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REVIEW ARTICLE

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The use of energy devices in the treatment of striae: a systematic literature review

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ABSTRACT

Background: Striae distensae are caused by rapid stretching of the skin. They are often secondary to obesity or pregnancy and can lead to significant cosmetic disfigurement.
Aim: To determine the efficacy, indications, and side effects of commonly used energy devices in the treatment of striae.
Methods: A comprehensive literature search was performed using the PubMed and Medline databases.
Results: A total of 41 relevant articles were identified. Radiofrequency (RF) was the commonest employed modality (11 studies), followed by the CO_2, and pulsed dye lasers (10 and 5 studies, respectively). The best results against striae alba were seen with a combination of RF, platelet-rich plasma and ultrasound (either excellent or very good results in 71.9%), followed by intense pulsed light in isolation (very good results in 40%). The response of SR was assessed by fewer studies. The best outcomes were seen after treatment with either the Nd:YAG (excellent results in 40% and good in 40%) or Er:Glass lasers (excellent results in 10% and good in 20%).
Conclusions: The therapeutic measures for striae are multiple and no current treatment offers consistent and complete resolution. However, energy devices are a safe and potentially effective modality in the treatment of striae.

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KEYWORDS
Striae; lasers; stretch marks; scars; scarring

Introduction

Striae distensae (SD), also known as stretch marks, are common cutaneous lesions characterized by linear bands of atrophic skin (1). They represent dermal scars with epidermal atrophy and pose a common source of cosmetic concern (2). SD result from changes in the reticular collagen, caused by rapid stretching of the skin, and are usually multiple and symmetrically distributed (3). The commonest affected sites include the abdomen, outer thighs, and breasts (4). Even though the exact pathogenesis is poorly understood, striae are commonly associated with mechanical stress (rapid weight changes and growth spurt) and hormonal changes (pregnancy, oral contraceptive use, increased adrenocortical function, and corticosteroid therapy) (3,4). The evolution of SD proceeds through several stages. In the acute stage they may be thin, pink and even pruritic. Over time they usually enlarge in length and width, may become raised, and acquire a reddish-purple appearance (striae rubra – SR). Finally, they become flat or depressed and hypopigmented (striae alba – SA) (1,3,5).

Studies have demonstrated that the varying colors of striae are influenced by melanocyte mechanobiology and that striae formation parallels the wound-healing process of regular scar formation (6).

Histologically, SD demonstrate a similar appearance to atrophic scars with epidermal atrophy, flattening of the rete ridges, loss of thickness in the dermis, as well as retraction and loss of collagen and elastin (7–9). Exact histopathological findings vary depending on the age of the lesions (1). Early lesions show superficial and deep perivascular infiltrates of lymphocytes and sometimes of eosinophils, as well as widely dilated venules and edema in the upper part of the dermis (1). Fully developed lesions show a scant infiltrate of lymphocytes around venules. Bundles of collagen in the upper third of the reticular dermis are thinned and aligned parallel to the skin surface (1). Contributing to the atrophied appearance of striae are the reduced amounts of fibrillin surrounding the dermal–epidermal junction, reduced elastin in the papillary dermis, and reorganization of elastin and fibrillin fibers in the deep dermis (10).

Several treatments have been utilized with variable therapeutic outcomes, cost, and side effects. At present, there is no universally accepted treatment against all types of SD and in all skin types, making improvement rather than complete resolution a more realistic clinical expectation (5,8). Available treatments include topical agents such as tretinoin and glycolic acid, chemical peels, microdermabrasion, and a multitude of both ablative and non-ablative energy-based devices (8). In the late stage of SD, after which the scarring process is complete, effective treatment has been found to be more difficult and incontinent (2,11).

In this study, we review all the available literature in order to help illuminate the efficacy and adverse reactions of a wide range of energy-based devices in the management of SD.

Objectives

To determine the evidence behind the efficacy, indications, and side effects of energy-based devices in the treatment of SD in the current published literature.

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Materials and methods

A comprehensive literature search was performed using the PubMed and Medline databases. A search using the keywords [(striae, stretch marks) AND (treatment)] was utilized. Only full, original research articles written in English were included. Individual case reports were excluded. After reading their full texts, a total of 41 articles were included in this review.

Results

Randomized controlled trials (RCTs)

A total of 11 RCTs were identified.

