The Efficacy of Picosecond Laser Treatment in Melasma: A Systematic Review

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Abstract

Melasma is one of the most common dermatologic conditions for which patients seek treatment. The pathogenesis is still unknown, and the treatment is still challenging. Topical treatment is considered the gold standard for the treatment, but the outcomes tend to be recalcitrant and relapse occurs when the treatment is discontinued. Due to its nature, patients often seek alternative treatments such as laser and light therapy. Picosecond laser is a new method for the treatment of melasma, which delivers ultra-short pulse duration in the picosecond range.

This systematic review investigates the efficacy of picosecond laser in treating melasma. We searched online databases such as PubMed and SCOPUS, with a study period of five years from 2020 to 2025. Five studies involving 162 participants, comprising two randomized controlled trials and three prospective split-face or cohort studies, were included. Although the studies varied in methodological design, with heterogeneity in laser parameters, sample size, and duration of follow-up, all studies demonstrated a significant reduction in MASI or mMASI scores. The 1064 nm picosecond Nd: YAG laser consistently showed comparable or superior efficacy compared with nanosecond Q-switched Nd: YAG lasers and topical hydroquinone, with fewer side effects. In contrast, the 755 nm picosecond Alexandrite laser showed more variable clinical outcomes, depending on the comparator treatment. Overall, picosecond lasers appear to be an effective and safe treatment modality for melasma, particularly among patients with darker skin types.

Keywords: *Melasma, 1064nm Picosecond Nd: YAG Laser, 755 nm Alexandrite Picosecond Laser, PIH*

1. Introduction

Melasma is a most common acquired dermatologic disorder presenting with symmetrical hyperpigmentation patches with irregular borders primarily on the face. The pathogenesis of melasma is still unknown, but many trigger factors like sun exposure, genetics, female hormones, and cosmetics can cause melasma (Alsaad et al., 2014). The treatment of melasma is still challenging due to its nature. It can develop recalcitrance and rebound hyperpigmentation which are the most unsatisfactory results for melasma (Babbush et al., 2021; Kwon et al., 2016). The clinical features are characterized by symmetrical, irregular-bordered brown patches affecting sun exposed-area, especially the face (forehead, molar region, upper lip, and chin), neck, and forearms. However, its histopathologic manifestations are divided into 3 types, namely epidermal, dermal, and mixed type, which are described by Wood's lamp examination (Passeron & Picardo, 2018). Topical depigmentation agents, especially Kligman's formulation, are the first-line therapy for melasma. Although they are effective in inhibiting melanogenesis, their long-term use is limited by adverse effects such as irritation, ochronosis, and poor patient adherence (Artzi et al., 2021). Moreover, relapse is common after discontinuation of the treatment, and lasers have become an alternative treatment for melasma.

Picosecond lasers represent a technological advancement characterized by ultra-short pulse duration in the picosecond range, producing a predominantly photomechanical rather than photothermal effect. This mechanism allows more efficient fragmentation of melanin particles with reduced thermal diffusion to surrounding tissues. The reduction in thermal diffusion is particularly important in patients with Fitzpatrick skin types III-IV, as they have a higher susceptibility to pigmentary complications, including post-inflammatory hyperpigmentation (PIH) following laser treatment. In dermatology, picosecond lasers, most commonly 1064 nm Nd: YAG and 755 nm Alexandrite wavelengths, have gained increasing attention for the treatment of melasma (Wu et al., 2021).

2. Objectives

1) To study the effectiveness of picosecond laser treatment for melasma.
2) To study the complications and treatment settings of picosecond laser interventions to inform future treatment strategies.

3. Materials and Methods

3.1 Search Strategy

This systematic review was conducted utilizing databases such as PubMed and Scopus, with a study period from 2020 to 2025. We searched thoroughly utilizing the MeSH terms and keywords such as "Picosecond Alexandrite" OR "1064 nm Nd: YAG" OR "Picosecond Nd: YAG" AND "Melasma" AND "Clinical Efficacy" to refine the search. The research question was structured using the PICO (Population, Interventions, Comparison, and Outcomes) framework to guide the eligibility criteria. The search strategy was confined to peer-reviewed studies available in the selected databases, and grey literature sources such as conference abstracts and unpublished manuscript were not considered.

Data collection was conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. The multi-stage process of study selection, from initial identification to final inclusion, was shown in the following PRISMA flow diagram (Figure 1).

