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Research Article

The Efficacy and Safety of a Low-Fluence 1064 nm Picosecond ND-YAG Laser Compared with Those of a Low-Fluence Photoacoustic Therapy Pulsed (PTP) Mode 1064 nm Q-Switched ND-YAG Laser for Treatment of Melasma: A Prospective Split-Face Study

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Melasma is a challenging pigmentation disorder to treat, and although low-fluence 1064 nm picosecond ND-YAG lasers have shown potential for treating benign pigmented disorders, data on the use of this laser for melasma treatment are currently insufficient. In this prospective split-face study, twenty-four patients with melasma on the face were enrolled and randomly assigned to receive treatment on one side of the face either with a low-fluence 1064 nm picosecond ND-YAG laser or with a low-fluence PTP mode 1064 nm Q-switched ND-YAG laser. Laser treatment was performed 5 times at intervals of 2 weeks, with evaluation conducted before each treatment and 2 months after the completion of 5 treatments. Clinical pictures using a standardized, digital photographic system and dermoscopy were taken on each day of the visit. The modified melasma area severity index (mMASI), melanin index (MI), dermoscopic scores of the pigmentary and vascular elements in melasma, pain during laser treatment, and patient satisfaction score were recorded. Twenty-one participants completed the study, and from week 2 in both groups, a significant decrease in mMASI and MI were confirmed. Although no statistically significant difference was observed, the decrease in mMASI and MI were greater in the 1064 nm picosecond ND-YAG laser group than in the 1064 nm Q-switched ND-YAG laser group. The 1064 nm picosecond ND-YAG laser group showed significant improvement in the pseudoreticular network and globular pattern of dermoscopic features between week 0 and week 16, while significant improvement in the globular pattern was shown in the 1064 nm Q-switched ND-YAG laser group. No significant difference was observed between the two groups in terms of the patient satisfaction score and pain during laser treatments. Notably, no adverse events were observed in either group. In conclusion, our study demonstrated that a low-fluence 1064 nm picosecond ND-YAG laser is as effective and safe in the treatment of melasma as a low-fluence PTP mode 1064 nm Q-switched ND-YAG laser.

1. Introduction

Melasma is an acquired pigmentary disorder characterized by irregular and symmetrical brownish hyperpigmented plaques, particularly on the face [1]. The prevalence of melasma varies in different populations, being approximately 1% in the general population, 13.4–15.5% in Arab Americans, and up to 8.8% in Latinos [2]. Although melasma is generally asymptomatic, it can have a negative impact on an individual's quality of life and self-esteem [3]. The exact pathogenesis of melasma remains unknown. This disease is influenced by ultraviolet (UV) exposure, female hormones, and genetic predisposition [4]. Melasma results from complex interactions between melanocytes,

keratinocytes, fibroblasts, immune cells, and endothelial cells, which can lead to inappropriate activation of melanocytes, increased mast cell numbers, solar elastosis, angiogenesis, and alterations in the basement membrane [5, 6]. The treatment of melasma remains challenging [7], with topical and oral agents, chemical peels, and laser treatments being the mainstay of therapy, along with strict sun protection [8]. However, effective and consistent therapeutic modalities have yet to be established due to the difficulty in achieving rapid and sustained clinical improvement.

Since 2007, the low-fluence 1064 nm Q-switched ND-YAG laser, also known as "laser toning," has been studied and widely utilized for treating melasma [9–11]. In particular, low-fluence PTP (photoacoustic therapy pulses or photoacoustic twin pulse or pulse to pulse) mode ND-YAG lasers have been demonstrated to be effective in the treatment of melasma [12]. Guo et al. reported that the low-fluence PTP mode Q-switched ND-YAG laser was as effective and less painful as the traditional low-fluence single-pulse mode Q-switched ND-YAG laser in treating melasma in a split-face study [13]. However, this treatment modality can produce adverse effects, such as mottled hypopigmentation and rebound hyperpigmentation, especially in individuals of Asian descent [14, 15]. Therefore, there is a need for safer and more efficacious laser treatment options for melasma.

The duration of the laser pulses can vary depending on the type of laser used. Q-switched lasers use nanosecond pulses lasting a billionth of a second [16, 17]. In contrast, picosecond lasers use even shorter pulses that last a trillionth of a second and are associated with high pulse energy, resulting in greater fragmentation of melanin with fewer thermal effects, which can minimize damage to the surrounding skin structures [18]. While picosecond ND-YAG lasers have been used to treat various benign pigmentary disorders, there is limited research on their efficacy and safety in treating melasma [18–20]. Consequently, this study aims to compare the efficacy and safety of low-fluence picosecond ND-YAG lasers to low-fluence PTP in treating melasma.