In a study of 14 patients with mixed striae, Harmelin et al. (12) assessed the effects of combination treatment with bipolar radiofrequency (RF), infrared (IR) light, and fractional bipolar RF to those of nonintervention control. In a different RCT, Alexiades-Armenakas et al. treated nine patients with SA. Lesions were randomized to either treatment with a 308 nm excimer laser or control (13).

Gungor et al. (14) compared the effects of treatment with the long-pulsed Nd:YAG and variable square pulse Er:YAG in three patients with SR and 17 with SA. In their first of three papers, Naeini and Soghrati (15) compared the effects of the fractional CO_2 laser against those of 10% glycolic acid and 0.05% tretinoin cream in six patients with SA. In their second study, they treated three patients with SA in order to assess the effects of the fractional CO_2 laser against those of combination treatment with both the CO_2 and PDL lasers (16). In their third study, Naeini et al. (17) treated 6 patients with SA with either fractional microneedling radiofrequency (FMR) in isolation or combined with the fractional CO_2 laser.

In another RCT of 14 patients with SA, Shin et al. (18) compared the efficacy of the ablative fractional CO_2 laser, CO_2 laser combined with succinylated atelocollagen, and isolated succinylated atelocollagen. El Taieb and Ibrahim randomized 40 patients to receive treatment with either a fractional CO_2 laser or intense pulsed light (IPL) (19).

Another study by Karia et al. (20) randomized 50 patients with SR to receive treatments with either topical tretinoin 0.1% gel, microdermabrasion combined with 30% trichloroacetic acid (TCA) peel, mesotherapy, Q-switched Nd:YAG laser, or combination treatment of microdermabrasion, salicylic acid and retinol peels. On a split-side study, Tay et al. (21) assessed the diode laser against control on 11 patients with mixed striae. Finally, Yang and Lee performed a double-blinded RCT on 24 patients with abdominal SA. Striae were randomly split in two halves, each receiving treatment with either Er:Glass fractional photothermolysis (FP) or a fractional ablative CO_2 laser (22).

Non-randomized controlled trials

A total of nine such studies were included in our review.

Al-Dhalimi and Abo Nasyria compared the effects of two different bands of IPL (650 nm vs. 590 nm) on 20 patients with SR (3). In a study of 30 patients, Ryu et al. (23) assessed treatment with a fractional CO_2 laser against that of fractional microneedling RF. Issa et al. compared the effects of fractional ablative RF with topical retinoic acid 0.05% and ultrasound against those of isolated fractional ablative RF in 16 patients with SA (11). Shokeir et al. (10) compared treatment with pulsed dye laser (PDL) against that with IPL in 20 patients with mixed striae. Elsaie et al. (24) compared the effects of 75 and 100 J/cm^2 of Nd:YAG in 45 patients with mixed striae. Khater et al. (25) compared the effects of the ablative fractional CO_2 laser against those of microneedling in 20 patients with mixed striae.

In a small study of four patients, Nouri et al. (26) compared the effects of short-pulsed CO_2 laser against those of the PDL. In another study, Goldberg et al. (27) compared the efficacy of an excimer laser against that of UVB light on 10 patients with SA. Finally, Wang et al. (28) compared the effects of two different wavelengths (1540 nm and 1410 nm) of Er:Glass FP on 10 patients with mixed striae.

Observational studies

A total of 21 observational studies were identified.

Seven studies looked into the effects of Er:Glass FP (51, 22, 20, 12, 10, 10 and 6 patients, respectively) (4–6,29–32). One study (10 patients) assessed the effects of non-fractional broadband IR, one of IPL (15 patients), and one of high-intensity narrow band UVB/UVA1 (9 patients) (1,8,33). Six studies reviewed the effects of different types of RF (33, 19, 18, 16, 17, and 5 patients respectively) (2,7,9,34–36). One study assessed treatment with PDL (20 patients), and one with PDL combined with non-ablative RF (37 patients) (37,38). Finally, one study utilized excimer laser (75 patients), one Nd:YAG (20 patients), and one fractional ablative CO_2 laser (27 patients) (39–41).

The findings of all the studies are summarized in Tables 1 and 2.

Discussion

Although numerous attempts have been made to improve the clinical appearance of SD, no 'gold standard' modality has emerged to date that consistently improves both pigment and textural irregularities with equivalent efficacy for SR and SA. Rather, with currently available methods of treatment, partial improvement in the appearance of striae, rather than complete removal, is the more realistic clinical endpoint (6,8).

