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ORIGINAL ARTICLE

The efficacy, satisfaction, and safety of carbon dioxide (CO2) fractional laser in combination with pulsed dye laser (PDL) versus each one alone in the treatment of hypertrophic burn scars: a single-blinded randomized controlled trial

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Abstract

The tendency to use less-invasive laser-based methods with far more obvious effectiveness has been taken into consideration today for improvement of burning scars. The present study thus aimed to assess the efficacy of two laser-based techniques including pulsed dye laser (PDL) and ablative fractional CO2 laser (AFCL) and its combination on improving different aspects of burning scars regardless of the types of scar as hypertrophic or keloid scars. This randomized single-blinded clinical trial was performed on patients suffering hypertrophic or keloid burning scars. The patients were randomly assigned into three groups scheduling for treatment with PDL alone, AFCL alone, or its combination. All patients were visited before and 40 days after the last treatment session, and their scars were assessed. In all groups, significant improvement was revealed in the Vancouver scar scale (VSS) score, the color of scar, vascular bed in the scar, the and height of scar and its pliability; however, the improvement in each item was more highlighted in the group receiving a combination therapy with PDL and AFCL techniques. In this regard, the highest improvement was found in vascular bed and pliability in the combination therapy group as compared to other groups. Although the superiority of the combined group was not statistically significant, due to the high percentage of improvement in total VSS and most of its indicators, it can be clinically significant. The efficacy of the treatment protocols was different considering subgroups of mature and immature scars (less than 1 year), so that more

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What is already known about this topic?
Laser therapy holds a unique role in the treatment of skin lesions.
particularly hypertrophic and keloid scars.
with two notable laser types being pulsed dye laser (PDL) and ablative fractional laser (AFCL).
Despite the fact that the effectiveness of each of the above lasers has been demonstrated in the literature.
there is a limited number of comprehensive clinical studies comparing the effectiveness of using the combination of these two lasers versus using each one individually.
What does this study add?
We demonstrated that although each of the targeted techniques improved different characteristics of scars.
the combination therapy was more effective and resulted in higher overall patient satisfaction compared to using PDL and fractional CO2 techniques alone.
We also made an interesting finding that the combined treatment of lasers showed significantly better results in treating immature scars compared to other types of scars.

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improvement in pliability of scar, vascularity, and color of scar was found in the group scheduling for PDL + AFCL as compared to those who were treated with PDL alone in immature scar group but not in mature scar group. Combined treatment can be much more effective in improving the appearance and pathological characteristics of scars than each individual treatment. This effectiveness can be seen mainly in immature scars.

Keywords Hypertrophic scar · PDL · AFCL · VSS · RCT · CO2 · PDL · Pulsed dye laser · Carbon dioxide laser · Burn scar · Scar · Laser · Trial · Satisfaction

Abbreviations

PDL	pulsed dye laser
AFCL	ablative fractional CO2 laser
VSS	Vancouver scar scale

Introduction

Burning is a significant global health issue, especially in middle- and low-income countries. The WHO reports 180,000 annual burn-related deaths worldwide. In the USA, over 2 million people experience burns each year, resulting in around 3000 deaths. Severe burns required medical attention for 11 million individuals in 2004, surpassing tuberculosis and HIV cases [1–3].

Two common types of scars after burning include hypertrophic scars and keloid. The prevalence of hypertrophic scar among these patients is reported to be about 70% [4–7]. Keloids are distinguished by their extensive growth beyond the boundaries of the initial wound, a characteristic not observed in hypertrophic scars [8]. The pathogenesis of the formation of hypertrophic and keloid scars is the proliferation of fibroblasts and the deposition of extracellular matrix components [9–11].

Treatment options available for these lesions encompass a range of approaches such as surgical intervention, the application of localized or injectable medications, radiation therapy, physical compression, and phototherapy [12–15]. Laser surgery has become a restorative tool that is progressing more and more [16]. The most important advantage of this treatment method is its non-invasiveness, as well as its selective effect on the skin structure. This can prevent the spread of scars, unlike surgery [17, 18].

The pulsed dye laser (PDL) is commonly used to remodel scars. It utilizes wavelengths of 585 nm and 595 nm. PDL reduces scar volume, improves texture and flexibility, and promotes new collagen formation. It works by coagulating microvasculature, targeting neovascularized tissue, and reducing inflammation. PDL selectively damages scar tissue through photothermolysis, converting light energy into thermal energy, which leads to coagulation necrosis [19, 20].