2. Materials and Methods

2.1. Study Design. This prospective split-face study was conducted in accordance with the Declaration of Helsinki and included patients who visited the Dermatology Outpatient Clinic of Kangnam Sacred Heart Hospital from October 2021 to May 2022. The study was approved by the Institutional Review Board of Kangnam Sacred Heart Hospital (IRB No. 2021-09-016-001), and the patients have given written informed consent.

Female patients aged 18–65 years with Fitzpatrick skin types III-IV, who were diagnosed with melasma by a dermatologist and with symmetrical lesions on the face, were included in the study. Those with certain medical conditions (autoimmune diseases, pregnancy or lactation, and bleeding diseases) and allergies to topical anesthetic agents were excluded. During the trial, the participants were restricted from taking oral contraceptive pills, photosensitive drugs, and hormone replacements. Cosmetic treatments such as laser and chemical peeling were also restricted.

2.2. Laser Treatment Procedure. The faces of the participants were divided into two parts: one part was treated with a low-fluence 1064 nm picosecond ND-YAG laser (PicoLO, Laseroptek, Sungnam, Republic of Korea) alone, and the other part was treated with a low-fluence PTP mode 1064 nm Q-switched ND-YAG laser (Iris, Blucore Company Co., Busan, Republic of Korea) alone. Both treatments were performed five times every two weeks with a local anesthetic cream (Encain®; a mixture of 2.5% lidocaine hydrochloride and 2.5% prilocaine; Kolma Korea Co., Seoul, Korea) applied 30 min before treatment. The treatment was performed in five sessions, with two-week intervals between sessions. The low-fluence 1064 nm picosecond ND-YAG laser was implemented using a collimated handpiece (20 mm spot size) of 0.08 J/cm^2 fluence and a frequency of 10 Hz. The low-fluence PTP mode 1064 nm Q-switched ND-YAG laser was implemented with a collimated handpiece (7 mm spot size) of 1.2–1.9 J/cm^2 fluence and a frequency of 10 Hz. The endpoint was the development of mild erythema but not petechiae. The patients were instructed to apply sunscreen and avoid sun exposure during the clinical trial.

2.3. Evaluation Methods. The patients were evaluated on six visit days: before each laser treatment (0 w, 2 w, 4 w, 6 w, and 8 w) and two months after the end of treatment (16 w) using the following evaluation methods:

(i) Clinical pictures: all subjects were photographed before treatment by the same physician with a high-resolution Canon-100D camera (Canon Inc., Tokyo, Japan) using a Janus-I measurement system (PIE Co., Gyeonggi-do, Republic of Korea) at fixed illumination and distance.

(ii) Modified melasma area and severity index (mMASI) score: Two dermatologists who were not involved in the laser treatments rated the mMASI scores based on the clinical pictures taken with the Janus-I standardized digital system in a blinded manner. The mMASI score is a subjective method for evaluating melasma on half of the face using three factors: total area, darkness, and homogeneity. The face was divided into four regions, and the calculation method is as follows:

$$\begin{aligned}\text{mMASI score} = {} & 0.15 \times (A \text{ of the forehead}) \\ & \times \{(D + H) \text{ of the forehead}\} \\ & + 0.3 \times (A \text{ of the malar region}) \\ & \times \{(D + H) \text{ of the malar region}\} \\ & + 0.05 \times (A \text{ of the chin}) \times \{(D + H) \text{ of the chin}\},\end{aligned} \tag{1}$$

where A (area of involvement) was rated on a scale of 0 (no involvement) to 6 (90–100% involvement), D (darkness) was rated on a scale of 0 (absent) to 4

(severe), and *H* (homogeneity) was rated on a scale of 0 (minimum) to 4 (maximum). The total mMASI score for each side ranges from 0 to 12.

(iii) Dermoscopic evaluation: The same physician used a Canon-600D camera (Canon Inc., Tokyo, Japan) and a portable dermoscope (DermLite, Dana Point, USA) to evaluate the fixed parts of the patients guided by anatomical indicators. The dermoscopic score was calculated based on the dermoscopic score of pigmentary and vascular elements in melasma [21], divided into six dermoscopic findings (pseudoreticular network, globular pattern, dotted pattern, arcuate pattern, visible telangiectasia, and perifollicular pigmentation), and scored from 0 to 3 points for each (0: not detected, 1: hardly detected, 2: detected, and 3: obvious).

(iv) The melanin index (MI): MI was measured at baseline, 4, 8, and 16 weeks using a spectrophotometer (Cortex Technology, Hadsund, Denmark) placed directly on the skin lesions for 2 min in a room with constant temperature (20–24°C) and humidity (28–38%).

(v) Safety profiles: side effects, such as postinflammatory hyperpigmentation, petechiae, and mottled hypopigmentation, were reported at all visits.

