Optimizing Q-switched lasers for melasma and acquired dermal melanoses

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Abstract

The Q-switched Nd:YAG laser is an established modality of treatment for epidermal and dermal pigmented lesions. The dual wavelengths of 1064nm and 532nm are suited for the darker skin tones encountered in India. Though this laser has become the one of choice for conditions such as nevus of Ota, Hori's nevus and tattoos, its role in the management of melasma and other acquired dermal melanoses is not clear. Despite several studies having been done on the Q-switched Nd:YAG laser in melasma, there is no consensus on the protocol or number of sessions required. Acquired dermal melanoses are heterogenous entities with the common features of pigment incontinence and dermal melanophages resulting in greyish macular hyperpigmentation. This article reviews the current literature on laser toning in melasma and the role of the Q-switched Nd:YAG laser in stubborn pigmentary disorders such as lichen planus pigmentosus. As the pathology is primarily dermal or mixed epidermal-dermal in these conditions, the longer wavelength of 1064nm is preferred due to its deeper penetration. Generally multiple sessions are needed for successful outcomes. Low fluence Q-switched Nd:YAG laser at 1064nm utilizing the multi-pass technique with a large spot size has been suggested as a modality to treat melasma. Varying degrees of success have been reported but recurrences are common on discontinuing laser therapy. Adverse effects such as mottled hypopigmentation have been reported following laser toning; these can be minimized by using larger spot sizes of 8 to 10mm with longer intervals (2 weeks) between sessions.

Key words: Acquired dermal melanosis, lichen planus pigmentosus, melasma, Q switched Nd:YAG laser

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Introduction

Disorders of pigmentation causing considerable social and psychological distress to patients are often encountered in clinical practice. Pigmentary conditions can be classified based on the location of pigment as epidermal, dermal and mixed epidermal-dermal lesions.[1] This rough classification is important as it dictates the choice of therapy. Epidermal lesions such as freckles, lentigines and café au lait macules are classical in presentation and have a predictable response to treatment.[2] The other two categories tend to be less distinct and generally have a variable response to laser therapy.

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Dermal melanosis can be broadly divided into two categories – congenital or acquired. Nevus of Ota, nevus of Ito, blue nevus and Mongolian spots are congenital in nature but nevus of Ota can appear later in life.[3] Hori's nevus (acquired bilateral nevus of Ota-like macules), dermal melasma and lichen planus pigmentosus are typically acquired later in life. Histologically, these lesions have melanin granules in the dermis, in melanophages or in nevoid cells.[4] Dermal melanoses are challenging in that they seldom respond to topical medical therapy or aesthetic procedures such as superficial peels. Lasers have played a significant role

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in the management of these conditions due to their precise selectivity, depth of penetration and the ability to spare the epidermis.[5]

Q-Switched Nd:YAG Laser-Tissue Interaction

The Q-switched Nd:YAG laser is the laser of choice for dealing with dermal and mixed epidermal-dermal pigmented lesions, particularly in dark skin.[6] The laser's ability to specifically target melanosomes in melanocytes, keratinocytes and melanophages, its ultra-short pulse width (in nanoseconds) and adjustable spot size are key factors that allow effective targeting of dermal pigment.[7] Depth of penetration and selectivity are functions of the wavelength of a laser. The Q-switched Nd:YAG laser has two wavelengths – a longer wavelength of 1064 nm and a shorter wavelength of 532 nm. The longer wavelength of 1064 nm is ideal for dermal lesions due to its deeper penetration and poor absorption in epidermal melanin.[8] These lasers have a large spot size up to 10 mm, which also allows deep penetration of the laser beam. Depth of penetration is directly proportional to the spot size of the beam, as more photons are likely to remain within the area.[6] The mechanism of action of these lasers includes both a photothermal effect and photomechanical/photoacoustic phenomenon that is based on the principle of selective photothermolysis.[8] To achieve successful outcomes and minimize side effects, it is necessary for the laser to have a "top-hat" beam profile where uniform energy is distributed over a given spot size area without producing undue "hot spots." Of late, a fractional handpiece has also become available for some Q-switched Nd:YAG laser systems, wherein the laser beam is split into microbeams, delivering laser energy to a part or fraction of the area treated.[9] The fractional handpiece is primarily used for rejuvenation, rhytides and pigmentary conditions such as melasma.

