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Combination of a 2940 nm Er:YAG laser with recombinant bovine basic fibroblast growth factor (rb-bFGF) and light-emitting diode-red light (LED-RL) for the treatment of striae alba: A pilot study

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Summary

Background: Striae distensae (SD) are a common dermatologic problem that plagues many people. Although there are many therapeutic modalities have been used to treat SD, effective method has been disappointing for striae Alba.

Aims: To evaluate the clinical and histopathologic efficacy and safety of the 2940-nm erbium yttrium aluminum garnet (Er:YAG) ablative fractional laser (AFL) with recombinant bovine basic fibroblast growth factor (rb-bFGF) and light-emitting diode-red light (LED-RL) for the treatment of striae alba.

Patients and methods: Thirty volunteers with striae distensae alba were enrolled. The subjects completed treatments with the 2940-nm Er:YAG AFL 6 times at 4-week intervals. Following this treatment, the subjects were required to spray rb-BFGF for 1 week at home. They then received LED-RL once every 7 days for three sessions between the two laser treatments. Two independent investigators evaluated clinical improvement at pretreatment and 1, 3, 6, and 12 months post-treatment, patients also provided self-assessments of clinical improvement. Two biopsies were obtained from two subjects, both of the same sites of striae alba, one before the first treatment and one 6 months after the last session.

Results: All 30 subjects demonstrated clinical improvement after treatment. Skin biopsies after treatment showed an increase in epidermal thickness, dermal thickness, and collagen and elastin density when compared to that at the baseline.

Conclusions: The combination of the 2940-nm Er:YAG laser with rb-bFGF and LED-RL for the treatment of striae alba was a safe and effective approach for improving the appearance of striae alba.

KEYWORDS
ablative fractional laser, 2940 nm Er:YAG laser, rb-bFGF, red light, striae alba

1 | INTRODUCTION

Striae distensae (SD) or "stretch marks" are depressed lines or bands of thin reddened skin caused by the tearing of the dermis, which may diminish over time but will not disappear completely. The occurrence of SD is usually found in rapid changes in body weight (increase or decrease), height (such as pubertal growth spurt), and muscle mass (such as weight lifting). SD also commonly occur during pregnancy. In addition, SD may be due to excessive endogenous or exogenous corticosteroids, usually caused by systemic and topical

long-term use of corticosteroids.[1] Two types of SD exist as follows: striae rubra, recent, or "immature" stretch marks that usually present with a red and slightly elevated appearance, over time they become a depressed atrophic epidermis with lighter or darker pigmentation called striae alba (mature stretch marks). It has been postulated that with the disappearance of early inflammatory response and vasodilatation over time, resulting in SD from a red and slightly elevated appearance to atrophic scar-like appearance.[2] The treatment of SD has plagued dermatologists and their patients for a long time, especially striae alba is more difficult to treat. Scientists have been trying to find more effective and safer methods, for example, topical drugs (olive oil, Victoria A acid),[1] laser treatments (intense pulsed light, fractional laser, copper bromide laser, and pumped pulsed-dye laser),[3] and other methods (needling[4] or superficial dermabrasion[5]), that are available, but none can completely eradicate SD. In the aforementioned methods, the fractional laser seemed to be a more effective treatment option for dermal remodeling than other treatments.[3] Nonablative fractional lasers (NAFLs) such as the 1565,[6] 1540, and 1410 nm,[7] and AFLs such as the 10 600-nm carbon dioxide fractional laser have been proposed as effective methods for improving the appearance of SD.[8] But few studies have been reported about using 2940 nm Er:YAG AFL devices for the treatment of SD. Gauglitz et al.[9] described case report of two patients with axillary SD, using 2940 nm Er:YAG AFL in comparison with a 585-nm PDL, found 2940-nm Er:YAG AFL had effect on improving the appearance of SD but lack of statistical evidence. Another study Gungor et al.[10] treated 20 women, compared the efficacy of 2940 nm variable square pulse (VSP) erbium: YAG laser and 1064 nm long pulse (LP) Nd:YAG laser in the treatment of SD, 17 striae alba had poor response and three striae rubra had moderate response to both two lasers. So there is an need for systematic treatment to improve the effect of 2940 nm Er:YAG AFL in striae alba and to overcome the problems associated with ablative skin resurfacing procedures. We will optimize 2940 nm Er:YAG AFL treatment parameters and take some combined therapy to promote epidermal and dermal growth after laser. There have been studies showing that topically applying exogenous growth factors can promoting collagen growth and wound healing after laser treatment. Fu et al.[11] treated 600 patients with superficial or deep second-degree burns using daily topical rb-bFGF. They found all patients had faster epidermal regeneration and granulation tissue formation than those in the placebo group. No locally or systemically side effects were observed with rb-bFGF. LED phototherapy is an emerging therapeutic modality for the treatment of skin diseases. LED-RL promotes the growth of skin cells at the edges of wounds and scrapes, promotes collagen production, removes redness, reduces inflammation, and improves the appearance of pigmented and vascular lesions. There is evidence demonstrating that LED-RL is capable of modulating key cellular characteristics associated with skin fibrosis.[12] Based on this knowledge, we adopted a combined approach to improve the clinical outcomes. The aim of this study was to evaluate the clinical and histopathologic efficacy and safety of a combination of the 2940-nm Er:YAG laser with rb-bFGF and LED-RL for the treatment of striae alba.