The use of energy-based treatment methods, often in combination, has been shown to offer clinical improvement due to reorganization of the collagen and dermal remodeling (10). Awareness and combination of newer treatment modalities could be key in achieving consistent resolution of SD in a large percentage of patients, and even in those with hypopigmented striae, whilst limiting the potential for adverse reactions, even in those with darker skin types (5,8).

RF was found to be the modality with the most available evidence (11 studies), followed by the CO_2 and Er:Glass lasers (10 and 9 studies, respectively).

An absolute comparison of efficacy between the different treatment modalities is difficult due to a number of study-specific limitations. These include the number of treatment sessions, patient number and ethnicity, duration of follow-up, and different outcome measures. Furthermore, it is worth noting that on the majority of the studies presented here evaluation of SD before and after treatment is performed retrospectively based on 2D photographs. Such assessment may not accurately represent improvement in all dimensions of SD, and does not take into account additional measurements such as skin roughness and elasticity (7,12). We argue that 3D computer analysis, complemented by clinical textural assessment, should be employed in the future as standard for all studies in this field.

- PDL

The PDL has been used for many years, mainly in the treatment of vascular lesions (16). It has also become a commonly employed treatment method against SD.

Table 1. A synopsis of all the studies that utilized non-laser energy devices.

Authors (study design)	Year	Type of striae	Number of patients	Treatment method	Outcome (unless specified otherwise: mild improvement 1–25%, moderate 26–50%, good 51–75%, and excellent >75%)	Reported adverse reactions
Al-Dhalimi and Abo Nasyria (non-randomized controlled study)	2016	Rubra	20	650 nm (Group 1) vs. 590 nm IPL (Group 2)	Group 1: reduction in the total number of striae from 256 to 240 and decrease in the sum of the lengths of striae from 935 cm to 830 cm Group 2: reduction in the total number of striae from 251 to 228 and decrease in the sum of the lengths of striae from 948 cm to 803 cm	Both groups: erythema, burning, pain, and hyperpigmentation
Dover et al. (observational study)	2014	n/a	16	Multipolar RF with pulsed electromagnetic fields	Mean reduction in the length of striae by 1.031 cm Mean reduction in the width of striae by 0.160 cm	None
Harmelin et al. (RCT)	2016	Mixed	14	Bipolar RF with infrared light and fractional bipolar RF (Group 1) vs. no interventions (Group 2)	Treatment achieved a mean reduction in the depth of striae by 21.64% ($p < .001$)	Pain, crusting, pruritus, and hyperpigmentation
Hernández-Pérez et al. (observational study)	2002	Alba	15	IPL	Improvement was moderate in 40%, good in 20%, and excellent in 40% The total number of striae decreased from 117 to 94 The sum of the length of all striae decreased from 375 cm to 239 cm	Burning and hyperpigmentation
Issa et al. (non-randomized controlled study)	2012	Alba	16	Fractional ablative RF with topical retinoic acid 0.05% and ultrasound (Group 1) vs. isolated fractional ablative RF (Group 2)	Group 1: mean improvement was statistically significant Group 2: mean improvement was not statistically significant	Group 1: erythema, burning and edema Group 2: erythema, burning, edema and hyperpigmentation
Kim et al. (observational study)	2012	n/a	19	Intradermal RF with autologous PRP	Improvement was excellent in 5.3%, good in 36.8%, moderate in 31.6%, and mild in 26.3%	Bruising
Manuskiatti et al. (Observational study)	2009	Mixed	17	Tripollar RF	Improvement was self-reported as excellent in 5.9%, and good in 26.5%	Erythema and edema
Mishra et al. (observational study)	2015	Mixed	5	Fractional ablative micro-plasma RF	Mean striae appearance improved by 20%	Pain, erythema, and edema
Pongsrihadulchai et al. (observational study)	2016	Alba	33	Nanofractional ablative RF	Total surface area decreased from $6.41 \pm 3.54\ cm^2$ to $2.55 \pm 1.52\ cm^2$	Pain and hyperpigmentation
Sadick et al. (observational study)	2007	Alba	9	High-intensity narrow band UVB/UVA1	Improvement was excellent in 22%, good in 33%, and mild in 44%	Hyperpigmentation and erythema
Shokeir et al. (non-randomized controlled study)	2014	Mixed	20	PDL (Group 1) vs. IPL (Group 2)	Percentage of striae mean width improvement Group 1: • Striae alba 11% (± 4.4%) • Striae rubra 32.2% (± 21.6%) Group 2: • Striae alba 13.5% (±5.1%) • Striae rubra 39.2% (±22.4%)	Erythema, pain, itching, and hyperpigmentation
Suh et al. (observational study)	2012	Alba	18	Plasma fractional RF with PRP and ultrasound	Improvement was excellent in 33%, good in 38.9%, moderate in 22.4%, and mild in 5.6%	Hyperpigmentation
Trelles et al. (observational study)	2008	Alba	10	Non-fractional broadband infrared light	Improvement was moderate in 20%, and mild in 40% No improvement was achieved in 40%	Erythema

