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Research Article

Efficacy and Safety of Ablative Fractional Er:YAG Laser in Treatment and Prevention of Early Post-Surgical Scars

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Abstract

Background: Scarring following surgery continues to represent a considerable clinical and psychological challenge. The Er:ZYAG laser (2,940 nm) provides highly targeted tissue removal at the optimal water absorption wavelength, positioning it as a valuable option for the early prevention of scars. However, research supporting well-defined post-operative Er:YAG laser treatment protocols among Iraqi patients remains limited.
Aim: To assess the effectiveness and safety of ablative fractional Er:YAG (2,940 nm) laser therapy in managing and preventing early post-surgical scars in Iraqi patients.
Patients and Methods: This was a prospective interventional study carried out at Al-Kufa University in Iraq between August 2017 and April 2019. A total of 31 patients, including 23 females and 8 males with Fitzpatrick skin types ranging from 3 to 5, who presented with early post-surgical scars, underwent three Er:YAG laser treatment sessions with parameters set at fractional + thermal mode with 3 pulses in 2 horizontal and vertical passes. Sessions were spaced four weeks apart and began 4 to 6 weeks following surgery. Treatment outcomes were evaluated through the Vancouver Scar Scale (VSS), the Patient and Observer Scar Assessment Scale (POSAS), and photographic records.
Results: A total response rate of 96.8% was established. Mean total VSS score improved from 7.23 ± 2.75 to 1.61 ± 1.94 (77.7% improvement; $p < 0.001$, Wilcoxon). The greatest improvement was in scar height (89.1%), followed by vascularity (75.5%), pliability (72.8%), and pigmentation (67.0%). Observer POSAS satisfaction was 77.0% (satisfied) and patient satisfaction was 65.8%. A statistically significant inverse correlation was identified between baseline VSS score and percentage improvement (Spearman rho=0.468, p=0.008). No significant sex-based differences were found (p=0.837). One non-responder had uncontrolled Type 1 Diabetes Mellitus.
Conclusion: Ablative fractional Er:YAG laser is a highly effective and safe modality for early post-surgical scar prevention. Earlier intervention on less severe scars yields superior outcomes. Pre-treatment metabolic screening is strongly recommended.

1. Introduction

Wound healing refers to a replacement of destroyed or damaged tissue by newly produced tissue. It passes through three phases: inflammatory and immune response, re-epithelization (proliferation), and matrix remodeling. Restoration of skin integrity and hemostasis following injury

is a fundamental process to ensure survival. Ideally, the wound healing response would lead to complete restoration of skin function, integrity, and morphology. Unfortunately, this is often not the final result of wound repair[1–3].

In most mammalian organ systems, the repair response involves a complex and dynamic interplay of numerous cell types, including cells that reside within the tissue (e.g., keratinocytes, endothelial cells, melanocytes, fibroblasts), hematopoietic cells attracted to the site of damaged tissue, chemical mediators, and growth factors. The cellular and molecular mechanisms underpinning tissue repair and its failure to heal are still poorly understood, and current therapies are limited [4, 5].

Poor wound healing after trauma, surgery, acute illness, or chronic disease conditions affects millions of people worldwide each year and is the consequence of poorly regulated elements of the healthy tissue repair response. The speed of wound healing depends upon many factors, including age, genetic susceptibility of the patient, the size and type of wounds (incisional or excisional), the depth of wounds, blood supply, anatomical location of wound, presence or absence of foreign bodies and microorganisms, health, nutritional condition, and drugs that the patients may be taking [6, 7].

Scars arise from either excessive or insufficient local inflammatory reactions with disorder in new collagen formation during the healing process, which may lead to atrophic, hypertrophic, or keloid formation. Scars affect 4–16% of the general population and negatively impact the psyche of patients, causing low self-esteem and feelings of psychological isolation [8].

