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ORIGINAL ARTICLE NON-SURGICAL AESTHETIC

Comparison of the Scar Prevention Effect Between a Carbon Dioxide Fractional Laser and a Continuous Ablative Carbon Dioxide Laser with a 595-nm Nd:YAG Laser

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Abstract

Purpose A linear surgical scar, when located in the head and neck region, can be a significant cosmetic concern. Laser skin resurfacing with a fractional laser and a pulsed dye laser has been proven to be useful for treating such scars. As alternatives, we used a classic ablative CO_2 laser in continuous mode with a 1-mm spot size and a 595-nm Nd:YAG laser. We investigated the effect of the combination of the continuous CO_2 laser and 595-nm Nd:YAG laser and compared it to the effect of fractional CO_2 laser monotherapy on linear scars.

Methods This was a retrospective, case-controlled study designed to compare the efficacy between fractional CO_2 laser therapy and combination therapy with a conventional CO_2 laser in continuous mode and a 595-nm Nd:YAG laser. Treatment efficacy was evaluated by two different scar scales: the Stony Brook Scar Evaluation Scale (SBSES) and the modified Vancouver Scar Scale (mVSS). Laser treatments were performed every month until the 6th month after surgery.

Results The SBSES and mVSS scores improved over time in both the monotherapy and the combination therapy ($P < 0.001$). No significant differences were found between the therapies for all the subcategories of the SBSES. However, among all the subcategories of the mVSS, pigmentation showed a better prognosis with combination therapy ($P = 0.04$).

Conclusion Monotherapy and combination therapy can provide similar positive effects on linear scar improvement after repeated treatment, whereas combination therapy exerts more favorable anti-pigmentation effects than monotherapy. The combination of a continuous ablative CO_2 laser with a 595-nm Nd:YAG laser can be used as a favorable alternative to a fractional CO_2 laser. The 1-mm spot size of the CO_2 laser beam may mimic the fractional laser form and offer more effective results for linear incision scars.

Level of Evidence III This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Facial injuries · Scar · Carbon dioxide · Pigmentation · Lasers

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Introduction

A linear surgical scar after surgery involving primary closure, scar revision or local flap, especially when located in the head and neck region, can be an important cosmetic concern. Multiple strategies have been developed to prevent or improve postoperative surgical scarring, including the use of taping, moisturization, compression using

silicone sheets, massage, hydration, topical corticoids, and laser therapy [1, 2].

Over the past decade, laser skin resurfacing with a fractional laser and a pulsed dye laser (PDL) has proven to be useful. Carbon dioxide (CO_2) and erbium-doped yttrium aluminium garnet (Er:YAG) lasers are popular fractional lasers for the treatment or prevention of scars [2–5]. Fractional lasers have been proven to be effective for linear scars in the head and neck region [4, 6, 7]. However, this approach was first used for large surface areas, such as acne scars, rather than linear scars.

The depth and purpose of the laser treatment are determined by the wavelength of the laser. A shorter wavelength results in a deeper invasion. PDLs are used for scar treatment and have been proven effective for scar pigmentation and vascularity [2, 3, 8, 9]. A Q-switched neodymium-doped yttrium aluminium garnet (Nd:YAG) laser can be used between 1064 nm and 595 nm. The 532- and 585-nm wavelengths of an Nd:YAG laser have been shown to have similar effects to those of a PDL [10, 11]. Since the wavelength of a PDL is 595 nm, we expected similar effects when using a 595-nm Nd:YAG laser.

We assumed that a CO_2 laser with a continuous mode would be more suitable for linear scars than a fractional CO_2 laser because the former can focus on only the scar, resulting in less damage to adjacent normal tissues. We expected that when used in combination with a 595-nm Nd:YAG laser, the CO_2 laser would provide additional pigmentation, erythema and hypertrophic scarring prevention effects. In this work, the effectiveness of the scar prevention treatment was evaluated.

Materials and Methods

A nonrandomized, retrospective, comparative study was conducted. The study protocol conformed to the guidelines of the Institutional Review Board (IRB). All procedures in studies involving human participants were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

This study was conducted in the outpatient clinic of our hospital. Patients were recruited from January 2014 until July 2017, each having undergone surgical intervention in the head and neck region. Primary closure of head and neck lacerations, scar revisions, Dingman incisions for the reduction in zygomaticomaxillary fractures, and excision of benign tumors were performed. The patients were of Korean or Chinese origin, aged 16–70 years, and had skin types III to IV.

