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Treatment of striae distensae: An evidence-based approach

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ABSTRACT

Striae distensae (SD), otherwise known as "stretchmarks," are a common presenting complaint, particularly in young healthy women. SD are hypothesized to form in a patient when the cross-linked collagen is "overstretched" and rupture of this collagen matrix causes the striae. Thus, many treatments work by increasing collagen synthesis. This review critically appraises the evidence to date for the treatment of SD, including both energy-based devices and topical treatments.

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Introduction

Striae distensae (SD), otherwise known as "stretchmarks," are a common presenting complaint, particularly in young healthy women. The incidence is poorly documented within the literature, with one study reporting an incidence of up to 87.7% (1). Although benign, they can cause considerable psychological distress. Causes can be both physiological and pathological, such as growth spurts, obesity, pregnancy or steroid application (topical or systemic), Cushing's syndrome, or surgery-induced such as breast augmentation. Histologically it is thought that collagen bundle damage and elastic fibers/fibrillin changes contribute to their appearance (2); however, the pathogenesis of SD is thought to be multifactorial with mechanical stress, genetic influences, and hormones all contributing toward it (3). Ultimately the diagnosis is a clinical one, with SD manifesting initially as linear red plaques – striae rubra (SR), which then progress to linear atropic plaques – striae alba (SA). The most common sites are the breast, abdomen, buttocks, and thigh muscle.

Most patients seek a treatment with high efficacy; however, SD are notoriously difficult to treat, particularly if they have progressed from SR to SA.

Non-ablative lasers such as pulsed-dye laser (PDL) and neodymium-doped:YAG (Nd-YAG) are thought to treat SD via targeting the hemoglobin content within the striae (4), which would support the theory of why SR respond better to treatment than SA. Traditional ablative lasers such as the carbon dioxide (CO_2) laser primarily target the epidermis, as opposed to the dermis, which non-ablative lasers target; however, with fractional ablative modes, deeper parts of the dermis can be reached now (5). Although ablative lasers have the potential for better results, one has to be aware that the side effects can be greater, particularly in patients with higher Fitzpatrick skin types, producing postinflammatory hyperpigmentation (PIH). Some clinicians advise avoidance of ablative lasers in these skin groups in the treatment of SD (6).

SD are hypothesized to form in patients where the cross-linked collagen is "overstretched" and rupture of this collagen matrix causes the striae. Therefore, organizing collagen fibers or increasing collagen production is a mechanism by which to repair or treat SD (7).

Fractional photothermolysis (FP) works by generating heat into a thermal injury zone, causing neocollagenesis. Due to the smaller target areas created by FP, the dermis is preferentially targeted (as opposed to the epidermis) and hence this avoids the SE created by traditional ablative lasers (5).

Topical treatments such as tretinoin and microdermabrasion are also hypothesized to work via neocollagenesis in the treatment of SD (8,9).

In this article, we review all of the relevant evidence for the treatment of SD to enable clinicians to make an evidence-based decision regarding the best treatment for their patient.

Method

A PubMed search was carried out in July 2017 with the search words "Striae Distensae," "Stretchmarks," and "Treatment." The search collated 168 results, of which 130 were excluded and 38 were selected. Criteria for selection included nonreview articles, human subjects, literature being specific to SD, and the study being available in English. Data collected included the type of study, the aim of the study, the type of SD (if available), the participant number, the therapy used, and the findings of each study.

Literature results

The results have been summarized in Table 1. They have been subdivided into treatment categories of laser/light therapy or topical treatment. The studies were documented in chronological order, with the most recent studies being listed first. A total of 30 studies were found, which used energy-based

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Table 1. Summary of studies included within literature search for striae distensae treatment.

