Am J Transl Res 2025;17(8):6391-6402
www.ajtr.org /ISSN:1943-8141/AJTR0166051

Original Article

Long-term efficacy and safety of carbon dioxide (CO_2) array laser versus erbium-doped yttrium aluminum garnet (Er:YAG) laser for acne scars

Chang Xiao*, Jun Zhang*, Jing Peng

*Department of Dermatology, Wuhan No. 1 Hospital, Wuhan 430345, Hubei, China. *Co-first authors.*

Received May 15, 2025; Accepted July 29, 2025; Epub August 15, 2025; Published August 30, 2025

Abstract: Background: Acne vulgaris is a prevalent skin condition that often leads to facial scarring, significantly affecting patients' quality of life. Laser therapies, particularly carbon dioxide (CO_2) array laser and erbium-doped yttrium aluminum garnet (Er:YAG) laser, are widely used for acne scar management. This study aimed to compare the long-term efficacy and safety of these two laser systems for the treatment of acne scars. Methods: A retrospective analysis was conducted on 254 patients with acne scars who were treated between January 2021 and January 2024. Among them, 124 patients received CO_2 laser treatment, while 130 received Er:YAG laser treatment. Clinical data encompassing demographics, scar improvement, inflammatory markers, and patient satisfaction, were collected over one year. Evaluations were based on Extended Cook's Corrected Acne Scarring (ECCA) scores, VISIA Skin Analysis, and Dermatology Life Quality Index (DLQI). Results: Er:YAG laser demonstrated significantly lower intraoperative pain (VAS: 3.12 ± 0.23 vs. CO_2: 3.19 ± 0.21; P = 0.011) and shorter erythema resolution time (2.93 ± 0.64 vs. 3.11 ± 0.7 weeks; P = 0.029). Post-treatment INF-γ levels were higher in the Er:YAG group (853.68 ± 113.56 vs. 815.3 ± 120.28 pg/mL; P = 0.009). CO_2 laser showed superior long-term scar reduction (ECCA), with the most pronounced improvement observed at 12 months (39.84 ± 3.26 vs. Er:YAG: 41.31 ± 4.88; P = 0.005). VISIA analysis revealed better outcomes for CO_2 laser in pore size (7.55 ± 1.86 vs. 8.16 ± 1.14; P = 0.002) and porphyrins (81.33 ± 4.11 vs. 83.24 ± 5.24; P = 0.001). Treatment efficacy favored CO_2, with significantly lower ineffective response rates (5.65% vs. 16.92%; P = 0.017), although persistent erythema was more common with CO_2 (6.45% vs. 0.77%; P = 0.035). At 12 months, DLQI improvement was superior greater in the CO_2 group (11.25 ± 1.98 vs. 12.01 ± 2.02; P = 0.003). Conclusion: The CO_2 laser demonstrated superior long-term efficacy for reducing acne scars compared to the Er:YAG laser, at the cost of increased persistent erythema. Conversely, the Er:YAG laser offered a better recovery profile with fewer adverse reactions.

Keywords: Acne vulgaris, CO_2 laser, Er:YAG laser, acne scars, treatment efficacy, dermatological therapy

Introduction

Acne vulgaris is a prevalent dermatologic condition that frequently results in facial scarring, affecting up to 40% of individuals with severe forms of the disease [1, 2]. Acne scars can profoundly affect patients' quality of life, leading to psychological distress and reduced self-esteem [3]. Clinically, acne scar treatment poses significant challenges due to varying scar morphology and depth. To address this, multiple approaches including chemical peels, dermabrasion, and advanced laser therapies have been developed [4, 5]. Among these, laser treatment has emerged as the preferred option due to its precision in skin regeneration and scar remodeling [6].

For acne scar treatment, the carbon dioxide (CO_2) array laser and the erbium-doped yttrium aluminum garnet (Er:YAG) laser are commonly used [7]. The CO_2 laser, working at 10,600 nm, is particularly effective due to its ability to penetrate deeper into the skin layers. This advantage makes it particularly suitable for treating thicker scars, as it actively stimulates collagen remodeling [8]. The CO_2 laser works by vaporizing damaged tissue and applying controlled heat to induce thermal coagulation, thereby promoting the skin's natural healing processes

https://doi.org/10.62347/WTMW1778

[9]. However, the deep and intense nature of this treatment usually leads to a longer recovery time, with an increased risk of side effects like prolonged redness and hyperpigmentation, particularly in individuals with darker skin tones.

On the other hand, the Er:YAG laser operates at 2940 nm and is known for its precision in tissue removal with minimal heat spread [10]. This allows for more controlled treatment and faster recovery. By targeting water in the skin, the Er:YAG laser efficiently renews the surface layers while protecting surrounding tissue from heat damage [11], making it a better option for patients concerned about recovery time or side effects. However, its limited depth penetration means it is less effective for treating deeper or more resistant scars.

The choice between the CO_2 and Er:YAG lasers depends on the type of scar and the patient's specific needs. With advances in laser technology, the safety and precision of these two therapies have been greatly enhanced. Nevertheless, more comprehensive comparative studies are required to evaluate their long-term efficacy in treating acne scars. Understanding the distinct advantages of each laser helps in selecting anoptimal treatment strategy for patients.

Most previous studies have focused on short-term results, with limited data on the long-term effects of laser treatments for acne scars. Our study represents a key advancement by conducting a comprehensive one-year retrospective analysis. We systematically compared long-term efficacy and safety of CO_2 and Er:YAG lasers. Instead of focusing mainly on short-term outcomes, we used the Extended Cook's Corrected Acne Scarring (ECCA) scores and the VISIA Skin Analysis System to evaluate changes in scar severity, skin texture, and erythema. Additionally, we monitored cytokine changes associated with immune responses, providing a more comprehensive understanding of treatment effects. These findings can assist clinicians in selecting the optimal laser treatment, ensurin effectiveness, patient safety, and comfort.

Patients and methods

Study design and ethical considerations

A retrospective analysis was conducted on 254 individuals with acne scars who underwent laser treatment at Wuhan No. 1 Hospital between January 2021 and January 2024. Ethical approval for this study was granted by the Institutional Review Board and Ethics Committee of Wuhan No. 1 Hospital.