2 | PATIENTS AND METHODS

2.1 | Subject population

A total of 30 Chinese patients aged 23-38 years with skin types III and IV with striae alba were enrolled including 20 located in abdomen, four in buttocks, four in thighs, and two in arms. The baseline characteristics of the subjects are presented in Table 1.

The clinical study protocol was approved by the ethics committee of Huadong Hospital, Fudan University, Shanghai, China. All subjects were informed of the purpose and possible risks and expectations of the study, and written consent was obtained from each subject. Clinical photographs were taken with the patients' permission. Exclusion criteria included any skin infections, a history of keloids, a history of malignant diseases, pregnancy or breastfeeding, light-sensitive conditions, a history of systemic lupus erythematosus (SLE), and a history of skin cancer such as basal cell carcinoma (BCC), squamous cell carcinoma (SCC), or melanoma.

2.2 | Study design and treatment parameters

The study was a prospective, pilot, and single-arm study. Patients were treated at the clinic of the department of dermatology of Huadong Hospital, Fudan University, Shanghai, China, using the existing treatment facilities. First, the physician degreased the patient's area to be treated with 70% isopropyl alcohol and covered all exposed areas with a protective shield excluding the area to be treated. A topical anesthetic cream (a compound of lidocaine and prilocaine, Qinghua Ziguang, Beijing, China) was applied before the laser. Following occlusion with a plastic film for 2 hours, the subjects received treatment with the 2940-nm Er:YAG AFL 6 times at 4-week intervals. According to our preliminary trial of two patients, we found after six times treatments the appearance of striae alba could achieve a significant improvement, combined with the studies[9,10] in

TABLE 1 Summary of demographic and baseline characteristics

Characteristics	Value
Gender (M/F)	6/24
Age (y)	27±5.5
Fitzpatrick Skin Type	
Type III	22
Type IV	8
Site	
Abdomen	20
Buttocks	4
Thighs	4
Arms	2
Duration of striae alba (y)	3.9±2.6