Study	Details	Aim	Striae type	Patient number	Therapy	Findings
Laser/light therapy						
Gokalp (10)	Treatment of pregnancy-induced striae using 1550-nm non-ablative fractional laser (NAFL).	Comparison of outcome of SR and SA using 1550-nm NAFL	SR and SA	$N = 16$	NAFL five high-energy sessions at 4-week intervals.	Striae width and length reduced and remained reduced at month 1, year 1 post treatment. Width: 6.94–3.25–3.13 mm Length: 6.06–2.88–2.75 cm.
Pongsirhadulchai et al. (28)	Efficacy and safety of nanofractional radiofrequency (NFRF) for SA.	Experimental assessor blind before and after study	SA	$N = 33$	NFRF three sessions at 4-weekly intervals.	Significant ($P < 0.001$) reduction in total surface area, width, and length of SA 4 weeks post last treatment. Histopathology: mean collagen and elastin bundles significantly increased ($P = 0.005$ and 0.012, respectively) Side effect (SE): PIH in 6.
Elsaie et al. (11)	Comparison of the effectiveness of two fluences using long-pulsed Nd:YAG laser in the treatment of striae distensae. Histological and morphometric evaluation.	Comparison study	SR and SA	$N = 45$	Fluences 75 and 100 J/cm^2 of long-pulsed Nd:YAG laser in 23 SR and 22 SA for 4 treatments at 3-weekly intervals.	Significant improvement in SA with 100 J/cm^2, and for SR with 75 J/cm^2 Histology: collagen and elastin increased post treatment.
El Taieb and Ibrahim (12)	Fractional CO_2 laser versus intense pulsed light (IPL) in treating striae distensae.	Comparison study	Not specified	$N = 42$	20 treated with fractional CO_2, 20 treated with IPL.	Length and width of largest striae showed significant improvement in both groups ($P < 0.05$). Fractional CO_2 laser demonstrated significant improvement in 5th sessions vs. improvement after 10th session with IPL.
Harmelin et al. (24)	Fractionated bipolar radiofrequency and bipolar radiofrequency potentiated by infrared light for treating striae.	A prospective randomized, comparative trial with objective evaluation	SR and SA	$N = 22$	Bipolar radiofrequency potentiated with infrared light and fractional bipolar radiofrequency either individually or in combination and then compared to the control (the untreated area of abdomen).	Combined treatment reduced mean striae depth by 21.64% at 6 month follow up (FU) versus 1.73% increase in striae depth in the control group ($P < 0.0001$). There was no significant difference in striae width between groups.
Khater, Khattab and Abdelhaleem (12)	Treatment of striae distensae with needling therapy versus CO_2 fractional laser.	A comparative study	Not specified	N = 20	Treatment with needling or CO_2 laser monthly, for three sessions.	90% needling patient showed improvement versus only 50% CO_2 laser-treated patients.
Wang et al. (13)	Evaluation of a 1540-nm and a 1410-nm nonablative fractionated laser for the treatment of striae.	A comparative study	Not specified	$N = 9$	Half of Abdomen treated either with six sessions of 1540-nm NAFL or with 1410-nm NAFL.	Improvement in both cohorts. No statistical difference between each group both clinically and histopathologically.
Nassar et al. (23)	Treatment of striae distensae with needling therapy versus microdermabrasion with sonophoresis.	A comparative study	Not specified	$N = 42$	Group 1: three needling sessions every 4 weeks Group 2: 10 sessions of microdermabrasion with sonophoresis.	Skin biopsies taken for histopathological review. Significant improvement in group one versus group 2 with increased collagen, fibroblast count, and epidermal thickness (90% vs. 50%).
Mishra et al. (29)	Fractional ablative micro-plasma radiofrequency device to treat striae	A case series	SR and SA	$N = 5$	Four treatments every 2 weeks.	Mean improvement of 20% 3 months' post treatment. SE: pain, erythema, edema. Patient questionnaire outcome: good to very good.
Malekzad et al. (30)	The safety and efficacy of the 1540 nm non-ablative fractional XD probe of Star Lux 500 device in the treatment of striae alba: before-after study.	A case series	Not specified	$N = 10$	Four treatments, 4-weekly with nonablative fractional laser 1540 nm.	Significant improvement from photographs of striae from week 4 of treatment to week 16 of treatment ($P < 0.0001$). SE: mild postinflammatory hyperpigmentation (PIH) in one patient/mild acne.

(*Continued*)

Table 1. (Continued).

