Treatment of Infraorbital Dark Circles Using a Low-Fluence Q-Switched 1,064-nm Laser

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OBJECTIVE To evaluate the efficacy and safety of the low-fluence 1,064-nm Q-switched neodymium-doped yttrium aluminium garnet (QSNY) laser in treating infraorbital dark circles.

PARTICIPANTS AND METHODS Thirty women with infraorbital dark circles (predominant color dark brown) participated in this open-label study. Participants underwent eight sessions of low-fluence QSNY laser treatment at 4.2 J/cm² at 3- to 4-day intervals. A spot size of 3.5 mm was used, with a pulse duration of 8 ns. The melanin deposition in the lesional skin was observed in vivo using reflectance confocal microscopy (RCM). Morphologic changes were evaluated using a global evaluation, an overall self-assessment, a narrow-band reflectance spectrophotometer, and a skin hydration measurement instrument.

RESULTS Twenty-six of 30 patients showed global improvement that they rated as excellent or good. Twenty-eight rated their overall satisfaction as excellent or good. The melanin index indicated a substantial decrease, from 225.84 at baseline to 182.65 (p < .05). RCM results showed a dramatic decrease of melanin deposition in the upper dermis. Adverse effects were minimal.

CONCLUSIONS The characteristic finding for dark-brown infraorbital dark circles is melanin deposition in the upper dermis. Treatment of infraorbital dark circles using low-fluence 1,064-nm QSNY laser is safe and effective.

The authors have indicated no significant interest with commercial supporters.

Infraorbital dark circles refer to darkness of the infraorbital eyelids. They can be a significant cosmetic concern, and many individuals seek treatment for this common condition, but limited literature exists regarding the cause and treatment of this condition. The etiology of infraorbital dark circles may include dermal melanin deposition, postinflammatory hyperpigmentation (PIH) secondary to atopic or allergic contact dermatitis, periorbital edema, superficial location of vasculature, blood flow stagnation, and shadowing due to skin laxity.1–3

Dark circles can be divided into two broad categories according to their predominant color—dark brown or red-violet. For the dark brown circles, dermal melanin deposition was hypothesized to be the pathophysiologial factor. Thus, we designed our study to evaluate whether dark brown circles could be treated effectively using the low-fluence 1,064-nm Q-switched neodymium-doped yttrium aluminium garnet (QSNY) laser.

Rather than taking a biopsy specimen from the lower eyelid skin before and after the procedure, we used in vivo laser confocal microscopy to study changes in dermal melanin deposition.

Patients and Methods

Patients

Thirty Chinese women with a mean age of 35.5 (range 20–42), Fitzpatrick skin type III to IV, and a
history of dark brown infraorbital dark circles for at least 1 year participated in this study. Exclusion criteria were any sign of infection or inflammation around the eyes, pregnancy, use of oral retinoids in the previous 12 months, current use of nonsteroidal antiinflammatory drugs, and exposure to ultraviolet irradiation within 4 weeks of treatment. The Medical Ethics and Human Research Committee of China Medical University approved the study. Before enrolling in the study, all participants were informed of the risks, benefits, and possible complications of the treatment, and each participant provided informed consent.

**Treatment Protocols:** Participants were treated using the low-fluence 1,064-nm QSNY laser (Quantum equipped with QSNY handpiece, Lumenis Co., Santa Clara, CA) at 3- to 4-day intervals. A spot size of 3.5 mm was used, with a fluence of 4.2 J/cm² and a repetition rate of 5 Hz. All areas were treated using two passes. The end point was slight redness. After the procedure, the treated areas were compressed with an ice bag for 5 to 10 minutes to reduce any burning sensation and erythema. Before the procedure, for ocular protection, participants received a drop of 0.5% proparacaine hydrochloride in the eye, and the eye was then protected using a sterile eye shield. Participants were instructed to avoid sun exposure and to wear a broad-spectrum sunscreen (sun protection factor/Sun Protection Factor) during and after the treatment.

**Evaluation Criteria:** Participants were required to rinse their face thoroughly using a neutral lotion and rest in a temperature- (20°C) and humidity-controlled (40%) room for at least 30 minutes before the examination. They were photographed using a digital camera (Nikon 40S, Tokyo, Japan) under the same lighting conditions before the session (T₀), during the treatment (Tₓ: 3 days after x sessions of treatment), 3 months after the last session (M₃), and 6 months after the last session (M₆).