Approach to Laser Treatment in Darker Skin

Treating pigmentary disorders in dark skin requires some precautions to attain best results.[1] These include:

- Strict sun-protective clothing and use of broad-spectrum sunscreens of SPF at least 30 and PA +++ prior to starting laser treatment and throughout the course of therapy
- Proper priming with skin-lightening agents such as hydroquinone, kojic acid, and/or other non-hydroquinone skin lightening agents. at least 2 to 3 weeks prior to the initiation of laser therapy
- Performing test treatments/test spots to choose the right fluence
- Individualizing the treatment parameters for the patient and indication
- Use of a laser with a "top-hat" beam profile, large spot size, and lower fluences in darker skin types.
- Avoiding stacking and too much overlap while treating
- Cooling the treated area with continuous air cooling (Zimmer)
- Postoperative ice pack application for a few minutes, application of emollients and a steroid ointment for 3 to 5 days (if blistering or crusting are anticipated).

These simple measures can go a long way in achieving good results while lowering the chance of damage to the skin.[1]

Role of Lasers in Melasma

Dermal melanoses such as nevus of Ota and nevus of Ito have a predictable response to Q-switched Nd:YAG lasers with

Figure 1: Nevus of Ota on the left cheek

Figure 2: Nevus of Ota after eight Q-switched Nd:YAG laser sessions

well-established protocols[10] [Figures 1 and 2]. This article will focus on melasma. Though melasma can be epidermal, dermal or mixed, it is the dermal component that poses significant challenges to topical or standard therapy. Laser therapy has opened up new possibilities to tackle this condition.

The concept of laser toning has gained popularity in Southeast Asia. This involves a low-fluence, multi-pass technique and multiple sessions at weekly intervals, and is based on the theory of subcellular selective photothermolysis proposed by Mun *et al*. in 2011.[11] Looking at ultrastructural changes in the melanosome using transmission electron microscopy, they found that, epidermal melanocytes had fewer dendrites after laser treatment than before and that laser treatment caused selective photothermolysis of Stage IV melanosomes. They concluded that laser toning was an effective method for treating melasma through subcellular-selective photothermolysis.

Traditional laser treatment is based upon the principle of selective photothermolysis which results in the destruction and death of pigment-containing cells.[5] However, in response to cell death, inflammation follows and results in repigmentation and recurrence. In contrast, high peak power, ultrashort pulse duration (5 ns) and a flat-top beam result in the destruction of only melanin in target cells, keeping the cell alive in the case of subcellular selective photothermolysis discussed above.[11] Because the fluence used is very low and there is no cell death, inflammation is kept to a minimum which could lead to less frequent recurrences.[11]

Review of Literature

A number of studies have reported the use of low-fluence Q-switched Nd:YAG laser treatment (laser toning) at weekly intervals for 8–10 sessions with some success.[12] Though it is effective effective, the risk of mottled hypopigmentation following multiple Q-switched Nd:YAG laser sessions at frequent intervals has been reported. Hence, caution needs to be exercised while performing this procedure and the risks should be explained to the patients. In our experience, modified laser toning with low fluence and large spot size of 10 mm with treatments performed once in 2 weeks instead of weekly treatments for 6–8 sessions is better as it decreases the risk of hypopigmentation. The chances of recurrence are very high after discontinuing the procedure with some studies noting figures as high as 81%.[12]