Study	Details	Aim	Striae type	Patient number	Therapy	Findings
Clementoni and Lavagno (31)	1565 nm non-ablative fractional device for stretchmarks	A case series	SR and SA	$N = 12$	Three treatments per patient	51–75% improvement in all patients, assessed by blinded and nonblinded reviewers SE: pain, transient erythema, severe edema-no long-lasting severe SE noted.
Naeini et al. (25)	Comparison of the fractional CO_2 laser and the combined use of a pulsed dye laser (PDL) with fractional CO_2 laser in striae alba treatment.	A comparative study	SA	$N = 3$ (88 SA lesions)	Group 1: fractional CO_2 laser Group 2: combination PDL and Fractional CO_2 laser.	Combination, i.e., group 2 was more effective. Mean surface area decreased in both groups after treatment.
Gungor et al. (14)	Evaluation of ablative and non-ablative laser in the treatment of striae distensae.	A comparative study	SR and SA	$N = 20$	Treatments randomized with one side of the body treated with VSP erbium: YAG laser and the other side with LP Nd:YAG laser monthly for three treatments.	Poor outcome found with both laser types in the treatment of SA (mature striae). Moderate response found in SR (immature striae). Skin biopsies showed increase in elastic fibers post treatment vs. pre treatment.
Shokeir et al. (15)	Pulsed dye laser vs. IPL to treat SD.	A comparison study	SR and SA	$N = 20$	Each side of body treated with PDL and IPL for five sessions 4 weekly.	After both treatments striae width reduced and skin texture improved. On skin biopsy results PDL induced greater collagen expression than IPL ($P < 0.001$ in PDL vs. P = 0.193 in IPL). SR had a better response with both treatments than SA.
Ryu et al. (26)	Clinical improvement of striae distensae in Korean patients using a combination of fractionated microneedle radiofrequency and fractional carbon dioxide laser.	A comparison study	Not specified	$N = 30$	Group 1: fractional laser Group 2: microneedle RF Group3: combination.	Improvement rated using visual analogue scale (VAS). Highest VAS score in combination group (3.4 vs. 2.2 in group 1 and 1.8 in group 2).
Naein and Soghrati (27)	Fractional CO_2 laser to treat striae.	A randomized clinical trial	SA	$N = 92$ striae	Group 1: five sessions laser, 2–4 weekly Group 2: 10% glycolic acid + 0.05% tretinoin cream at night.	Mean difference of striae surface area reduced significantly in group 1 vs. group 2 $P > 0.001$. Mean VAS significantly higher in group 1 vs. group 2, $P > 0.001$.
Guimaraes et al. (32)	SD post breast augmentation treated with non ablative fractionated 1550-nm erbium glass laser.	A case series	Not specified	$N = 10$	Treated with nonablative 1550-nm erbium glass.	Review of photographs before and at 4 weeks. High satisfaction rate.
Al-Dhalimi and Abo Nasyria (16)	A comparative study of the effectiveness of IPL wavelengths (650 nm vs. 590 nm) in treatment of SD.	A comparative study	Not specified	$N = 20$	Five sessions of IPL 2 weekly (different wavelength on each side of body)	Overall reduction in width and length with both wavelengths statistically significant ($P < 0.0001$). Reduction in erythema on statistically significant in 590-nm wavelength ($P = 0.0157$). Overall 590 nm more effective/more patient satisfaction.
Park et al. (38)	SD treated with needling therapy.	A pilot study	SR and SA	$N = 16$	Three treatments, 4 weekly.	Marked to excellent improvement in 43.8% ($n = 7$), minimal to moderate in 37.5% ($n = 6$). SE: mild pain, erythema, spotty bleeding.
Yang andLee (17)	Treatment of striae distensae with nonablative fractional laser versus ablative CO(2) fractional laser.	A randomized controlled trial	SA	$N = 24$	1550 nm fractional Er:glass laser to one half of abdomen, three times, 4 weekly and ablative fractional CO_2 laser to the other side of the abdomen.	No difference between treatment. Significant clinical and histopathological improvement in both.

(*Continued*)

Table 1. (Continued).