(vi) Pain assessment: the Wong–Baker FACES pain rating scale (ranged from 0 to 10) was used to record pain levels after completion of the five treatments (8 w) [22].

(vii) Patient satisfaction: patient satisfaction was evaluated using a Likert satisfaction scale (1: very satisfied, 2: dissatisfied, 3: neither satisfied nor dissatisfied, 4: satisfied, and 5: very satisfied) at the final visit (16 w).

2.4. Statistical Analysis. Data were analyzed using IBM SPSS Statistics (version 23.0; IBM Corp., Armonk, NY, USA). The treatment efficacy between the two groups was compared using repeated-measure analysis of variance with Bonferroni's method. The dermoscopic scores were compared using the chi-square test. Patient satisfaction and pain were analyzed using a paired *t*-test with a 95% confidence interval. $P < 0.05$ was considered significant.

3. Results

3.1. Clinical Demographics. Twenty-four female Asian participants were initially enrolled, with 21 participants completing the study (18 Koreans, 2 Chinese, and 1 Vietnamese). Their ages ranged from 31 to 64 years, with a mean age of 49.62 ± 8.75 years. Three participants dropped out due to scheduling issues. Among the participants, 12 (57.1%) had Fitzpatrick skin phototype III, while 9 (42.9%) had Fitzpatrick skin phototype IV.

3.2. mMASI Score. There was no significant difference in the mMASI scores between picosecond and PTP mode Q-switched ND-YAG laser groups at baseline (picosecond ND-YAG laser: 7.88 ± 3.38, PTP mode Q-switched ND-YAG laser: 7.85 ± 3.40, and $P = 0.998$). Both groups showed a significant decrease in mMASI scores from 2 w (picosecond ND-YAG laser: 6.45 ± 3.20, $P = 0.001$; PTP mode Q-switched ND-YAG laser: 6.77 ± 3.30, $P = 0.021$), and the decreases continued until 16 w (picosecond ND-YAG laser: 4.87 ± 2.56, $P < 0.001$; PTP mode Q-switched ND-YAG laser: 5.76 ± 2.20, $P < 0.001$) compared with the baseline. The decrease in mMASI was greater in the 1064 nm picosecond ND-YAG laser group than in the 1064 nm Q-switched ND-YAG laser group. However, between the groups, there was no significant difference in the decrease in the mMASI score from week 2 to 16 ($P = 0.607$) (Figure 1). Although at 16 week the mMASI score increased significantly in both the groups compared to that at 8 w (picosecond ND-YAG laser: $P = 0.006$; PTP-mode Q-switched ND-YAG laser: $P = 0.012$), both the groups showed statistically significant reductions in the mMASI score compared to the baseline. Figure 2 shows images of representative cases in this study.

3.3. Melanin Index. There was no significant difference in MI between the picosecond and PTP mode Q-switched ND-YAG laser groups at the baseline (picosecond ND-YAG laser: 41.82 ± 3.96, PTP mode Q-switched ND-YAG laser: 42.03 ± 4.49, and $P = 0.908$). Both groups showed a significant decrease in MI from 2 w (picosecond ND-YAG laser: 38.59 ± 5.29, $P = 0.004$; PTP mode Q-switched ND-YAG laser: 38.82 ± 5.97, $P = 0.021$) until the follow-up 16 w visit compared with the baseline (picosecond ND-YAG laser: 36.18 ± 4.50, $P < 0.001$; PTP mode Q-switched ND-YAG laser: 38.12 ± 4.72, $P < 0.001$). The decrease in MI was greater in the 1064 nm picosecond ND-YAG laser group than in the 1064 nm Q-switched ND-YAG laser group. However, there was no significant difference in the decrease in MI from week 2 to 16 between the two groups ($P = 0.455$) (Figure 3). At the follow-up 16 w visit, the average mMASI score increased significantly in both groups compared to that at 8 w (picosecond ND-YAG laser: $P = 0.014$; PTP-mode Q-switched ND-YAG laser: $P = 0.009$). However, both groups showed statistically significant reductions in the average mMASI score compared to the baseline.

3.4. Dermoscopic Evaluation. Of these 21 patients, 15 underwent dermoscopic evaluation. The baseline dermoscopic scores did not differ significantly between the groups (picosecond ND-YAG laser: 8.73 ± 2.69; PTP mode Q-switched laser: 8.60 ± 2.82, $P = 0.899$). Compared with the baseline, both groups showed a significant decrease in dermoscopic scores at 16 w (picosecond ND-YAG laser: 6.33 ± 2.30, $P < 0.001$; PTP-mode Q-switched ND-YAG laser: 7.20 ± 2.48, $P = 0.001$); however, no significant difference was observed between the two groups ($P = 0.800$). The picosecond ND-YAG laser demonstrated significant therapeutic effects on the pseudoreticular network and globular pattern ($P = 0.043$ and $P = 0.032$, respectively) based on the pigmentation and vascularity patterns before and after

