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Combination Treatments of Facial Atrophic Post-Acne Scars: Retrospective Analysis of 248 Pairs of Pre- and Post-Treatment Photographs

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Abstract

Background: Fractional laser treatment (FR, 1550nm) is combined with other methods, including chemical reconstruction of skin scars (CROSS), subcision (SB), non-ablative laser treatment (SM, 1450nm) or/and ablative laser treatment (CS, CO_2 and Er:YAG), for the treatment of post-acne scars in a dermatologic clinic where multiple doctors practice.

The purpose of this article is to extract information on post-acne scar treatment beyond what is currently known by statistically comparing the effectiveness of combinations to each other and to the solitary use of fractional laser.

Materials and Methods: A total of 248 pairs of pre- and post-treatment photographs (Fitzpatrick's skin type III–IV) were evaluated by five professionals on a scale of 0–100% improvement. A result showing no change was rated as 0%. An evaluation of the treated area as normal was rated as 100%. Aggravated areas received negative ratings. The severity of the pre-treatment state was graded with the Modified Quantitative Scar Grading System. The evaluators' scores were weighted with the MQSG score and were analyzed with SPSS software, version 14.0K.

Results: The combinations of FR+SB+CR+SM+CS, FR+CR+SM+SB, FR+CR, FR+CR+SM, FR+CR+SB, and FR+SM produced significantly better outcomes than the use of FR only. Optimal Temporal Treatment Interval would be 3 to 4 weeks. Laser sculpting results in better outcomes when performed after other treatments.

Conclusion: Better outcomes can be expected if FR is appropriately combined with other methods. Better results could be achieved when the CS (ablative laser treatment) was temporally located after other treatments, and a particular sculpting technique provided additional improvement.

Keywords: Post-acne scars; Combination laser treatments; Fractional laser; Laser resurfacing; Ablative lasers; Non-ablative lasers; Subcision; CROSS

Abbreviations

CG: Combination Groups; CR: CROSS (chemical reconstruction of skin scar); CROSS: Chemical Reconstruction of Skin Scar; CS: Ablative Llaser Treatment; Er: YAG: Erbium: Yttrium-Aluminum-Garnet; FAPS: Facial Atrophic Post-Acne Scars; FR: Fractional Laser; IP: Improving Power,

IP=WS/(total number of Treatment sessions); MQSG: Modified Quantitative Scar Grading System; MIZ: Microscopic Treatment Zone; Nd: YAG: Neodymium: Yttrium-Aluminumgarnet; OTI: Optimal Temporal Treatment Interval; PIH: Post-inflammatory Hyperpigmentation; SB: Subcision (subcutaneous incisionless surgery); SM: Smooth Beam; TCA: Trichloroacetic Acid; WS: Weighted Scores, $WS = score \times \left(\frac{MQSG}{57}\right) \times 10$

Background

Post-acne scarring is one of the disfiguring disorders that can place limitations on self-esteem, social interactions, or daily activities, and it can even be an risk factor for suicide [1-4]. Many different treatments have been used to ameliorate this type of atrophic scarring, with varying degrees of success [5].

In the Dermatology Clinic, where multiple doctors practice, five modalities (fractional laser, subcision, CROSS, non-ablative laser and ablative lasers) are primarily used in combinations individualized according to the pre-treatment status of the scars as well as the patient's desires and

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expectations. The purpose of this retrospective study was to extract useful information about facial atrophic post-acne scar [3,6-8] (FAPS) treatment from the data accumulated in medical records.

The scope of this study was limited to FAPS and was focused on the contour of scars. Although FAPS are frequently accompanied by dyschromia, conditions such as post-inflammatory hyperpigmentation (PIH) and/or erythema, for which different chromophores are targeted, were excluded from the scope of this study.

It was considered redundant to describe recovery times and possible side effects of each treatment option mentioned in this article because they are already well-documented [9-20].

Combination Treatments of Post-Acne Scars

Combination treatments have the benefit of taking advantage of the unique characteristics of each treatment modality to achieve the ultimate goal, namely aesthetic improvement [9], with a lower risk of side effects, while any single treatment method is not capable of complete scar removal.

Ablative lasers

While highly effective in recontouring the skin and improving scar appearance, laser skin resurfacing with carbon dioxide (CO_2) and erbium: yttrium-aluminum-garnet (Er: YAG) lasers has been associated with extended recovery periods, prolonged erythema, and other untoward side effects [10-16]. The combined usage of CO_2 laser and Er:YAG laser has also become popular for ablative resurfacing [3,7,9,10,17-23]. However, there is no reproducible method that encompasses the majority of acne scar types and that correlates the lesions with the specific techniques used to repair them [24].