Chan *et al*. reported a series of patients with facial depigmentation after the use of low fluence Q-switched Nd:YAG laser. They concluded that laser toning with low fluence Q-switched 1064 nm Nd:YAG laser for skin rejuvenation and melasma can be associated with mottled depigmentation.[13]

Laser toning can be combined with triple combination therapy (fixed dose combination cream containing hydroquinone, tretioin and fluocinolone). Jeong *et al*. studied low-fluence Q-switched Nd:YAG laser for melasma with pre- or posttreatment triple combination cream. Laser treatment after topical triple combination cream was found to be safer and more effective than the posttreatment use of topical agents. Use of the triple combination may therefore be a good priming method prior to low fluence Q-switched laser therapy.[14]

Laser toning can be combined with intense pulse light treatment. Na *et al*. observed that such combination treatment may provide more rapid clinical resolution in mixed-type melasma with possible long-term clinical benefits when compared to laser toning alone.[15]

A study was conducted to investigate the efficacy and safety of 694-nm fractional Q-switched ruby laser combined with sonophoresis on levorotatory vitamin C for the treatment of 26 chinese melasma patients. Mean melasma area severity index score decreased from 15.51 ± 3.00 before treatment to 10.02 ± 4.39 3 months after the final treatment ($P < 0.01$). Side effects were minimal.[16]

Tian reported a novel technique using a combination of fractional 2940-nm Er: YAG and 1064-nm Q-switched Nd:YAG lasers. They achieved a rapid improvement in two cases of melasma in Chinese type III skin, seen within a month of treatment. Follow-up at 6 months showed sustained results with no complications. Though these results are encouraging, a definite conclusion is not possible with only two cases.[17]

Yue *et al*. found the fractional mode (Pixel) Q-switched Nd:YAG 1064-nm laser an effective and safe treatment for melasma. What was interesting was that they noted that the recurrence rate was lower than with large-spot low-fluence QS Nd:YAG laser. Mean melasma area severity index scores decreased from 12.84 ± 6.89 to 7.29 ± 4.15 after treatment ($P = 0.000$). Seventy percent of the patients got moderate-to-good improvements after all the treatments (8 sessions). They reported partial recurrence in 40% of the patients at the 3-month follow-up.[9]

Long-term recurrence rates may be high after low-fluence 1064-nm Q-switched Nd:YAG laser treatment in melasma. Gokalp *et al*. evaluated 34 melasma patients using a 1064-nm Q-switched-Nd:YAG laser. The parameters used were 6 mm spot size and 2.5 J/cm^2 fluence with multiple passes for 6–10 (median 8) sessions at 2-week intervals. After the low-fluence 1064-nm Q-switched Nd:YAG laser treatments, the mean modified melasma area severity index score decreased from 6.7 ± 3.3 to 3.2 ± 1.6 ($P < 0.01$). After treatment completion, 58.8% of the patients rated themselves as having at least a 50% reduction in melasma severity. One year after the last treatment, recurrence was observed in 20 patients (58.8%) and the mean modified melasma area severity index score had increased from 3.2 ± 1.6 to 5.8 ± 1.9

in all patients. This was one of the few studies where the follow-up duration was fairly long (1 year).[18]

A study by Kim *et al*. was done to investigate the efficacy and adverse effects after repeated low-fluence 1064 nm Q-switched Nd:YAG laser treatment with photoacoustic twin pulse mode in Asian women with melasma.[19] They found that after 5 sessions of laser therapy, approximately 60% of the patients showed significant improvement. It was concluded that a few sessions of repeated laser toning treatment using the photoacoustic twin pulse mode is a safe and effective way to treat facial melasma. Photoacoustic twin pulse involves splitting of the laser pulse into two with an interval of 100 microseconds between the two pulses. The energy is thus halved rather than a single high peak energy pulse. This mode is recommended for patients with sensitive skin or a low pain threshold.