Patients were divided into two groups based on the type of laser treatment they received: the Er:YAG Laser group (n = 130) and the CO_2 Laser group (n = 124). Patient information was collected from the hospital's case management system, encompassing demographic details, treatment protocols, levels of inflammatory factors, ECCA scores, VISIA scores, treatment outcomes, adverse reactions, and patient satisfaction.

Inclusion and exclusion criteria

Inclusion criteria: (1) age ≥ 18 years; (2) diagnosis of acne scars in accordance with established criteria [12]; (3) patients exhibited various degrees of symptoms such as local tissue thickening, changes in skin color at lesional sites, hyperpigmentation or hypopigmentation, uneven scar surfaces, and abnormal tissue tension [13]; (4) scar duration exceeding 3 months; (5) complete medical records; (6) regular follow-up visits.

Exclusion criteria: (1) presence of other facial inflammatory conditions; (2) history of hypertrophic scarring; (3) presence of photosensitive skin disorders; (4) history of retinoid use [14]; (5) inability to tolerate laser treatment; (6) diagnosis of neurological disorders or abnormal mental or cognitive status.

Therapeutic method

After selecting the treatment area, the patient's skin was thoroughly cleaned, and a topical anesthetic cream, Compound Lidocaine Cream (Approval No. H20063466, containing 25 mg Prilocaine and 25 mg Lidocaine per gram, Tongfang Pharmaceutical Group Co., Ltd.), was applied. The laser area was then covered with plastic wrap for approximately one hour. Subsequently, the anesthetic was wiped off, and the area was cleaned and disinfected with 75% alcohol.

For the Er:YAG laser group, a 2940 nm Er:YAG laser (LovelyII, Alma Lasers, Israel; Registration No. 2013 3243839) was used. A 1 mm × 1 mm spot size with an energy density of 100-1400

mJ per pulse in a resurfacing mode, and a 4 mm × 4 mm spot size with a coagulation depth achieved by 1400-1800 mJ per pulse were used to gently ablate the surrounding scar tissue into a smooth slope. Residual skin debris was removed using saline-soaked cotton swabs until the treated area appeared pink and uniformly smooth, with a slight yellow tint. Comprehensive facial treatment was performed using a 7 mm × 7 mm spot size, a 5 Hz pulse frequency, a medium pulse duration of 1400-1800 mJ per pulse, and a long pulse width of 2000-2500 mJ per pulse in a fractional mode.

For the CO_2 laser group, the UltraPulse Encore™ system (Lumenis, USA) with DeepFX and ActiveFX handpieces was used. DeepFX settings included energy levels of 10-20 mJ, a density of 5%-10%, a frequency of 300 Hz, and a time interval of 0.5 seconds. ActiveFX settings involved energy levels of 100-175 mJ and a frequency of 25-50 Hz. Depending on the lesion's size and shape, different Computerized Pattern Generator (CPG) parameters were selected, with dot patterns of 1-8, spot sizes of grade 3-7, densities of 10%-100%, and a scanning pattern delay of 0.1-0.3 seconds. The handpiece was correctly focused at the lesion distance and applied vertically to the treatment area, scanning locally with the DeepFX handpiece first, followed by ActiveFX to extend the coverage. Energy and density were increased appropriately for more severe lesions.

Following the procedure, a 30-minute ice therapy was administered. Patients were instructed to apply Fluticasone Propionate Cream (Timi, Approval No. H20103501, Hubei Hengan Fulin Pharmaceutical Co., Ltd.) twice daily, in the morning and evening, for three days. Recombinant human epidermal growth factor gel (Yifu, Approval No. S20020111, Guilin Huanowi Gene Pharmaceutical Co., Ltd.) was applied for seven days. Post-procedure, patients were advised to use sunscreen with a sun protection factor (SPF) greater than 30. Follow-up visits were scheduled every three months for one year.

Basic information

Patient information was collected through the hospital's medical record system, including age, gender, history of other diseases, education level, duration of illness, grade according to the Qualitative Global Scarring Grading System (GSS), and scar location.

The GSS evaluates the overall appearance and quality of scars, categorizing them into four severity grades [15].

Grade I (Mild): scars are nearly indistinguishable from normal skin, presenting with only minor discoloration, flatness, soft consistency, minimal abnormal vasculature, and no pain or itching. They do not restrict movement or function. Grade II (Moderate): scars show slight color changes, with mild redness or hyper/hypopigmentation, mild elevation, and a slightly hardened but mobile consistency. Small vessels may be visible, and there might be occasional mild pain or itching, with minimal effect on activity or function. Grade III (Severe): scars are clearly distinct from normal skin, with notable redness and pigment changes, significantly raised hypertrophic characteristics, hardened and less mobile texture, increased abnormal vasculature with vessel dilation, and frequent pain or itching. These scars may limit joint movement or other functions. Grade IV (Very Severe): scars display extreme color changes, such as intense red/purple, dark, or fully depigmentation. They are highly hypertrophic, potentially keloidal, very hardened or fixed, with extensive vessel dilation and congestion, causing persistent severe pain or itching. These scars significantly affect quality of life, severely restrict movement, and may lead to disability or long-term functional impairment.

Treatment process and short-term recovery

Following the initial treatment, patients were asked to complete survey questionnaires to assess several metrics: the Visual Analog Scale (VAS) [16] for self-recorded pain intensity, the duration until pain resolution, and the time required for erythema to resolve. The timing began immediately post-treatment.

The VAS was employed to measure the intensity of pain experienced by the patients. This scale ranges from 0 to 10, where 0 indicates no pain and no impact on sleep, a score of ≤ 3 indicates mild pain that does not disrupt sleep, scores of 4-6 indicate moderate pain that affects sleep, and scores of 7-10 indicate severe pain causing insomnia or pain-related awakenings. Higher scores reflect greater pain

intensity. The Cronbach's alpha for the VAS was 0.79 [17]. The cost of each patient's treatment was recorded using the hospital case system.

Inflammatory factors

Prior to treatment and three months after treatment, 5 mL of venous blood was drawn from each patient. The venous blood samples were processed using a refrigerated high-speed centrifuge (TLD 12A, Hunan Xiangxi Scientific Instrument Factory, China) at 3000 rpm for 10 minutes. The separated plasma was then stored at -80°C. The levels of interleukin-4 (IL-4) and interferon-gamma (INF-γ) were measured using an automated biochemical analyzer (AU5811, Shanghai Kehua Bio-engineering Co., Ltd.).