The data extraction was conducted by two reviewers using Microsoft Excel with subsequent cross-checking to ensure transparency. The following study characteristics were recorded: author, study location, year of publication, study design, number of participants, laser settings, complications and adverse events, duration of follow-up, Melasma Area and Severity Index (MASI) score.

Evaluation of the quality of the included studies was performed utilizing the Newcastle-Ottawa Scale, as shown in Table 1, and studies were rated as low, moderate and high risk of bias.

Table 1 Quality assessment of included articles

Newcastle-Ottawa scale	Selection domain	Comparability domain	Outcome domain	Overall quality assessment
Hong et al., (2022)	3	1	2	6/9 Moderate
Liang et al., (2023)	3	1	3	7/9 Low
Lee et al., (2023)	3	1	2	6/9 Moderate
Feng & Huang (2023)	3	1	2	6/9 Moderate
Liang et al., (2025)	3	2	3	8/9 Low

Maximum 4 stars for the selection domain
Maximum 2 stars for the comparability domain
Maximum 3 stars for outcome domain

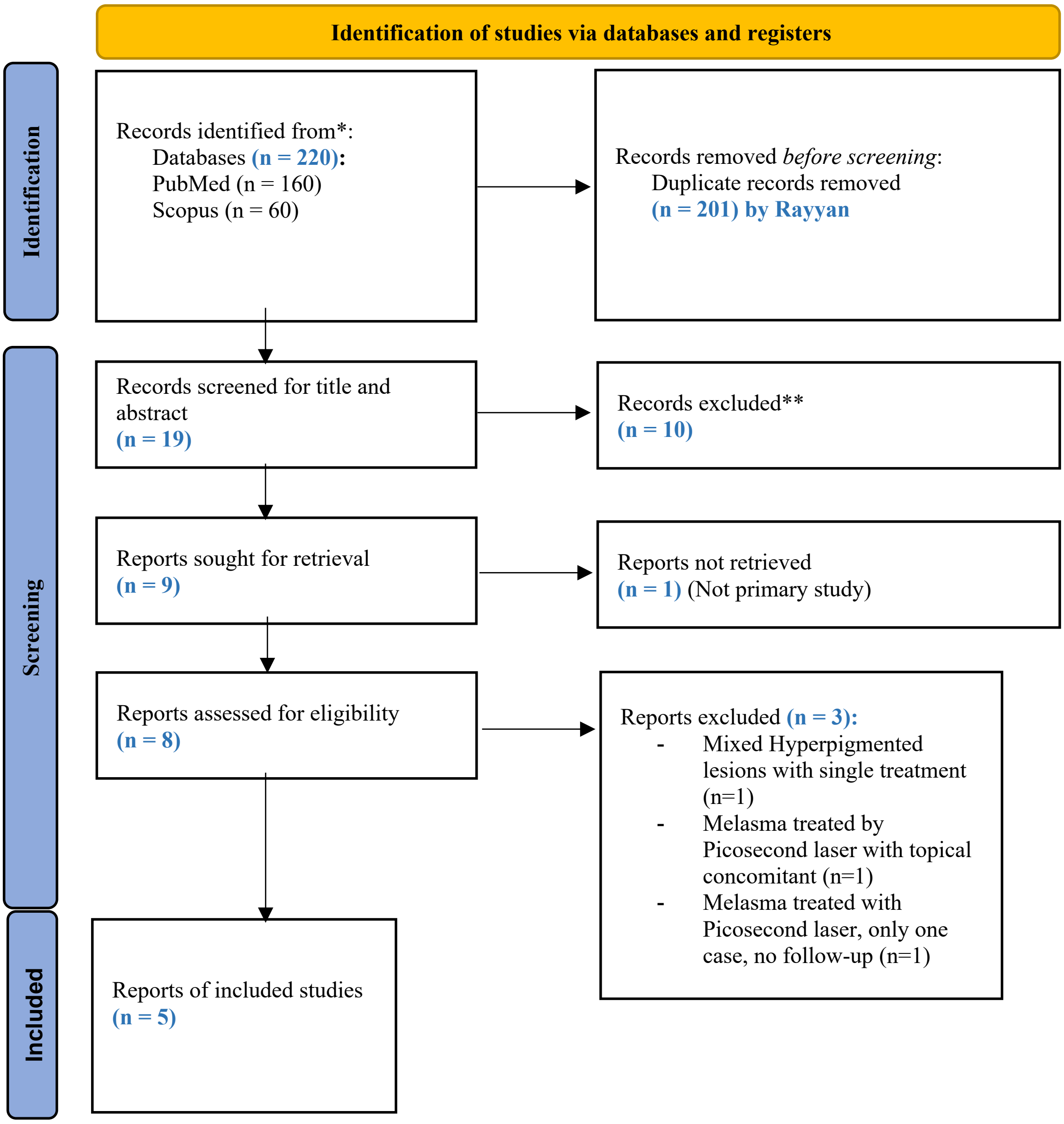

Figure 1 PRISMA flow diagram, summary of the study selection process

4. Results and Discussion

4.1 Results

Following the search process, nine articles were retrieved. Through subsequent stages, three articles were excluded: one was a study on mixed hyperpigmentation (Kim et al., 2021), another one was a split-face study of a Picosecond laser concomitant with topical treatment in melasma (Lyons et al., 2019), and one involved single treatment with no follow-up (Zawodny et al., 2024).

A total of five studies were included after meticulous review of full-text articles. The included studies were published between 2020 and 2025 consisted of randomized controlled trials, prospective split-face studies, and evaluator-blinded comparative trials. All studies involved human participants aged 18 years and above with a clinical diagnosis of melasma by a dermatologist. The study population included both sexes, while female patients constituted the majority, reflecting the epidemiology of melasma. Most participants had Fitzpatrick skin types III-IV, consistent with populations at high risk of pigmentary complications.

The primary interventions were picosecond lasers, specifically 1064 nm Nd: YAG and 755 nm Alexandrite wavelengths. Comparator groups included nanosecond Q-switched Nd: YAG lasers, combined Q-switched and long-pulse Nd: YAG lasers, and topical 2% hydroquinone. Clinical efficacy was mainly evaluated using MASI or mMASI scores, with follow-up duration ranging from 3 weeks to 24 weeks.