Wounds were closed primarily in a layered fashion with subcutaneous absorbable sutures (polyglactin 5-0). The wound surface was closed with separate epicutaneous sutures (nylon 6-0).

Patients who visited our clinic from January 2014 to December 2015 were treated with a fractional CO_2 laser (Mega Scan Fractional Laser®, Beijing Broad Laser Science and Technology, Beijing, China). Patients who visited our clinic from December 2016 to July 2017 were treated with a combination of an ablative CO_2 laser in continuous mode (UM-L30®, Union Medical Co. Ltd., Seoul, Korea) and a dual-mode Q-switched Nd:YAG laser (Lutronic Spectra XT®, Koyang, Korea) at a 595-nm wavelength.

The continuous ablative CO_2 laser was applied first. The beam had a diameter of 0.3 mm and 2 W of power. The adjacent laser spot was placed in a nonoverlapping manner, which eventually mimicked the fractional laser form (Fig. 1). A consecutive Nd:YAG laser was applied immediately in the same manner (diameter of 5 mm, 0.40 J/cm^2, 5-Hz repetition rate).

The exclusion criteria included additional treatment besides laser treatment, a history of hypertrophic scarring or keloid, photosensitivity, pigmentation due to recent exposure to sunlight, a follow-up loss of fewer than 3 times for treatment, pregnancy and immunosuppressive drug use.

The following protocol was followed to prevent and evaluate unfavorable scars in our scar clinic. Treatment was initiated 1 month after surgery. The treatment was performed every month, and photographs were taken at each visit in our clinic. Before the treatment, a 5% lidocaine/prilocaine cream (EMLA 5% cream, AstraZeneca, London, United Kingdom) was applied to the treated area for half an hour under occlusion. All laser treatments were performed by the same plastic surgeon. After treatment, to minimize edema and infection, a topical antibiotic ointment (Terramycin®, Pfizer, Seoul, Korea) was applied. The patients were instructed to avoid sunlight for 3 months.

The scar scale was evaluated postoperatively at 1, 3, and 6 months. The scoring was performed by two physicians, one of whom was a treating physician.

Treatment efficacy and improvement were evaluated by 2 different scar scales, the Stony Brook Scar Evaluation Scale (SBSES) and the Modified Vancouver Scar Scale (mVSS). Two evaluators who were trained to score in similar manners evaluated the patients after 1 and 3 months and the final month of surgery during a visit.

The following scoring systems were used:

1. The Stony Brook Scar Evaluation Scale (SBSES) [12]

Before treatment, the evaluator assesses the width, height, color, suture marks, and overall appearance of the scar and determines a score of 0 or 1 for each category, where 1 is the better score. A scar that is < 2 mm, flat, the same color or lighter, has no suture marks and has a good overall appearance receives 5 points.