Non-ablative laser

Because of the potential risks from the use of ablative lasers, non-ablative technology using long-pulsed infrared (1,450-nm diode and 1,320-nm neodymium: yttrium-aluminum-garnet [Nd: YAG]) laser systems were developed. The absence of epidermal damage significantly decreases the severity and duration of treatment-related side effects and downtime [25]. If the cryogen spray is properly set, the main drawback of ablative lasers can now be overcome with little downtime, if any. However, the major drawback of non-ablative lasers is their limited efficacy [25,26]. Although the wound response in the thermally injured dermis produces new collagen, non-ablative laser techniques have less, or unpredictable, efficacy compared with ablative laser techniques or fractional laser resurfacing [26-28]. However, this characteristic makes non-ablative lasers a good choice for the purpose of preventing the regenerative cascade from receding if treatment sessions are scheduled between fractional laser procedures [3,7,9,21-23].

Fractional lasers

Although the length of downtime was significantly shortened with this method compared to ablative laser surgery [29], fractional laser surgery could result in erythema, edema [18], and/or sometimes post-inflammatory hyperpigmentation (PIH), especially in certain ethnic groups [30,31].

However, fractional laser has the unique benefit of re-epithelialization, with fewer side effects and downtime [32] because the tissue surrounding each microscopic treatment zone (MTZ) consists of intact, residual epidermal and dermal cells that contribute to rapid healing [15]. Proportional re-epithelialization is completed with every treatment within one day [29]. And the treatment is typically scheduled every 4-6 weeks [33].

The benefits of fractional lasers lie in the textural improvement [34] and upward growth of the depressed part of the scar by the reorganization of new collagen fibers [32,35], thus reducing the scar depth [12]. However, a shortcoming of this device is its limited efficacy in sculpting the contour of the scar, especially when the margin of the scar is sharply angled, or/and the scar surface is highly irregular [3,9,22,23,36,37].

CROSS (Chemical Reconstruction of Skin Scar)

Trichloroacetic acid (TCA) is known to be effective for acne scars when used as a superficial peel or in 'combination peels' of medium depth for acne scars [9,49-52]. Use of peels containing high TCA concentration is very risky and definitely not recommended [9,53] because of possible reticular dermis healing with scarring. Focal application of higher concentrations of Trichloroacetic acid (TCA) with a sharpened wooden applicator [38] or a 1-mL syringe with a fine-gauge needle [39] is suggested to avoid such complications. This technique, CROSS, performed with 65% or 100% TCA alone, does not involve classic full-face chemical resurfacing but rather can be used for focal chemical scar reconstruction [38] by stimulating the production of collagen, glycosaminoglycan, and elastin [38,40,41] of the depressed area only. This treatment produces multiple, frosted white spots on each acne scar. Consequently, the exclusive increase in the dermal volume of the depressed area more efficiently reduces the depth of atrophic scars. If TCA were to stimulate simultaneously the adjacent tissue that is not depressed, the depth – the difference in levels between the depressed area and normal area – would barely be altered, resulting in little change in the contour of the scarred skin. This differentiated stimulation of collagen production is more effective in reducing the depth of atrophic scars (Figure 1).

Subcision (Subcutaneous Incisionless Surgery) [3,7,42,43]

Subcision is the method of cutting under a depressed scar or wrinkle using a tri-beveled hypodermic needle inserted under the skin through a needle puncture [44]. The effectiveness of subcision for correcting various types of skin depressions depends on two distinct phenomena. First, the act of surgically releasing the skin from its attachment to deeper tissues results in skin elevation. Second, the introduction of controlled trauma initiates wound healing, with the consequent formation of connective tissue, which augments the depressed site [44-48]. This procedure also produces pooling of blood under the defect. The blood acts as a spacer, keeping the scar base from immediately reattaching to the surface layers. The subsequent

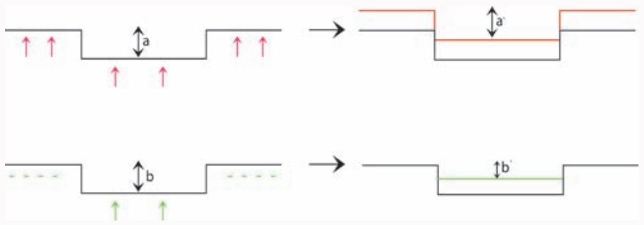

Figure 1: The differentiated stimulation of collagen production sparing the adjacent tissue that is not depressed seems to reduce the depth of the atrophic scars more effectively. (a=a', b>b').

organization of this blood clot induces a longer-term correction by the formation of connective tissue [49].

Subcision is useful when the subdermal tether precludes treatment from the surface above it, and correction of the subdermal component is essential for treatment success, by reaching depths below those reached with conventional skin resurfacing options [45].