ECCA

The ECCA score was recorded at intervals of three months, six months, and one year post-treatment [18]. This scoring system effectively classifies facial scars by both the characteristics and distribution of the scars. The scar score is calculated as a × b, where 'a' represents the nature of the acne scars, and 'b' indicates the semi-quantitative value of scar density (scar count).

The 'a' value was determined by categorizing scars based on their nature, evaluating the severity, morphology, and progression of lesions. The 'b' value measures scar density in units of the forehead or one cheek, with 0 for no scars, 1 for a few scars (≤ 5 scars), 2 for a moderate number of scars (more than 5 but ≤ 20 scars), and 3 for a large number of scars (more than 20 scars).

VISIA

One year after treatment, the VISIA Skin Analysis System (VISIA 7th Generation, Canfield Scientific Inc., USA) was used to examine and quantify skin characteristics in both groups, thereby assessing the effectiveness of the treatment [19]. This assessment included measurements of erythema, texture, pores, and porphyrins. Erythema indicates conditions such as acne, inflammation, and capillary dilation. Texture refers to skin smoothness, highlighting the presence of scars or uneven areas. Pores relate to the openings of sebaceous glands on the skin surface, reflecting the severity of acne scarring. Porphyrins are positively correlated with acne lesions.

Treatment outcomes and adverse reactions

One year post-treatment, patient outcomes and adverse reactions were recorded. An outcome was classified as "significant" if there was more than an 80% improvement in lesions, with scars becoming smooth, visually uniform, and their color closely resembling the surrounding normal skin. An outcome was deemed "effective" if there was a 50% to 80% reduction in scar unevenness and notable reduction in discoloration. An outcome was considered "ineffective" if there was less than a 50% improvement or resolution of lesions, with no significant changes in scar texture or color. Additionally, ineffective outcomes included cases where new scars formed or there was noticeable hyperpigmentation or depigmentation [20].

Patient satisfaction

The Dermatology Life Quality Index (DLQI) comprises ten questions designed to assess the impact of skin problems on various aspects of life, including symptoms and feelings, daily activities, leisure, work or school performance, personal relationships, and treatment, during the previous week [21]. Patients respond to these questions, yielding an overall score ranging from 0 to 30. A higher score indicates more severe disease. The DLQI demonstrated high internal consistency reliability, with a Cronbach's alpha of 0.91.

Statistical analysis

Statistical analyses were conducted using SPSS 29.0 software (IBM Corp., Armonk, NY, USA). Categorical data were summarized as frequencies and percentages ([n (%)]) and analyzed using the chi-square test. Continuous variables were first evaluated for normality with the Shapiro-Wilk test. For normally distributed data, means and standard deviations (M ± SD) were reported, while non-normally distributed data were presented as medians and interquartile ranges [median (Q1, Q3)]. The Wilcoxon rank-sum test (also known as the Mann-Whitney U test) was applied to compare non-normally distributed continuous variables

Table 1. Comparison of demographic characteristics between the two groups

Indicator	Er:YAG laser group (n = 130)	CO_2 laser group (n = 124)	t/χ^2	P
Age (years)	26.58 ± 4.12	26.51 ± 4.35	0.135	0.893
Female/Male	61 (46.92%)/69 (53.08%)	60 (48.39%)/64 (51.61%)	0.055	0.815
Body mass index (kg/m^2)	23.08 ± 2.74	23.16 ± 2.65	0.257	0.798
Smoking history (Yes/No)	24 (18.46%)/106 (81.54%)	26 (20.97%)/98 (79.03%)	0.252	0.616
Drinking history (Yes/No)	30 (23.08%)/100 (76.92%)	31 (25%)/93 (75%)	0.129	0.72
Hypertension (Yes/No)	1 (0.77%)/129 (99.23%)	2 (1.61%)/122 (98.39%)	0.002	0.967
Diabetes (Yes/No)	2 (1.54%)/128 (98.46%)	3 (2.42%)/121 (97.58%)	0.003	0.957
Educational level (Junior college graduate/College graduate or higher)	69 (53.08%)/61 (46.92%)	75 (60.48%)/49 (39.52%)	1.418	0.234
Marital status (Married/Unmarried)	55 (42.31%)/75 (57.69%)	54 (43.55%)/70 (56.45%)	0.04	0.842
Ethnicity (Han/Other)	120 (92.31%)/10 (7.69%)	113 (91.13%)/11 (8.87%)	0.116	0.733
Course of illness	5.61 ± 1.51	5.59 ± 1.32	0.106	0.916
GSS grade			1.452	0.693
I class	27 (20.77%)	19 (15.32%)		
II class	31 (23.85%)	34 (27.42%)		
III class	26 (20%)	27 (21.77%)		
IV class	46 (35.38%)	44 (35.48%)		
Scar location			1.374	0.503
Cheeks	46 (35.38%)	52 (41.94%)		
Forehead	37 (28.46%)	29 (23.39%)		
Entire face	47 (36.15%)	43 (34.68%)		

GSS: qualitative global scarring grading system.

between groups. A two-tailed *p*-value < .05 was considered significant.

Results

Basic data

The mean age for the Er:YAG group was 26.58 ± 4.12 years, while the CO_2 group had a mean age of 26.51 ± 4.35 years (t = 0.135, P = 0.893) (**Table 1**). The gender distribution showed 46.92% female and 53.08% male in the Er:YAG group compared to 48.39% female and 51.61% male in the CO_2 laser group (χ^2 = 0.055, P = 0.815). Body Mass Index (BMI) was similar between the groups, with the Er:YAG group averaging 23.08 ± 2.74 kg/m^2 and the CO_2 laser group 23.16 ± 2.65 kg/m^2 (t = 0.257, P = 0.798). Smoking and drinking histories did not differ significantly, with smoking reported by 18.46% in the Er:YAG group and 20.97% in the CO_2 group, and drinking history reported by 23.08% and 25% respectively (P > 0.05).