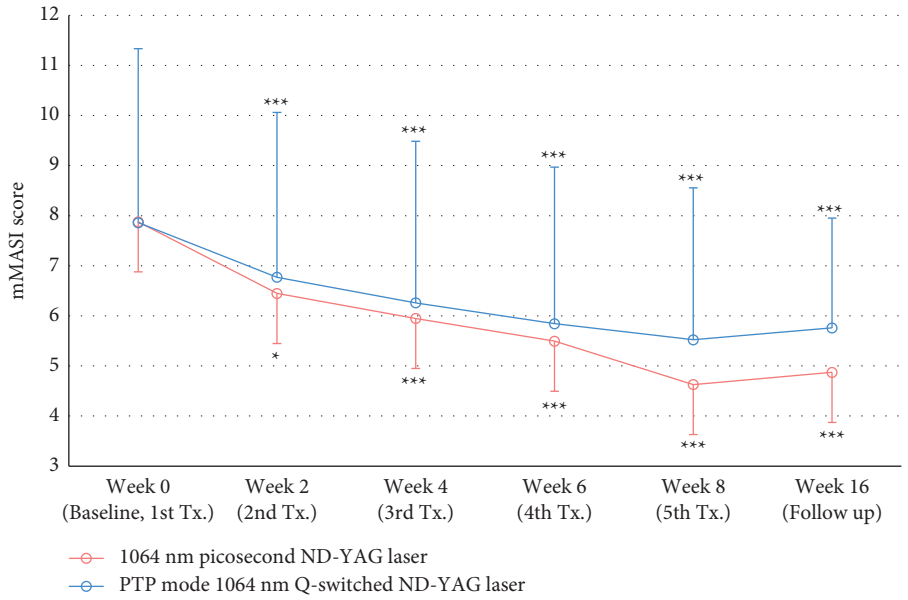

Figure 1: Changes in the modified melasma area severity index (mMASI). In both treatment groups, the significant reductions in the mMASI score at each visit compared to the baseline were confirmed by the paired t-test. The asterisks (* and ***) imply a significant difference compared to the baseline (*: $P < 0.05$; ***: $P < 0.001$).