Study	Details	Aim	Striae type	Patient number	Therapy	Findings
De Angelis et al. (33)	Fractional nonablative 1540-nm laser treatment of SD in Fitzpatrick skin types II to IV: clinical and histological results.	A clinical study	Not specified	*N* = 51	2–3 passes with 2–4 treatments 4–7 weekly.	Nonblinded clinical assessments >50% improvement for all patients at 6 months' post treatment. Blinded evaluators = mean improvement 51-75% 3 months post treatment. No recurrence of SD at 18–24 months. SE: Transient dema/erythema, transient PIH. Histology: thickened epidermis/dermis/neocollagenesis/ increased elastin 1 month post treatment.
Lee et al. (34)	Treatment of SD using an ablative 10,600-nm carbon dioxide fractional laser.	A retrospective review	Not specified	*N* = 27	Single treatment.	Clinical improvement ranked 1–4, 3 months' post treatment. 7.4% = grade 4 51.9% = grade 3 33.3% = grade 2 7.4% = grade 1.
Manuskiatti,	Boonthaweeyuwat and Varothai (34)	Treatment of SD with a TriPollar radiofrequency device.	A pilot study	Not	specified	*N* = 17
6× weekly treatment.	1 week post final treatment; 38.2% had 25–50% improvement and 11.8% has 51–75% improvement. No significant difference in striae surface smoothness at week one and week 6 versus baseline. Overall 65% of study subjects very satisfied,23% satisfied and 12% slightly satisfied.					
Bak et al. (36)	Treatment of SD with factional photothermolysis.	A case series	SA and SR	*N* = 22	Two sessions of fractional photothermolysis: pulse energy 30 mJ, 8 passes, 4 weekly.	27% excellent improvement, 63% varying depress improvement on clinical review of photograph. Majority of excellent results were SA. Histology: average epidermal and dermal thickness greater than baseline, increased immunoreactivity of procollagen type1 post treatment. SE: erythema, mild pigmentation.
Stotland et al. (18)	Safety and efficacy of fractional photothermolysis to treat SD.	A case series	SA and SR	*N* = 22	SD randomized to treatment, with site-matched normal control areas. Six treatments of 1550-nm, erbium-doped fiber laser 2–3 weekly.	Independent assessors of photographs of eight randomly selected patients: 26–50% improvement in 63% and <25% improvement in dyschromia in 50% patients. SE: transient post-treatment erythema.
Kim et al. (37)	Fractional photothermolysis to treat SD to treat SD in Asian skin.	A case series	SA	*N* = 6	1550-nm FP laser.	Improvement found at 8 weeks post treatment. Increase in epidermal thickness, collagen and elastic fiber deposition. SE: transient pain and hyperpigmentation.

(*Continued*)

Table 1. (Continued).

Study	Details	Aim	Striae type	Patient number	Therapy	Findings
Suh et al. (19)	RF and 585-nm PDL of SD.	A case series	Not specified	$N = 37$	Total of three sessions with fluences of 53–97 J/cm^2 and PDL at fluences of 3.0 J/cm^2	Subjective assessment: 89.2% = good and very good overall 59.4% = good and very good elasticity. All increased collagen and increased elastic fibers.
Tay,Kwok and Tan (20)	Non-ablative 1,450-nm diode laser for SD.	A case–control	SR and SA	$N = 11$	SD on half of body treated with laser, the other half was a control. three laser treatments, 6 weekly. (skin types 4, 5, 6).	No improvement in laser side versus nontreated side 2 months' post treatment. SE: transient erythema, PIH in 64%.
Jimenz et al. (21)	Treatment of SR and SA with 585-nm PDL.	A case–control study	SR and SA	$N = 20$	Treatment at baseline and 6 weeks late, untreated SD of same patient were control.	Laser had moderate/beneficial effect in reduce erythema in SR but none in SA. Collagen per gram of dry weight increased in SD treated with PDL versus control.
Hernandez-Perez, Colombo-Charrier and Valencia-Ibiett (22)	IPL to treat SD.	A prospective study	Not specified	$N = 15$	IPL, five sessions in total, 2 weekly.	Statistically significant difference in post treatment dermal thickness ($P < 0.01$) and overall clinical improvement.
Nouri et al. (6)	Comparison of 585 nm PDL and short pulsed CO_2 laser to treat SD in skin types 4 and 6.	A case series	Not specified	$N = 4$	SD divided into three sections. Section A – short pulse CO_2 Section B – control Section C – 585 nm PDL.	At 20-week FU, type 4 skin no improvement, type 6 hyperpigmenetation. Short pulsed CO_2 section = persistent erythema in type 4 and PIH in type 6. Outcome: avoid laser in types 4, 5, and 6 skin in treatment of SD due to PIH.
Topical treatment						
Bogdan,Lurian, Tomatu et al. (41)	*Punica granatum* seed oil and *Croton lechleri* resin extract in striae.	Interventional non randomized study	Not specified	$N = 20$	Review of skin post cream application using Ultrasound and biophysical parameters.	Striae reviewed at beginning, 3 and 6 weeks. Increase in dermis thickness, hydration, and elasticity in both groups 6 weeks post cream application.
Bitencourt et al. (44)	Safety and patient subjective efficacy of using galvanopuncture for the treatment of striae distensae.	Prospective single center study	SA	$N = 32$	SA treated with galvanopuncture once weekly for 10 weeks.	Patient satisfaction and clinical improvement noted in photography.
Ibrahim et al. (9)	Comparison between the efficacy and safety of platelet-rich plasma (PRP) vs. microdermabrasion in the treatment of striae distensae.	Clinical and histopathological study.	Not specified	$N = 68$	Group 1: PRP Group 2: microdermabrasion Group 3: combination microdermabrasion/PRP. Maximum six sessions, 2-weekly intervals. Skin biopsies off some patients at baseline, 3 months, after final session.	Significant improvement in groups 1 and 3 versus group 2. Group 3 had better results after a shorter duration of treatment. Histology: collagen and elastic fibers increased in dermis at end of treatment.
Hexsel et al. (39)	Superficial dermabrasion vs. topical tretinoin.	A randomized, pilot study	SR	$N = 32$	Group 1: 16, weekly sessions microdermabrasion Group 2: 0.05% tretinoin cream daily.	Both showed improvement, no significant difference between the groups. Histology of group 1: improvement in epidermal and dermal layers.
Kim et al. (42)	Efficacy of intradermal radiofrequency in combination with autologous platelet rich plasma in SD.	A pilot study	Not specified	$N = 19$	Three sessions of intradermal RF combined with autologous PRP per patient, 4 weekly.	Only 5.3% ($n = 1$) = excellent improvement, 36.8% ($n = 7$) marked improvement, 31.6% ($n = 6$) moderate improvement, 26.3% ($n = 5$) mild improvement.