1064 nm Picosecond Nd: YAG Laser

Studies evaluating the 1064 nm Picosecond Nd: YAG laser consistently demonstrated significant improvement in melasma severity. In split-face randomized trials comparing picosecond Nd: YAG with nanosecond Q-switched Nd: YAG lasers, both treatments significantly reduced hemi-mMASI scores (from 2.31 ± 1.49 to 0.71 ± 0.62 at 3 months), with no statistically significant difference between modalities (p= 0.873) (Feng & Huang, 2023). A prospective, split-face study comparing 1064 nm Picosecond Nd: YAG laser toning with 1064 nm Q-switched Nd: YAG laser toning (Hong et al., 2022) showed that the 1064 nm Picosecond Nd: YAG laser effectively reduced the severity of melasma, as demonstrated by significant mMASI reduction from baseline ($p< 0.01$), indicating that picosecond Nd: YAG laser is non-inferior to conventional laser treatment.

Low-fluence treatment protocols further showed that reductions in mMASI and melanin index tended to be greater earlier with the picosecond Nd: YAG laser, although between group differences were not always statistically significant (p= 0.607) (Lee et al., 2023). These findings suggest that picosecond Nd: YAG may offer an advantage in pigment clearance rather than absolute efficacy. When compared with topical therapy, a randomized controlled trial demonstrated that 1064 nm Picosecond Nd: YAG laser achieved the greatest MASI reduction ($p< 0.001$) from week 4 to week 24. Liang et al. (2023) performed a comparison of the efficacy and safety of Picosecond Nd: YAG 1064 nm, Picosecond Alexandrite laser 755 nm, and 2% hydroquinone cream. Sixty participants were recruited and randomized into 3 groups, with 20 participants in each group.

The study showed that the Picosecond Nd: YAG laser is highly effective in reducing melasma severity demonstrated by significant and sustained MASI reduction. Within-group significant MASI reduction from baseline was observed at all time points from week 4 to week 24 ($p<0.001$), mean MASI reduction at week 24: -5.6 points, representing the largest improvement among the included studies. Clinical improvement was observed as early as the first session and maintained up to 24 weeks and showed greater MASI reduction than the 755 nm Picosecond Alexandrite laser (mean difference -1.3; p= 0.016) and 2% Hydroquinone cream (mean difference -1.3; p= 0.018) (Liang et al., 2023).