treatment of SD using 2940-nm Er:YAG AFL devices and the patient's economic strength, the final choice was six times. The operator wore goggles, and the patient wore an eye mask. The laser used was the Pixel Er:YAG system (LovellyII platform, Alma Laser, Israel). The window of the laser handpiece covered an 11×11 mm treatment area with 49 microbeams (7×7 dots). The laser beam was divided into microbeams through a handpiece equipped with a beam splitter. The system has three treatment pulse length programs: long (2 milliseconds), medium (1.5 milliseconds), and short (1 millisecond). The recommended settings for the laser were the long pulse length program/repetition rate 2 Hz/output pulse energy 1200 (Fitzpatrick Skin Type IV)-1400 mJ (Fitzpatrick Skin Type III)/pulse. Six stacked laser passes and one sweeping laser pass were performed. After the laser treatment, a cold wet towel was applied to the treatment skin area for 20 minutes to relieve burning pain. The subjects were required to spray rb-bFGF (Essex Bio-Pharmaceutical Co., Zhuhai, China) on the treatment area three times a day for 1 week at home following the instructions. Rb-bFGF is a colorless transparent liquid, the concentration of which was 4200 IU/mL, absorbed by microscopic thermal wounds of the skin after 2940-nm Er:YAG AFL. The patients were advised to avoid hot water for a week. If severe redness or edema persisted for more than 1 week after the laser treatment, chlortetracycline eye ointment was suggested to use two times a day for 5-7 days and the patients who had this performance have to be removed of the study. Commencing 1 week following every 2940-nm Er:YAG AFL treatment, the subjects were exposed to LED-RL (Shanghai Sigma High Tech Co. Ltd, Shanghai, China) at a wavelength of 633±6 nm and an output intensity of 100 mW/cm^2 for 20 minutes according to the instructions of the device. The large wrap-around panels contained high-intensity LED lamps. The subjects received LED-RL once every 7 days for three sessions between the two 2940-nm Er:YAG AFL treatments. The subjects were instructed to avoid using other remedies during the course of treatment.

2.3 | Clinical evaluations

Photographs using identical camera settings, lighting, and positioning were taken at the baseline before treatment and 1, 3, 6, and 12 months after the last treatment. Two independent dermatologists evaluated the photographs for comparison with the baseline, including the area and color of striae alba. Clinical improvement was assessed using a quartile grading clinical scale: 0=no change (0%), 1=mild improvement (<25%), 2=fair improvement (25%-50%), 3=good improvement (51%-75%), and 4=excellent improvement (76%-100%).

2.4 | Patients' self-assessment and treatment tolerance

The patients' self-evaluation based on the improvement of the area, volume, tightness, texture, elasticity, and color of striae alba at the follow-up assessment was graded as one of the four categories: slightly better, fair, good, and excellent corresponding to the following numeric responses denoting less than 25%, 25%-50%, 51%-75%, and 76%-100% improvement compared to the baseline. After all treatments and follow-up assessments, patients subjectively gave their satisfaction graded as NS=unsatisfied, FS=somewhat satisfied, S=satisfied, and VS=very satisfied.

Patients' assessment of procedure-related pain and discomfort was evaluated using a 0-10 visual analog scale (VAS), where 0 represents no pain and 10 represents intolerable pain, and the results were graded as follows: extremely painful (10-9), very painful (8-7), bearable pain (6-4), little pain (1-3), and no pain (0).

2.5 | Histopathologic assessment

To evaluate the histologic effects of this treatment, two of the 30 patients were selected by a computer randomizer to have a biopsy taken from representative lesions. Biopsies were taken from the same lesion sites before treatment and 6 months after the last treatment. These were positioned as closely as possible yet at a distance sufficient to avoid getting scar tissue induced by the previous biopsy. Specimens were fixed in 10% formalin and embedded in paraffin. Specimens were stained using an ordinary hematoxylin-eosin (H&E) stain, with special stains such as Weigert's stain for elastic fibers and Masson's trichrome stain for collagen fibers to study any histopathological changes and the efficacy of treatment.

2.6 | Adverse effects

Any adverse effects, including edema, erythema, pain, pruritus, vesicles, exfoliation, loss of epidermis, scarring, prolonged erythema, and PIH throughout the therapy period were recorded in detail at each treatment and follow-up visit. Immediate and short-term responses (erythema, edema, etc.) were assessed within 30-minute post-treatment, according to a 4-level scale: 1=mild, 2=moderate, 3=marked, and 4=severe. Downtime was defined as the period of time following the procedure during which the patient had edema and/or erythema and felt uncomfortable. We also recorded the time to resolve, the treatment measures, and the outcome of any adverse effects.

2.7 | Statistical analysis

Software (SPSS version 19.0, SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Continuous variables were presented as mean±standard deviation. Categorical variables were shown as valid cases and percentages of each class. To compare the frequency of striae alba and other categorical variables among the study groups, the chi-square test was used, and statistical significance was accepted for P values less than .05.

3 | RESULTS

Thirty patients with striae alba were treated with a combination of a 2940-nm Er:YAG laser with rb-bFGF and LED-RL in our department.