(*Continued*)

Table 1. (Continued).

Study	Details	Aim	Striae type	Patient number	Therapy	Findings
Ash et al. (43)	Comparison of topical therapy for SA (20% glycolic acid/0.05% tretinoin versus 20% glycolic acid/10% L-ascorbic acid).	A case series	SA	$N = 10$	Daily topical application of 20% glycolic acid + 10% L-ascorbic acid, 2% zinc sulfate, and 0.5% tyrosine to half to the treatment area and 0.05% tretinoin emollient cream to the other half of the treatment area, daily for 12 weeks.	Overall improvement as per objected blinded and unblended viewers. SE: minimal irritation.
Pribanich et al. (40)	Low-dose tretinoin dose not improve SD	A double-blind, placebo-controlled study	Not specified	$N = 11$	0.025% tretinoin applied daily for 7 months versus placebo.	No difference in improvement.

N = number of patients within study, except if clearly expressed otherwise, e.g., N can also be = number of SD.

devices as a treatment of SD between 1999 and 2017. Of these studies, laser categories included nonablative fractional laser (NAFL), radiofrequency (RF), long pulsed Nd:YAG, fractional CO_2 laser, fractional bipolar RF, fractional ablative microplasma RF, PDL, and intense pulsed light (IPL). A total of eight studies were found, which used topical therapy as a treatment of SD between 1994 and 2017. Treatment therapy included *Punica granatum* seed, oil and *Croton lechleri* resin extract, galvanopuncture, platelet-rich plasma (PRP), topical tretinoin, glycolic acid, and ascorbic acid. Needling and microdermabrasion was also reported in few studies.

Of the studies that used energy-based devices as a treatment, 16 were comparative studies (2,6,10–23), 4 were combination studies (24–27), and the remaining 10 were noncomparative/noncombination studies (28–38).

Of the studies that used topical therapy as a treatment, three were comparative studies (9,39,40), three were combination studies (41–43), and two were noncomparative/noncombination studies (38,44).

Noncomparative/noncombination studies

Pongsirhadulchai et al. (28) reviewed the efficacy and safety of nanofractional radiofrequency (NFRF) for SA in 33 subjects with SA of thighs, buttocks, or abdomen. Three sessions of NFRF were undertaken at 4-weekly intervals and post-treatment results were assessed using digital Pictzar software to determine whether the length and width of SA had reduced. They found a significant reduction in the length and width of the SA from baseline ($P < 0.001$). Histopathology of the SD was also reviewed post treatment, which demonstrated collagen and elastin bundles were found to be significantly increased ($P = 0.005$ and0.0012, respectively) (28).