**Global Improvement Seen in Blind Evaluation**
A blind evaluation was undertaken in which three investigators rated improvements based on before-and-after photographs using four grades (0 = no improvement (<25% clearance), 1 = fair improvement (25–49% clearance), 2 = good improvement (50–74% clearance), and 3 = excellent improvement (>75% clearance)).

**Satisfaction Assessment of Participants**
Participants were required to assess their satisfaction on a 4-point scale (0 = no improvement (not satisfied at all), 1 = fair improvement (slightly satisfied), 2 = good improvement (moderately satisfied), and 3 = excellent improvement (very satisfied)).

**Noninvasive Measurement of Skin Color**
The skin colors at the darkest point of the lower eyelid and the highest point of the cheekbone (self-control) were measured as the melanin index (MI) and erythema index (EI) using a narrow-band reflectance spectrophotometer (MX18, Courage and Khazaka, Electronic GmbH, Cologne, Germany) according to the European Group on Efficacy Measurement of Cosmetics and Other Topical Products Recommendations. Each site was measured three times, and the mean value was calculated.

**In Vivo Laser Reflectance Confocal Microscopy**
Reflectance confocal microscopy (RCM) relies on an 830-nm diode laser as the light source and yields images covering an area of 400 × 400 μm with lateral digital resolution of 1 to 2 μm per pixel and an axial resolution of 3 to 5 μm per pixel. Dermal melanin deposition was examined using RCM before and after laser therapy. One trained dermatopathologist read the series of horizontal scanning fields of vision and rated the decrease of melanin granules in the dermis using four grades (0 = < 25% clearance, 1 = 25–49% clearance, 2 = 50–74% clearance, and 3 = ≥ 75% clearance).

**Adverse Effects Recorded**
Adverse effects were determined by questioning patients and observing skin responses, including erythema, edema, and dyspigmentation. Participants
were also asked to report an average pain score on a scale of 1 to 10, with 1 as mild pain and 10 as severe bee-sting-like pain.

Statistics: For database management and statistical analysis, we used SAS software, version 6.12 (SAS Institute, Inc., Cary, NC). Continuous variables and categorical variables were presented as means and frequencies, respectively. Means were compared using analysis of variance procedure t-tests (least significant difference). All statistical tests were two-tailed and \( p < .05 \) was considered statistically significant.

Results

Global Improvement Found in Blind Evaluation

Twenty-six of 30 patients (86.67%) achieved excellent or good improvement after eight treatment sessions. The mean score was 2.47 (range 0–3) after the final treatment and remained at 1.97 at the 6-month follow-up visit. See Figures 1 through 3 for details.

Assessment of Overall Satisfaction of Participants:

After eight treatment sessions, 93.3% of patients rated their results as excellent or good, which indicated that they were satisfied or extremely satisfied with the treatment. The mean satisfaction score was 2.33 (range 0–3) after the series of treatments and remained at 2.00 at the 6-month follow-up visit. See Figures 1 through 3 for details.

Effects of QSNY Treatment on MI and EI:

There was a decrease in MI measured at the darkest point of the infraorbital dark circles from 225.84 (T0) to 211.66 (T2, \( p > .05 \)), 203.45 (T4, \( p > .05 \)), 193.56 (T6, \( p > .05 \)), 182.65 (T8, \( p < .05 \)), 178.28 (M3, \( p < .005 \)), to 180.67 (M6, \( p < .005 \)). See Figure 4A for details.

Meanwhile, the EI at the darkest point of the infraorbital dark circles decreased from 406.89 (T0) to 378.41 (T2, \( p > .05 \)), increased a little to 386.12 (T4, \( p > .05 \)), and then dropped to 369.56 (T6, \( p > .05 \)), 373.01 (T8, \( p > .05 \)), 361.08 (M3, \( p < .005 \)), and 367.27 (M6, \( p > .05 \); Figure 4B).

The MI and EI at the highest point of the cheekbone (self-control) remained unchanged with treatment.

Effects of QSNY Treatment on Melanin Deposition in the Dermis According to RCM:

Before treatment, RCM images showed greater melanin deposition in the upper dermis of the dark circles area than in cheekbone skin, although there was no significant difference in epidermal melanin density in the dark circles than in the cheekbone area (Figures 5 and 6). After eight treatment sessions, four of 30 subjects (13.3%) obtained more than 75% clearance of melanin deposition in the upper dermis, 16 (53.3%) obtained 50% to 74% clearance, eight (26.7%) obtained 25% to 49% clearance, and two obtained less than 25% clearance (Figure 7). Meanwhile, the melanin granules in the control site (the highest
point of the cheekbone) remained at a low level during and after each treatment.