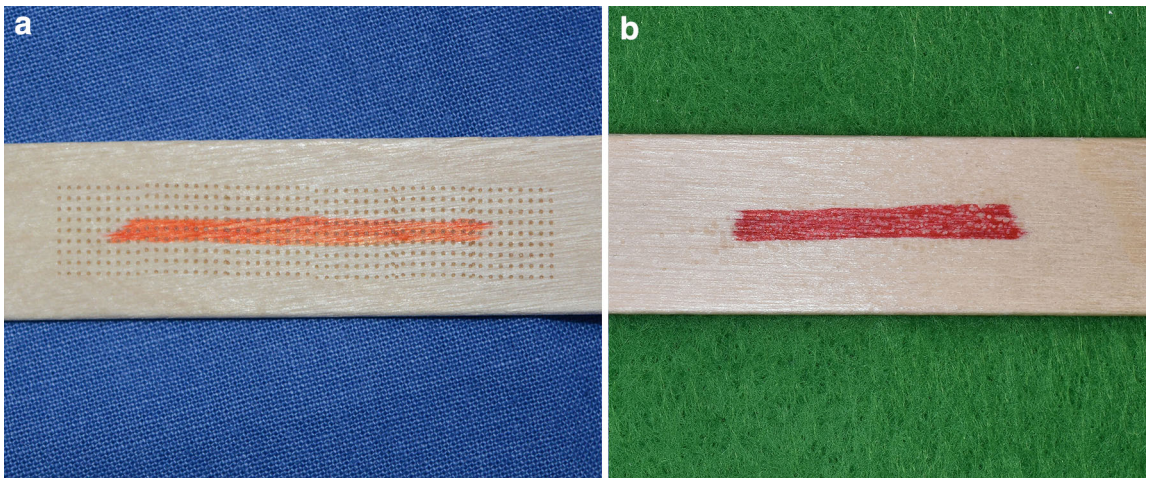

Fig. 1 **a** The fractional Er:YAG laser produces a regularly fractionalized laser spot. The size of the framing square is relatively large for a linear scar. Normal skin is damaged by the laser. **b** An ablative CO_2 laser in continuous mode was used in our clinic. After passing the scar, the spots were spread to mimic a fractional laser

2. The Modified Vancouver Scar Scale (mVSS) [12]

The evaluator examines the vascularity, pigmentation, pliability, height, pain, and pruritus of the scar before treatment.

The vascularity is scored as normal (0), pink (1), red (2), or purple (3), and pigmentation is scored as normal (0), hypopigmentation (1), mixed pigmentation (2), or hyperpigmentation (3). The pliability is scored as normal (0), supple (1), yielding (2), firm (3), ropes (4), or contracture (5), and the height is scored as flat (0), < 2 mm (1), 2–5 mm (2), or > 5 mm (3). Pain and pruritus are each scored as none (0), occasional (1), or requiring medication (2).

Statistical analyses were performed using the IBM SPSS Statistics for Macintosh, version 21.0 and GraphPad Prism version 7.00 for Windows (GraphPad Software, La Jolla CA, USA, www.graphpad.com.). A repeated measures ANOVA was used to confirm the effects of the laser therapy from 1 to 6 months and determine whether the different laser therapies resulted in improvements. A Mann–Whitney *U* test was used to compare the effectiveness after 6 months of treatment.

Results

The total 297 patients were evaluated by scar scales. But, some of them didn't receive a laser treatment. They visited our clinic from April 2014 to August 2017. Overall, 212 patients were excluded because they did not visit our clinic after 3 months of surgery. Among 85 patients, 61 patients were treated with methods other than lasers, such as triamcinolone injection and botulinum toxin injection, or were not treated with lasers. Twenty-four patients with a linear surgical scar in the head and neck region were ultimately included (Table 1). The male/female ratio was 11/13. The group included 12 cases of primary closure of head and neck lacerations, 7 cases of scar revisions, 1 case of a scar on the eyebrow after open reduction and internal fixation (ORIF) of a maxilla fracture, and 3 cases of excision of a benign tumor. The mean age of the patients was 37.4 ± 17.0 years.

1) Study 1: Stony Brook Scar Evaluation Scale scores (Table 2)

The results of monotherapy and combination therapy showed improvements over time (with the number of treatments) (Table 2, Fig. 2). The *P* value of most subcategories was < 0.001, except for the suture mark. The month-laser section indicates whether an interaction was observed between the laser treatment modality and the course of improvement for the subcategories. A within-subject effect was not present.

No significant differences in scar improvement were identified between combination therapy and monotherapy for the 1st and 6th months.

Fractional CO_2 laser monotherapy produced gradual improvements in scar width and erythema (Fig. 3).

2) Study 2: Modified Vancouver Scar Scale scores (Table 3)

The results of monotherapy and combination therapy showed improvements over time (with the number of treatments) (Table 3, Fig. 4). Within-subject effects were expected for pigmentation but were not statistically significant.

Combination therapy showed a better prognosis for pigmentation upon comparison of the results for the 1st and

Table 1 Patient demographics

Monotherapy				Combination therapy			
Sex	Age	Operation	Follow-up (months)	Sex	Age	Operation	Follow-up (months)
F	34	Primary closure	7	F	22	Scar revision	4
M	61	Scar revision	7	F	18	Scar revision	4
F	48	Primary closure	5	F	47	Scar revision	4
M	25	Primary closure	6	M	25	Scar revision	4
M	33	Primary closure	5	M	26	Scar revision	7
M	63	Primary closure	3	M	41	Scar revision	9
M	66	Primary closure	5	F	52	Primary closure	6
M	17	ORIF	6	F	53	Primary closure	4
F	56	Excision	5	F	63	Primary closure	4
F	22	Excision	5	M	15	Primary closure	5
				M	20	Primary closure	4
				M	43	Primary closure	7
				M	28	Local flap	6
				F	20	Excision	6