Materials and Methods

Retrospective study

Electronic medical records from May 2005 to July 2008 were searched for patients who were treated for FAPS for more than 6 months. In total, 148 Asian patients (Fitzpatrick's skin type III–IV, 45 male and 103 female subjects) were included in the study, after excluding Caucasians and cases without proper photographs. The patients were 15.5 to 49.5 years of age (average age: 28.5 years old) when they commenced the treatments.

In total, 48 pairs of photographs were excluded from 296 pairs of pre- and post-treatment photos of both cheeks of 148 patients because they were out of focus, or the angles of the pre-treatment and post-treatment photos were different.

Treatment procedures

These patients were randomly assigned to doctors who set treatment schedules that considered the pre-treatment status and the circumstances of the patients. The recommended treatment intervals were two to four weeks. Usually 5 sessions to 10 sessions of treatments were contracted, and upon the completion of the contracted treatment sessions, more treatment sessions were scheduled, subject to the patient's demands. However, if there was no demand by the patient, the treatment sessions were concluded. Post-treatment photographs were obtained every 2-3 months with the patients' consent. The latest possible photographs were used for comparison with the pretreatment photographs.

CROSS [3,7,42,43]: The 0.3ml syringe was filled with approximately 0.05ml of 100% TCA, and the plunger was removed slowly while the barrel was held upright. Gentle tapping of the barrel with the index finger removed air bubbles caused by the removal of the plunger, and the TCA flowed down toward the needle. The application area became frosted in appearance within a few seconds of a single application.

Subcision [3,7,42,43]: An 18-gauge Nokor needle was mounted on a 1ml syringe filled with 1% lidocaine and epinephrine 1:100,000. The tip of the Norkor needle can be kept horizontal by mounting it parallel to the finger bars of the syringe. In this way, the position of the triangular tip remains visible, even when the tip is inserted into the tissue, thus avoiding unnecessary pulling out and re-penetration of the skin. The position of the summit of the Norkor needle's triangular tip can also be recalled by remembering on which side the gauges are inscribed on the barrel of the syringe.

Fractional laser treatment: A topical anesthetic cream (EMLA®) was applied to the scar, which was then occluded with plastic wrap for at least 30 minutes. Fractional laser (1,550nm) treatment with air cooling was performedon the basis of 500–1,000 MTZ, depending on the state of the scar. The energy was increased up to the level (20–45mJ) that the skin could bear by closely observing the region being treated. After each treatment session, topical cream containing copper tripeptide-1, EGF (epidermal growth factor), and bFGF (basic fibroblast growth factor) was applied [50,51] to the treated region, and the patient was advised to apply the cream as frequently as possible (at least three times per day) [3,9,36,37].

Table 1: In order to grade scars with the MQSG system, let us first look at a pre-treatment photograph of one cheek. This form will be sequentially filled in by counting the number of scars starting with the mild scars. After counting all types of scars, we add up the scores to get the MQSG score of a given pre-treatment photograph. The total score can range from zero to 57.

Type	Number of lesions		
	1(1-4)	2(5-8)	3(8-12)
MILDER SCARRING(1 point each)			
Shallow dish-like	1		
MODERATE SCARRING(2 point each)			
Deep dish-like		4	
Shallow punched – out scars(<5mm)			
Shallow but broad atrophic areas			
SERVICE SCARRING(3point each)			
Deep punched – out scars(<5mm)	3		
Ice-pick(<5mm)			
Linear or troughed derm al scarring			
Deep broad atrophic areas			
		Total	8

Non-ablative laser treatment: A topical anesthetic cream (EMLA®) was applied to the scar, which was then occluded with plastic wrap for at least 30 minutes. Smooth Beam® (1450nm) treatment was performed at 10-12.5J/cm^2 (6mm spot size) and 25-30msec of cooling spray. The beam overlapped 20-30%. After the first pass of shots, an ice bag was applied to relieve the pain for a brief period of time, after which a second pass of shots was performed. Finally, the ice bag was reapplied intermittently until the pain was relieved.

Ablative laser treatment [36,37]: Five days of antiviral agents and broad-spectrum antibiotics were prescribed on the day of ablative laser treatment. The scar was anesthetized with topical anesthetic cream (EMLA®) and was occluded with plastic wrap for more than 30 minutes.

Er:YAG laser (Fotona®) was set at a 2mm spot size, VSP and 140-180mJ; CO_2 laser (SNJ®) was set at a 1mm spot size, 800 W, 0.1-0.2msec pulse duration and 50-200Hz frequency when combination ablative laser scar sculpting was performed.