The use of laser technology for the treatment of existing surgical scars, as well as the minimization of new postoperative scars, has gained considerable attention from the dermatologic and plastic surgery communities in recent years. Laser scar treatment is based on Anderson and Parrish's theory of selective photothermolysis, and lasers are classified into non-ablative (PDL 585, KTP 532, DIODE 810/1450, ND:YAG 1064/1320, Er.Glass 1540), ablative (CO2 10600 or Er:YAG 2940), or IPL (which is not an actual laser). Therefore, in this study, we evaluate the efficacy of Er:YAG in the prevention and treatment of early post-surgical scars [9–13].

2. Aim of the Study

This study was planned to evaluate the efficacy and safety of ablative fractional Er:YAG (2940 nm) laser in treatment and prevention of early post-surgical scars in Iraqi patients.

3. Patients and Methods

This was a prospective, interventional study conducted from August 2017 to April 2019 at the dermatology department, Al-Kufa University, Iraq. Informed consent was obtained from all participants after providing them with oral information about the research.

A total of 34 Iraqi participants (25 females, 9 males, Fitzpatrick skin types 3–5) who had previous surgery performed by one surgeon using the same surgical procedure, with healthy skin and no major medical illness, were included in this study. Three patients did not complete the study for unknown reasons. Exclusion criteria were: pregnancy, lactation, use of anticoagulant drugs, history of malignancy, use of isotretinoin within the last six months, and susceptibility to keloids and hypertrophic wound healing.

All treatment sessions done by using the Quanta System Light D Er:YAG Laser (Quanta System S.p.a Via November 116, 21058 Solbiate Olona (VA) , Italy; Serial No. LID 0864-1110 in November 2010. The device classified as a class 4 laser, CE-certified (CE 0476) with type B applied parts and electrical protection class1.

Laser sessions started 4–6 weeks after the operation, or 2 weeks after suture removal, consisting of three consecutive sessions 4 weeks apart. The treatment area was sterilized with 70% alcohol, and topical anesthetic cream (2.5% lidocaine + 2.5% prilocaine) under occlusion was applied for 30-45 minutes before each session. Eyes were protected with goggles. An ablative fractional Erbium:YAG laser (QUANTA System, Italy) was used. The device parameters and technologies used in this study are summarized in Table 1.

Table 1: Specification of the Er:YAG Laser Device Used in the Study

Parameter	Specification
Laser type	Ablative Fractional Er:YAG
Manufacturer	QUANTA System, Italy
Wavelength	2940 nm
Laser mode	Fractional + thermal
Pulses	3 Hz
Electrical requirement	220–230 V, 16 A, 50–60 Hz

In each session, two passes of overlapping pulses were delivered, scanning the affected area in multiple directions (vertically, horizontally, and obliquely). Follow-up continued for the next session with assessment for erythema, infection, and/or pain; neither infection nor severe erythema was reported. Post each session patients were advised to use topical antibiotics and emollient for five days after each session and to continue sunblock use to reduce the risk of infection, erythema, and pigmentation.

Two dermatologists independently assessed scar improvement using photographic documentation, the Vancouver Scar Scale (VSS), and the Patient and Observer Scar Assessment Scale (POSAS). Photographs were obtained at baseline, before each session, and three months after the last treatment session. Improvement was graded as: not improved $<50\%$, moderately improved 50-75% and improved $>75\%$.

VSS includes four parameters: pigmentation, height, pliability, and vascularity of scars, measured at baseline and three months after sessions completion. POSAS, developed by Draaijers et al., has observer and patient components. Observers scored six parameters: vascularity, pigmentation, thickness, relief, pliability, and surface area, plus overall opinion, each on a 10-point scale. Patients scored six parameters: scar-related pain, itching, color, stiffness, thickness, and irregularity, plus overall opinion, each on a 10-point scale. Patients were blinded from observers during POSAS scoring [14, 15].

4. Results

4.1. Study Population

A total of 31 patients with early post-surgical scars were enrolled and treated with Er:YAG laser (2,940 nm), comprising 23 females (74.2%) and 8 males (25.8%). All patients completed the full treatment protocol and were evaluated using the VSS and POSAS.