The fractional CO2 laser targets intracellular water, which vaporizes and coagulates the surrounding extracellular protein. Collagen remodeling in the treated scar is similar to normal skin, with an increase in the ratio of type III collagen compared to type I collagen. The laser's depth and density need to be adjusted based on the thickness of the scar [20, 21].

In recent years, limited studies have reported the effects of combining these two treatments, but the results have varied [22–24]. However, there has been no comprehensive study comparing each of these two lasers and their combination in the treatment of hypertrophic scars. In the study conducted by us, we investigated the effectiveness and safety of PDL, fractional CO2 lasers, and the combination of the two in the healing of hypertrophic scars based on specific criteria. Finally, the results in the three groups were evaluated and compared.

Materials and methods

The present participants in this project were adhered to all Helsinki ethical principles (IRCT20201005048928N1). This research was approved by the Research Council with the ethics code number IR.IUMS.FMD.REC.1399.411.

Study population

This randomized single-blinded clinical trial was performed on patients suffering hypertrophic or keloid burning scars referred to a referral dermatology clinic in Tehran in 2022. All patients aged 11 to 63 years without evidences of pregnancy or lactating, without history of receiving local or systemic corticosteroids within the last month, without history of diseases interacting with scar improvement (such as diabetes mellitus), and without scheduling for laser therapy within the last month. In this regard, sensitivity to treatment planned, history of systemic disorders or malignancies, and appearance of intolerable treatment-related side effect were considered as the exclusion criteria. We made an effort to divide the hypertrophic scars of each person into three intervention groups as evenly as possible, aiming to ensure that the average age in each group is similar.

The study was ethically approved by the ethical committee at Iran University of Medical Sciences, and written informed consent was signed by all participant before participating the study.

Study interventions and assessments

All patients who entered the study, before receiving any type of treatment, first undergo accurate and high-quality imaging of their hypertrophic scars. The entire laser intervention process was performed by an experienced dermatologist with expertise in all types of lasers and the treatment of burn patients. The dermatologist who performed the procedure is fully familiar with laser therapy for burn patients, and she has successfully treated a large number of patients with burn scars.

Before interventions, the patients were randomly (using the block randomization method) assigned into three groups that were treating with [1] PDL laser performed once in one treatment session that repeated up to 3 sessions, [2] fractional CO2 laser (AFCL) performed once in one treatment session and repeated up to 3 sessions; and [3] combined treatment included onetime of PDL laser and one time of fractional CO2 laser, both of which were performed in one treatment session and repeated up to 3 sessions. In a previous study, it has been demonstrated that the combination of PDL and fractional CO2 lasers has a synergistic effect in reducing MMP-2 and TIMP-1, resulting in improved hypertrophic scars [25]. The random list was generated by the design statistician and was provided directly to the drug manufacturing company. In this study, patients and statisticians will be completely unaware of the randomization method. PDL was performed by Synchro VasQ instrument and fractional CO2 laser by smartxide DOT/RF instrument that both tools were manufactured by Deka Company in Italy. The Synchro VasQ tool was set as pulse of 595 nm, power of 6.5 j/cm^2, single duration of 0.5 ms, and spot size of 7 mm. Smartxide DOT/RF AS was also set as fractional power of 10,600 nm, power of 12 J/cm^2, stack of 2, dwelling time of 800 ms, and space of 900 mm^2. When choosing the PDL parameters, we took into account the manufacturer's guidelines for treating hypertrophic scars and the firsthand experience of the experienced dermatologist using the laser. When it comes to the CO2 fractional laser settings, we carefully considered the extensive experience of a skilled dermatologist who has treated hypertrophic burn scars for several years.

All patients were visited again 40 days after the last treatment session, and their scars were photographed again. They were also examined in terms of prolonged side effects and patients' satisfaction of treatment protocols. Patient satisfaction with treatment is evaluated based on the overall assessment, which includes the following rating options: no response (0 points), little (1 point), somewhat (2 points), good (3 points), and excellent (4 points) [26]. Patients were asked oral questions regarding the occurrence of any complications during and up to 40 days after the completion of the treatment sessions in order to evaluate long-term side effects.