Likewise, there were no notable differences in hypertension, diabetes prevalence, educational level, marital status, ethnicity, course of illness, GSS grade, or scar location between the two groups. Hypertension and diabetes were reported in minimal numbers across both groups without statistical significance (P > 0.05). The distribution of the qualitative global scarring grading system and scar location were also not significantly different, ensuring a balanced foundation for subsequent analysis of efficacy and safety outcomes.

Treatment process and short-term recovery

The cost of treatment was similar between both groups, with the Er:YAG group averaging 8012.35 ± 219.56 yuan versus 8035.56 ± 265.32 yuan for the CO_2 group (t = 0.758, P = 0.449) (**Table 2**). However, the VAS scores indicated significantly less pain in the Er:YAG group (3.12 ± 0.23) compared to the CO_2 group (3.19 ± 0.21) (P = 0.011). Furthermore, pain resolution time was shorter in the Er:YAG group at 2.29 ± 0.12 hours compared to 2.34 ± 0.15 hours in the CO_2 group (t = 2.631, P = 0.009). Shedding time was not significantly different between the groups, averaging 6.57 ± 1.82 days for the Er:YAG group and 6.65 ± 1.89 days for the CO_2 group (t = 0.327, P = 0.744). Erythema resolution time was significantly shorter in the Er:YAG group at 2.93 ± 0.64 weeks compared to 3.11 ± 0.7 weeks in the CO_2 group (t = 2.198, P = 0.029). These results suggest notable differences in patient experiences regarding pain and recovery time

Table 2. Comparison of treatment cost and short time recovery between the two groups

Indicator	Er:YAG laser group (n = 130)	CO_2 laser group (n = 124)	t	P
Cast (yuan)	8012.35 ± 219.56	8035.56 ± 265.32	0.758	0.449
VAS	3.12 ± 0.23	3.19 ± 0.21	2.553	0.011
Pain resolution time (h)	2.29 ± 0.12	2.34 ± 0.15	2.631	0.009
Shedding time (d)	6.57 ± 1.82	6.65 ± 1.89	0.327	0.744
Erythema resolution time (week)	2.93 ± 0.64	3.11 ± 0.7	2.198	0.029

VAS: Visual Analog Scale.

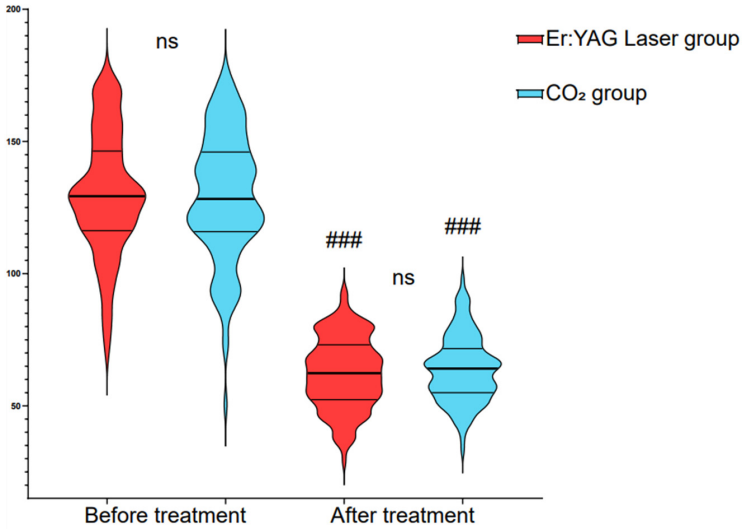

Figure 1. Comparison of IL-4 levels between the two groups before and after treatment. IL-4: Interleukin-4. ns: no significant. ###: comparison of before treatment and after treatment, P < 0.001.

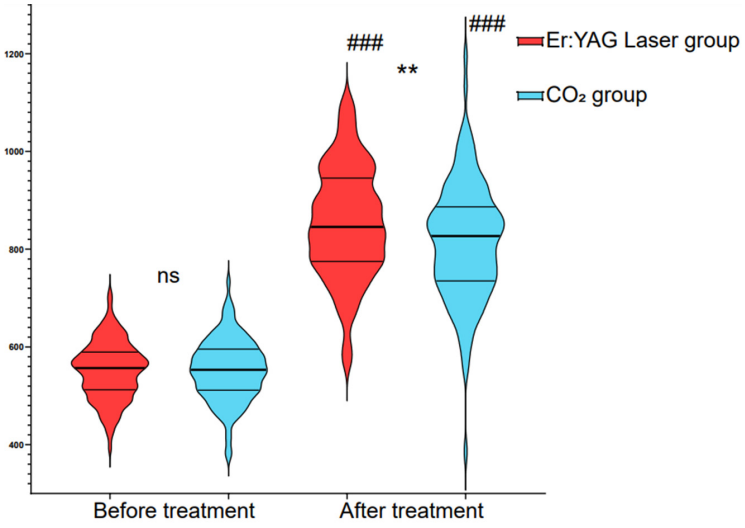

Figure 2. Comparison of INF-γ levels between the two groups before and after treatment. INF-γ: Interferon-gamma. ns: no significant difference, **P < 0.01. ###: comparison of before treatment and after treatment, P < 0.001.

between the two laser treatment modalities.

Inflammatory factors

Before treatment, IL-4 levels were similar between the Er:YAG (130.28 ± 23.32 pg/mL) and the CO_2 group (129.17 ± 24.07 pg/mL; t = 0.374, P = 0.709) (**Figure 1**). After treatment, IL-4 levels decreased in both groups, with the Er:YAG group showing 62.29 ± 13.33 pg/mL and the CO_2 group showing 63.85 ± 12.43 pg/mL, with no significant difference (t = 0.96, P = 0.338). Conversely, INF-γ levels, which were initially comparable between groups (Er:YAG: 551.37 ± 58.84 pg/mL vs. CO_2: 552.34 ± 62.37 pg/mL; t = 0.126, P = 0.9) (**Figure 2**), displayed a significant difference post-treatment. The Er:YAG group showed an increase to 853.68 ± 113.56 pg/mL, significantly higher than 815.3 ± 120.28 pg/mL in the CO_2 group (t = 2.616, P = 0.009). These results indicate a differential effect on INF-γ levels between the two laser modalities.