The next step was to place an occlusive dressing; the newly created wound was cleansed gently with a cotton ball soaked in normal saline and then was dried by gentle patting with dry gauze. Topical cream, such as that used after fractional laser treatment, was applied [50,51] and a Vaseline® gauze was placed on top of it, followed by dry gauze fixed with adhesive plasters. The dressing was not removed for 10 to 13 days. Whenever the adhesive plaster became unstable, it was replaced or stabilized without detaching the underlying Vaseline® gauze.

Evaluations [36,37]

Blinded and independent evaluations by one plastic surgeon and four dermatologists were performed, using a scale of 0–100% improvement, on 248 pairs of pre- and post-treatment photographs of cheeks. A result indicating no change was rated as 0%. If the evaluator judged the treated area to be normal in appearance, it was rated as 100%. If the area was aggravated, a negative rating was given.

Table 2: Combinations of treatments studied and the number of pre- and post-treatment photos.

Combination Groups (CG)	No. of pairs of pre- and post- treatment photographs	Combined Treatments	Means of weighted scores
1	44	FR+CR+SB+SM	161.13
2	29	FR+CR+SB	108.02
3	30	FR+CR+ SM	106.01
5	2	CR+SB+SM	2.63
6	51	FR+CR	97.96
7	27	FR+SM	72.25
10	43	FR	43.15
13	2	SM	85.53
14	20	FR+CR+SB+SM+CS	265.79

The evaluators were asked not to consider changes in color or other conditions so that the scores would represent the improvement of the contour only.

The severity of the pre-treatment state was graded by the author, using the Modified Quantitative Scar Grading System (MQSG). The quantitative global scarring grading system [52] proposed by Dr. Goodman and Dr. Baron was incorporated into the MQSG. To grade scars with the MQSG system, we first examine a pre-treatment photograph of one cheek. This form (Table 1) is sequentially completed by counting the number of scars, starting with the mild scars. For example, if the photo includes six deep, dish-like scars and two deep, punched-out scars less than 5mm in diameter, they will be given four points and three points, respectively. Moderate scars between 5 and 8 in number will be scored by multiplying 2 by 2, while severe scars between 1 and 4 in number will be scored by multiplying 1 by 3. After counting all types of scars, we total the scores to obtain the MQSG score of a given pre-treatment photograph. The total score can range from zero to 57. It was not considered that multiple observers were needed to score the MQSG because the quantitative global scarring grading system did not show inter-observer difference [52].

Statistical analysis [36,37]

Statistical analysis was performed with SPSS 14.0K. The significance level was setto $p < 0.05$. The combinations of treatments studied are shown in Table 2.

Eliminating bias: The evaluators' scores were weighted with the MQSG score to eliminate selection bias and allocation bias. Weighted scores (WS) were calculated using the following equation:

$$WS = score \times \left(\frac{MQSG}{57}\right) \times 10$$

WSs (weighted scores) were analyzed with SPSS® software, version 14.0K. Three of the five evaluators' assessments showed no significant differences with each other after being weighted with the MQSG. These weighted evaluations (WS) of the three were used for further analyses to eliminate observational bias.

Comparing the effectiveness of combination groups (cgs): One-way ANOVA and multiple comparison tests (LSD) were performed. CG5 and CG13 were excluded from the analysis because there were too few pre- and post-treatment photographs.

Optimal temporal treatment interval (oti) [3,36,37]: The OTI is defined as the temporal interval between treatment sessions that allows each treatment to result in the most improvement. To obtain the OTI, another variable is necessary -- which is the improving power (IP), which can be calculated by dividing weighted scores (WS) by total numbers of treatment sessions.

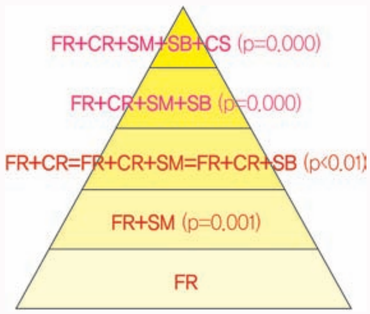

Figure 2: Better outcomes result from combining other devices appropriately than from treating with fractional laser only. However, this outcome is not exclusively related to the number of devices combined, with significant differences between CG6 (FR+CR) and CG7 (FR+SM) as well as no significant difference between CG6 (FR+CR), CG3 (FR+CR+SM) and CG2 (FR+CR+SB).

It was speculated that the IP of a given CG (combination group) would increase until it reached a peak as the intervals were prolonged. After passing the peak (OTI), the IP would begin to decrease. This outcome could be expressed as a quadratic equation, rather than a simple or cubic equation. Regression analysis was performed to find quadratic equations for each group of combinations by setting IP as the dependent variable and the average time intervals between treatments as independent variables. Treatment intervals of more than 60 days were excluded from this analysis because they were considered outliers.

