, and for the patient's comfort, ice compresses were applied before the sessions to anesthetize the area. Immediately after the procedure, low-power LED was applied, with a wavelength of 660 nm, 3 J of energy, 450 nm, 2.13 minutes. For this, the ANTARES equipment with cluster P1 was used, developed and manufactured the Indústria Brasileira de Equipamentos Médicos - IBRAMED.
Evaluation
All evaluations were made before and after treatment.
Phototype classification
Skin phototype was classified according to the Fitzpatrick Scale (table 1).

Table 1. Fitzpatrick scale for classifying skin phototype.

Phototypes	Characteristics	Sensitivity to the sun
I - White	Burns easily, never tans	Very sensitive
II - White	Burns easily, tans very little	Sensitive
III - Light Brunette	Burns moderately, tans moderately	Normal
IV - Moderate Brunette	Burns little, tans easily	Normal
V - Dark brunette	Burns rarely, tans a lot	Not very sensitive
VI - Black	Never burns, fully pigmented	Insensitive

Source: Suzuki *et al.,* 2011.

Photo analysis

For photographic recording, the iPhone 16 camera was used at a standardized distance of 80 cm from the patient. For support, a tripod was positioned in front of the patient and adjusted according to his or her height in order to properly frame the patient's face. It was centralized, with only the patient moving to reach the determined positions: frontal, lateral and 45° (between frontal and lateral), with the gaze directed towards the horizon. The background was kept white, using standard lighting (central focus of white light). The shots were taken at zoomof 1.2 mm, using top flash. The images were taken before and after treatment.

Graduation of tattoo clearing

The clearing of the tattoo pigment was graded using a scale as shown in Table 1. For this evaluation, 5 was determined as the highest clearing percentage and 1 as the lowest clearing percentage.

Table 1 - scale for determining clearing of the ink

Grade	% Clearing
1, poor	<25
2, fair	25-50
3, good	51-75
4, excellent	75-95
5, evident	96-100

Scale adapted from Kilmer et al., 1993

1) Evaluation of the patient's sensory perception in relation to treatment

During the procedure, the patient was asked about the sensation of pain, discomfort and warmth. To quantify this information, the individual indicated on the Visual Analog Scale (VAS) the number that best represented the sensation at the time of application. The VAS ranges are detailed in Table 2.

Table 2. Representation of the subjective visual analog scale

Grade	Description
0	No sensation
1 - 2	Light sensation
3 - 7	Moderate sensation
8 - 10	Intense sensation

Source: Adapted from Omi, 2017.

2) Evaluation of patient comfort and satisfaction with the treatment

Patient satisfaction and comfort were determined using a subjective scale of 1-5 (1 = very dissatisfied/very uncomfortable, 2 = dissatisfied/uncomfortable, 3 = no difference/no opinion, 4 = satisfied/comfortable, 5 = very satisfied/very comfortable) (Noyman et al., 2021).

Evaluation of adverse events

Adverse events such as erythema, edema, dryness, peeling, burns, blisters, hyperpigmentation, hypopigmentation, tingling and itching were evaluated after each treatment session and at 24 hours and 15 days after the treatment session, based on patient reports collected by the researcher.

Results

The patient was classified as phototype 3. The results showed a good improvement in the condition with the protocol used, considering only 3 treatment sessions, the first two of which were carried out with a wavelength of 1064 nm and the last with a wavelength of 755 nm. The photographic analysis showed significant clearing of the tattoo in the total area considered for treatment, mainly related to the dark pigments. Furthermore, in the region of green coloration, it was possible to identify a difference after the end of the protocol, showing that only the light green pigment content remained, which was probably used in the mixing of pigment colors. These changes are shown in figure 1. The grading of the clearing was also assessed using a quantitative scale, with a 51-75% reduction in color compared to the initial treatment, indicating the treatment as good. Regarding the sensation at the time of laser application, the patient rated it 6, which describes a moderate sensation associated with the mechanical impact and the heat generated in the tissue. Regarding the evaluation of satisfaction and comfort with the treatment, the patient's report was 4, which indicates satisfaction and comfort with the treatment. The adverse events recorded were erythema and edema after application, which are considered common due to the onset of local inflammation. No serious adverse events related to hypopigmentation, hyperpigmentation or burning were reported during treatment.

Figure 1 – Photographic demonstration of the before and after application of the protocol using the Q-Switched 1064 nm and 755 nm lasers.

Discussion

Q-switched lasers are often used to remove tattoos. This type of laser operates by the mechanism of selective photothermolysis, and for this to occur, it is necessary to choose the appropriate wavelength in relation to the target chromophore of interest, and to determine the appropriate tissue depth to be reached. In the case of tattoos and micropigmentation, the target chromophore is the pigment. Pigments are electron conjugates in molecules of different colors and are therefore able to absorb light in a specific spectral range (Sardana et al., 2014; Hałasiński et al., 2023; Kent and Graber, 2011; Williams, 2014; Gomez et al., 2010).