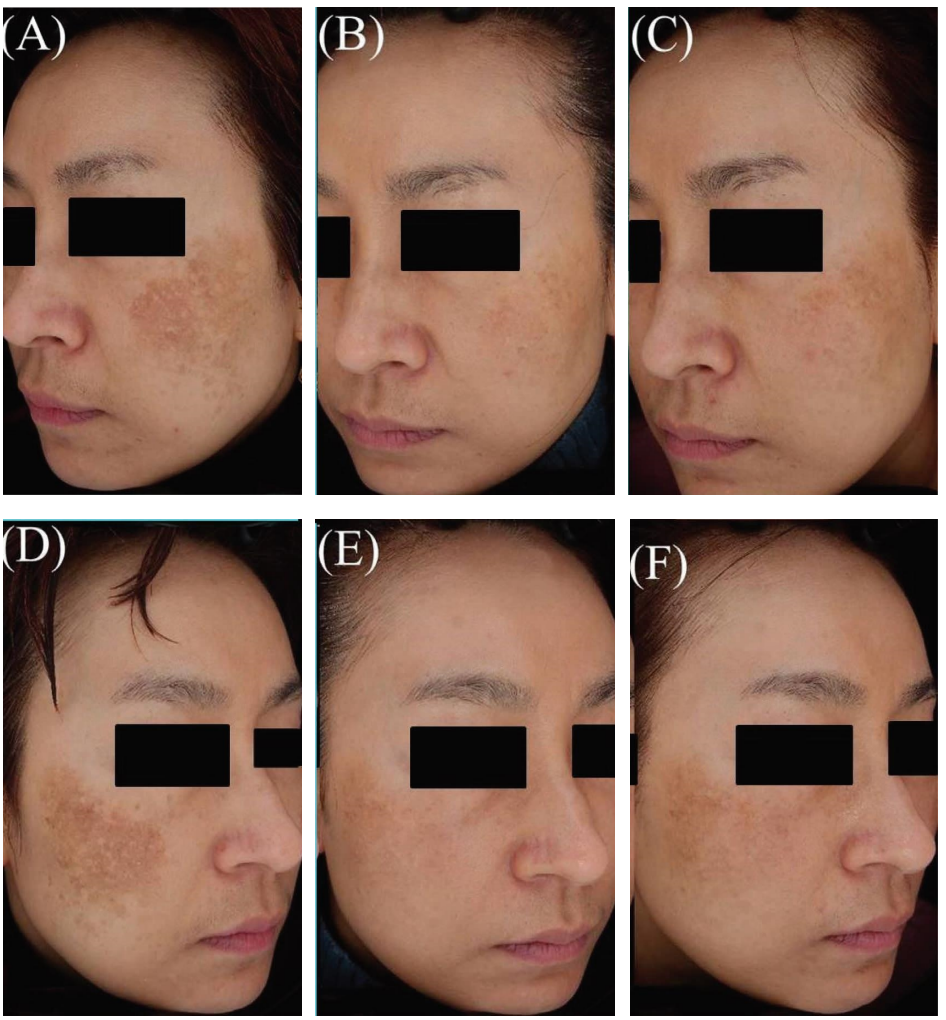

Figure 2: A 51-year-old female patient with melasma of Fitzpatrick skin type III. The left side of the face was treated with a PTP mode 1064 nm Q-switched laser (A–C), and the right side was treated with a 1064 nm picosecond ND-YAG laser (D–F). Baseline (week 0), the mMASI scores were 11.55 (A) and 12.30 (D), respectively. On the 5th visit (week 8), the mMASI scores were 3.60 (B) and 3.80 (E). On the follow-up visit (2 months after last treatment), the mMASI scores were 5.00 (C) and 4.80 (F).

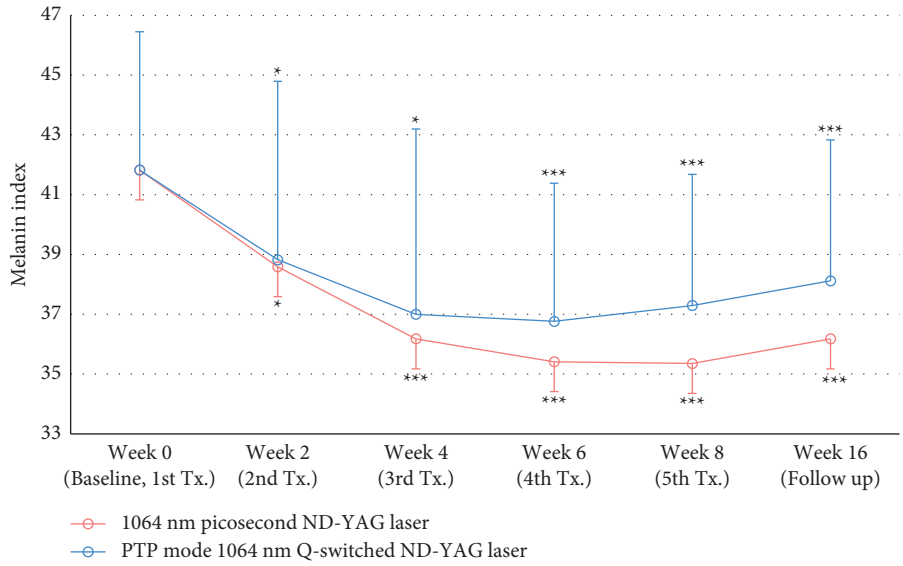

FIGURE 3: Changes in the melanin index (MI). In both treatment groups, the significant reductions in MI at each visit compared to the baseline were confirmed by a paired t-test. The asterisks (* and ***) imply a significant difference compared to the baseline (*: $P < 0.05$; ***: $P < 0.001$).

treatment, and the PTP-mode Q-switched ND-YAG laser showed a significant decrease in the globular pattern ($P = 0.021$) (Tables 1 and 2; Figure 4).

3.5. Likert Satisfaction Scale. No significant difference in patient satisfaction was found between the two groups ($P = 0.999$) at the 16-week follow-up visit (10 patients being very satisfied and 9 patients satisfied in the picosecond ND-YAG laser group, whereas 11 patients were very satisfied and 10 patients were satisfied in the PTP-mode Q-switched ND-YAG laser group) (Figure 5).

3.6. Wong–Baker FACES Pain Rating Scale. Pain levels of 2 (slightly hurt), 4 (hurt little more), and 6 (even hurt) points were scored by 9, 9, and 3 participants, respectively, in the picosecond group and 10, 7, and 3 participants, respectively, in the PTP-mode Q-switched group. One participant scored 8 points (severely hurt) in the PTP-mode Q-switched group. No significant differences were observed between the two groups ($P = 0.876$).

3.7. Adverse Effects. No significant adverse effects, including mottled hypopigmentation or postinflammatory hyperpigmentation, were observed in either group. Mild erythema was reported in 87.5% of patients, but it was temporary and disappeared within 1-2 days, without affecting the continuation of treatment.