Table 2 Evaluation by the SBSES

	Fractional CO_2 laser			Continuous ablative CO_2 laser+ 595-nm ND:YAG laser			P* value	$P^{\dagger}$ value of the correlation	$P^{\ddagger}$ value for the final month
	1 Month	3 Months	6 Months	1 Month	3 Months	6 Months			
Width	0.20 ± 0.42	0.60 ± 0.52	0.80 ± 0.42	0.00 ± 0.00	0.36 ± 0.50	0.64 ± 0.50	< 0.001	0.931	0.83
Height	0.30 ± 0.48	0.50 ± 0.53	0.60 ± 0.52	0.29 ± 0.47	0.71 ± 0.47	0.86 ± 0.36	< 0.001	0.298	0.20
Color	0.00 ± 0.00	0.20 ± 0.42	0.50 ± 0.53	0.07 ± 0.27	0.50 ± 0.52	0.86 ± 0.36	< 0.001	0.324	0.15
Suture marks	0.50 ± 0.53	0.80 ± 0.42	0.90 ± 0.32	0.79 ± 0.43	0.93 ± 0.27	0.93 ± 0.27	0.002	0.242	0.16
Overall appearance	0.00 ± 0.00	0.30 ± 0.48	0.90 ± 0.32	0.07 ± 0.27	0.21 ± 0.43	1.00 ± 0.00	< 0.001	0.483	0.80
Total score	1.00 ± 0.82	2.40 ± 1.07	3.70 ± 0.82	1.21 ± 0.80	2.71 ± 1.27	4.29 ± 0.91	< 0.001	0.608	0.31

P* value number of treatments and the result (repeated measures ANOVA)

$P^{\dagger}$ value correlation between the number of treatments and the laser modality (repeated measures ANOVA)

$P^{\ddagger}$ value comparison for the two-laser modality between the initial and final months (Mann–Whitney U test)

6th months after surgery, and greater pigmentation improvements were observed with combination therapy.

Continuous ablative CO_2 laser and 595-nm Nd:YAG laser combination therapy produced dynamic improvements in scar width and erythema, preventing hypertrophic scarring (Figs. 5, 6).

Discussion

Fractional laser treatment was developed for safer and more effective skin resurfacing. Ablative laser skin resurfacing techniques such as CO_2 and Er:YAG laser treatments are effective but are associated with unfavorable complications. Severe pain, persistent erythema, hyperpigmentation, hypopigmentation, and scarring are all common side effects. Fractional resurfacing creates microscopic thermal wounds with spatial separation between damaged tissues, which results in short migratory paths for keratinocytes. It also leads to quicker re-epithelization and healing than conventional ablative resurfacing, lowering the incidence and degree of side effects [13–15].

Fractional lasers have an excellent effect on irregular surfaces of skin, such as acne scars [16, 17], and are useful for treating large rugged skin surfaces. A linear scar due to trauma or surgery also has an irregular surface. Because of the narrow characteristics of such scars, a fine laser beam size is required rather than a fractional laser with a larger beam area, which is more suitable for acne scars. A conventional ablative CO_2 laser with a fine beam size can be