ECCA

Prior to treatment, ECCA scores were comparable between the Er:YAG group (87.23 ± 23.41) and the CO_2 group (85.23 ± 24.25; t = 0.669, P = 0.504) (**Figure 3**). However, three months post-treatment, the CO_2 group exhibited a signifi-

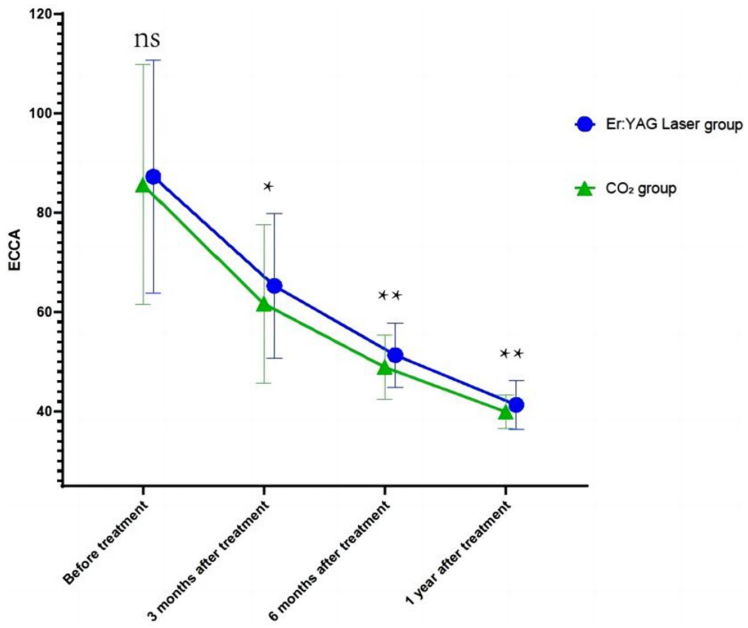

Figure 3. Comparison of ECCA score between the two groups before and after treatment. *P < 0.05, **P < 0.01. ECCA: Extended Cook's Corrected Acne Scarring score.

Table 3. Comparison of VISIA scores between the two groups

Indicator	Er:YAG laser group (n = 130)	CO_2 laser group (n = 124)	t	P
Erythema	40.05 ± 8.52	38.21 ± 3.93	2.232	0.027
Texture	47.12 ± 5.21	45.57 ± 3.01	2.916	0.004
Pores	8.16 ± 1.14	7.55 ± 1.86	3.101	0.002
Porphyrins	83.24 ± 5.24	81.33 ± 4.11	3.242	0.001

VISIA: Visualizing Skin Imperfections and Attributes.

cantly lower ECCA score (61.41 ± 15.81) compared to the Er:YAG group (65.24 ± 14.54) (t = 2.009, P = 0.046). This trend continued at six months, with the CO_2 group achieving a more pronounced reduction in scarring (48.76 ± 6.51) compared to the Er:YAG group (51.32 ± 6.47) (t = 3.149, P = 0.002). One year post-treatment, the CO_2 group maintained superior outcomes with a score of 39.84 ± 3.26 compared to 41.31 ± 4.88 in the Er:YAG group (t = 2.841, P = 0.005). These results indicate that the CO_2 laser was more effective in reducing acne scars over the long term compared to the Er:YAG laser.

VISIA

Erythema levels were significantly lower in the CO_2 group (38.21 ± 3.93) compared to the Er:YAG group (40.05 ± 8.52) (t = 2.232, P = 0.027) (**Table 3**). In terms of skin texture, the CO_2 group again showed superior results with a mean score of 45.57 ± 3.01 versus 47.12 ± 5.21 in the Er:YAG group (t = 2.916, P = 0.004). Regarding pore visibility, the CO_2 treatment yielded a lower score (7.55 ± 1.86) compared to the Er:YAG group (8.16 ± 1.14) (t = 3.101, P = 0.002). For porphyrins, the CO_2 group also achieved better outcomes, with a score of 81.33 ± 4.11 compared to 83.24 ± 5.24 in the Er:YAG group (t = 3.242, P = 0.001). These results suggest that the CO_2 laser offers greater efficacy in improving various skin attributes related to acne scars.

Treatment effect

In the CO_2 group, 37.1% of patients experienced significant improvement, compared to 30.77% in the Er:YAG group (**Table 4**). Additionally, the effective response rate was higher in the CO_2 group at 57.26%, compared to 52.31% in the Er:YAG group. Notably, the incidence of an ineffective treatment response was substantially lower in the CO_2 group, with only 5.65% of patients reporting no improvement, compared to 16.92% in the Er:YAG group. The comparison of treatment effects between the Er:YAG Laser group and the CO_2 Laser group revealed a significant difference in overall efficacy (χ^2 = 8.105, P = 0.017). Overall, these results suggest that the CO_2 laser provides more effective treatment outcomes in the management of acne scars. Facial images of a typical case are shown in **Figure 4**.

Adverse reactions

The occurrence of blisters was negligible, with 0.77% in the Er:YAG group compared to 1.61% in the CO_2 group (χ^2 = 0.002, P = 0.967) (**Table 5**). Hyperpigmentation was reported in 1.54%

Table 4. Comparison of treatment efficacy between the two groups

Indicator	Er:YAG laser group (n = 130)	CO_2 laser group (n = 124)	χ^2	P
Significant improvement	40 (30.77%)	46 (37.1%)	8.105	0.017
Effective	68 (52.31%)	71 (57.26%)		
Ineffective	22 (16.92%)	7 (5.65%)		