There were 24 women and six men with an average age of 27±5.5 years. The duration of striae alba ranged from 1 to 10 years (mean 3.9±2.6 years). All 30 patients completed the entire course of treatment and were followed up on time.

3.1 | Clinical assessment

As shown in Figure 1, at the 1-month follow-up, the improvement of the subjects' SD was recorded as mild improvement in 33.3% (10/30), fair in 26.7% (8/30), good in 26.7% (8/30), and excellent in 13.3% (4/30). At the 3-month follow-up, the improvement of the subjects' SD was recorded as mild improvement in 6.7% (2/30), fair in 23.3% (7/30), good in 46.7% (14/30), and excellent in 23.3% (7/30). At the 6-month follow-up, the clinical improvement in the appearance of SD significantly progressed and was graded as mild improvement in 3.3% (1/30), fair in 6.7% (2/30), good in 30% (9/30), and excellent in 60% (18/30). At the 12-month follow-up, the improvement of the subjects' SD was recorded as mild improvement in 0% (0/30), fair in 10% (3/30), good in 30% (9/30), and excellent in 60% (18/30). There was a statistically significant difference in clinical improvement of SD at the 3-month follow-up compared to that at the 1-month follow-up (P=.024<.05) and at the 6-month follow-up compared to that at the 3-month follow-up (P=.029<.05). However, there was no further improvement of SD at the 12-month follow-up compared to the 6-month follow-up (P=.753>.05). Clinical photographs from two typical patients before and after treatment showed obvious improvements (Figure 2).

3.2 | Patients' self-evaluation and treatment tolerance

At the 12-month follow-up visit, 24 patients (80%) were "very satisfied" and six (20%) were "satisfied" with the improvement in striae alba. The majority of patients (70%, 21 of 30 subjects) assessed themselves as achieving an excellent improvement in striae Alba at the 12-month follow-up visit, especially the area and elasticity of striae alba. No subject considered themselves to have a worse appearance of striae alba after the combination treatment. All patients tolerated the laser therapy and LED-RL therapy. Despite the use of a topical anesthetic cream, the average pain score described by the patients was 2.5±1.3 (mean±SD) on a scale of 10 when treated with the 2940-nm Er:YAG AFL. When treated with LED-RL, almost all patients experienced a hot sensation.

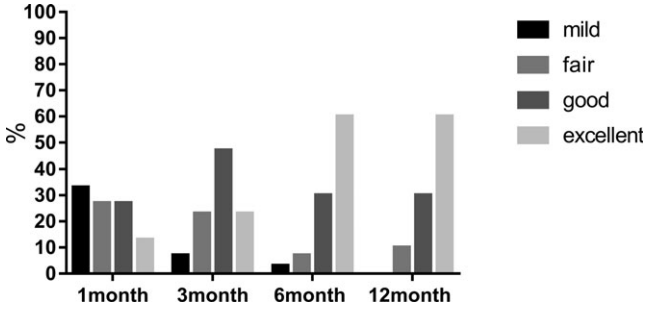

FIGURE 1 The improvement of striae alba in 30 patients after treatment. Evaluations were conducted by two blinded independent dermatologists according to photographs taken before and 1, 3, 6, and 12 mo after combination treatment, using a quartile grading clinical scale

3.3 | Histopathological analysis

The general histopathological of all specimens obtained at baseline showed thinning epidermal with thin, short, disorganized dermal collagen, and elastic fibers. The elastic fiber network appeared markedly disrupted in striae alba. There were more loose matrices, more mucopolysaccharides, fewer collagenous elastic fibers, and the presence of epidermal atrophy; this outcome was very similar to a pitting scar. At the 6-month follow-up biopsy, the epidermis was thickened, and the density of the dermal collagen and elastic fibers had increased (Figure 3).