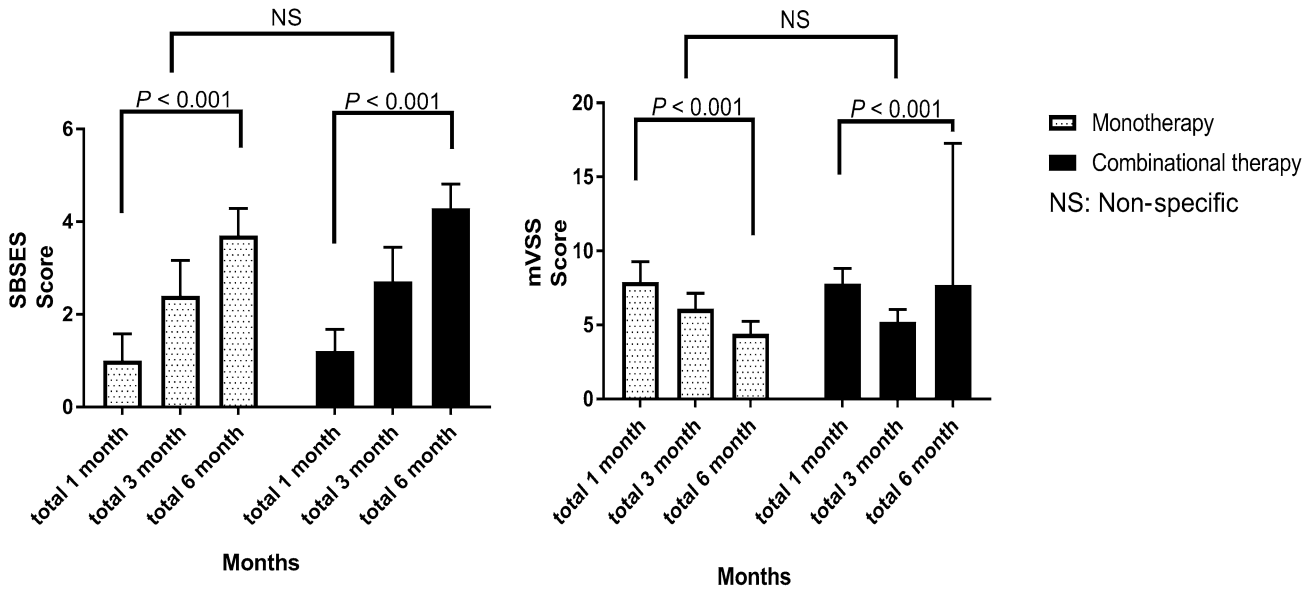

Fig. 2 Changes in the estimated average total score for each laser treatment for each month. The graph shows gradual improvements in the scars over time (number of laser treatments). The laser treatment modality did not affect the course of improvements

Fig. 3 A chin scar showed gradual improvement after repeated monotherapy treatment with an ablative fractional CO_2 laser. After primary closure due to a knife injury, five laser treatments were performed. Erythema, suture mark and width improvements were noted. The pictures show the postoperative results at **a** 1 month, **b** 3 months, and **c** 6 months

Table 3 Evaluation by the mVSS

	Fractional CO_2 laser			Continuous ablative CO_2 laser+ 595-nm ND:YAG laser			P* value	$P^{\dagger}$ value of the correlation	$P^{\ddagger}$ value for the final month
	1 Month	3 Months	6 Months	1 Month	3 Months	6 Months			
Vascularity	2.00 ± 0.67	1.70 ± 0.67	1.10 ± 0.57	1.93 ± 0.62	1.14 ± 0.77	0.79 ± 0.70	$T < 0.001$	0.239	0.53
Pigmentation	2.20 ± 0.79	1.30 ± 0.67	1.10 ± 0.57	2.50 ± 0.76	1.43 ± 0.76	0.71 ± 0.61	< 0.001	0.072	0.04
Pliability	2.60 ± 084	2.20 ± 1.03	1.50 ± 0.53	2.14 ± 0.66	1.64 ± 0.74	1.29 ± 0.83	< 0.001	0.518	0.61
Height	1.10 ± 0.32	0.90 ± 0.32	0.70 ± 0.48	1.21 ± 0.58	1.00 ± 0.39	0.71 ± 0.47	< 0.001	0.855	0.64
Total score	7.90 ± 1.91	6.10 ± 1.42	4.40 ± 1.79	7.79 ± 1.81	5.21 ± 1.42	3.50 ± 1.79	< 0.001	0.239	0.27

P* value: number of treatments and the result

$P^{\dagger}$ value: correlation between the number of treatments and the laser modality

$P^{\ddagger}$ value: comparison for the two-laser modality between the initial and final months

used on a linear scar with an irregular surface without injury to adjacent normal tissues, with a better peeling effect on the scar. The very small spot can mimic the fractional laser as we previously demonstrated (Fig. 1).

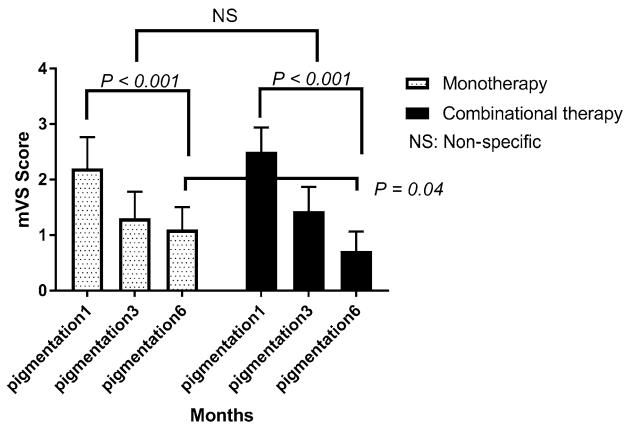

Fig. 4 Changes in the estimated average pigmentation for each laser treatment. The graph shows gradual improvements in the scars over time. Combination treatment produced significant improvements