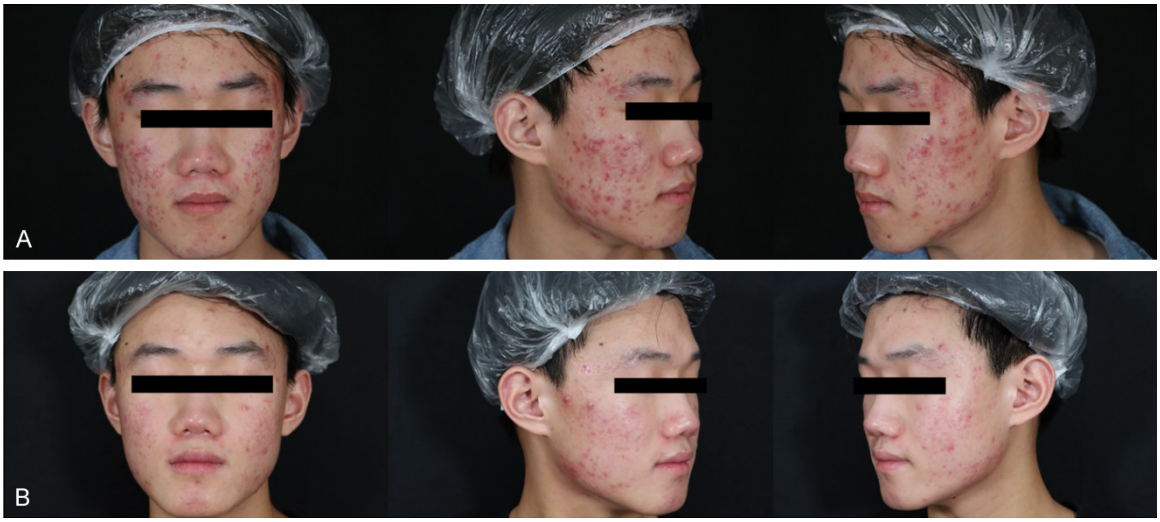

Figure 4. A patient with acne scars. A: Before treatment. B: After treatment.

Table 5. Comparison of adverse reactions between the two groups

Indicator	Er:YAG laser group (n = 130)	CO_2 laser group (n = 124)	χ^2	P
Blisters	1 (0.77%)	2 (1.61%)	0.002	0.967
Hyperpigmentation	2 (1.54%)	4 (3.23%)	0.223	0.637
Itching	1 (0.77%)	3 (2.42%)	0.304	0.581
Persistent erythema	1 (0.77%)	8 (6.45%)	4.449	0.035
Scar hyperplasia	3 (2.31%)	1 (0.81%)	0.208	0.648

of the Er:YAG group and 3.23% of the CO_2 group (χ^2 = 0.223, P = 0.637). Itching occurred in 0.77% of the Er:YAG patients and 2.42% of those in the CO_2 group (χ^2 = 0.304, P = 0.581). A significant finding was the higher incidence of persistent erythema in the CO_2 group (6.45%) compared to the Er:YAG group (0.77%), with a χ^2 of 4.449 and a *P*-value of 0.035. Scar hyperplasia rates were low in both groups, occurring in 2.31% of the Er:YAG group and 0.81% of the CO_2 group (χ^2 = 0.208, P = 0.648). These results suggest that while persistent erythema was significantly more common in the CO_2 laser treatment, other adverse reactions were relatively infrequent and comparable between the two groups.

Dermatology Life Quality Index (DLQI)

The impact of laser treatment on the quality of life in patients was evaluated using DLQI (**Table 6**). Prior to treatment, the Er:YAG laser group exhibited a mean value of 16.52 ± 2.35, which was comparable to 16.81 ± 2.15 in the CO_2 group (t = 1.007, P = 0.315). At the 3-month post-treatment assessment, the mean DLQI value in the Er:YAG group decreased to 13.25 ± 2.18, significantly lower than 14.02 ± 2.25 in the CO_2 group (t = 2.766, P = 0.006). By the 6-month post-treatment mark, the Er:YAG group further declined to 12.24 ± 2.20, while the CO_2 group reduced to 11.58 ± 2.01 (t = 2.500, P = 0.013). At the 1-year post-treatment evaluation, the Er:YAG Laser group had a mean value

Table 6. Comparison of DLQI scores between the two groups

Indicator	Er:YAG laser group (n = 130)	CO_2 laser group (n = 124)	t	P
Before treatment	16.52 ± 2.35	16.81 ± 2.15	1.007	0.315
3 months after treatment	13.25 ± 2.18	14.02 ± 2.25	2.766	0.006
6 months after treatment	12.24 ± 2.20	11.58 ± 2.01	2.500	0.013
1 year after treatment	12.01 ± 2.02	11.25 ± 1.98	3.029	0.003

DLQI: Dermatology Life Quality Index.

of 12.01 ± 2.02, significantly higher than 11.25 ± 1.98 in the CO_2 group (t = 3.029, P = 0.003). Initial improvements in patient quality of life were observed with both treatments, but the improvements from CO_2 laser therapy were more enduring.

Discussion

In our study, we evaluated the long-term efficacy of CO_2 array laser and Er:YAG laser treatments for acne scars. ECCA scores indicated that the CO_2 laser was more effective in reducing acne scar severity. This aligns with earlier research highlighting the CO_2 laser's strengths in penetrating deep into the skin and promoting collagen remodeling [22]. Several reasons could explain the superior performance of the CO_2 laser. Operating at a 10,600 nm wavelength, the CO_2 laser reaches deeper layers of the skin, effectively removing scar tissue and stimulating collagen production [23-25]. The combination of deep penetration and tissue coagulation likely contributes to more significant skin tightening and smoother texture [26, 27]. In contrast, the Er:YAG laser, with a shorter wavelength of 2940 nm, absorbs more superficially, limiting its impact on deeper scars but enabling precise ablation with minimal lateral thermal damage [28].

Improvements in skin texture, pore size, and erythema, measures by the VISIA Skin Analysis System, further support the CO_2 laser's deeper penetration capabilities. The dual benefit of resurfacing and remodeling, driven by the CO_2 laser's coagulative and ablative action, played a crucial role in treating moderate to severe acne scars [29, 30]. Over the one-year follow-up period, the consistent reduction in ECCA scores in the CO_2 group underscores its effectiveness in generating lasting changes within the skin matrix.

However, the efficacy advantage comes with a trade-off. Our study found a higher incidence of persistent erythema in patients with the CO_2 laser treatment, likely due to its deeper penetration and greater potential for collateral thermal damage. This persistent erythema could be attributed to prolonged inflammatory responses and neovascularization induced by the thermal injury, which are common with more aggressive resurfacing methods. Previous research has shown that deeper laser treatments, like CO_2 laser, tend to cause more inflammation and require longer recovery times [31]. In contrast, the Er:YAG laser works more superficially, resulting in fewer cases of erythema and blistering. This is because it limits heat spread into the surrounding skin tissue. Due to these safety advantages, Er:YAG lasers are especially useful for patients concerned about prolonged recovery times or those with skin types more prone to post-inflammatory hyperpigmentation [32].