Combination Group 14: CG 14 can be subdivided into two groups, depending on the temporal location of CS (ablative laser treatment). In some cases, CS was performed prior to other treatments (CG14b), and in other cases, CS was performed after other treatments (CG14a). The independent variable t-test was used to compare the effectiveness of these two subgroups.

Results

Effectiveness of combination groups (cgs)

The combination of FR (fractional laser), SB (subcision), CR (CROSS), and SM (smooth beam®) produced significantly better outcomes than did the use of FR only (p=0.000) or other combinations of the four methods (p=0.000). FR produced better outcomes when combined with CR (p=0.000), SM (p=0.001), CR+SM (p=0.000), or CR+SB (p=0.000) than when used alone. There were no significant differences among the combinations of FR+CR, FR+CR+SM

Table 3: CG 14 can be subdivided into two groups, depending on the temporal location of CS. In some cases, CS was done prior to other treatments (CG14b), and in other cases, CS was done after the sessions of other treatments (CG14a). Independent variable t-test was done to compare the effectiveness of these two subgroups. CG14a had significantly better outcomes than did CG14b (p<0.05).

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diffreence	Std. Error Difference
Zero_weighted_score	Equal variances assumed	3.951	.052	2.107	56	.040	67.38946	31.98441
	Equal variances not assumed			2.762	23.097	.011	67.38946	24.40242

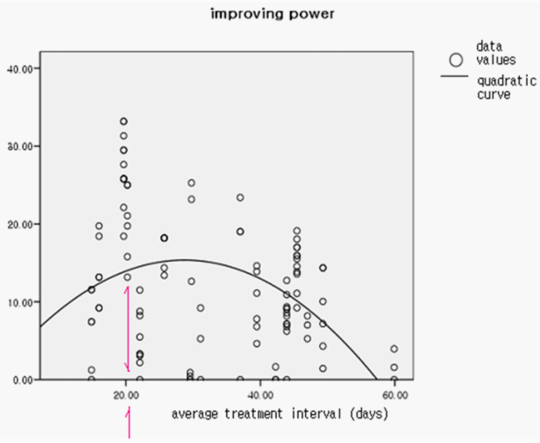

Figure 3: Quadratic Cruve from CG1: Calculating from the quadratic equations, the OTI is 4 weeks. However, there are many high values of IP are dotted around the interval of 20 days on the quadratic curve from CG1, CG7, and CG14. So, we can recommend the patients to make follow-up visits every 3 to 4wekks.

and FR+CR+SB (p>0.05). However, these three combinations produced significantly better outcomes than FR+SM (p<0.01). If FR+SB+CR+SM was combined with CS (ablative laser treatment), it improved the outcomes further (p=0.000) (Figure 2).

Equation of optimal temporal treatment interval

The coefficients of the quadratic equations for OTI were significant (p<0.01) in CG1, CG7, and CG14. The quadratic equations for these CGs were y=-0.919x^2+1.07x, y=-0.022x^2+1.277x, and y=-0.014x^3+0.746x, respectively. The value of the independent variable (temporal intervals) when the dependent variable reached its peak on the quadratic curve was $x=-\frac{b}{2a}$, if the equation was assumed to be $y=ax^2+bc+c$. Using this equation, we could obtain the OTIs, which were 28.687 days, 28.82221 days, and 26.49082 days, respectively (average= 28.00001 days). However, there were many high values of IP dotted around the interval of 20 days on the quadratic curves from CG1, CG7, and CG14. Consequently, we can recommend that the patient schedule follow-up visits every 3 to 4 weeks, considering his or her circumstances (Figure 3). This result corresponds to a report that the increase in the total amount of collagen after injury reaches its peak in 2-3 weeks [53] and provides a good rationale for speculation that the activated regenerative cascade can be prevented from receding if treatments are applied every 3-4 weeks.

No coefficients of cubic equations were statistically significant (p>0.01).

Temporal location of ablative laser treatment

CG14a had significantly better outcomes than CG14b (p<0.05) (Table 3). Two operators followed the CG14b protocol (ablative laser sculpting performed before other treatments), and no significant inter-operator differences were seen in the outcomes (WS). However, five operators followed the CG14a protocol (ablative laser sculpting performed after other treatments), and one of these operators was better than the other four (p<0.05). This operator followed the sculpting procedure as described in the author's publications on scars [3,7,9,21,22,23,36,37] (Table 4).

Table 4: Five operators followed CG14a and one of them was better than other four operators (p<0.05). This operator followed the sculpting procedure as described in the author's previous article on non-hypertrophic scars.