Prior studies have shown that the PDL is effective in improving the erythema, pigmentation, height, texture, and pliability of scars [8, 9, 18, 19]. The PDL is preferentially absorbed by hemoglobin, causing local thermal injury. It is thought that the PDL produces microvascular destruction, leading to ischemia, which may deprive a scar of nutrients or may impair the proliferation of fibroblasts [6, 20]. It is effective in the treatment of hypertrophic scars or keloids [2, 9, 18, 21].

Numerous studies have been published on the similar effects of short-wavelength Nd:YAG lasers compared to PDLs with wavelengths near 585 nm [10, 11]. Therefore, we expected that a 595-nm Nd:YAG laser can be used as an alternative to a PDL, and our study produced the expected results.

The idea of early laser treatment for scar management is a relatively recent concept. George W. Elgart et al. used a 585-nm PDL on linear surgical scars right after suture removal with a 4–10-week interval for a total of 3 treatments. With a split-scar method, half of the scar was treated, and the other half was not. At 1 month after the final treatment, the scar was evaluated by the Vancouver Scar Scale (VSS). The article concluded that the 585-nm PDL is effective and safe to use on a surgical scar on the day of suture removal [6].

There are some studies about the efficacy of the early use of ablative fractional lasers, including fractional CO_2 and 1550-nm fractional erbium-glass lasers [7]. Christopher J. Miller et al. used a 10,600-nm CO_2 fractional laser on linear facial surgical scars. With a split-scar method, half of the scar was treated, and the other half was not. The scars were treated on the day of suture removal, and after 12 weeks, the scars were evaluated by the VSS and visual analog scale (VAS). Although there were no significant differences in the VSS between the treated and the control halves after 12 weeks of treatment, the VAS showed better

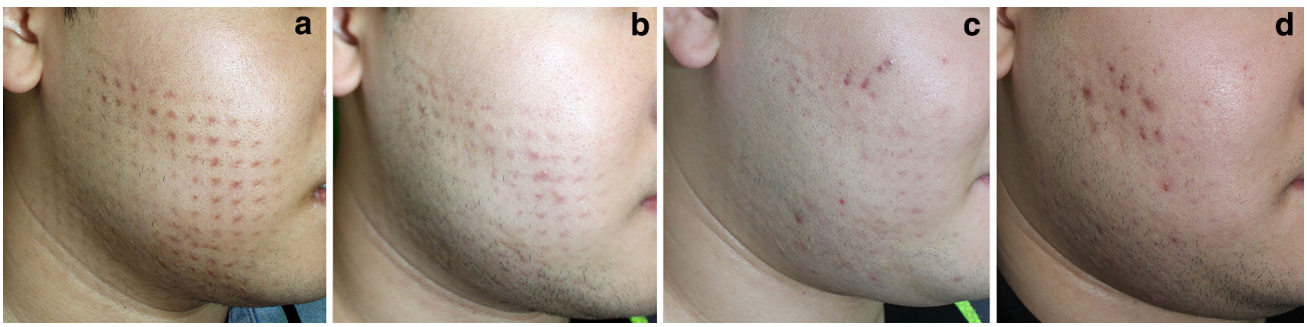

Fig. 5 The patient bumped his face against a pole while on his bike, and foreign body impactions were evident on his right cheek. The foreign bodies were removed, and primary closure was performed. Repeated treatments with combination laser therapy prevented hypertrophic scarring, erythema and pigmentation. The pictures show the results at **a** 1 month, **b** 3 months, **c** 6 months, and **d** 9 months after treatment