Table 2. A synopsis of all the studies that utilized lasers.

Authors (trial type)	Year	Type of triae	Number of patients	Treatment method	Outcome (unless specified otherwise: mild improvement 1–25%, moderate 26–50%, good 51–75%, and excellent >75%)	Reported adverse reactions
Alexiades-Armenakas et al. (RCT)	2004	Alba	9	Excimer laser (Group 1) vs. untreated control (Group 2)	Mean pigmentation after laser treatment improved by 32%	Erythema
Bak et al. (observational study)	2009	n/a	22	Er:Glass fractional photothermolysis	In 27% improvement in appearance ranged from moderate to excellent In 73% improvement was mild	Erythema, crusting, and hyperpigmentation
De Angelis et al. (observational study)	2010	Mixed	51	Er:Glass fractional photothermolysis	Non-blinded assessment: 50% mean improvement in appearance Blinded assessment: 51–75% mean improvement in appearance	Edema, erythema, hyperpigmentation
Elsaie et al. (non-randomized controlled study)	2016	Mixed	45	Nd:YAG laser 75 J/cm^2 (Group 1) vs. 100 J/cm^2 (Group 2)	Mean improvement in striae appearance from 5 ± 2.38 to 2.81 ± 2.33 ($p > .001$) (Based on the 5 points Global Aesthetic Improvement Scale – GAIS)	Pain and hyperpigmentation
El Taieb and Ibrahim (RCT)	2016	n/a	40	Fractional CO_2 laser (Group 1) vs. IPL (Group 2)	Group 1: • The mean width reduced from 6.95 to 3.25 mm ($p < .001$) • The mean length reduced from 13.1 to 9.3 mm ($p < .001$) Group 2: • The mean value of width reduced from 7.0 to 4.4 mm • The mean length reduced from 13.2 to 10.3 mm ($p < .005$) There was a significant difference in the improvement of striae width in those treated with laser than those treated with IPL in favor of laser ($p < .005$) There was no significant difference in the improvement of striae length between the two groups ($p > .05$)	Erythema, feeling of heat, pruritus, and hyperpigmentation
Goldberg et al. (observational study)	2003	Alba	75	Excimer laser	Improvement in striae appearance was reported by 80% of subjects, and no improvement in appearance by 20% All subjects achieved ≥76% darkening of their striae	Erythema and hyperpigmentation
Goldberg et al. (non-randomized controlled study)	2005	Alba	10	Excimer laser (Group 1) vs. UVB light (Group 2)	All subjects showed some evidence of clinically significant improvement in the color of striae Results were similar in both groups	n/a
Goldman et al. (observational study)	2008	Rubra	20	Nd:YAG laser	Physician assessors reported response as poor in 20%, good in 40%, and excellent in 40% (Poor response <30% improvement, good 30–70%, and excellent >70%)	Edema and erythema
Gungor et al. (RCT)	2014	Mixed	20	Nd:YAG laser (Group 1) vs. Er:YAG laser (Group 2)	All patients with striae alba had a poor response to either treatment All subjects with striae rubra had moderate response to both treatments (poor response <30% improvement, good 33–66%, and excellent >66%)	Erythema and hyperpigmentation
Guimaraes et al. (observational study)	2013	Rubra	10	Er:Glass fractional photothermolysis	All patients showed a marked improvement in the appearance of striae Mean physician evaluation of improvement: 8.4 (0–10 range, 0 = no response, 10 = complete resolution)	Discomfort, erythema, crusting, and hyperpigmentation
Jiménez et al. (observational study)	2003	Mixed	20	PDL	100% of striae rubra achieved some improvement in color None of the striae alba achieved any improvement in color	n/a
Karia et al. (RCT)	2016	Rubra	50	Topical 0.1% tretinoin gel (Group 1) vs. microdermabrasion and 30% TCA (Group 2) vs.	Group 1: 10% achieved good response, 10% moderate, and 80% mild Group 2: 10% achieved excellent response, 10% good, 60% moderated, and 20% mild	n/a

(continued)

Table 2. Continued.