4.2. VSS Score Outcomes — Wilcoxon Signed-Rank Test

Wilcoxon signed-rank tests confirmed statistically significant improvement in all four VSS parameters ($p<0.001$). The mean total VSS score decreased from 7.23 ± 2.75 to 1.61 ± 1.94 — an overall improvement of 77.7%. Greatest improvement noticed in scar height (89.1%), followed by vascularity (75.5%), pliability (72.8%), and pigmentation (67.0%).

Table 2: VSS Parameters — Mean ± SD, % Improvement, and Wilcoxon Results

Parameter	Before Mean ± SD	After Mean ± SD	% Improvement	Z (Wilcoxon)	p-value
Pigmentation	1.06 ± 0.77	0.35 ± 0.49	67.0%	-	<0.001***
Vascularity	2.77 ± 1.02	0.68 ± 0.75	75.5%	4.00	<0.001***
Pliability	2.13 ± 1.34	0.58 ± 0.89	72.8%	27.00	<0.001***
Height	1.19 ± 0.70	0.13 ± 0.43	89.1%	10.50	<0.001***
VSS Total	7.23 ± 2.75	1.61 ± 1.94	77.7%	3.00	<0.001***

% Improvement = (Mean Before - Mean After) / Mean Before × 100. ***p <0.001.

4.3. VSS Improvement Categories

Based on percentage of reduction in VSS, 24 patients (77.4%) achieved significant improvement (>75%), 6 patients (19.4%) achieved moderate improvement (50–74%), and 1 patient (3.2%) did not improve (<50%).

Table 3: VSS Improvement Category Distribution (n=31)

Category	Threshold	N	%	Mean VSS After
Improved	$\geq$ 75% VSS reduction	24	77.4%	0.88
Moderately Improved	50–74% VSS reduction	6	19.4%	3.33
Not Improved	<50% VSS reduction	1	3.2%	9.00
Total		**31**	**100%**	**1.61**

4.4. VSS Improvement by Sex — Mann-Whitney U & Chi-Square

Statistically no significant difference in VSS improvement was found between male and female patients (Mann-Whitney U=97.0, p=0.837; Chi-square χ^2=5.10, df=2, p=0.078). All moderately improved patients (6 patients) were female; while not improved patient was uncontrolled Type 1 Diabetes Mellitus male.

Table 4: Continuous VSS Variables by Sex — Mann-Whitney U Test (n=31)

Variable	Female (n=23) Median (Mean)	Male (n=8) Median (Mean)	U Statistic	p-value
VSS Before	8.0 (7.70)	6.0 (5.88)	—	—
VSS After	1.0 (1.52)	1.5 (1.88)	—	—
% Improvement	87.5% (82.7%)	81.7% (70.8%)	97.0	0.837 (ns)

Table 5: Improvement Category Distribution by Sex — Chi-Square Test (n=31)

Category	Female N (%)	Male N (%)	χ^2 (df=2)	p-value
Improved ($\geq$75%)	17 (73.9%)	7 (87.5%)	5.10	0.078 (ns)
Moderately Improved (50–74%)	6 (26.1%)	0 (0.0%)		
Not Improved (<50%)	0 (0.0%)	1 (12.5%)		
Total	**23 (100%)**	**8 (100%)**		

ns = not significant (p >0.05). Chi-square p=0.078 suggests a trend but does not reach statistical significance

4.5. POSAS Satisfaction Outcomes

Observer satisfaction: 24 patients (77.0%) satisfied, 6 (19.8%) moderate, 1 (3.2%) disappointed.
Patient satisfaction: 20 patients (65.8%) satisfied, 10 (31.0%) moderate, 1 (3.2%) disappointed. The combined satisfaction rate was 96.8% across both POSAS components.

Table 6: POSAS Satisfaction — Observer vs Patient (n=31)

Satisfaction	Observer N	Observer %	Patient N	Patient %	POSAS Score
Satisfied	24	77.0%	20	65.8%	1–3
Moderate Satisfaction	6	19.8%	10	31.0%	4–6
Disappointed	1	3.2%	1	3.2%	7–10
Total	31	100%	31	100%	

Score 1–3 = Satisfied; 4–6 = Moderate Satisfaction; 7–10 = Disappointed

4.6. Comparison of VSS and POSAS Outcomes

High consistency was observed between VSS objective improvement (77.4%) and observer POSAS satisfaction (77.0%), validating both assessment tools. Patient satisfaction was lower (65.8%), in agreement with the well-documented observer-patient gap in scar assessment.