4. Discussion

In this prospective split-face comparison study, we evaluated the efficacy and safety of picosecond ND-YAG laser treatment for melasma. We observed significant reductions in the mMASI score and MI that were sustained at all visits from two weeks after the initial laser session to the 16-week follow-up visit, in both the picosecond and PTP mode Q-switched ND-YAG laser groups, relative to the baseline. No significant differences were noted between the groups concerning the mMASI scores or MI at any visit. Dermoscopic evaluation also supported our findings of treatment efficacy. At the 16-week follow-up visit, the picosecond group exhibited substantial improvements in both the pseudoreticular network and globular pattern compared to the baseline, whereas the PTP-mode Q-switched group showed significant improvement only in the globular pattern. We observed no significant adverse reactions in either group.

In recent years, laser toning for melasma has gained attention [9, 10, 23]. Laser toning, with a low fluence of 1-2 J/cm^2, a collimated beam with a large spot size, and a frequency of 5–10 Hz, performed every one or two weeks, has emerged as a safer and more effective treatment option [24]. A low-fluence 1064 nm Q-switched ND-YAG laser is thought to work through a process called "subcellular selective photothermolysis" which selectively destroy melanosomes in melanocytes, keratinocytes, and melanophages without damaging the surrounding cells [25, 26]. Evidence supporting this theory includes a decrease in the dendrites of epidermal melanocytes and in the volume of melanocytes and mature melanosomes observed in ultrastructural analyses after laser toning [26].

However, previous reports have indicated that even a low-fluence Q-switched ND-YAG laser can cause mottled hypopigmentation if the recovery period is insufficient or if there is a high cumulative fluence when repeatedly performed [15, 27–29]. Rebound hyperpigmentation is also a common occurrence, particularly in Asians with Fitzpatrick skin types III or IV [30]. To minimize side effects, this study utilized the PTP mode in conjunction with low-

Table 1: Dermoscopic scores of the pigmentary and vascular elements in melasma at week 0 and week 16 in the 1064 nm picosecond ND-YAG laser group.

Dermoscopic findings		Not detected no. (%)	Hardly detected no. (%)	Detected no. (%)	Obvious no. (%)	P value
Pseudoreticular network	Week 0	3 (20)	1 (6.7)	5 (33.3)	6 (40)	0.043 (*)
	Week 16	3 (20)	3 (20)	9 (60)	0 (0)	
Globular pattern	Week 0	1 (6.7)	1 (6.7)	7 (46.7)	6 (40)	0.032 (*)
	Week 16	0 (0)	8 (53.3)	5 (33.3)	2 (13.3)	
Dotted pattern	Week 0	6 (40)	7 (46.7)	1 (6.7)	1 (6.7)	0.985
	Week 16	7 (46.7)	6 (40)	1 (6.7)	1 (6.7)	
Arcuate pattern	Week 0	10 (66.7)	2 (13.3)	2 (13.3)	1 (6.7)	0.790
	Week 16	11 (73.3)	2 (13.3)	2 (13.3)	0 (0)	
Visible telangiectasia	Week 0	5 (33.3)	4 (26.7)	3 (20)	3 (20)	0.902
	Week 16	6 (40)	3 (20)	4 (26.7)	2 (13.3)	
Perifollicular pigmentation	Week 0	1 (6.7)	4 (26.7)	6 (40)	4 (26.7)	0.260
	Week 16	3 (20)	7 (46.7)	4 (26.7)	1 (6.7)	

*: $P < 0.05$.

Table 2: Dermoscopic scores of the pigmentary and vascular elements in melasma at week 0 and week 16 in the low-fluence PTP mode 1064 nm Q-switched ND-YAG laser group.

Dermoscopic findings		Not detected no. (%)	Hardly detected no. (%)	Detected no. (%)	Obvious no. (%)	P value
Pseudoreticular network	Week 0	3 (20)	3 (20)	3 (20)	6 (40)	0.150
	Week 16	3 (20)	4 (26.7)	7 (46.7)	1 (6.7)	
Globular pattern	Week 0	1 (6.7)	1 (6.7)	7 (46.7)	6 (40)	0.021 (*)
	Week 16	4 (26.7)	6 (40)	4 (26.7)	1 (6.7)	
Dotted pattern	Week 0	7 (46.7)	5 (33.3)	2 (13.3)	1 (6.7)	0.941
	Week 16	8 (53.3)	5 (33.3)	1 (6.7)	1 (6.7)	
Arcuate pattern	Week 0	9 (60)	3 (20)	2 (13.3)	1 (6.7)	0.632
	Week 16	10 (66.7)	2 (13.3)	3 (20)	0 (0)	
Visible telangiectasia	Week 0	7 (46.7)	2 (13.3)	3 (20)	3 (20)	0.863
	Week 16	8 (53.3)	1 (6.7)	4 (26.7)	2 (13.3)	
Perifollicular pigmentation	Week 0	1 (6.7)	3 (20)	6 (40)	5 (33.3)	0.105
	Week 16	1 (6.7)	4 (26.7)	10 (66.7)	0 (0)	

*: $P < 0.05$.

fluence 1064 nm Q-switched ND-YAG laser treatment. The PTP mode applies the pulse duration of a low-fluence 1064 nm Q-switched ND-YAG laser by distributing 50% of the power output at intervals of 60–100 us, theoretically reducing the cumulative fluence and side effects. In our study, no significant side effects were observed after low-fluence PTP mode 1064 nm Q-switched ND-YAG laser treatment, and it showed good efficacy in melasma treatment.