Twenty patients were treated with 10 weekly sessions of low-fluence 1064-nm Q-switched Nd:YAG laser at 1-week intervals by Hofbauer Parra *et al*.[11] They used a modified melasma area severity index for evaluation up to 6 months after the last session. Epidermal melanin quantification was performed on 10 biopsy samples and compared before

Table 1: Summary of recent studies on the use of lasers in melasma

Journal	Title and authors	Conclusion	Remarks
Lasers Med Sci 2016 Jul 23	Yue B, *et al*. (2016)	The fractional mode (pixel) QS Nd:YAG 1064-nm laser is an effective and safe treatment for melasma. The recurrence rate was lower than that reported in studies with large-spot low-fluence QS Nd:YAG laser	The lower recurrence rate could be due to a lesser thermal effect with a fractionated beam
J Cosmet Dermatol 2016 Jun 28	Gokalp H, *et al*. (2016)	The recurrence rate after low-fluence 1064-nm QS Nd:YAG laser in melasma was high when the long-term results were considered	This result may be attributed to certain patient and treatment-related factors such as family history, exposure to sun light, parameters used.
Ann Dermatol 2016 Jun 28	Kim JY, *et al*. (2016)	After five sessions of laser therapy alone, about 60% of melasma patients showed significant improvement. A few sessions of repeated laser toning treatment using the photoacoustic twin pulse mode is a safe and effective way to treat facial melasma	Photoacoustic twin pulse involves splitting of the laser pulse in two with an interval of 100 microseconds between the two pulses. The energy is divided into half rather than a single high peak energy pulse
Skin Therapy Lett 2016 Jan	Sofen B, *et al*. (2016)	Combining topical therapy with procedures such as chemical peels, IPL, fractional nonablative lasers or radiofrequency, pigment lasers (microsecond, picosecond, QS) and microneedling enhances results.	
Dermatol Surg 2016 Apr	Hofbauer Parra CA, *et al*. (2016)	The results confirm the safety and effectiveness of low-fluence QS Nd:YAG laser for treating melasma; however, the high recurrence suggests poor long-term results when the laser is used as a monotherapy	High rate of recurrence precludes use of laser toning as first-line therapy
Ann Dermatol 2015 Jun	Jang YH, *et al*. (2015)	Laser toning-induced hypopigmentation is characterized by almost- destroyed melanosome pigments and a preserved number of melanocytes, which seem to be functionally downregulated not to produce fully-matured melanosomes.	This study endorses the subcellular selective photothermolysis theory and shows that after laser toning the melanocytes are down regulated rather than destroyed
Lasers Surg Med 2014 Sep	Fabi SG, *et al*. (2014)	Both low-fluence QS Nd:YAG and low-fluence QS Alexandrite laser were equally effective at improving moderate to severe mixed-type facial melasma	Both low fluence QSNY and QS alexandrite laser seem effective but long-term follow-up is needed with QS Alexandrite laser due to higher risk of hyper & hypo pigmentation
Am J Clin Dermatol 2014 Aug	Jalaly NY, *et al*. (2014)	Low-power fractional CO2 laser is safe and effective in the treatment of melasma	The results seem encouraging in this randomized split-face study, though caution needs to be exercised in darker skin types

IPL: Intense pulsed light, QS: Q-switched

and after treatment. All patients showed improvement by modified melasma area severity index scores, ranging from 21% to 75% from baseline. No permanent adverse effects were found but the recurrence rate was 81%. These results confirm the safety and effectiveness of low-fluence Q-switched Nd:YAG laser for treating melasma, but the high recurrence rate suggests poor long-term results when the laser is used as a monotherapy.

An update and expert opinion on melasma and post-inflammatory hyperpigmentation published by Sofen *et al*. opined that combining topical therapy with procedures such as peels, intense pulsed light, fractional nonablative lasers or radiofrequency, pigment lasers (microsecond, picosecond, Q-switched) and microneedling enhanced the results in management of melasma.[20] Their conclusion was that with proper treatment, melasma can be controlled, improved and maintained.