3.4 | Side effects

All the patients experienced edema and erythema induced by the 2940-nm Er:YAG laser, which persisted but slowly faded within 7 days. Then, 60% of the patients experienced slight exfoliation with minor scaling and dryness, and 40% of the patients presented with marked dryness, scaling, and desquamation. All of these decreased in severity and disappeared at the 1-month follow-up visit. At the 1-month follow-up, PIH was 20% (six of 30 subjects). All subjects with PIH were graded as mild, except one case rated as moderate. The average time of duration of PIH was 8 weeks (range 6-12 weeks). By 3 months, there were two subjects (6.7%) with PIH graded as mild. At 6 months, no patient had persistent PIH. No erosion, scarring, bacterial infection, viral infection, or hypopigmentation were observed at the follow-up visits up to 12-month post-treatment. The treatments were well tolerated with no significant long-lasting adverse effects.

4 | DISCUSSION

Striae distensae is a common skin problem that disturbs those patients of all ethnicities, genders, ages. A variety of therapies used for SD have been listed in the introduction, the most recent treatment modalities are laser and light therapies, especially fractional lasers.[13] Fractional photothermolysis (FP) produces arrays of small laser beams of microscopic thermal wounds called microscopic treatment zones (MTZs) at specific depths with only a fraction of the skin, leaving undamaged surrounding tissue and providing the opportunity for rapid epidermal repair. The first fractional lasers introduced to the market were NAFLs that reached the dermis but left the epidermis untouched. The study evaluating the efficacy and safety of the nonablative fractional 1565 nm laser was performed by Tretti clementoni et al.[6] on 12 Caucasian patients. All subjects were

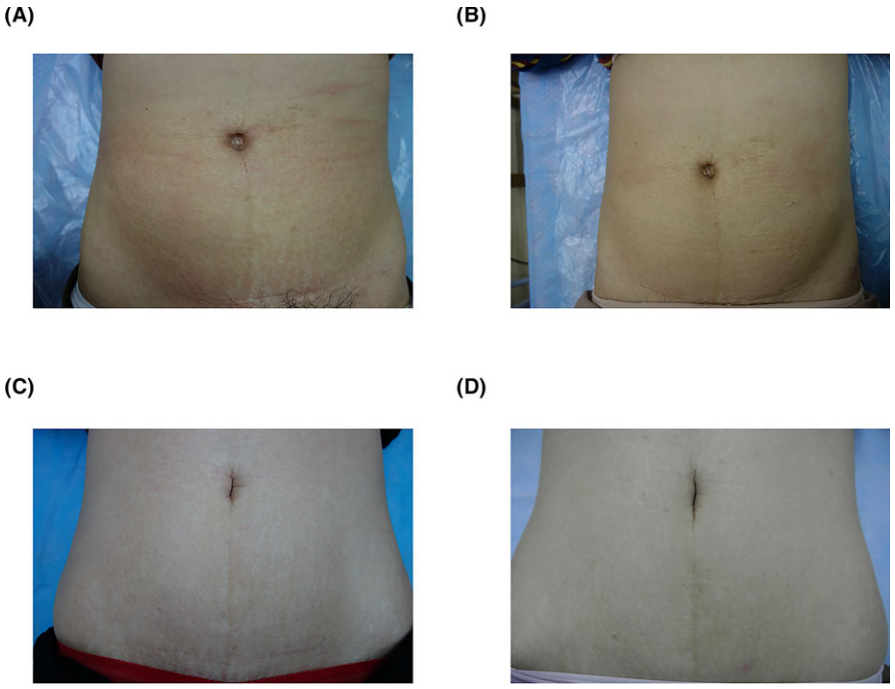

FIGURE 2 Photographic image of a representative patient's abdomen with striae alba (A) before treatment (Patient 3: striae alba of 3 y in skin types IV); (B) 6-mo follow-up after treatment with combination of 2940 nm Er:YAG laser with rb-bFGF and LED-RL, improvement was graded as excellent; the patient was highly satisfied (Patient 3); (C) before treatment (Patient 26: striae alba of 5 y in skin types III); (D) 6-mo follow-up after treatment with combination of 2940 nm Er:YAG laser with rb-bFGF and LED-RL, improvement was graded as good; the patient was satisfied (Patient 26)