Statistical analysis

For statistical analysis, results were presented as mean ± standard deviation (SD) for quantitative variables and were summarized by frequency (percentage) for categorical variables. Continuous variables were compared using *t* test or Mann–Whitney test whenever the data did not appear to have normal distribution or when the assumption of equal variances was violated across the study groups. The categorical variables were compared using the Chi-square test or Fisher's exact test if required. p values of ≤ 0.05 were considered statistically significant. For the statistical analysis, the statistical software SPSS version 23.0 for windows (IBM, Armonk, NY) was used.

Results

Baseline characteristics of study subjects are summarized in Table 1. In total, 20 patients with 60 erythematous hypertrophic scars due to burning were included into the study. The average age of the patients was 23.35 ± 4.59 years, and 80.0% were female. Overall, 80% of the patients were single, and only 10% had academic educational degree. Regarding job status, most of the patients were unemployed (65.0%), and only 10.0% were employed. Regarding characteristics related to burning scar (Table 2), the most common mechanism for burning was firing in 50.0% followed by gas leak in 25.0%. In total, 40% patients had not undergone any treatment until assessment time. Among the 60 scar samples taken in terms of location, 14.5% were located on the face, 8.1% on the neck, 10.0% on the chest, and 4.8% on the abdomen and sides. There were 20 scars on the upper limb (32.2%) and 16 scars on the lower limb (25.8%).

Of 60 scars included into analysis, 18 were treated with PDL technique, 19 with AFCL technique, and 25 with a combination of PDL and AFCL techniques. The mean age of patients in the three groups was 24.11 ± 4.66 years, 21.84 ± 4.23 years, and 23.87 ± 4.11 years indicating no difference ($p = 0.456$).

Comparing the characteristics of scars across the three treatment groups before and after treatment (Table 3) showed that in all groups, significant improvement was revealed in Vancouver scar scale (VSS), the color of scar, vascular bed in the scar, and its pliability; however, the improvement in each item was more highlighted in the group receiving a combination therapy with PDL and AFCL techniques

Table 1 Baseline characteristics of the study population

Gender, %	
4 (20.0)	Male
16 (80.0)	Female
Age groups, %	
13 (65.0)	10 to 25 years
5 (25.0)	26 to 40 years
2 (10.0)	> 40 years
Marital status, %	
16 (80.0)	Single
4 (20.0)	Married
Ethnicity%	
17 (85.0)	Iranian
3 (15.0)	Afghan
Education level, %	
11 (55.0)	Undergraduate
5 (25.0)	Diploma
2 (10.0)	Bachelor
Job status, %	
13 (65.0)	Unemployed
1 (5.0)	Worker
2 (10.0)	Employed
3 (15.0)	Self-employed

Table 2 The characteristics of burning scar

Burning mechanism	
10 (50.0)	Firing
5 (25.0)	Gas leak
3 (15.0)	Hot fluid
2 (10.0)	Other
Last year's number of burns	
5 (25.0)	< 1 year
4 (20.0)	1 to 5 years
8 (50.0)	> 5 years
History of previous treatments	
6 (30.0)	Graft alone
2 (10.0)	Corticosteroid injection alone
2 (10.0)	Graft + corticosteroid injection
Location of scar	
9 (14.5)	Face
5 (8.1)	Neck
2 (3.2)	Chest
3 (4.8)	Abdomen and sides
7 (11.3)	Back
20 (32.2)	Upper limb
16 (25.8)	Lowe limb