Mottled hypopigmentation has been frequently reported as a complication of laser toning. Jang *et al*. found that laser toning-induced hypopigmentation was characterized by almost-destroyed melanosome pigments and a preserved number of melanocytes, which seem to be functionally downregulated not to produce fully-matured melanosomes.[21] The presence of such downregulated melanocytes might allow some degree of recovery. Early discontinuation of laser toning, use of tacrolimus ointment and excimer light targeted phototherapy may therefore help in this situation.

Most of the data available on low-fluence laser toning is for Q-switched Nd:YAG laser. Fabi *et al.* compared low-fluence Q-switched Nd:YAG laser with low fluence Q-switched Alexandrite 755 nm laser.[22] They observed that both modalities were equally effective at improving moderate-to-severe mixed-type facial melasma.

Low-power fractional CO_2 laser too may be considered in the treatment of melasma. Jalaly *et al*. compared low-powered fractional CO_2 laser with low-fluence Q-switched Nd:YAG laser in melasma in a randomized, controlled split-face study.[23] The differences between the mean melanin index and modified melasma area severity index scores at baseline and 2-month follow-up were compared between the two treatments. It was seen that the reduction of scores was significantly more on the fractional CO_2 laser-treated side than on the Q-switched 1064 nm Nd:YAG laser-treated side ($P < 0.001$). A summary of the recent evidence on laser therapy of melasma is shown in the Table 1.

In the author's experience, laser toning with a Q-switched 1064 nm Nd:YAG laser with a 10 mm spot size at 1.2 J/cm^2, and a 10 Hz repetition rate with a multipass technique to an end-point of erythema without frosting, done once in 2 weeks for 6–10 sessions works best. In patients with sensitive skin, the Q-switched Nd:YAG laser pulse can be split into two (in select models) with a 100-microsecond interval between the two pulses, thereby lowering the discomfort or pain. This is called photoacoustic twin pulse

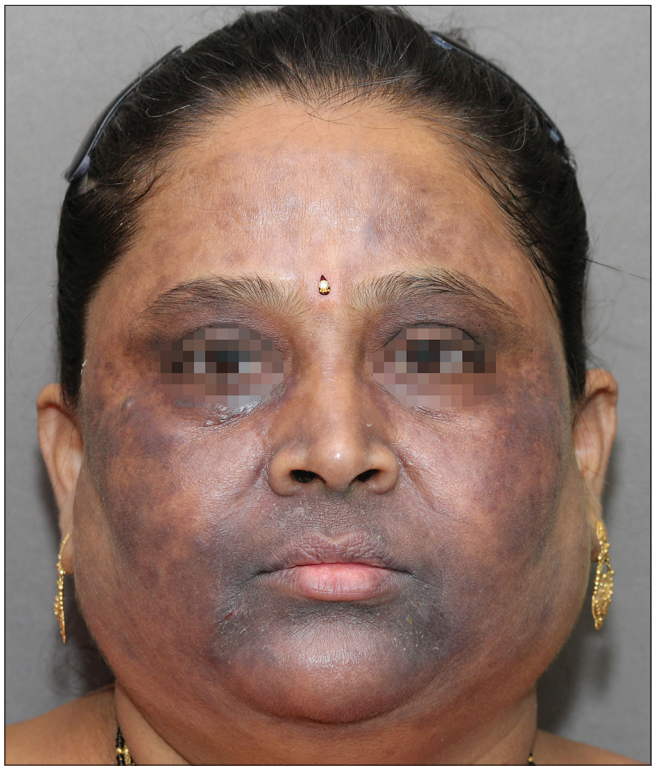

Figure 3: Lichen planus pigmentosus before laser therapy

Figure 4: Lichen planus pigmentosus after five sessions with the Q-switched Nd:YAG laser