treated with three sessions and at 3-month post-treatment evaluation, most patients displayed improvement of 50% in lesion color and the volume of depressions, without long-lasting or severe adverse effects. A split-lesion study conducted by Wang et al.[7] compared the safety and efficacy of a 1540-nm NAFL and a 1410-nm NAFL on nine patients with abdominal SD. All subjects received six sessions—half of the abdomen accepted 1540-nm NAFL, whereas the other half accepted 1410-nm NAFL. All subjects demonstrated bilateral clinical improvement after treatment. There were no statistically significant differences in clinical and histopathological results between the two lasers. Soon after AFLs were introduced, compared to NAFLs, AFLs caused greater damage to the dermis and epidermis, resulting in a more robust healing and fibroplasia process.[14] Commonly used AFLs are the 10 600-nm CO_2 AFL or the 2940-nm Er:YAG AFL. There have been some studies that provided supportive evidence to the effectiveness of fractional 10 600-nm CO_2 laser on the treatment of SD. El Taieb and Ibrahim[15] reported 40 patients with SD, 20 of them were treated with CO_2 AFL with five sessions at intervals of 4 weeks, and 20 were treated with intense pulse light (IPL) with 10 sessions at intervals of 2 weeks. Both groups showed significant improvement, CO_2 AFL was more effective in the treatment of SD compared with IPL. Both groups showed minimal adverse effects. A split-lesion study conducted by Yang and Lee[13] comparing the 10 600-nm CO_2 AFL to the 1550-nm Er:Glass NAFL was on 22 Korean female volunteers with abdominal atrophic striae alba. Each half of the abdominal lesion was treated with the same laser three treatments at intervals of 4 weeks. Both two lasers showed statistically significant clinical and histopathologic improvement compared to baseline. It revealed a trend favoring the CO_2 AFL over the 1550-nm Er:Glass NAF by the subjects themselves and blinded physicians assessment; however, the difference between two lasers was not statistically significant. The 10 600-nm CO_2 laser has been shown to be highly efficacious for resurfacing and stimulating collagen and elastin regeneration and remodeling. However, patients typically present obvious side effects such as burning, edema, oozing, crusting, and other discomfort during the first week following CO_2 AFL treatment. Prolonged erythema is subsequently a common adverse effect. In addition, the risk of PIH is unacceptable for many patients, especially in patients with skin phototypes IV-VI. Considering the absorption of 2940 nm, Er:YAG is closer to the maximum absorption wavelength of water (3000 nm), it can deliver heat more accurately to avoid excess thermal damage on the surrounding tissue, thereby promoting quicker wound healing and recovery of the skin than CO_2 AFL. And the side effects including erythema, edema, PIH, scarring, or skin infection induced by Er:YAG AFL are much milder than those induced by CO_2 AFL, especially in darker skin phototypes, the 2940-nm Er:YAG AFL is introduced as a mild alternative to the CO_2 AFL.[16] But we found only two studies about 2940 nm Er:YAG AFL on SD. One was case report of two patients with axillary SD, compared 2940 nm Er:YAG AFL with a 585-nm PDL, found 2940-nm Er:YAG AFL had effect on improving the appearance of SD with 3-5 treatment sessions, PDL treatment particularly was a good candidate for striae rubra, but lack of statistical evidence.[9] Another split-lesion study conducted by Gungor et al.[10] compared the efficacy of 2940 nm variable square pulse (VSP) erbium: YAG laser and 1064 nm long pulse (LP) Nd:YAG laser on 20 female volunteers of SD, all subjects received three treatments monthly. It reported 17 of 20 striae alba, who had mature lesions (striae alba) had poor response on both sides, three subjects with immature (striae rubra) had a moderate response on both sides. They suggested that variable square pulse Er:YAG and long pulse Nd:YAG lasers are not useful in the treatment of striae alba. The