755 nm Picosecond Alexandrite Laser

Significant reductions in MASI scores were also observed with the 755 nm Picosecond Alexandrite. However, its comparative efficacy varied depending on the comparator. In direct comparison with the 1064 nm Picosecond Nd: YAG, the Alexandrite wavelength demonstrated less pronounced MASI improvement. Furthermore, evidence from Liang at al. (2025) suggested that the 755-nm Picosecond Alexandrite laser was less effective than a combined Q-switch plus long-pulse Nd: YAG modality (p=0.010), suggesting that optimized conventional combination therapy may achieve superior outcomes to the Picosecond Alexandrite laser in certain clinical settings.

Picosecond Laser Therapeutic Setting

Heterogeneity in laser parameters, including fluence, spot size, pulse duration, frequency, and number of sessions, was observed across the studies. Despite this variability, low-fluence protocols, typically 3-5 sessions at 2 to 4 weeks intervals, commonly utilized, with endpoints defined as mild erythema. However, no standardized optimal settings could be established.

Complications and Safety

Picosecond laser treatment demonstrated a consistent safety advantage across all included studies. The most frequently reported adverse effects were transient erythema, mild edema, and temporary discomfort, all of which resolved spontaneously without intervention. Findings from split-face trials showed that pain scores were consistently lower with picosecond lasers compared to nanosecond Q-switched Nd: YAG lasers. No serious adverse events were reported. The recurrence rate ranged from 6% to 13% did not differ significantly between picosecond lasers and comparator treatments.

4.2 Discussion

This systematic review demonstrated that picosecond laser therapy is effective in reducing melasma severity, as evidenced by consistent and statistically significant reductions in MASI and mMASI scores across multiple primary studies. These findings provide a direct and affirmative answer to the research question focusing on the effectiveness of picosecond lasers in melasma treatment. The results of this review align with, and extend, previous research, including studies by Wu et al. (2021), which reported that picosecond lasers demonstrate improved pigment clearance with reduced thermal injury compared with nanosecond devices.

The therapeutic effectiveness of picosecond lasers is attributed to their ultrashort pulse duration, which induces a predominantly photomechanical effect. This process promotes efficient melanin fragmentation with minimal thermal effects. This mechanism likely explains the comparable efficacy and improved tolerability of picosecond lasers compared with nanosecond Q-switched lasers. A comparison of wavelengths demonstrated that the 1064-nm Picosecond Nd: YAG laser was the most consistent and showed the most robust efficacy, including superiority over topical hydroquinone and comparable outcomes to laser toning techniques. Conversely, the 755-nm Picosecond Alexandrite laser showed less consistent and more variable results, especially when compared with advanced combination laser therapies.

The included studies presented considerable heterogeneity in laser parameters, such as fluence, spot size, pulse duration, frequency, and number of treatment sessions. Nevertheless, despite these differences, several common treatment patterns were identified. Most studies employed low-fluence protocols, 3-5 treatment sessions, and treatment intervals of 2-4 weeks, with mild erythema commonly used as the clinical endpoint. Spot size generally ranged from 6 to 10 mm, with fluence values between 0.5 and 2.5 J/cm^2 depending on the wavelength and device used. These parameters appear to illustrate commonly used clinical settings in current practice.

Picosecond lasers demonstrated a low incidence of complications in darker skin types (III-IV), where the risk of post-inflammatory hyperpigmentation is higher. Factors such as reduced pain and minimal recovery time further enhance patient acceptability. Although picosecond lasers demonstrated a promising safety and efficacy profile, their cost is considerably higher than conventional topical therapies such as hydroquinone. Therefore, considerations of cost-effectiveness are important when selecting treatment options, particularly in resource-limited settings. Furthermore, melasma recurrence remains a persistent issue. Strict photoprotection, patient education, and long-term maintenance strategies should be recommended in laser therapy.

However, the evidence base is limited by small sample sizes, short follow-up, and heterogeneity in laser settings. Consequently, a formal meta-analysis to derive quantitative summary estimates was not feasible.