Table 7: Comparison of VSS vs POSAS Observer vs POSAS Patient (n=31)

Category	VSS N	VSS %	Observer N	Observer %	Patient N	Patient %
Improved / Satisfied	24	77.4%	24	77.0%	20	65.8%
Moderate	6	19.4%	6	19.8%	10	31.0%
Not Improved / Disappointed	1	3.2%	1	3.2%	1	3.2%
Total	31	100%	31	100%	31	100%

4.7. Spearman Correlation — VSS Baseline vs % Improvement

A statistically significant inverse correlation was found between baseline VSS score and percentage improvement (rho=-0.468, p=0.008). Patients with lower VSS baseline scores (milder scars) showed a higher percentage of improvement, while patients with more severe baseline scars achieved a less percentage in VSS score reduction — supporting the significance of early laser intervention just before scar maturation.

Table 8: Spearman Correlation — VSS Before vs % Improvement

Variables	Spearman rho	p-value	Interpretation
VSS Before vs % Improvement	-0.468	0.008**	Moderate inverse correlation

4.8. Summary of Findings

Er:YAG laser achieved a 96.8% overall response rate with significant improvement across all VSS parameters ($p<0.001$). No significant sex-based differences were identified (p=0.837). The moderate inverse correlation between baseline VSS and the percentage of scar improvement supports that the early laser intervention an optimal treatment method. POSAS outcomes supported VSS findings, together confirming Er:YAG laser as an effective early intervention to prevent post-surgical scar maturation.

5. Clinical Photographs

The following figures are representative cases from the study, represent scars improvement before and after Er:YAG laser treatment.