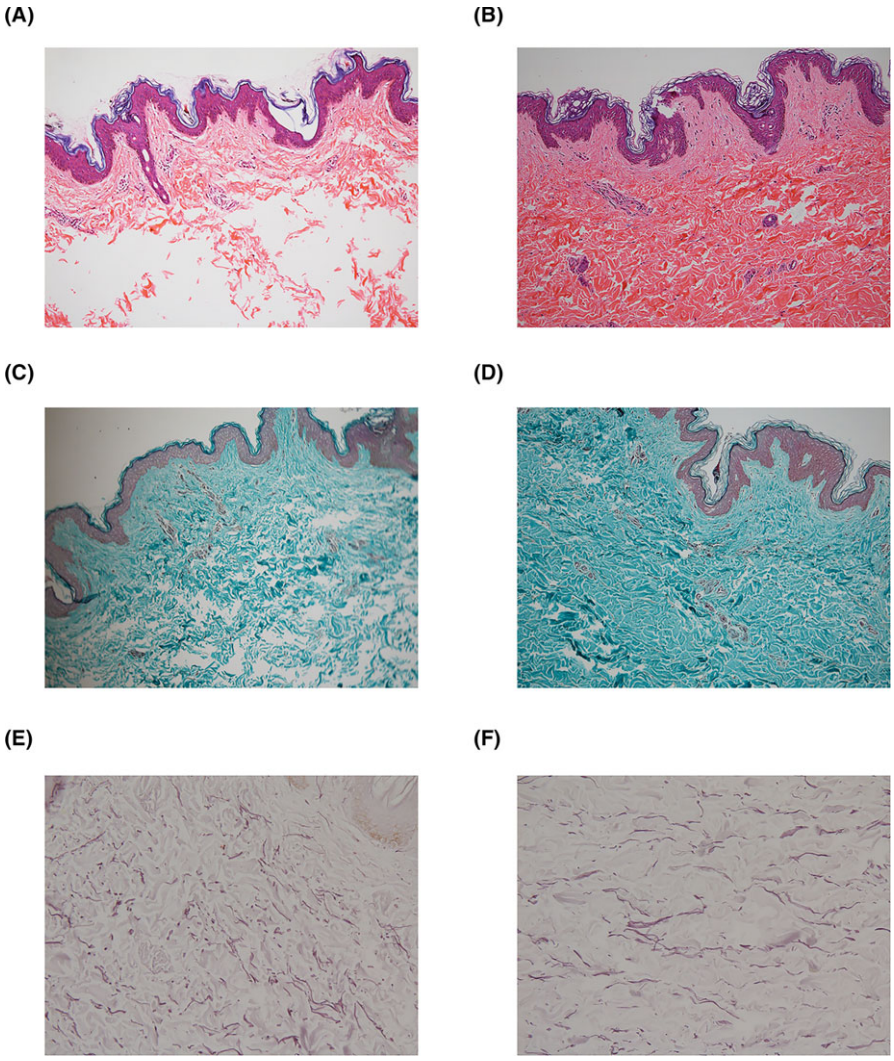

FIGURE 3 Skin biopsies of (A) Abdominal striae distensae (SD) before treatment (hematoxylin and eosin, 100×); (B) the same site 6 mo after last treatment, increases in epidermal thickness, dermal thickness, and collagen density (hematoxylin and eosin, 100×); (C) Abdominal SD before treatment (Masson trichrome stain, 100×); (D) the same site 6 mo after last treatment, increases in dermal collagen density (Masson trichrome stain, 100×); (E) Abdominal SD before treatment (Weigert stain, 100×); (F) the same site 6 mo after last treatment, diminished and fragmented dermal elastic fibers changed to normalized pattern (Weigert stain, 100×)

two studies had controversial results about efficacy of 2940 nm Er:YAG. Our results were not consistent with the study of 2940 nm Er:YAG AFL conducted by Gungor et al. We infer that the significantly progressed therapeutic improvement of SD in our study was related to the following factors: multiple passes of 2940 nm AFL increased thermal effects in the dermis and resulted in more epidermal ablation, six sessions had better effect than three sessions, and the combination therapy after 2940 nm AFL could promote skin repair and accelerate collagen production. In our study, to overcome less effective for dermal collagen remodeling of 2940 nm Er:YAG AFL compared with CO_2 AFL, we adopted a low density(7×7)/long pulse length, the maximum pulse energy output being 1400 mJ/P/6 stacked laser passes and one sweeping laser pass to produce better skin remodeling, which could make obvious clinical improvements similar to CO_2 AFL.[17] Trelles et al.[18] reported that multiple passes of fractional Er:YAG increased thermal effects in the dermis and resulted in more epidermal ablation. In addition, the clinical results also correlate with the volume and area of SD being treated.