Figure 5: Lichen planus pigmentosus before laser therapy

Figure 6: Lichen planus pigmentosus after five Q-switched Nd:YAG laser treatments at 1-month intervals

Figure 7: Lichen planus pigmentosus on the temple area

Figure 8: Lichen planus pigmentosus after five sessions of Q-switched Nd:YAG laser

or quick pulse-to-pulse mode in specific laser systems. For instance if a fluence of 1200 mJ is to be used, then by using a split-pulse two quick pulses of 600 mJ with an interval of 100 microseconds are delivered. The use of air cooling with the Zimmer cooling system also aids in minimizing patient discomfort.

Acquired Dermal Melanoses

Riehl's melanosis characterized by diffuse gray-to-black hyperpigmentation around the face is a challenge to treat. Kwon *et al*. in a pilot study using a triple combination approach (low fluence Q-switched Nd:YAG laser, hydroquinone cream and oral tranexamic acid) for the

Figure 9: Hori's nevus

Figure 10: Hori's nevus after five Q-switched Nd:YAG laser sessions

treatment of Riehl's melanosis in 8 patients found significant improvement after 10–18 sessions.[24]

Lichen planus pigmentosus is characterized by bluish-gray macular hyperpigmentation that is often distributed on the face, neck, upper trunk and arms. Histological features include an interface dermatitis, pigment incontinence and dermal melanophages. The pigmentation can be persistent and recalcitrant to medical therapy. Once disease activity ceases, the residual pigmentation can be tackled by a Q-switched Nd:YAG laser. In the author's experience, multiple (around 5) sessions of Q-switched Nd:YAG at 4–6 week intervals using a large spot size and moderate fluences (which vary with the laser used) yield excellent results. In a series of 10 patients (unpublished data), very good clearing was observed using this protocol, as seen in Figures 3-8. The parameters used in (lichen planus pigmentosus) with the Q-switched Nd:YAG laser were 1064 nm wavelength, 8 mm spot size, 1.5–1.8 J/cm^2 fluence and a 5–10 Hz repetition rate.

Hori's nevus or acquired bilateral nevus of Ota-like macules is another condition that responds well to Q-switched Nd:YAG treatment[1,7]. It is differentiated from nevus of Ota by later onset, lack of scleral involvement and its bilateral nature. Around five sessions are needed at 4–6 week intervals with the 1064 nm wavelength, 5 mm spot size, fluence of 4–5 J/cm,^{2} [Figures 9 and 10]. Recurrences are uncommon[7].

Key points

- Lasers can be used in selected resistant cases of melasma when medical therapy fails or the patient is intolerant to topical medication For melasma, most evidence available is for laser toning (low fluence, multi-pass Q-switched Nd:YAG laser technique).
- Nevus of Ota and Hori's nevus respond well to Q-switched Nd:YAG laser. Recurrences are very rare upon clearing of the lesion
- Lichen planus pigmentosus should be treated only when the condition has stabilized and there is no spread of the disease. Laser can be used in selected cases when activity ceases, and Q-switched Nd:YAG at 1064 nm can help clear the residual hyperpigmentation. However, multiple sittings are necessary.

Conclusion

Significant strides have been made in laser technology aiding in the successful management of dermal melanoses and melasma. Though a large number of studies have been done on melasma with various lasers including Q-switched Nd:YAG, Q-switched alexandrite lasers, ablative fractional lasers, intense pulse light, and non ablative fractional lasers there is no clear consensus on the correct protocol or combination. Most of these studies have shown encouraging results in melasma and other dermal conditions. Though results are good, recurrence rates reported have been particularly high for melasma, precluding the use of lasers as first line or even second line therapy. They are used at best as a last option in recalcitrant melasma or those intolerant to

other modalities. Conditions such as Hori's nevus, Riehl's melanosis and lichen planus pigmentosus do show a good response to laser therapy and further studies will help establish the role of lasers in these dermal melanoses.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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