Case 1: Abdominal Post-Surgical Scar

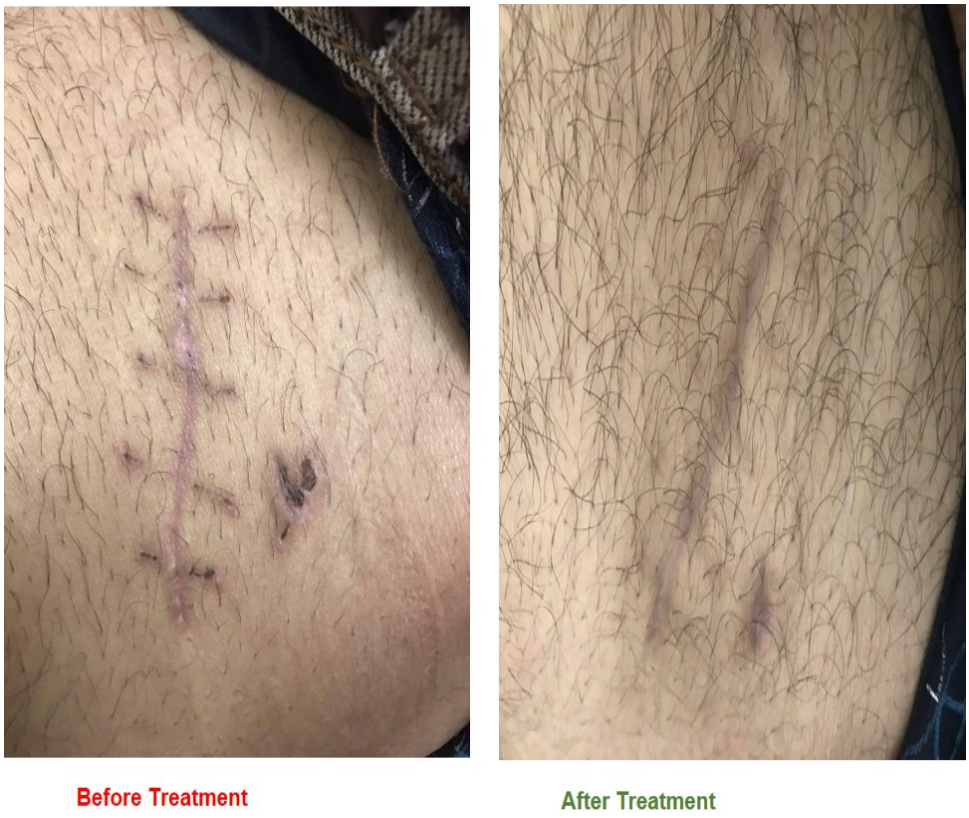

Figure 1: Abdominal post-surgical scar before and after three sessions of Er:YAG laser (2940 nm), showing significant improvement in scar height, vascularity, and pliability

Case 2: Neck/Thyroid Post-Surgical Scar

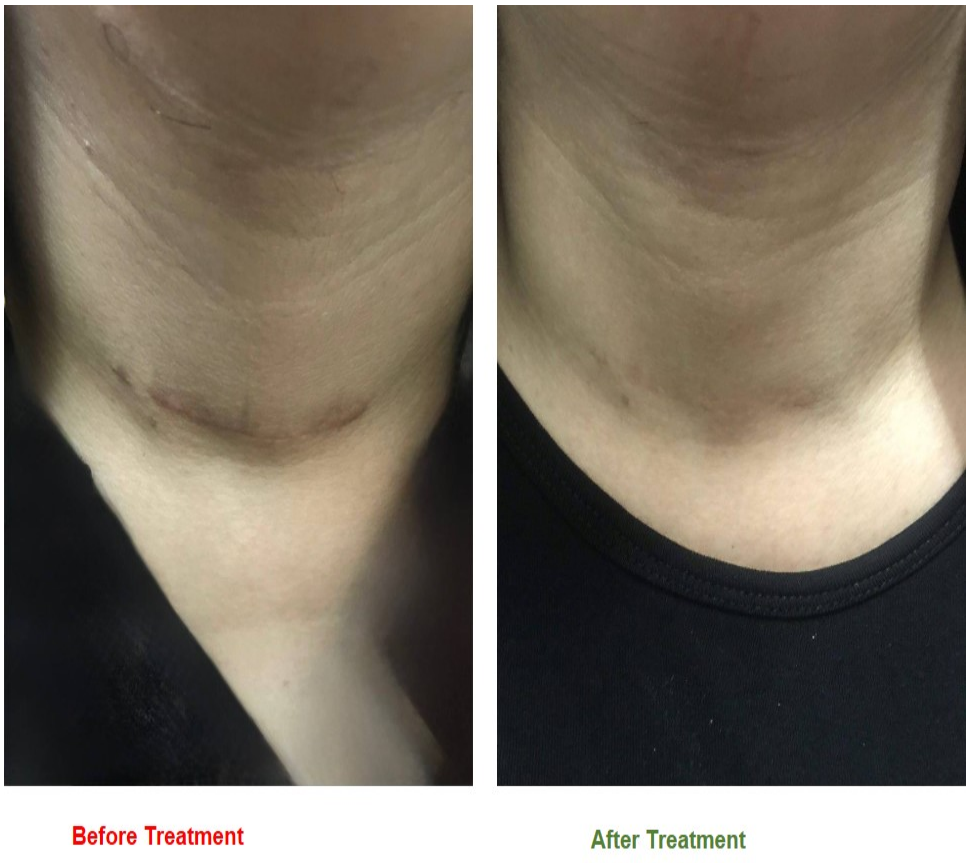

Figure 2: Neck/thyroid post-surgical scar before and after three sessions of Er:YAG laser (2940 nm), showing significant improvement in scar pigmentation and skin texture

6. Discussion

This study evaluated the efficacy of Er:YAG laser (2,940 nm) in treatment and prevention of early post-surgical scars in 31 Iraqi patients using both VSS and POSAS. Results show a highly favorable overall response rate of 96.8% (30/31 patients), with Wilcoxon signed-rank tests that confirming statistically significant improvement in all four VSS parameters ($p < 0.001$). These findings are supporting the evidence that early ablative laser intervention should be confirmed as a first-line strategy in post-surgical scar prevention.