Table 2 Clinical characteristic of included studies

Author	Location	Sample Sizes	Age (year)	M, F	Skin type	Intervention	Comparator	Follow-up	Complication/ Adverse events
Hong et al., (2022)	Korea	20	Adult (mean age not reported)	Not reported	III-IV	1064 nm Picosecond Nd: YAG laser toning: . brand: PicoLo™ . spot size: 10 mm . Fluence: 1.5-2.5 J/cm² . Frequency: 10Hz . 3-5 passes . end point: erythema	1064 nm Q-switched Nd: YAG laser toning (spit-face) . brand: RevLite . Spot size: 8 mm . Fluence: 2.0-3.0 J/cm² . 3-5 passes . end point: erythema	4 weeks after final laser session	. Mild to moderate erythema . Itching . Papular eruption . Mild pain . No PIH
Liang et al., (2023)	China	60	18-65	F	III-IV	Picosecond Nd: YAG 1064 nm . brand: not reported . spot size: 7 mm . fluence: 0.75-0.90 J/cm² . frequency: 8Hz . 2 passes . pulse duration: 450ps . 3 sessions (4-week intervals) Picosecond Alexandrite 755 nm . brand: not reported . spot size: 6-8 mm . fluence: 0.40-0.71 J/cm² . frequency: 10 Hz . 2 passes . pulse duration: 750 ps . 3 sessions (4-week intervals)	2% Hydroquinone (apply twice daily)	24 weeks	. Recurrence rate: 6.8% . Post-inflammatory hyperpigmentation: 5% . Hypopigmentation: 1 patient of Hydroquinone . Erythema, Itching . Mild to moderate pain

Author	Location	Sample Sizes	Age (year)	M, F	Skin type	Intervention	Comparator	Follow-up	Complication/ Adverse events
Lee t al., (2023)	Korea	24	31-64 Mean age 49±8.8	Not reported	III-IV	. Low-fluence 1064 nm Picosecond Nd: YAG laser . brand: PicoLo . spot size: 2 mm . fluence: 0.08 J/cm^2 . frequency: 10 Hz	Low-fluence PTP mode 1064 nm Q-switched Nd: YAG laser . Brand: Iris . spot size: 7 mm . fluence: 0.08 J/cm^2 . frequency: 10 Hz	. Evaluate at baseline . Every 2 weeks during treatment . 2 months after 5^{th} session (16 weeks)	. No PIH . Mild to moderate erythema . Mild pain
Feng & Huang (2023)	China	18	18-50 Mean age 41±5	Not reported	III-IV	Picosecond Nd: YAG laser 1064 nm . brand: not reported . spot size: 8 mm . fluence: 0.5-0.7 J/cm^2 . frequency: 10 Hz	Nano Q-switched Nd: YAG laser 1064 nm . brand: not reported . spot size: 8 mm, 6 mm . fluence: 2.3, 2.5-2.8 J/cm^2 . frequency: 10 Hz	3 months	. Mild erythema . Low pain . Acneiform eruption in 31.3% of Q-switched Nd: YAG laser treated side . No scar, no PIH
Liang et al., (2025)	China	40	18-65 Mean age . PSAL group: 39±6.3 . QLNYL: 41±8.3	Not reported	III-IV	755 nm Picosecond Alexandrite laser (PSAL) . brand: Picosure . spot size: 6-8 mm . fluence: 0.40-0.70 J/cm^2 . frequency: 10.0 Hz . sessions: 3 (4-week intervals) . pulse width: 750 ps	Combined Q-switched and Long-pulse Nd: YAG laser (QLNYL 1064 nm) Q-switched 1064 nm Nd: YAG laser . brand: not reported . spot size: 7 mm . fluence: 1.0-1.3 J/cm^2 . pulse width: 6-20 ns Followed by Long-pulse width 1064 nm . brand not reported	. At baseline, 4, 8, 12, and 24 weeks	Overall adverse reaction rate 15.0% (PSAL 15% and QLNYL 10%) . PSAL group: PIH 5%, rebound hyperpigmentation 5%, higher pain score (VAS 5.3±1.5) . QLNYL: transient erythema, no PIH
							. spot size: 4 mm . fluence: 10.0 J/cm^2 . frequency: 10.0 Hz . Pulse width: 0.3 ms		. Recurrence rate at 24 weeks PSAL group 10.5%, QLNYL 0%

[1]PSAL: Picosecond alexandrite laser, [2]QLNYL: Q-switched and long-pulse Nd: YAG lasers, [3]PTP: Photoacoustic Therapy Pulsed, [4]VAS: Visual analog scale for pain, [5]PIH: post-inflammatory hyperpigmentation

5. Conclusion

This review concludes that picosecond laser treatment, particularly 1064 nm Nd: YAG laser, effectively reduces melasma severity with a favorable safety profile. While these lasers offer advantages over conventional therapies, their superiority is dependent on both wavelength and comparator. Current evidence suggests that the 1064-nm Picosecond Nd: YAG laser appears to provide the most consistent clinical improvement and may be considered the preferred wavelength for the treatment of melasma. Furthermore, recurrence remains a challenge. Further large-scale, standardized trials with longer follow-up periods are required to define optimal treatment strategies.

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