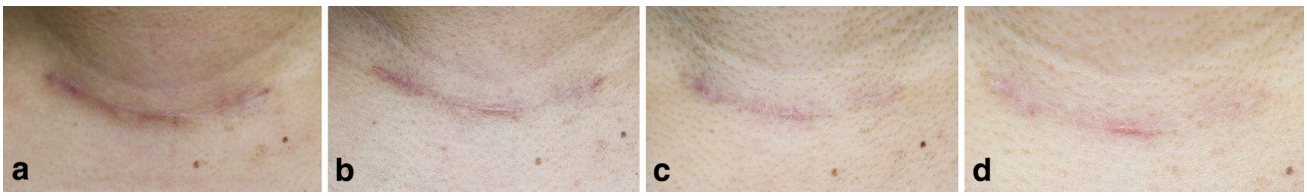

Fig. 6 The neck is a susceptible area for hypertrophic scarring. The patient underwent a total thyroidectomy for thyroid cancer. After repeated treatments with combination laser therapy, only slight hypertrophic scarring without pigmentation was evident. The pictures show the postoperative results at **a** 1 month, **b** 3 months, **c** 6 months, and **d** 9 months

scar improvement in treated halves than the control halves, and this difference was statistically significant [22]. One study conducted by Ju Hee Lee et al. suggests that early postoperative fractional CO_2 laser treatment of thyroidectomy scars is effective and safe. The treatment was performed at 2–3 weeks after surgery [23]. Seung Min Nam et al. conducted another study using a fractional CO_2 laser on traumatic facial linear scars. The patients were treated at 4 weeks after surgery. The study suggests that early use of the fractional CO_2 laser is safe and effective in minimizing scar formation [24].

More studies should be carried out to prove the effectiveness of early laser treatment compared to normal scar maturation. We think the split-scar method is the best way to prove it. However, the split-scar method is hard to perform because patients are usually not fond of it due to concerns about asymmetry and delayed scar improvement of the untreated halves. Although prior studies suggest that early ablative fractional laser treatment is effective in scar management, additional and more controlled studies can help to prove the issue.

We expected that combination therapy would be more effective for certain subcategories; however, we cannot confirm such differences. This result is due to our small sample size and the limitation in scar scale for expressing subtle changes. The difference is noted only via mVSS and not via SBSES due to the broad spectrum of the evaluation of SBSES. The scoring system of SBSES is only 0 or 1 for each subcategory, and the standard for the 0 point is relatively high for a facial scar. Additionally, suture marks are usually absent when plastic surgeons suture wounds. There are many scar scales that have attempted to estimate scars in an objective way. However, all scales have a subjective nature; a scar scoring approach that includes all scar characteristics is impossible.

The fractional Er:YAG laser is a good alternative to the fractional CO_2 laser because the Er:YAG laser produces less thermal damage and is confined to only the dermal layer [7]. As a result, the fractional CO_2 laser is known to elicit more complications, such as edema, oozing, crusting, prolonged erythema and postoperative bleeding. However, it is also known to be more effective in treating rhytides and solar elastosis than the Er:YAG laser [13–15]. We considered the fractional CO_2 laser as a good control group because it has long been a laser widely used in aesthetic clinics and conventional therapies for scars and because many surgeons are accustomed to limiting the above complications.

Fractional lasers and PDLs are the only accepted lasers for linear scar treatment according to guidelines [2]. However, not all clinics have these lasers. Some have other lasers for treating different skin lesions. The dual-mode Q-switched Nd:YAG laser can operate at different wavelengths and with variable hand pieces. This laser can be used for pigmentation, erythematous lesions, melasma and toning [10]. The operator can treat a variety of skin lesions with one laser. This study suggests that in addition to fractional lasers, the PDL, the continuous ablative CO_2 laser and the Nd:YAG laser can be used for linear scar treatment. Thus, the usage of lasers can be extended.

The long pulse mode (1064 nm) of the Nd:YAG laser is already known to be effective for treating hyperpigmentation. Additionally, we suggest that the 595-nm Nd:YAG laser is effective for hyperpigmentation. The different effects can be revealed upon further evaluation.

Many other lasers have yet to be evaluated for certain skin lesions; therefore, their use is limited. The various uses and effectiveness of other lasers should be confirmed to extend the usage of lasers.

Conclusion

A continuous ablative CO_2 laser with a fine beam size is as effective as a fractional CO_2 laser for treating linear surgical scars. A Q-switched 595-nm Nd:YAG laser achieves effects similar to those of a PDL; thus, we suggest the use of a 595-nm Nd:YAG laser as an alternative to a PDL. Moreover, the combination of a continuous ablative CO_2 laser and a 595-nm Nd:YAG laser has better effects on pigmentation than a fractional CO_2 laser.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflicts of interest to disclose.

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