The Er:YAG laser at 2,940 nm is the wavelength most readily absorbed by water in human tissue, which makes it an incredibly precise ablative laser for treating superficial tissue layers while causing minimal thermal damage to the surrounding tissue. This precise selectivity is an advantageous in early post-surgical scars, where the collagen matrix is still in an active remodeling phase. The fractional delivery mode generates microscopic thermal ablative zones (MTZ) surrounded by unaffected tissue, stimulating fibroblast activity that lead to an organized, basket-weave collagen resembling normal skin, rather than the disorganized parallel fibers of hypertrophic and or keloid scars [12].

The appropriate time for LASER intervention is so critical. During the proliferative phase of wound healing (weeks 1–12), matrix metalloproteinases and growth factors are highly active, Establishing the ideal therapeutic window for LASER-induced scar remodeling. Leszczynski et al. confirmed in a Cochrane systematic review that early laser intervention — particularly within the first 3 months — optimizing the scars outcomes compared to treatment of established, mature scars [16].

The mean total of VSS score decreased from 7.23 ± 2.75 to 1.61 ± 1.94, which represent a 77.7% overall improvement ($p<0.001$). Greatest improvement noticed in scars height (89.1%), which is clinically significant as elevation is strongly associated with functional impairment and poor aesthetic outcomes. These findings goes with Kang et al., who reported that 61.1% of patients found the intraoperatively Er:YAG treated side cosmetically superior to non-treated patients. Our higher improvement rate may reflect the benefit of a structured post-operative protocol at a defined early essential stage [17].

Vascularity (75.5%) and pliability (72.8%) improvements are in concordant with Kim et al., who demonstrated significant POSAS and VSS score improvement with fractional Er:YAG laser starting at suture removal. Agamia et al. suggesting combined therapies may further enhance results in future protocols by combined both Er:YAG with platelet-rich plasma (PRP) produced superior outcomes compared to monotherapy,. Despite we using monotherapy alone, our significant response rate supports the standalone efficacy of early Er:YAG treatment [18, 19].

All four VSS parameters achieved $p<0.001$ on Wilcoxon testing, confirming statistically significant improvements not linked to chance or natural scar maturation. The Spearman correlation revealed an inverse correlation between baseline VSS and percentage improvement (rho=-0.468, p=0.008): patients with milder baseline scars reached to a higher percentage of improvement. From a clinical standpoint, this supports the concept of intervening early, before scars fully mature or deteriorate further.

This inverse relationship should also be clearly communicated to patients. Those presenting with more severe scars at baseline should be informed that, although improvement in VSS scores may still hold meaningful clinical value, the relative percentage of score reduction is likely to be modest, and their expectations should be adjusted accordingly.

Mann-Whitney U testing (U=97.0, p=0.837) and Chi-square analysis (χ^2=5.10, df=2, p=0.078) revealed no statistically significant sex-based differences. However, the Chi-square p-value of 0.078 is nearing significance and warrants further study. Male had a greater rate of meaningful improvement (87.5% vs 73.9%) whereas all six moderately improved patients were female. This difference in sex improvement may partly be explained because of hormonal effects on the healing of wounds as estrogen stimulates more collagen deposition and cross-linking, which may put females at a greater risk for more prominent scars and broader improvement distribution. In contrast, testosterone has the tendency to act more evenly in collagen remodeling, permitting better laser-mediated reorganization. Female patients also had higher baseline VSS scores (mean 7.70 vs 5.88 in males), which — given the inverse Spearman correlation — that added another point to explain the relatively lower percentage improvement in females [20, 21].