Authors (trial type)	Year	Type of triae	Number of patients	Treatment method	Outcome (unless specified otherwise: mild improvement 1–25%, moderate 26–50%, good 51–75%, and excellent >75%)	Reported adverse reactions
				mesotherapy (Group 3) vs. Nd:YAG (Group 4) vs. microdermabrasion with salicylic acid and retinol peels (Group 5)	Group 3: 20% achieved good response, 40% moderate, and 40% mild Group 4: 10% achieved excellent response, 20% good, 40% moderate, and 30% mild Group 5: 20% achieved excellent response, 60% good, 10% moderate, and 10% mild	
Khater et al. (non-randomized controlled study)	2016	Alba	20	Fractional CO_2 laser (Group 1) vs. microneedling (Group 2)	Group 1: Physician scoring 10% good improvement, 30% moderate, 10% mild, and 50% no improvement Group 2: Physician scoring 30% good improvement, 40% moderate, 20% mild, and 10% no improvement	Erythema and hyperpigmentation
Kim et al. (observational study)	2008	Alba	6	Er:Glass fractional photothermolysis	Overall striae appearance improved substantially	Pain and hyperpigmentation
Lee et al. (observational study)	2010	Alba	27	Fractional CO_2 laser	Improvement was excellent in 7.4%, good in 51.9%, moderate in 33.3%, and mild in 7.4%)	Erythema, pruritus, crusting or scaling, oozing, and hyperpigmentation
Malekzad et al. (observational study)	2014	Alba	10	Er:Glass fractional photothermolysis	25% of patients had no improvement and 75% had mild response	Acne and hyperpigmentation
Naeini et al. (RCT)	2012	Alba	6	Fractional CO_2 laser (Group 1) vs. 10% glycolic acid with 0.05% tretinoin cream (Group 2)	The surface area of striae significantly decreased in both groups Both patients and physician assessors found laser therapy more effective than topical therapy ($p > .001$)	Erythema and hyperpigmentation
Naeini et al. (RCT)	2014	Alba	3	Fractional CO_2 laser (Group 1) vs. fractional CO_2 laser and PDL (Group 2)	The mean surface area of the lesions decreased significantly in both groups ($p = .011$ for Group 1 and .001 for Group 2) The mean improvement in surface area was more significant in Group 2 than Group 1 ($p = .03$)	Erythema, edema, and hyperpigmentation
Naeini et al. (RCT)	2016	Alba	6	Fractional microneedling RF with fractional CO_2 laser (Group 1) vs. FMR (Group 2)	Group 1: surface area of striae decreased from 257.43 ± 161.75 to 140.92 ± 133.62 ($p < .001$) Group 2: surface area of striae decreased from 259.05 ± 159.79 to 164.67 ± 124.63 ($p < .001$) Combination treatment was more effective at reducing the surface area of striae ($p = .001$)	Group 1: erythema, pain, edema, and hyperpigmentation Group 2: erythema, pain, and edema
Nouri et al. (non-randomized controlled study)	1999	n/a	4	Short-pulsed CO_2 laser (Group 1) vs. PDL (Group 2)	No improvement in the appearance of striae was identified in either group	Hyperpigmentation and erythema
Ryu et al. (non-randomized controlled study)	2013	n/a	30	Fractional CO_2 laser (Group 1) vs. fractional microneedling RF (Group 2) vs. combination of fractional CO_2 laser and fractional microneedling RF (Group 3)	Group 1: improvement in striae appearance by 2.2 Group 2: improvement in striae appearance by 1.8 Group 3: improvement in striae appearance by 3.4 (Based on the 4 points Visual Analogue Scale – VAS)	All groups: hyperpigmentation, pain, and pruritus
Shin et al. (RCT)	2016	Alba	14	Fractional CO_2 laser (Group 1) vs. fractional CO_2 laser with succinylated atelocollagen (Group 2) vs. isolated succinylated atelocollagen (Group 3) vs. placebo (Group 4)	There was significant improvement in appearance between groups 2 and 4 in favor of group 2 ($p = .03$), and also between groups 3 and 4 ($p = .03$) in favor of group 3	Erythema, pruritus and hyperpigmentation (adverse reaction per group not specified)

(*continued*)

Table 2. Continued.