Table 3 The improvement in characteristics of burning scar after treatments

Item	PDL	AFCL	PDL + AFCL
Modified VSS score			
Before	2.41 ± 9.06	2.16 ± 8.84	2.14 ± 9.76
After	2.17 ± 6.83	2.16 ± 7.21	2.14 ± 7.24
Percentage	22.47 ± 24.31	16.67 ± 20.01	25.55 ± 14.59
P value	0.001	0.001	0.001
Color of scar			
Before	0.77 ± 2.39	0.63 ± 2.21	0.64 ± 2.40
After	0.70 ± 1.83	0.40 ± 1.95	0.64 ± 2.00
Percentage	22.22 ± 28.00	6.14 ± 31.03	15.33 ± 19.79
P value	0.001	0.050	0.001
Vascular bed of scar			
Before	1.13 ± 2.00	1.10 ± 2.00	0.90 ± 2.30
After	0.76 ± 1.33	1.01 ± 1.37	1.00 ± 1.44
Percentage	29.16 ± 31.91	22.54 ± 62.06	40.00 ± 36.95
P value	0.006	0.020	0.001
Pliability			
Before	0.51 ± 2.50	0.51 ± 2.53	0.60 ± 2.88
After	0.58 ± 1.89	0.62 ± 1.95	0.53 ± 1.96
Percentage	21.29 ± 32.23	21.05 ± 27.68	30.33 ± 19.52
P value	0.004	0.002	0.001
Height of scar			
Before	0.70 ± 2.17	0.73 ± 2.11	0.57 ± 2.20
After	1.01 ± 1.72	0.91 ± 1.95	0.81 ± 1.80
Percentage	18.51 ± 55.97	4.38 ± 36.36	15.33 ± 39.94
	0.080	0.422	0.010

(Fig. 1). In this regard, the highest improvement was found in vascular bed and pliability in the combination therapy group as compared to other groups. The improvement in height and color of scar was however found in the group treated with PDL (Fig. 2). Overall, the highest improvement rate in total VSS score was found in the group scheduling for combination therapy as compared to other subgroups. The percentage of recovery in the group receiving the combination of two lasers was 25.55% ± 14.59%. In the groups receiving PDL and fractional CO2 laser, the percentages of recovery were 24.31% ± 22.47% and 16.67% ± 20.01%, respectively.

After adjusting pre-treatment characteristics of scar (Table 4), we showed no difference in the improvement of vascularity, height, and pliability of the scars as well as total modified VSS score between the three groups, but the improvement in color remained significant between AFCL (Fig. 3) and PDL subgroups (Fig. 2). Regarding the patients' satisfaction of the different treatment protocols, we found no difference in the level of satisfaction in AFCL group as compared to PDL group as the reference (OR = 0.21, 95%CI, − 0.45 to 0.88, $p = 0.52$). However, the level of

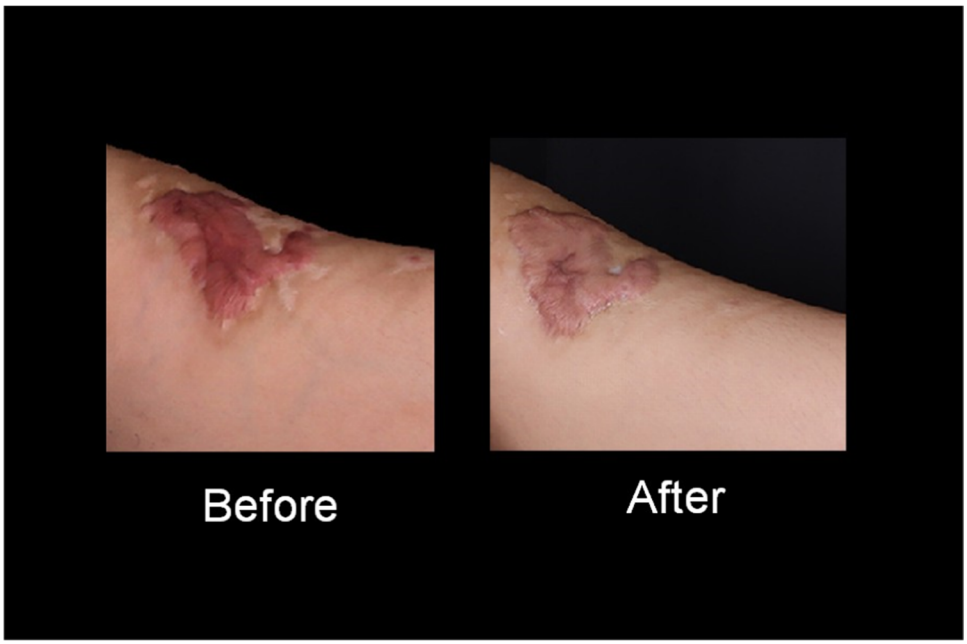


Fig. 1 Comparison of hypertrophic scar on the arm before and after 3 treatment sessions with a combination of fractional CO2 laser and PDL



Fig. 2 Comparison of hypertrophic scar on the hand before and after 3 treatment sessions with PDL

satisfaction was slightly higher in PDL + AFCL group as compared to PDL alone (OR = 0.55, 95%CI, − 0.04 to 1.12, $p = 0.052$).