One male patient (3.2%) was unresponsive to sessions of Er:YAG laser, with worsening in VSS from 6.00 to 9.00 post-treatment. This patient's type 1 diabetes mellitus was proven to be poorly controlled which is a major recognized systemic factor that negatively impacted wound healing and scar remodeling. Out of control diabetes negatively impacts all phases of wound healing: chronic hyperglycemia inhibits neutrophil and macrophage activity, decreases fibroblast proliferation and migration, microvascular deficiency and low collagen production. Advanced glycation end-products (AGEs) that cross-link collagen fibers in an abnormal manner, producing a stiffer extracellular matrix resistant to laser-induced remodeling. This paradox of exacerbation might be an iatrogenic, overstimulated–driven immune response of metabolically compromised tissue to laser micro-injury. So it's critically significance to confirm that the patients underwent a pretreatment metabolic screening as well as glycemic control, with an HbA1c goal <7.5% before treatment initiation [22, 23].

Observer satisfaction (77.0%) was also higher than patient satisfaction (65.8%), whereas moderate satisfaction was more common in patients (31.0% vs 19.8%). The gap is well-known and described in scar assessment researches. Observers assess objective criteria — color, elevation, surface texture — while patients scoring subjective symptoms such as itching, stiffness, pain, and psychological stress not completely accounted for by objective scar scores.

Draaijers et al. specifically developed POSAS to encompass this dual viewpoint, indicating that patient- the reported outcomes often do not match the clinician's judgment. Van de Kar et al. demonstrating patients consistently score their own scars more harshly than observers in his linear surgical scars. The robust agreement between VSS objective increase (77.4%) and POSAS observer satisfaction (77.0%) the observed agreement between these scores strong support for further establish their combined use. A combined satisfaction rate of 96.8% represents clinically significant and patient-relevant outcome outcome [15, 24].

Limitations

First, decrement in the power of statically analysis especially in sex comparison because of relatively small sample size (31 patients). So future studies preferred to be with larger, sex-balanced populations in order to clarify the role of sex and hormonal factors in Er:YAG laser scar outcomes.

Second, the absence of a control group is a critical limitation of this study design. For the future trials it's recommended to start a split-scars study — where one half of the scar is treated and the other remain as an internal control — would provide stronger evidence of laser-specific efficacy.

Third, as scar biology and laser-tissue interactions may differ between different ethnic population and lighter skin type and as the study accomplished in a single-center at Al-Kufa University, Iraq, with a predominantly Fitzpatrick skin type 3–5 patients. So, recommend to conduct the future study in multiple centers with different ethnic and lighter photo type populations.

Fourth, although their exclusion is unlikely to be an important or altered the research outcomes. Three of the original 34 enrolled patients did not complete the study for unknown reasons. Should be follow-up for their data to get ride from a bias that cannot be fully accounted for.

Fifth, as uncontrolled diabetes mellitus impaired wound healing capacity makes those unsuitable candidates for early laser scar intervention, so the non-responding patient should be excluded or deferred before session starting until adequate glycemic control is achieved (HbA1c $<7.5\%$). Pre-treatment metabolic screening established as a mandatory inclusion criterion.

Despite these limitations, the prospective design, validated dual-assessment methodology (VSS + POSAS), and consistent treatment protocol provide a reliable foundation for the conclusions drawn, and the findings meaningfully contribute to the existing evidence base for early ablative laser scar prevention.

7. Conclusion

This study demonstrate that Er:YAG laser (2,940 nm) is highly significant and effective strategy in the prevention and treatment of early post-surgical scars. Almost all patients achieving a 96.8% overall response rate with highly significant improvements across all VSS parameters while the only non-responding male with uncontrolled type 1 diabetes mellitus highlights the critical importance of pre-session metabolic screening. The inverse correlation between baseline scar severity and percentage improvement confirmed that an early intervention lead to an optimal result. Gender differences, although not statistically significant, it's suggested the possibility of hormonal and physiological roles. Finally, the strong alignment between VSS and observer part of POSAS validates that the dual-assessment approach gives more complete picture about scar assessment. However, the difference between the clinician and the patient's assessment shows that the patient's satisfaction should be always be considered as a valuable part in assessment of treatment success.

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Informed Consent: Written informed consent was obtained from all participants.

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Disclaimer (Artificial Intelligence): The author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.), and text-to-image generators have been used during writing or editing of manuscripts.

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