Authors (trial type)	Year	Type of triae	Number of patients	Treatment method	Outcome (unless specified otherwise: mild improvement 1–25%, moderate 26–50%, good 51–75%, and excellent >75%)	Reported adverse reactions
Stotland et al. (observational study)	2008	Mixed	20	Er:Glass fractional photothermolysis	Improvement in appearance was good in 63% Improvement in striae color was mild in 50%	Erythema and edema
Suh et al. (observational study)	2007	Mixed	37	PDL with non-ablative RF	59.4% of patients had good or excellent improvement in respect to skin elasticity, and 89.2% in respect to the overall appearance The sum of the width of the striae decreased from a total of 126 to 97 mm (mean decrease of 3.41–2.62 mm per patient)	Hyperpigmentation and purpura
Tay et al. (RCT)	2006	Mixed	11	Diode laser	No improvement in the appearance of striae was identified	Discomfort, erythema, hyperpigmentation
Tretti Clementoni et al. (observational study)	2015	Mixed	12	Er:Glass fractional photothermolysis	51–75% improvement in appearance was observed in all patients by blinded reviewers, unblinded reviewers, and 3D computer analysis The mean improvement in the color of striae was 54%	Pain, erythema, and crusting
Wang et al. (non-randomized controlled study)	2016	Mixed	10	1540 nm (Group 1) vs. 1410 nm Er:Glass fractional photothermolysis (Group 2)	Group 1: 33% of patients had good to excellent improvement in appearance, and 66% had mild to moderate improvement Group 2: 28% had good to excellent improvement in appearance, and 72% had mild to moderate improvement The difference in efficacy between the 2 groups was not statistically significant ($p = .747$)	Both groups: pain, pruritus, and hyperpigmentation
Yang and Lee (RCT)	2011	Alba	24	Er:Glass fractional photothermolysis (Group 1) vs. fractional CO_2 laser (Group 2)	Both skin elasticity and width of striae showed statistically significant improvement after treatment with either laser ($p < .001$) There was no statistically significant difference between the two laser modalities	Erythema, hyperpigmentation, pain and crusting

It has been shown to offer some improvement to the appearance of SR, mainly in the form of color normalization. Unfortunately, studies show it to have little to no effect against SA (37).

Naeini et al. (16) identified some possible synergistic effects when used alongside with the CO_2 laser. This may also hold true when used in parallel to non-ablative RF, however, further studies are required in order to quantify this further (38).

Post-inflammatory hyperpigmentation is a significant side effect after treatment with the PDL in the melanin-rich skin types (IV–VI) because melanin acts a competing chromophore with hemoglobin for the light energy (3,10,11,37).

- Er:Glass laser

Treatment with Er:Glass FP employs arrays of microscopic thermal damage at specific depths in the dermis, which in turn stimulate a therapeutic response. Because uninjured tissue surrounds each tiny area of thermal damage, keratinocytes have a shorter migration path, and healing is much quicker (4). In addition, use of the 1550 nm wavelength, targeting water as a chromophore in a pixelated fashion, reduces the risk of pigmentary sequelae in dark-skinned individuals (4).

The skin-rejuvenating effects of FP have been attributed to increased rete ridges in the dermal-epidermal junction, increased mucin deposition, evidence of enhanced myofibroblast activity, and neocollagenesis. Thus far, FP has been successfully used against photodamaged skin, leucodermic scars, acne scars, melasma, thermal burn scars, and surgical scaring (6).

Despite some variability across studies, SD seem to respond moderately well to treatment with this modality. Given some conflicting results across different studies, it is hard to conclude whether both SR and SD respond equally well or not.

Most patients tolerated well the pain associated with this treatment. Side effects were transient and limited to erythema, edema, and infrequent hyperpigmentation.

- Excimer laser

The excimer laser is being used across different medical specialties. In dermatology, it was initially developed for the treatment of localized psoriasis in order to limit the adverse effects of chronic UVB exposure from conventional phototherapy. Following the successful treatment of plaque psoriasis, the uses of the excimer laser have been expanded for treatment of various localized leukodermas, such as vitiligo, hypopigmented scars, as well as that of striae alba (39).

We identified three studies that used this laser against atrophic striae alba and it was shown to be effective in achieving scar regimentation. On direct comparison, outcomes were comparable to those of treatment with UVB light.