The sub-analysis was also performed considering the immature scars (burning less than 1 year) and mature scar (burning more than one year). As shown in Table 5, the efficacy of the treatment protocols was different considering subgroups of mature and immature scars so that more improvement in pliability of scar, vascularity, and color of scar was found in the group scheduling for PDL + AFCL as compared to those who were treated with PDL alone in immature scar group.

Discussion

Burn scars have high social and financial burden on each community. Due to prolonged healing and overgrowing of scar as well as the likelihood of potential complications such as infection and ultimately impaired patient's quality

Table 4 The improvement in characteristics of burning scar adjusting baseline condition of characteristic

Item	OR	95%CI for OR	*P* value
Vascular bed of scar			
PDL	Reference	1.00	
AFCL	−0.21	−0.66 to 0.23	0.344
PDL + AFCL	−0.35	−0.10 to 0.29	0.288
Before treatment	−0.77	−0.64 to −0.90	0.001
Pliability of the scar			
PDL	Reference	1.00	
AFCL	−0.17	−0.56 to 0.21	0.381
PDL + AFCL	−0.19	−0.46 to 0.07	0.115
Before treatment	0.37	0.21 to 0.53	0.001
Height of the scar			
PDL	Reference	1.00	
AFCL	0.08	−0.16 to 0.33	0.487
PDL + AFCL	0.02	−0.37 to 0.42	0.922
Before treatment	0.49	0.29 to 0.69	0.001
Color of the scar			
PDL	Reference	1.00	
AFCL	0.21	0.03 to 0.38	0.010
PDL + AFCL	0.15	−0.12 to 0.44	0.283
Before treatment	0.56	0.37 to 0.75	0.001
Total VSS score			
PDL	Reference	1.00	
AFCL	0.16	−0.48 to 0.80	0.62
PDL + AFCL	−0.17	−1.30 to 0.95	0.76
Before treatment	0.60	0.39 to 0.81	0.001

of life, the management of these adverse events with the aim of early healing burning-related scar is necessary. This issue seems to be more important when the esthetic and psychological sequels of burning scar appear, leading to prolonged medical along with psychological treatments. Thus, the main goal of treatment approaches in burning scar is to minimize clinical limitations of scar along with improving the appearance of scar in terms of color, pliability, color, and vascularity of scars as much as possible. Timely surgery, fluid resuscitation, and physical therapy along with psychological support have been widely employed to achieve this goal; however, the evidence has shown that the therapeutic effects of these methods are limited and reversible to a large extent, and they are accompanied by potential side effects and are not accompanied by the desired satisfaction of the patients. Among the disadvantages of surgical treatment for hypertrophic scars, the following can be mentioned [11, 25]:

1. Risk of additional scarring: Surgery, like any invasive procedure, carries a risk of creating new scars or worsening the existing ones.
2. Surgical complications: There can be complications associated with surgery, such as infection, wound healing issues, bleeding, or adverse reactions to anesthesia.
3. Cost and time commitment: Surgery for hypertrophic scar treatment can be expensive, and the process may require multiple sessions or follow-up visits, leading to additional time and financial commitment.
4. Potential recurrence: Even after surgical removal, hypertrophic scars may still reoccur and require further intervention or management.



Fig. 3 Comparison of hypertrophic scar on the posterior trunk before and after 3 treatment sessions with CO2 fractional laser

Table 5 The improvement in characteristics of burning scar considering scar maturity