Picosecond lasers used in dermatology have a pulse duration of 300–900 picoseconds (10^{-12}), which results in higher energy delivery and more effective melanin fragmentation through photoacoustic stress [31]. Therefore, picosecond lasers operate at lower power outputs than previous lasers, due to their shorter pulse duration and lower associated thermal effects. It has been suggested that picosecond lasers with short pulse duration can achieve satisfactory results with low-fluence, minimizing the risk of scarring or postinflammatory hyperpigmentation by reducing damage to surrounding skin structures due to heat diffusion [32–35]. Based on this theory, picosecond lasers have been shown to be effective in removing tattoos [36]. Subsequently, it has shown favorable results for various pigmentations such as nevus of Ota, Hori's macules, and solar lentigines [37]. Despite their potential, the effectiveness of picosecond lasers for treating melasma remains unclear and inconsistent because of the differences in laser parameters, such as wavelength, spot size, fluence, and the use of fractional mode [18, 19, 38–41].

There has been little research for a 1064 nm picosecond laser for melasma treatment. In a comparative study of dual-wavelength 1064 nm and 595 nm picosecond lasers combined with topical 2% hydroquinone versus topical hydroquinone alone, the combined therapy showed superior efficacy without any serious side effects [38]. Another study, which compared the combination therapy of a fractional picosecond 1064 nm laser with 4% topical hydroquinone versus topical hydroquinone alone, also showed the effectiveness of combination

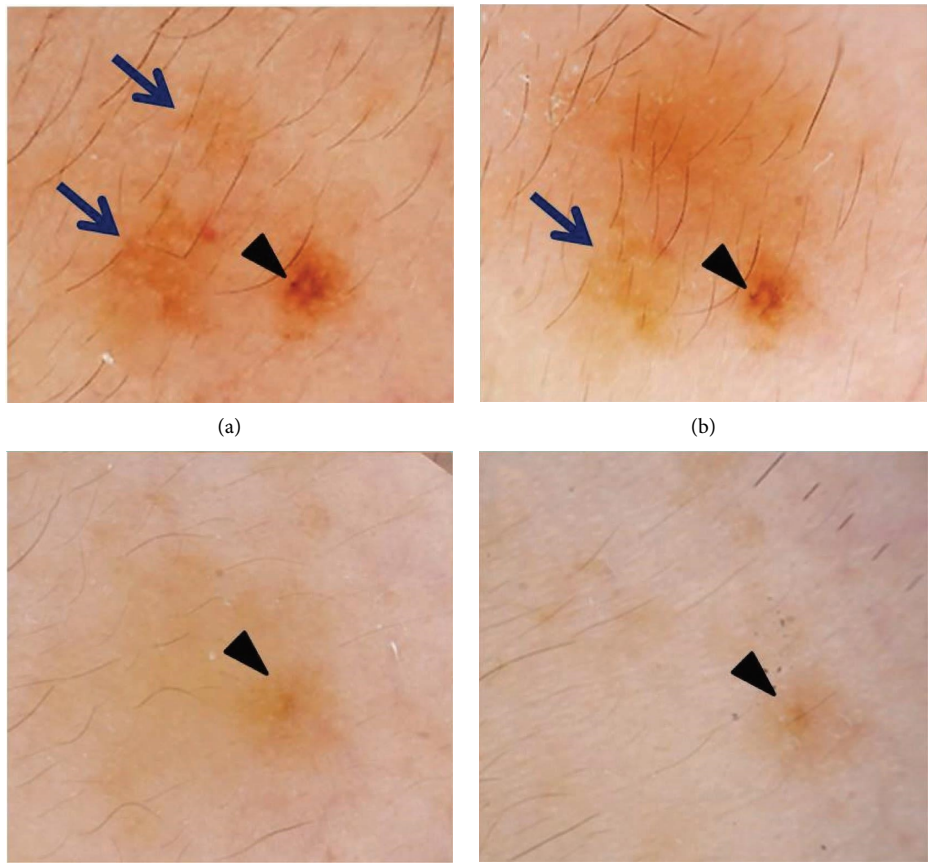

Figure 4: Dermoscopic assessments of a 31-year-old female patient with melasma. After the treatment of the 1064 nm picosecond ND-YAG laser, the pseudoreticular network (arrows) and the globular pattern (arrowheads) have been lightened in the left front cheek of the female patient ((a) dermoscopic picture of the baseline; (b) dermoscopic picture at week 6; (c) dermoscopic picture at week 8; (d) dermoscopic picture at follow-up visit).