To speed up skin repair, we sprayed rb-bFGF on the treatment area after Er:YAG AFL. Rb-bFGF can increase the formation of collagen and the number of fibroblasts at an earlier stage of healing.[19] Some studies have shown that rb-bFGF-stimulated mRNA, DNA, and protein synthesis in many cell types, such as neuroectodermal and mesodermal tissues (eg fibroblasts and endothelial cells). In addition, rb-bFGF stimulates vascular endothelial cell, fibroblast, and keratinocyte division in vitro and granulation tissue formation and epidermal regeneration in vivo.[20] Another concern is the possible risk of rb-bFGF in hypertrophic scar, but none of the patients in our study had hypertrophic scars or allergic problems after rb-bFGF. The use of rb-bFGF decreased healing time and accelerated wound healing, which was beneficial for reducing the risk of infection. One week after Er:YAG AFL, the patients received LED-RL every 7 days for three sessions between the two 2940 nm Er:YAG AFL treatments. Lee et al.[21] demonstrated that during the 633 nm LED treatment in vivo, an increased production of TNF-α, IL-1β, and matrix metalloproteinases might clear the photo-damaged collagen fragments and facilitate the biosynthesis of new collagen fibers. LED-RL is absorbed by the mitochondria in the cells. It stimulates ATP production, triggers cell activity, and enhances cellular activity. LED-RL is largely absorbed by the fiber cells, accelerating collagen production

causing skin smoothing, wrinkle reduction, and improving the elasticity of fragile skin surfaces. LED-RL also reduced redness due to inflammation or skin irritation after laser treatments.[22]

Our results showed at the 1-month follow-up, 12 patients (40%) have been evaluated to have improvement in the appearance of SD more than 50%, at the 6-month follow-up, 27 patients (90%) have been evaluated to have improvement more than 50%. In the study about using CO_2 AFL conducted by Yang and Lee,[13] three patients (13.6%) have been evaluated to have improvement in the appearance of SD more than 50% at the 1-month follow-up after three sessions; while El Taieb and Ibrahim[15] reported 17 patients (80%) have been evaluated to have improvement in the appearance of SD more than 50% at the 1-month follow-up after five sessions using CO_2 AFL. Compared with CO_2 AFL treatment, our follow-up results at 1 month were better than three sessions of CO_2 AFL treatment but worse than five sessions of CO_2 AFL treatment. During the follow-up, we observed that there was significant improvement in striae alba in the previous 6 months, but no further improvement of the subjects' striae alba at the 12-month follow-up compared to the 6-month follow-up. This phenomenon showed that the collagen fiber and elastic fiber reconstruction and biosynthesis occurred mainly in the 6 months after the combination therapy. Histopathological analysis and the patients' self-evaluations also compared well with the clinicians' evaluations.

Nanni and Alster[23] reported that transient PIH after CO_2 AFL was observed in 37% of patients with all skin types, but in type IV skin, the rate of PIH was more than 70% or higher.[24] However, Hu et al.[25] reported a 3% lower rate of PIH using the 2940-nm Er:YAG AFL in type IV skin for the treatment of acne scars. Although a 20% incidence of mild PIH was high at the 1-month follow-up in our clinical trial, no patient had PIH at the 6-month follow-up.

5 | CONCLUSIONS

The limitations of this study are that the sample size is relatively small and we test a combined therapy without any control. Because of the lack of control, it is difficult to distinguish the difference of efficacy between one of the treatments and the three combined treatment. Improved approach is that we will take treatments in the same patient tried the treatment alone and combined, comparing the results. Another way is that patients will be divided into groups for different combination of treatments, comparing the efficacy and results between the groups. Nevertheless, significant clinical improvements were observed that appeared to be supported by the pathology and showed a very significant increase in elastic fibers and collagen fibers. The combination of the 2940-nm Er:YAG laser with rb-bFGF and LED-RL for the treatment of striae alba was a safe and effective approach for improving the appearance of striae alba. It was well tolerated and caused no significant long-lasting adverse effects. In the future we will compare the efficacy and safety of 2940-nm Er:YAG AFL and other laser treatments on SD.

CONFLICT OF INTEREST

The authors have no conflict of interests to disclose.

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