Clementoni and Lavgno treated 12 Caucasian patients with three sessions of nonablative 1565 nm fractional laser and reviewed the results at 3 months post therapy. Good clinical improvement was found in all patients treated, with volume of the depressions and improvement of lesion color being the subcategories that were optimized the most. Side effects included transient erythema and severe edema; however, neither were long lasting (31).

Another study involving 22 patients with SD used two sessions of FP (NAFL 1550 nm) at 4-weekly intervals, and evaluated the results using clinical photography and skin biopsies. Twenty-seven percent showed "good to excellent" improvement, and the remaining 63% showed various degrees of improvement. Skin biopsy showed that both epidermal and dermal thickness increased as well as the immunoreactivity of procollagen type 1 (36). Interestingly, the lesions that responded the best were SA, given that SA are usually more recalcitrant to treatment than SR due to the maturity of the striae (45).

Park et al. carried out a pilot study in 16 patients with either SA or SR where they received three treatments of microneedling, every four weeks. Outcomes were assessed using quartile grading scale, and 43.8% demonstrated marked to excellent improvement and overall 37.5% of patients were highly satisfied, 50% somewhat satisfied, and 12.5% unsatisfied (38).

Comparative studies

Gokalp compared the outcome of SR ($N = 8$) and SA ($N = 8$) using 1550 nm NAFL in pregnancy-induced SD in 16 women. Each candidate had five sessions at 4-weekly interval. It was found that overall strial width and length reduced at 1 month and 1 year post treatment, respectively (10).

A comparative split-striae study comparing two different settings of long-pulsed Nd:YAG laser to treat both SR ($N = 23$) and SA ($N = 22$) using 75 versus 100 J/cm^2 was performed. A significant improvement was found in SA treated with 100 J/cm^2, and in SR a greater improvement was found in treatment with 75 J/cm^2. Again, both collagen and elastin increased histologically post treatment (11).

El Taieb and Ibrahim compared fractional CO_2 laser versus IPL in 40 patients with SD. Both treatments modalities showed significant improvement with fractional CO_2 laser showing improvement sooner than IPL – with results evident by 5 sessions versus 10 sessions with IPL (2).

A prospective randomized, comparative trial with fractionated bipolar RF and bipolar RF in conjunction with infrared light to treat SD on the abdomen of 22 patients (with a total of 384 SR and SA) was performed. Results demonstrated that mean striae depth reduced by 21.64% 6 months post treatment in the combination group versus an increase of 1.73% in the control group – the remaining untreated quadrant ($P < 0.0001$). Histological review post treatment demonstrated thicker collagen fibers in the noncontrol group (24).

An interesting comparative study comparing microneedling therapy with fractional CO_2 laser in the treatment of SD in 20 Egyptian female patients found microneedling to be more beneficial with 90% of patients showing clinical improvement versus only 50% in the CO_2 laser group (12).

Wang et al. compared two different wavelengths of NAFL (1540 and 1410 nm) in the treatment of SD in a split-abdomen study involving six patients. Both clinical improvement (based on photography) and histological improvement from skin biopsy were found in each group, with no statistical differences. Skin biopsy demonstrated increased epidermal and dermal thickness, increased collagen and elastin density in comparison to pretreatment biopsies (13).

A study comparing the long-pulsed Nd:YAG 1064 nm versus the 2940 nm tunable pulsewidth Er:YAG was performed in 22 patients (SR = 3, SA = 17). Both treatment types were randomly allocated to both sides of the body, and all subjects were treated weekly for a total of three sessions. Patients with SA lesions were found to have poor response to treatment on photographic review of treatment, whereas patients with SR had moderate responses (on both sides). Interestingly, although clinical outcome was poor in both groups, histological improvement was still noted post treatment, in all samples, in comparison to pretreatment's skin biopsies (14).

A randomized-controlled trial (RCT) comparing two modalities of fractional lasers (ablative CO_2 versus 1550 nm NAFL Er;glass) in a split-abdomen study on 24 patients showed no significant difference between the two groups (three treatments in total 4-weekly) despite both groups showing clinical and histological improvement (17).