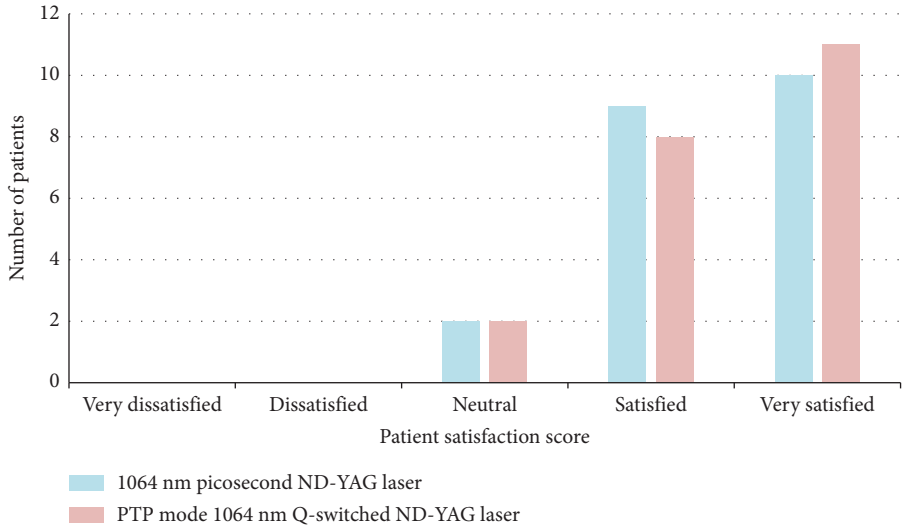

Figure 5: Patient satisfaction score (Likert satisfaction scale) at the last visit (week 16).

therapy [18]. Hong et al. found that a low-fluence 1064 nm picosecond laser was effective and safe for treating melasma in Korean patients [42]. However, it did not provide better results in clearing melasma than the 1064 nm Q-switched ND-YAG laser. We proved the significant efficacy of a low-fluence 1064 nm picosecond ND-YAG laser for

melasma treatment without any safety concerns. Furthermore, this study showed that there were no significant differences in the therapeutic efficacy and safety for melasma treatment between a low-fluence 1064 nm picosecond ND-YAG laser and a low-fluence PTP mode 1064 nm Q-switched ND-YAG laser.

In particular, our study evaluated treatment responses in melasma using dermoscopic scoring, which visualizes the clinical patterns of skin structures that are not visible to the naked eye. Previous studies have reported that dermoscopic evaluation is superior to other evaluation tools such as Wood's light, in terms of pigmentation and vascularity detection [21, 43, 44]. Our study found a significant improvement in the pseudoreticular network and globular pattern after picosecond ND-YAG laser treatment. The PTP-mode Q-switched ND-YAG laser also showed a significant reduction in the globular pattern, consistent with a previous study [21]. In the vascular components of melasma, both laser treatments did not change in our study.

In our study, both groups showed a significant decrease in the mMASI score and MI at follow-up compared to the baseline, but a tendency for an increase in the mMASI score and MI was observed 2 months after the end of treatment. This trend was also observed in previous studies where prolonged follow-up periods resulted in the deterioration of clinical improvement [45, 46]. Melasma is a chronic and refractory condition that can be easily aggravated by various triggers, such as increased sunlight during summer. Although patients were instructed to limit sun exposure and apply sunscreen, uncontrolled daily sun exposure may have affected treatment outcomes because of the spring season of the follow-up period. Dermoscopic evaluation showed that the vascular component did not improve in either laser group, indicating that untreated vascular factors may lead to more frequent relapses [47–49]. Recently, it is demonstrated that vascular components play a significant role in melasma pathogenesis [50]. Combining treatments targeting both the vascular and pigment components may lead to a more favorable therapeutic effect against melasma. Therefore, a combination approach in addition to a picosecond laser may be considered to achieve better treatment outcomes.

This study has several limitations, including its small sample size and short follow-up period. Therefore, larger clinical trials with extended follow-up periods are necessary to confirm our findings. Further research is also required to determine the optimal treatment settings for picosecond ND-YAG lasers to improve therapeutic efficacy.

5. Conclusions

Our study showed that a low-fluence 1064 nm picosecond ND-YAG laser is an effective and well-tolerated treatment option for melasma, similar to a low-fluence PTP mode 1064 nm Q-switched ND-YAG laser.

Data Availability

The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

Disclosure

So Yeon Lee and Hye Ran Kim should be considered as co-first authors.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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