Multiple Comparisons
Dependent Variable: weighted_Score

*	(I) operator	(J) Operator	Mean Difference (I-J)	Sig.
LSD	Dr. B	Dr. A 0.007	-90.96352*	0.007
		Dr. BC 0.051	85.33138	0.051
		Dr. D 0.760	16.47173	0.760
		Dr. E 0.123	98.92788	0.123
	Dr. A	Dr. B 0.007	90.96352*	0.007
		Dr. C 0.000	176.29490*	0.000
		Dr. D 0.036	107.43525*	0.036
		Dr. E 0.003	189.89140*	0.003
	Dr. C	Dr. B 0.051	-85.33138	0.051
		Dr. A 0.000	-176.29490*	0.000
		Dr. D 0.232	-68.85965	0.232
		Dr. E 0.837	13.59649	0.837
	Dr. D	Dr. B 0.760	-16.47173	0.760
		Dr. A 0.036	-107.43525*	0.036
		Dr. C 0.232	68.85965	0.232
		Dr. E 0.267	82.45614	0.267
	Dr. E	Dr. B 0.123	-98.92788	0.123
		Dr. A 0.003	-189.89140*	0.003
		Dr. C 0.837	-13.59649	0.837
		Dr. D 0.267	-82.45614	0.267

*The mean difference is significant at the .05 level.

Pre- and post-treatment photographs

Some of the pre- and post-treatment photographs used in this study are shown in Figures 4-6. Figure 4 is Pre- and post-treatment photograph of 25 year-old female treated in combination of FR, CR, and SB (CG1). Figure 5 is pre- and post-treatment photograph of 40 year-old male treated in combination of FR, CR, SB, SM, and CS (CG14a). Pre- and post-treatment photograph of 39 year-old female treated in combination of FR, and CR (CG6).

Discussion

Discussion on difficulties in studying in post-acne scars

Several difficulties have emerged in the study of FAPS treatments. The first is that a controlled, double-blind study is impossible because it is difficult to find control groups. Some authors have used split face

Figure 4: Pre- and post-treatment photograph of 25 year-old female treated in combination of FR, CR, and SB (CG1).
[FR: Fractional laser, CR: CROSS, SB: Subcision, CG1: Combination group 1].

Figure 5: Pre- and post-treatment photograph of 40 year-old male treated in combination of FR, CR, SB, SM, and CS (CG14a).
[FR: Fractional laser, CR: CROSS, SB: Subcision, SM: Smooth beam, CS: Ablative laser treatment, CG14a: Combination group 14a].

Figure 6: Pre- and post-treatment photograph of 39 year-old female treated in combination of FR and CR (CG6).
[FR: Fractional laser, CR: CROSS, CG6: Combination group 6].

[54] methods to evaluate effectiveness of laser devices. Although these methods are among the best methods to evaluate scar treatments, there are differences between both cheeks, and it is difficult to find a person who has sufficiently identical FAPS on both cheeks to serve as a control group for the other side. Because acne is not identical on each side of one's face, FAPS are not identical on both sides of the face (Figure 7). The problem of lacking a control group could be compensated for by employing normal skin, which professionals recognize as normal, as a standard and goal for treatments.

The second problem is that there is no objective scale for the evaluation of aesthetic improvement after treatment [24]. Some authors have used certain devices to measure the height [55,56] and redness of the scars. These outcomes are excellent means to evaluate the effectiveness of laser equipment, but the improvement measured by such devices is not always directly correlated with the patient's aesthetic improvement. Even when the height or the redness of the scar can be decreased to a significant degree, the scar might still be noticeable and annoying to the patient. It is necessary to employ an evaluation system that reflects the improvement of the aesthetic state of the patient.

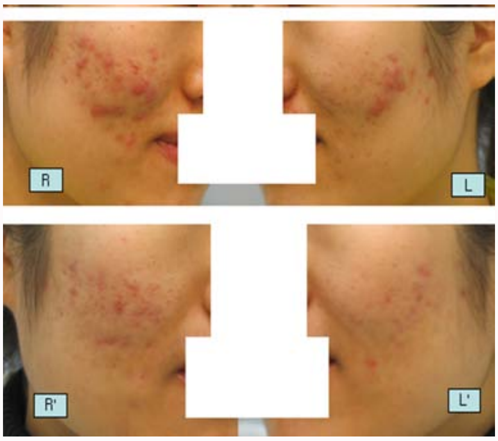

Figure 7: Pre- (Oct. 2006) and post- treatment (Dec. 2006) photographs of acne on face. As acne itself is not identical on each side of the face, FAPS are never be identical on both sides of the face. As R and L (acne) are not identical, R' and L' (FAPS) are not identical on both sides of the face.