Patients reported that the Er:YYAG laser was more comfortable and allowed for quicker recovery compared to the CO_2 laser. Those treated with Er:YAG experienced less pain, and their discomfort subsided faster. This may be associated with the Er:YAG laser's precise targeting of tissue, minimizing heat spread and thus reducing nerve irritation [33]. The faster fading of erythema also suggests a quicker short-term recovery with the Er:YAG laser [34].

Both treatments significantly reduced IL-4 levels and increased INF-γ levels. This shift from an anti-inflammatory state toward a more active immune response seems beneficial for wound healing and scar remodeling. Our finding aligns with earlier work showing these cytokine changes are crucial for skin repair [35]. Despite the CO_2 laser having a deeper effect on the skin, the Er:YAG group exhibited a greater rise in INF-γ levels. This suggests that the Er:YAG laser may promote a more controlled inflammatory response, minimizing excessive cellular stress while still supporting the body's regenerative processes.

Patients in both groups started with similar DLQI scores, indicating comparable quality of life before treatment. Three months later, the Er:YAG Laser group showed a greater reduction in DLQI scores, suggesting a quicker initial benefit. However, by six months and one year post-treatment, the CO_2 group had much lower DLQI scores, indicating a more sustained improvement in their quality of life. This suggests a more lasting improvement in their skin-related quality of life. While these trends are promising, further research is needed to confirm these results and better understand the underlying mechanisms.

Our findings highlight the need to personalize acne scar treatment. Choosing between CO_2 and Er:YAG lasers requires careful consideration of factors like scar severity, the patient's pain tolerance, and their risk of pigmentation changes. A balance must be sought between achieving the best results and ensuring patient safety and comfort. Ultimately, the aim is to achieve excellent clinical outcomes with high patient satisfaction.

While this study offers valuable insight into the long-term outcomes of CO_2 and Er:YAG lasers for acne scars, several limitations warrant consideration. Our relatively small sample size limits the statistical power and generalizability of these findings. Since the majority of participants had lighter skin tones, it is hard to predict the treatment response in dark-skinned people. We acknowledge that patient-reported satisfaction measures are inherently subjective, potentially introducing bias. Although the one-year follow-up provided meaningful long-term data, extended observation could reveal additional delayed effects either beneficial or adverse. Finally, potential influences from concurrent acne therapies, medications, or lifestyle factors on healing and outcomes were not systematically controlled. Future work should prioritize larger, more diverse patient cohorts, incorporate objective scar assessment tools, and extend follow-up periods to strengthen these observations.

Conclusion

CO_2 laser therapy delivers superior long-term improvement for acne scars but carries a higher risk of prolonged redness. Conversely, Er:YAG laser treatment is a safer alternative with faster recovery and fewer adverse events. Our evidence supports a personalized approach to clinical decision-making, carefully balancing efficacy against potential complications. Future studies should refine treatment protocols and investigate combined approaches that benefits of both laser systems. Such strategies could enhance scar resolution while minimizing unwanted effects. It would also be helpful to include a broader range of patients, such as those with different skin types and severe scarring, to optimize laser treatment.

Disclosure of conflict of interest

None.

Address correspondence to: Jing Peng, Department of Dermatology, Wuhan No. 1 Hospital, No. 215 Zhongshan Avenue, Qiaokou District, Wuhan 430345, Hubei, China. E-mail: 17786108743@163.com

References

[1] Heng AHS and Chew FT. Systematic review of the epidemiology of acne vulgaris. Sci Rep 2020; 10: 5754.
[2] Heath CR and Usatine RP. Acne vulgaris. Cutis 2021; 108: 167.
[3] Mavranezouli I, Daly CH, Welton NJ, Deshpande S, Berg L, Bromham N, Arnold S, Phillippo DM, Wilcock J, Xu J, Ravenscroft JC, Wood D, Rafiq M, Fou L, Dworzynski K and Healy E. A systematic review and network meta-analysis of topical pharmacological, oral pharmacological, physical and combined treatments for acne vulgaris. Br J Dermatol 2022; 187: 639-649.
[4] Layton AM and Ravenscroft J. Adolescent acne vulgaris: current and emerging treatments. Lancet Child Adolesc Health 2023; 7: 136-144.
[5] Habeshian KA and Cohen BA. Current issues in the treatment of acne vulgaris. Pediatrics 2020; 145 Suppl 2: S225-S230.
[6] Bittar J, Hooper P and Dover JS. 1726 nm lasers for the treatment of acne vulgaris. Skin Therapy Lett 2024; 29: 5-7.
[7] Al-Dhalimi MA and Dahham Z. Split-face clinical comparative study of fractional Er:YAG (2940 nm) laser versus long pulsed Nd:YAG (1064 nm) laser in treatment of atrophic acne scar. J Cosmet Laser Ther 2021; 23: 35-40.
[8] Hammoda TM, Ahmed NA and Hamdino M. Fractional CO(2) laser versus 1064-nm long-pulsed Nd:YAG laser for inflammatory acne vulgaris treatment: a randomized clinical trial. Lasers Med Sci 2023; 38: 187.

[9] Kwon HH, Yang SH, Lee J, Park BC, Park KY, Jung JY, Bae Y and Park GH. Combination treatment with human adipose tissue stem cell-derived exosomes and fractional CO2 laser for acne scars: a 12-week prospective, double-blind, randomized, split-face study. Acta Derm Venereol 2020; 100: adv00310.

[10] Hympanova L, Mackova K, El-Domyati M, Vodegel E, Roovers JP, Bosteels J, Krofta L and Deprest J. Effects of non-ablative Er:YAG laser on the skin and the vaginal wall: systematic review of the clinical and experimental literature. Int Urogynecol J 2020; 31: 2473-2484.

[11] Wang X, Yuan C, Wo Y, Qian L, Liu K, Zhang Z, Zhang Y, Xu H, Chen X and Biskup E. Will repeated ablative Er:YAG laser treatment sessions cause facial skin sensitivity? Results of a 12-month, prospective, randomized split-face study. Rejuvenation Res 2020; 23: 122-129.