Item	Immature scar			Mature scar		
	OR	95%CI for OR	*P* value	OR	95%CI for OR	*P* value
Pliability of the scar						
PDL	Reference	1.00		Reference	1.00	
AFCL	−0.06	−0.24 to 0.10	0.455	−0.20	−0.69 to 0.29	0.414
PDL + AFCL	−0.31	−0.40 to −0.22	0.001	−0.12	−0.46 to 0.22	0.481
Before treatment	0.21	0.08 to 0.34	0.010	0.39	0.19 to 0.59	0.001
Vascularity of the scar						
PDL	Reference	1.00		Reference	1.00	
AFCL	−0.26	−0.35 to −0.17	0.001	−0.26	−0.84 to 0.31	0.366
PDL + AFCL	0.41	0.03 to 0.78	0.032	−0.52	−1.15 to 0.11	0.104
Before treatment	1.39	0.86 to 1.91	0.001	0.81	0.65 to 0.96	0.001
Height of the scar						
PDL	Reference	1.00		Reference	1.00	
AFCL	0.42	0.24 to 0.59	0.001	0.13	−0.21 to 0.46	0.45
PDL + AFCL	0.23	−0.29 to 0.87	0.462	0.11	−0.38 to 0.62	0.64
Before treatment	0.29	−0.22 to 0.80	0.266	0.44	0.16 to 0.72	0.002
Color of the scar						
PDL	Reference	1.00		Reference	1.00	
AFCL	0.17	−0.11 to 0.46	0.225	0.21	−0.01 to 0.43	0.060
PDL + AFCL	0.79	0.65 to 0.92	0.001	−0.10	−0.34 to 0.14	0.412
Before treatment	0.82	0.54 to 1.10	0.001	0.65	0.42 to 0.88	0.001
Total VSS score						
PDL	Reference	1.00		Reference	1.00	
AFCL	1.02	0.45 to 1.59	0.001	−0.46	−1.22 to 0.30	0.233
PDL + AFCL	1.33	−0.22 to 2.08	0.099	−0.81	−1.66 to 0.04	0.069
Before treatment	0.41	−0.18 to 1.00	0.171	0.77	0.54 to 0.99	0.001

On the other hand, physical treatments used to heal hypertrophic scars also have the following limitations:

1. Time-consuming: Physical therapy for hypertrophic scars usually requires frequent sessions over a prolonged duration, which can be inconvenient for individuals with busy schedules.
2. Discomfort: Certain physical therapy techniques, like massaging or stretching the scar tissue, may induce temporary discomfort or pain.
3. Varying outcomes: The effectiveness of physical therapy can differ from person to person, and not everyone may observe substantial improvement in their hypertrophic scar

For this reason, the tendency to use less-invasive methods with far more obvious effectiveness has been taken into consideration today, and in this regard, techniques based on laser therapy have found a special place. Laser treatment offers several advantages over other modalities in the treatment of hypertrophic scars [15, 17, 26]:

1. Precision: Laser technology grants the ability to precisely target particular areas, ensuring that the treatment focuses specifically on the scar tissue while minimizing any potential harm to the surrounding healthy skin.
2. Non-invasive: Laser treatments, usually non-invasive in nature, do not necessitate surgical incisions. As a result, they diminish the chances of complications, scarring, and downtime that are commonly associated with traditional surgical procedures.
3. Minimal discomfort: Patients generally tolerate laser therapy well, experiencing minimal discomfort throughout and following the procedure.
4. Controlled energy delivery: Laser devices have the capability to administer energy at controlled and customizable levels. This feature enables dermatologists to personalize the treatment according to each patient's specific requirements, maximizing its efficacy while minimizing potential negative outcomes.
5. Selective targeting: Laser therapies possess the ability to specifically focus on scar tissue, initiating the process of collagen remodeling and enhancing the generation

of healthier skin cells. As a result, hypertrophic scars can experience notable advancement in both their visual appearance and texture.

6. Customizability: Various lasers can be employed based on the specific attributes of the scar and the individual requirements of the patient. This adaptability grants dermatologists the freedom to select the laser modality that best suits each case.
7. Reduced recovery time: Compared to traditional surgery, laser treatments often involve shorter recovery periods. Patients can typically resume their normal activities sooner, leading to improved convenience and quality of life.

The present study thus aimed to assess the efficacy of two laser-based techniques including PDL and fractional CO2 and its combination on improving different aspects of burning scars regardless of the types of scar as hypertrophic or keloid scars. As the first important findings, we showed that although each of the pointed techniques could improve different characteristics of scars, the combination therapy was more effective that each of PDL and fractional CO2 techniques alone. In this regard, the highest improvement rate in total VSS score was found in the group scheduling for combination therapy as compared to other subgroups. This combined technique also led to significantly higher ultimate patients' satisfaction of treatment method. The results of this study suggest that the combined treatment of PDL and fractional CO2 laser can be a suitable option for improving the appearance of scars, yielding favorable outcomes and high patient satisfaction. This finding gains further significance when considering that laser treatment is non-invasive and free from the complications and limitations associated with surgical and physical treatments mentioned earlier.