It is true that the most important aspect of any treatment is the patient's satisfaction. However, a patient's evaluation and a doctor's evaluation can be significantly different [9,57] because patients can have different levels of expectations, and there can be different standards from patient to patient, which tend to be subjective.

Patients' grading of pre-treatment status was not employed because the determination of disease burden in terms of patient perception of severity is intrinsically imperfect, due to varying degrees of subjectivity among individuals [58].

So, perspectives of professionals are needed to measure aesthetic improvements, but there can also be differences between the perspectives of professionals. This problem can be compensated for by statistical analysis [3,9,59,60].

There is one more difficulty that makes this analysis more complicated, which is pleomorphism and the diverse degrees of severity of the pretreatment status of FAPS. This problem was compensated for using the MQSG.

Discussion on statistical analysis

Class intervals are frequently used to assess the aesthetic improvement of scar treatments [17,57], but the intervals of the classes are determined by custom or subjectively. For example, if the class intervals were defined as excellent (more than 80% improvement), fair (more than 70% improvement), and good (more than 60%) and so on, there would be no rationale to define class intervals in this manner because some might consider 90% improvement excellent, while others might consider 80% excellent. The author prefers and recommends using a ratio scale exactly like the evaluators used and not to reduce the variable from a ratio scale to an ordinal scale because it can cause loss of information [61]. There is a rationale for converting age (ratio scale) to age groups (ordinal scale) because there are obvious physiological differences between age groups; for example, a pre-pubertal age group (<15 years of age) has obvious differences from a post-pubertal age group (≥15 years of age) due to hormonal activity [3,9,59,60]. In addition, the ordinal variables of age groups are usually used as independent variables but not as dependent variable like the improvement scores in scar treatment studies [3,9,59,60].

The scores assessed by the evaluators represented the degree to which the scarred skin appearance approached that of normal skin; WS (weighted score) referred to how much the scarred skin improved from the diverse baselines.

As the statistical analysis demonstrated, there were no significant differences among three of the five evaluators whose scores were weighted with MQSG. The author could have used the other three evaluations, who showed no significant differences among each other without being weighted with MQSG. However, this plan was not considered relevant because the purpose of this study was to compare the effectiveness of the combinations of treatments studied. If the author used the scores without MQSG weighting, this article would have been a comparison of how close the scarred skin of the CGs could approach normal skin in appearance after treatments, regardless of the diverse baseline status.

IP could have been used to compare the effectiveness of the CGs. However, because it was speculated that more treatment sessions would result from greater patient compliance from the patients, WSs were used to consider the patient's compliance with treatment protocols. A short period downtime does not always result in greater compliance. Any patient can drop out of treatment sessions if disappointed by limited efficacy, although there might be virtually no downtime. Thus, it can be speculated that the patients' compliance is one of the important factors to contributing continued treatments, resulting in increased numbers of treatment sessions and consequently more improvement and better outcomes.

Discussion on ablative laser treatments for facial atrophic post-acne scars (FAPS)

Combination laser treatment is effective for non-hypertrophic scars [6-9,21,36,37], which include atrophic scars, and it appears that the same treatment protocol can be applied for FAPS. However, there are a few unique characteristics that make FAPS a separate entity. Usually, FAPS are clusters of small, pleomorphic, atrophic scars congregated close to each other. Frequently, the openings are narrow, compared to the depth of the scar.

These are the reasons why ablative laser resurfacing is known to be effective for FAPS, but it is associated with an undesirable side effect profile, a lengthy recovery period, and a risk of infection, as well as potential pigmentary alterations [62].

FAPS, densely congregated atrophic scars: If FAPS are sculpted down first, the epidermal component can easily be excessively removed, leaving few pilosebaceous units or long-lived interfollicular epithelial stem cells [50,51] from which regeneration can ensue. It also places too great a distance between adjacent unaffected skin and adnexal structures, resulting in an increase in the risk of hypopigmentation or further scarring (Figure 8).

FAPS, deep and narrow: If this type of scar is sculpted first, an excessive amount of normal tissue must be removed, and the depth of sculpting can be excessive, increasing the risk of hypopigmentation or scarring (Figure 9), which means that the operator cannot sufficiently re-contour the scar to avoid side effects. In other words, the operator must stop sculpting long before he or she attains the desired contour. In contrast, if CS (ablative laser sculpting) is performed after the atrophic scars are rendered shallower with other treatments; the operator can re-contour with greater confidence and have better outcomes by sculpting sufficiently down to the desired contour with a lower chance of side effects. This difference was demonstrated in the comparison of CG14a and CG14b.