[12] Cenk H and Sarac G. Effectiveness and safety of 2940-nm multifractional Er: YAG laser on acne scars. Dermatol Ther 2020; 33: e14270.

[13] Chen L, Wang Y, Jiang L, Fang J and Ren J. Comparison of 2940 nm Er: YAG laser treatment in the microlaser peel, fractional ablative laser, or combined modes for the treatment of concave acne scars. Medicine (Baltimore) 2021; 100: e26642.

[14] Lee SH, Kim DH, Jo SJ, Lim Y, Lee JW, Lee JH, Kim TM, Kim SR, Kang J, Yoon JY and Suh DH. The efficacy and safety of low- versus high-fluence fractional picosecond Nd:YAG 1064-nm laser in the treatment of acne scars: a randomized split-face comparison study. Photodermatol Photoimmunol Photomed 2024; 40: e12922.

[15] Goodman GJ and Baron JA. Postacne scarring: a qualitative global scarring grading system. Dermatol Surg 2006; 32: 1458-1466.

[16] Trinh B, Rasmussen SJ, Brøgger-Jensen ME, Engelhard CA, Lund A, Tavanez AR, Vassilieva A, Janum S, Iepsen UW, Kiens B, Møller K, Pedersen BK, Van Hall G and Ellingsgaard H. Inhibition of basal IL-6 activity promotes subcutaneous fat retention in humans during fasting and postprandial states. Cell Rep Med 2025; 6: 102042.

[17] Heller GZ, Manuguerra M and Chow R. How to analyze the visual analogue scale: myths, truths and clinical relevance. Scand J Pain 2016; 13: 67-75.

[18] Lyu J, Jiang L, Tang M, Zheng L and Liu S. Microneedle fractional radiofrequency associated with drug delivery for facial atrophic acne scars and skin rejuvenation. J Cosmet Laser Ther 2024; 26: 61-68.

[19] Ma L, Huang X, Qiu Y and He Y. Analysis of facial redness by comparing VISIA and YLGTD. Skin Res Technol 2023; 29: e13356.

[20] Liu F, Zhou Q, Tao M, Shu L and Cao Y. Efficacy and safety of CO(2) fractional laser versus Er:YAG fractional laser in the treatment of atrophic acne scar: a meta-analysis and systematic review. J Cosmet Dermatol 2024; 23: 2768-2778.

[21] He Z, Lu C, Basra M, Ou A, Yan Y and Li L. Psychometric properties of the Chinese version of Dermatology Life Quality Index (DLQI) in 851 Chinese patients with psoriasis. J Eur Acad Dermatol Venereol 2013; 27: 109-115.

[22] Artzi O, Sprecher E, Koren A, Mehrabi JN, Katz O and Hilerowich Y. Fractional ablative CO2 laser followed by topical application of sodium stibogluconate for treatment of active cutaneous leishmaniasis: a randomized controlled trial. Acta Derm Venereol 2019; 99: 53-57.

[23] Ziai K and Wright HV. Carbon dioxide laser rejuvenation of the facial skin. Facial Plast Surg Clin North Am 2022; 30: 331-346.

[24] Alomari O, Mokresh ME, Hamam M, Teker AU, Caliskan CS, Sadigova S, Ertan SN, Wojtara M and Filinte G. Combined stromal vascular fraction and fractional CO2 laser therapy for hypertrophic scar treatment: a systematic review and meta-analysis. Aesthetic Plast Surg 2025; 49: 885-896.

[25] Lin L, Liao G, Chen J and Chen X. A systematic review and meta-analysis on the effects of the ultra-pulse CO2 fractional laser in the treatment of depressed acne scars. Ann Palliat Med 2022; 11: 743-755.

[26] Wang H, Yang F, Wang H, Qin T, He J and Zhao C. Effect of CO2 fractional laser combined with recombinant human epidermal growth factor gel on skin barrier. Medicine (Baltimore) 2024; 103: e37329.

[27] Zhang DD, Zhao WY, Fang QQ, Wang ZC, Wang XF, Zhang MX, Hu YY, Zheng B and Tan WQ. The efficacy of fractional CO(2) laser in acne scar treatment: a meta-analysis. Dermatol Ther 2021; 34: e14539.

[28] Meghe SR, Khan A, Jangid SD, Sarda B, Vangala N and Saoji V. Shedding light on acne scars: a comprehensive review of CO2 vs. Erbium-Doped Yttrium Aluminium Garnet (Er:YAG) laser therapy. Cureus 2024; 16: e57572.

[29] Ziai K and Wright HV. Carbon dioxide laser rejuvenation of the facial skin. Clin Plast Surg 2023; 50: 421-436.

[30] Jordão JM, Stoliar MFF, Melo SS, de Campos GLM, de Forville Mesquita LA and Skare TL. Low-fluence and low-density CO2 laser: histological analysis of collagen fiber changes in skin and its clinical repercussions in photorejuvenation. Lasers Med Sci 2022; 37: 905-911.

[31] Trelles MA, Shohat M and Urdiales F. Safe and effective one-session fractional skin resurfacing using a carbon dioxide laser device in su-

per-pulse mode: a clinical and histologic study. Aesthetic Plast Surg 2011; 35: 31-42.
[32] Zaresharifi S, Robati RM, Dadkhahfar S, Forouzanfar MM and Zaresharifi N. Efficacy and safety of cryotherapy, electrodesiccation, CO2 laser, and Er:YAG laser in the treatment of seborrheic keratosis. Dermatol Ther 2021; 34: e15083.
[33] Mokhtari F, Safavi Z, Faghihi G, Asilian A and Shahmoradi Z. A comparative study on the usefulness of fractional CO(2) and fractional Er:YAG in acne scars: a split-face trial. Adv Biomed Res 2023; 12: 90.
[34] Albalat W, Ehab R, AbouHadeed MH, Abd Allah TN and Essam R. Combined low-dose isotretinoin and long-pulsed nd: YAG laser in the treatment of post-acne erythema. Arch Dermatol Res 2024; 316: 359.
[35] Wang ZC, Zhao WY, Cao Y, Liu YQ, Sun Q, Shi P, Cai JQ, Shen XZ and Tan WQ. The roles of inflammation in keloid and hypertrophic scars. Front Immunol 2020; 11: 603187.