Another point that was very interesting was that considering the type of scar in terms of being mature and immature, the effects of combined treatment were completely different, so that in immature scars or those that remained for less than a year, the effects of combination therapy were observed far more often. Our findings regarding the remarkable effectiveness of combined laser treatment for immature scars are significant because the treatment of these scars is inherently challenging. Immature scars have the potential to spread over time, and their delicate nature makes multiple scar treatments unsuitable. The results of our study demonstrate that combined laser treatment not only avoids the progression of lesions post-treatment but also effectively halts their advancement in the early stage. This treatment option offers both therapeutic and preventive benefits, which are highly valuable.

Therefore, in summary, it can be said that, firstly, the combined treatment of these two techniques has far more effectiveness and improvement than each of these two techniques, and this effectiveness can be seen mainly in the case of immature scars.

Several studies have been conducted regarding the comparison of these two techniques or their combination in the treatment of burn scars, but they have been associated with conflicting results. In a study by Alster et al. [24], it was shown that the simultaneous use of high-energy CO2 laser and PDL is superior to CO2 laser alone for revision of non-erythematous hypertrophic scars. Xie and colleague [27] evaluated the clinical effect of sequential PDL and fractional CO2 laser treatments on hypertrophic burn scars in the early stages and found that sequential treatment with PDL and fractional Co2 laser was effective and its effectiveness was increased by starting earlier and by increasing the times of therapy. Another study by Lei et al. [28] in 2020 with the aim of measuring the effect of the combination of PDL and UFCL treatments on children's burn scars in the early stages showed that the combined treatment with PDL and fractional CO2 had a significant effect on reducing the length of the treatment period and reducing the complications, and it also reduced the symptoms and increased the quality of life of children, although the target population studied in this study was different in terms of age from the sample studied in our research. Some studies, in line with our study, have shown the significant effectiveness of combined treatment in improving immature scars. Ouyang and colleagues (16) also conducted a study on patients with immature erythematosus hypertrophic scars who had less than 3 months of burn wound healing. They found that the total score of VSS and the score of color, height, vessels, and pliability in both the control group (PDL) and the treatment group (combination of PDL laser and fractional CO2) were significantly reduced after treatment, which is in line with the findings of our study, but on the other hand, in the comparison between the groups, the total score of VSS, and the melanin score, height, vessels, and pliability in the group with combined laser decreased significantly more than the group under PDL laser, and as a result, in this study, it was concluded that the clinical effect of PDL laser combined with fractional CO2 laser for the treatment of immature red hypertrophic scars is better than PDL alone. Of course, it should be kept in mind that the sample size of our study was small due to the unavailability of more samples and the patients' dissatisfaction with the treatment with these techniques, which will affect the non-significance of some potential statistical relationships. We attempted to address the small sample size limitation by taking into account multiple scars in each patient. However, increasing the sample volume and including a larger number of lesions would yield more accurate results. The patients' dissatisfaction primarily stemmed from the lack of clear understanding regarding the clinical progression of their lesions and unrealistic expectations regarding treatment outcomes. Throughout the treatment process, we

endeavored to provide comprehensive information about the course of lesions and available treatment options, aiming to establish realistic expectations in patients. Consequently, we made concerted efforts to minimize the influence of these two factors on the outcomes of our study.

Conclusion

As a final conclusion, combined treatment can be much more effective in improving the appearance and pathological characteristics of scars than each individual treatment. This effectiveness can be seen mainly in immature scars, so the faster start of combined treatment can have far better clinical results.

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Author contribution A.G. conceived the manuscript topic and developed the study design. M.K.K. and A.J. conducted the data collection and interpretation of results as well as drafted the final manuscript. F.S.B. and S.S. performed the data analysis. M.K.K., A.J., and A.G. reviewed and commented on the final and revised manuscript draft. M.K.K. and A.J. contributed in finalizing the revised paper. All authors read and approved the final manuscript.

Declarations

Conflict of interest The authors declare no competing interests.

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