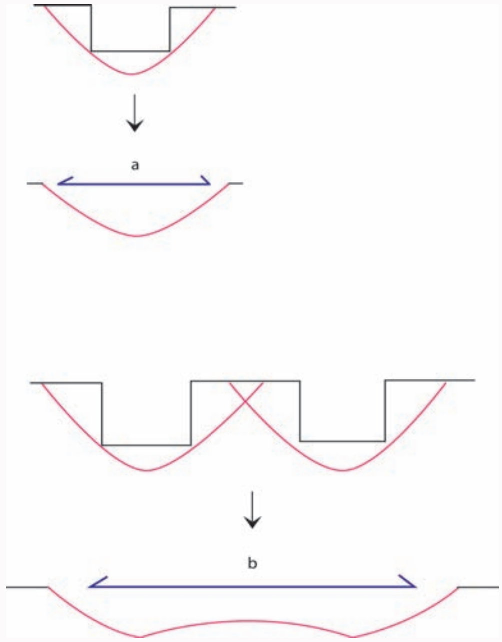

Figure 8: a<b: If FAPS are sculpted down first, the epidermal component can easily be excessively removed, leaving few pilosebaceous units or long-lived interfollicular epithelial stem cells from which regeneration can ensue. It also places too great a distance between adjacent unaffected skin and adnexal structures, resulting in an increase in the risk of hypopigmentation or further scarring.

Figure 9: Green area < purple area: If FAPS are sculpted first, an excessive amount of normal tissue must be removed, and the depth of sculpting can be excessive, increasing the risk of hypopigmentation or scarring, which means that the operator cannot sufficiently re-contour the scar to avoid side effects. In other words, the operator must stop sculpting long before he or she attains the desired contour.

Suggestions on FAPS treatment

From the results of this study, an ideal combination treatment protocol can be suggested, which can be adjusted depending on the diverse circumstances of the patient and the pre-treatment state, on a case by case basis.

CROSS and SB (subcision) should be performed on the same day to reduce the periods of downtime as the initial treatment to prime the regenerative cascade. If these treatments are performed on separate days, the patient will suffer two periods of downtime. It is speculated that the severity of the downtime will not increase synergistically because CROSS affects the outer surface of the dermis, while SB treats the other aspect of the dermis. If the operator performs three procedures (CROSS, Subcision, and Fractional laser) on one day, he or she might have reduced three periods of downtime to one. However, there would also be a risk that the severity of the downtime would be excessively increased because FR (fractional laser), like CROSS, also affects the outer surface of the dermis.

After a one-day procedure of CROSS and SB (subcision), an alternate treatment of SM (smooth beam®) and FR (fractional laser) every 3 to 4 weeks (OTI) could be performed for several sessions of treatments, depending on the responses to the treatments. CS (ablative laser sculpting) can be performed thereafter if acute-angle-margined atrophic scars are still noticeable, although the depth of the atrophic scars will have become significantly shallower because these types of scars accumulate make-up and sunscreen lotion, and the projections of their margins cast dark shadows on the bottom [24]. If CS (ablative laser sculpting) is performed afterward, the area of sculpting can also be reduced because some atrophic scars improve satisfactorily without CS (ablative laser sculpting). More sessions of SM (smooth beam®) and FR (fractional laser) would be recommended after CS (ablative laser sculpting) because additional treatments of SM (smooth beam®) and FR (fractional laser) would improve the outcomes [3,9,36,37].

Further study

Acne scars are known to improve when surgical revision is followed by additional laser skin resurfacing [45]. Therefore, further study of the combinations of surgical revision and the treatment options mentioned above, as well as newly developed devices, must be undertaken [45,63].

Conclusion

Better outcomes result from combining other devices appropriately than from treating with fractional laser only (Figure 2). However, this outcome is not exclusively related to the number of devices combined, with significant differences between CG6 (FR+CR) and CG7 (FR+SM) as well as no significant difference between CG6 (FR+CR), CG3 (FR+CR+SM) and CG2 (FR+CR+SB).

OTI is 3 to 4 weeks.

Ablative sculpting produces better outcomes when placed temporally after other treatments than before. The sculpting technique previously published by the author resulted in better outcomes with same temporal location as mentioned above.

Declarations

Conflict of interest

The author's spouse has Korean patent 'Scar and Skin Lesion Treatment Systems and Methods Utilizing Lasers'. The author is Co-CEO of Oh & Lee Medical Robot, Inc., and the editor of 'Scars and Scarring: Causes, Types and Treatment Options'; and has the copyright of Chinese version of 'Scars and Scarring: Causes, Types and Treatment Options'.

For this type of study, formal consent is not required.

Informed consent was obtained from all individual participants included in the study. And additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

The Datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

YL analyzed and interpreted the data regarding the treatment results of scars and was the sole author in writing the manuscript.

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