Assessment of Adverse Effects: The low-fluence QSNY laser caused mild pain (mean score of 2.43 on a scale of 1–10). No participant needed any topical anesthetic or systemic sedative.

Transient erythema and slight edema were observed and usually resolved within 0.5 to 1 hours after the procedure. No scarring, hyperpigmentation, hypopigmentation, or other side effects were observed. All patients could return to work and resume normal daily activity without downtime immediately after each treatment.

Discussion

Although infraorbital dark circles are a common cosmetic concern, there is limited research on their etiology, histology, and therapy. Watanabe and colleagues conducted a study of 12 patients with...
bilateral suborbital homogenous pigment macules. They found that all 12 patients demonstrated dermal melanocytosis with the Masson-Fontana silver stain and S-100 stain.\textsuperscript{1} Thus, a variety of melanin-targeted lasers, including the Q-switched ruby (694 nm) laser\textsuperscript{1,3,5} and the Q-switched alexandrite (755 nm) laser,\textsuperscript{6} have been tried in treating dark brown infraorbital dark circles. Some results have been encouraging, although the treatment induced PIH and erythema in some patients. A large-scale study is still necessary to obtain a better understanding of this condition.

The low-fluence QSNY laser was safe in treating PIH, café-au-lait spots, and melasma without tissue splatting, bleeding, or crust formation.\textsuperscript{7–10} Thus, the fluence of 4.2 J/cm\textsuperscript{2} was chosen for our study based on previous clinical experience with this laser.

For ethical reasons, we did not biopsy the dark circles before or after the procedure. Instead, we used noninvasive RCM to study the dermal melanin deposition during the treatments. Optical “sectioning” of the skin allows for the assessment of tissue pathology at a cellular-level resolution. Before treatment, RCM images showed greater melanin deposition in the upper dermis of the dark circles area than in the cheekbone area. Meanwhile, there was no significant difference in epidermal melanin density between the dark circles and the cheekbone, indicating that the dark-brown infraorbital circles might be attributed to melanin deposition in the upper dermis.

Based on these results, we chose the QSNY laser to treat dark brown infraorbital dark circles.

Our study showed that, after eight treatment sessions, mean MI values decreased significantly ($p<.05$). No recurrence was observed during the 6-month follow-up.

The RCM images showed a clear and significant decrease in melanin granules in the upper dermis with ongoing treatment sessions.

The nanometer-scale pulse width of QSNY is not sufficient for the vascular vessels to become thermocoagulated, although with the increased metabolic rhythm induced by QSNY, the stagnation of blood vessels got some alleviation simultaneously, as the finding that mean EI at the darkest point of the infraorbital dark circles also decreased gradually with each QSNY treatment suggested. At the 6-month follow-up visit, EI still remained at a lower level.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{Effects of low-fluence 1,064-nm Q-switched neodymium-doped yttrium aluminum garnet laser on (A) melanin index and (B) erythema index in women with infraorbital dark circles.}
\end{figure}
Assessment of adverse effects revealed that participants had minimal downtime. The erythema and edema induced by the treatment lasted for approximately 0.5 to 1 hour. None of the patients developed pigmentary disorders, crust formation, or pinpoint bleeding. The average pain score was rated as low, and the pain was considered tolerable.

This is the first report on treating dark-brown infraorbital dark circles in Chinese women using the low-fluence 1,064-nm QSNY laser. Because this is a preliminary noncontrolled study, further studies with posttreatment histological examinations and longer follow-ups are still needed.

**Figure 5.** Epidermal melanin (indicated by the red arrow) shown using reflectance confocal microscopy: (A) epidermal melanin of infraorbital dark circles and (B) epidermal melanin of cheekbone. There was no significant difference between the epidermal melanin density of the dark circles and that of the cheekbone.

**Figure 6.** The melanin deposition in the upper dermis (indicated by the red arrow) shown using reflectance confocal microscopy (RCM): (A) melanin deposition of infraorbital dark circles and (B) melanin deposition of cheekbone. The RCM images showed greater melanin deposition in the upper dermis than in the cheekbone area.
Conclusion

The treatment of dark-brown infraorbital dark circles with low-fluence 1,064-nm QSNY laser is safe and effective in Chinese women.

Acknowledgments

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