The absorption of light generates internal heating that is capable of fragmenting the pigments, which is why the pulse duration of the emission must be short, in the order of nanoseconds. The short pulse duration facilitates the delivery of high energy intensity, which produces the heating necessary for particle fragmentation, but without the risk of transferring this heat to adjacent tissues, characterizing the safety of this technology (Gómez et al., 2010; Hałasiński et al., 2023; Kent & Graber, 2012; Sardana et al., 2015; Williams, 2014). However, tattoos with similar colors may contain a mixture of different pigments, and this will reflect on the absorption of laser light, which can influence the final result of their removal. Therefore, for an adequate therapeutic result, all these details must be considered, and only then will it be possible to determine the ideal number of sessions for each case (Bäumler and Weiß 2019; Kirby, Desai, and Desai 2009).

The aim of this study was to evaluate the effects of the Q-switched laser at wavelengths of 755 nm and 1064 nm for tattoo removal. The results showed a good progression of the treatment, with more than 50% of the tattoo clearing. The treatment strategy was to use the ND:Yag 1064 nm laser in the first two sessions and the ND:Yag 755 nm laser in the third session. The literature is scarce on the 755 nm wavelength of the ND:Yag laser, since the laser cited at this wavelength is the Alexandrite (Moreno-Arias and Camps-Fresneda 1999). In our study, in addition to evaluating this technological innovation related to wavelength, we also used a fractionated tip with the intention of reaching the smallest particles in the dermis in addition to the colored pigments.

With regard to the clearing obtained, the study by (Kilmer et al., 1993) showed that, in fair-skinned people, the Q-switched Nd:Yag laser is able to clear black tattoos in 4 sessions, achieving a 75% reduction in color in 77% of the patients, reaching a 95% reduction in color in 28% of the individuals treated. These findings partially corroborate our results, differing in the number of sessions. If we consider that the clearing obtained in the protocol presented by this study, in a smaller number of sessions, we can hypothesize that a result superior to that found in the study by (Kilmer et al., 1993.) On the other hand, the study by (Sardana et al. 2015) reported that 3-5 treatment sessions were required to clear the tattoo, using the Nd:Yag 1064 nm laser, 6 ns pulse duration, frequency of 1-3 Hz, pulse energy of 250 mJ, and spot area of 1-4 mm, with persistent erythema one day after the session.

Although dark pigments interact well with this type of light, the literature points to a challenge in relation to green and blue pigments. The study by Kilmer et al., 1993, mentions that multicolored tattoos did not respond well to treatment and showed great resistance to fragmentation even after a few treatment sessions. On the other hand, (Anderson1983) found that green and red pigments absorb their complementary colors the most, with dark colors responding effectively to the 600 to 800 nm spectrum. On the other hand, studies by (Bäumler & Weiß, 2019; Beute et al., 2008), (Hodersdal et al., 1996) pointed out that the green color can be removed with the 755nm alexandrite laser. In a comparison of lasers for removing this type of pigment, Levine and Geronemus reported that Alexandrite and Nd:Yag showed similar results, with the difference being a greater number of complications related to hypopigmentation in the Alexandrite laser. In addition, the authors evaluated two Nd:Yag wavelengths, 532 and 1064 nm, and reported that the shorter wavelength may be more effective in removing colored pigments.

We therefore used 755 nm Nd:Yag in our protocol with the intention of fragmenting the smaller-scale dark pigments present on the surface and also acting on the green pigments. The results indicated a modification in the green coloration, which induces a clearing of the color, but the evidence in the removal of this color from the tattoo was much lower when compared to the dark pigments, and in this case, a greater number of sessions and the association with a shorter wavelength could be more effective. However, there is a clear need for future clinical studies to accurately answer this fact and establish the best clinical strategy to act on these types of pigments specifically.

Looking at the action mechanism, long wavelengths penetrate deeper into the dermis, so they are not quickly absorbed by melanin, which leaves the overlying epidermal melanocytes intact and reduces thermal injury problems. In addition, the pulse duration is directly related to the energy delivery that will reflect the quality of pigment fragmentation, i.e. Nd:Yag at 10 ns seems to be more advantageous compared to alexandrite at 100 ns and Ruby at 25 ns (Lin et al. 2009; Leuenberger et al. 1999).

However, although there are several studies evaluating the action of lasers for tattoo removal, there are difficulties in comparing protocols, since variables such as skin type, pigment type and quality can interfere with the final result, with some reports showing total removal and others only partial removal. Another big question is the number of sessions required, which will depend on the size of the tattoo as well as the factors mentioned above. The variation in the number of sessions found in the literature is between 5 and 15 for amateur tattoos and between 15 and 20 for professional tattoos. Karsai S, Raulin C, et al., 2011. In professional tattoos, (Sardana et al. 2015) reports the need for fewer sessions when compared to previous studies. In our study, it was possible to identify significant and satisfactory clearing with just 3 sessions.

As a result, it was possible to conclude that the use of Nd:yag at a wavelength of 1064 nm is effective in reducing tattoos, especially dark pigments. While Nd:Yag 755 nm has the potential to act on more superficial pigments, promoting greater pigmentation as well as clearing green pigments. Therefore, this treatment protocol shows promise as it significantly cleared the pigments in the first three treatment sessions. In addition, it should be noted that no complications were recorded, which reinforces the safety of the Nd:Yag laser as already demonstrated in the literature. The findings of this study contribute to the field of high-powered lasers for tattoo removal by evaluating a 755nm Nd:Yag with a fractionated tip, but future studies are still needed mainly to investigate an alternative treatment for colored pigments.

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