The use of 585-nm PDL in both SR and SA of 22 patients demonstrated a moderate improvement in the erythema of SR with little change in SA. Importantly, the authors suggested avoiding PDL in Fitzpatrick skin types V and VI due to the higher risk of PIH (21).

Combination studies

A study comparing the combination of fractional CO with PDL versus fractional CO_2 alone in the treatment of 88 SA lesions of three female patients showed the combination treatment to be more effective with a significant greater reduction in post-treatment surface area ($P = 0.03$) and a significantly higher visual analogue scale (VAS) score ($P < 0.001$) (25).

Ryu et al. reviewed combination therapy with fractionated microneedle RF and fractional CO_2 laser on SD of 30 patients with moderate to severe striae. A third were treated with fractional CO_2 laser only, a third with microneedle RF only, and the final third used a combination of both treatments. Mean improvements using VAS were 2.2, 1.8, and 3.4, respectively. Histology demonstrated thickened epidermis and higher number of collagen fibers in the combination-treated sites (26).

Naein and Soghrati (27) carried out a RCT on 92 SD comparing fractional CO_2 laser in group 1 (five sessions of laser, 2–4 weekly) with group 2 who were treated with 10% glycolic acid + 0.05% tretinoin cream at night for the duration of the study. Group 1 showed a significantly reduced surface area of SD compared with group 2, and the mean VAS was higher in group 1. No statistically significant difference was noted though (27).

Suh et al. reviewed the outcome of treating abdominal SD in 37 Asian patients, initially with RF in combination with PDL and then with two subsequent sessions of PDL at 4 and 8 weeks. Subjective assessment demonstrated 89.2% of patients showed "good and very good" overall improvement, and 59.4% demonstrated the above regarding elasticity, with the authors deducing RF with PDL an overall effective treatment (19).

Another study among19 Asian patients used the combination of intradermal RF combined with autologous PRP at 4-weekly intervals for a total of three sessions. Only one patient had an excellent improvement, seven had marked improvement, six had moderate improvement, and five mild improvement. None had a worse outcome, and 63.2% of patients were satisfied to very satisfied (42).

A study looking at comparison between two different combinations of topical therapy in SD (20% glycolic acid/0.05% tretinoin versus 20% glycolic acid/10% L-ascorbic acid) in 10 patients, whereby they treated half of area with each treatment subset, daily for 12 weeks and both were found to improve the appearance of SD as we(43)ll as increase epidermal thickness and decrease papillary dermal thickness in comparison to untreated SD (43).

Discussion and limitations

This review demonstrates that there is evidence for a multitude of treatment options for SD; however, the majority of the

studies available for evaluation have small sample sizes and are nonrandomized and nonblinded studies. As discussed earlier, SA are harder to treat than SR (4) and tend to respond better to laser treatment, although a lot of studies do not specify SD as either SR or SA. Precautions must be taken by the clinician to review the suitability of the patient, depending on their Fitzpatrick skin type – with higher types being at more risk of PIH and one study demonstrating persistent erythema in types 4–6 (6).

NAFLs have demonstrated reduction in both length and width of SD; however, the longest follow-up documented is that of 1 year post treatment (10). Even if results have not been clinically beneficial, the histology has almost always demonstrated increase in collagen elastin bundles from pre- and post-treatment skin biopsies highlighting the potential discrepancy between clinical and histological improvement (9,11,13,14,17,19,21–23,28,36,37,39,41).

Common side effects included erythema, mild PIH, and edema, which were transient. One study showed no improvement in nonablative laser-treated side versus control side (20). Low-dose tretinoin was also not found to improve SD in a small double-blind control trial of 11 patients (40).

Importantly, it is almost impossible to compare treatment outcomes between the studies presented. This is partly because each laser study may use a different number of treatments, with different intervals and different fluencies (high versus low), added to the difference in outcome measurements methodology that was inconsistent in studies. Some studies used subjective measurement from the patient, others clinical photography with independent/blinded assessors or VAS scores. What is clear however is that there is high scope for improvement in the treatment of SD, with a need for large blinded RCTs to be carried out in order to aid the clinician to make an evidence-based decision based on skin type, striae type, and downtime that is deemed acceptable to the patient.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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