A major limitation of this new therapeutic intervention for pigment correction of scars and striae alba is the need for maintenance treatments. Although the frequency of maintenance treatment was not formally evaluated, the pigment levels gradually declined toward base- line values during the follow-up period (13).

- Nd:YAG laser

The Nd:YAG laser is yet another popular modality that is commonly employed against SD. The absorption of laser by its target, oxyhemoglobin leads to improvement in redness. Moreover, like other lasers, it also induces the formation of new collagen thus improving atrophy of the skin and the appearance of striae (24). More specifically, the presence of dilated venules and a superficial perivascular lymphocytic infiltrate in immature striae represent a desirable target for the Nd:YAG laser due to the presence of oxyhemoglobin in the vessels. In addition, the 1064 nm wavelength has good skin penetration and is often used for vascular alterations. Thus, the combination of these qualities enables the photothermal effect of the non-ablative Nd:YAG laser to effectively treat immature striae (14,40).

Moderate but statistically significant clinical results were achieved in most, but not all, studies, with SR being seemingly more responsively to this treatment than SA.

In the treatment of SR in particular, results were found to be comparable to those of microdermabrasion plus TCA, superior to those of tretinoin gel and mesotherapy, and inferior to those achieved by microdermabrasion plus salicylic acid/retinol peels (20).

- CO_2 laser

The ablative fractional CO_2 laser is one of the most widely used devices against SD. It is also commonly used against acne and surgical scars, as well as wrinkles. According to the concept of FP, these lasers deliver energy in a novel beam pattern and ablate only a fraction of the epidermis and dermis in the treatment area, creating microscopic thermal zones. Adjacent to these areas, the epidermis and dermis are spared. With this method, unlike the conventional CO_2 resurfacing laser technique, healing is more rapid, and recovery time is dramatically reduced (18).

This modality was found to be effective in reducing the size of SD, and capable of producing clinically measurable improvement in striae appearance, mainly against mature striae. On direct comparison it was more effective than IPL, fractional microneedling RF, and topical agents, equally effective as treatment with Er:Glass FP, and inferior to microneedling. Furthermore, some synergistic effects were noted when used alongside with the PDL, and fractional microneedling RF (16,23).

Adverse reactions were few and self-limiting. Downtime is however a limitation as it is longer than with any other modality reviewed here. Post-inflammatory hyperpigmentation can also be a problem but it seems to resolve spontaneously in the immediate few months after treatment.

- Diode laser

The non-ablative 1450 nm diode laser has been shown to improve atrophic facial acne scars by increasing the amount of dermal collagen. Against SD, it was only utilized by one study where it did not lead to any meaningful benefits in appearance against either SA or SR. At the same time, a significant incidence of post-laser hyperpigmentation (64%) was also observed (21).

- IPL

IPL is a device that uses a flash lamp that emits a high intensity, non-coherent and polychromatic broad-spectrum light (from 400 to 1200 nm). The light is emitted in pulses with various pulse durations and intervals. A number of cutoff filters are used to deliver a variety of wavelengths (3). It is used in the treatment of telangiectasias, lentigines, vascular malformation, as well as tattoo elimination, facial aging and rhytides (1).

The exact mechanism of action of IPL in the treatment of SD is unknown. It is thought to induce controlled wounds on the skin that subsequently stimulate a healing process, leading to an increased amount of fibroblasts, and collagen fibers (3).

IPL was utilized in a number of studies with variable success rates. Conflicting efficacies were documented between different studies on SD and SA (1,10).

Two different wavelengths of IPL (650 nm and 590 nm) were tested in the literature, with the 590 nm one being the most effective (3).

It is worth noting the good safety profile of IPL, and importantly its benefit of no downtime (1). The occurrence of hyperpigmentation however, can be a significant drawback due to the absorption of light by melanin (3,5).

- RF

RF energy devices are commonly used in the noninvasive management of skin tightening, wrinkle reduction, cellulite improvement, and body contouring enhancement (34). The RF energy is high-frequency alternating electrical current that passes into the dermis and hypodermal tissues without disruption of the epidermal-dermal barrier. The high-frequency oscillating electrical current is transformed into heat, mediating thermal damage to the surrounding connective tissue, which is responsible for the partial denaturation of preexisting elastic fibers and collagen bundles. Initial collagen denaturation within thermally modified deep tissue is thought to represent the mechanism for immediate tissue contraction; subsequent neocollagenesis further tightens the dermal tissue and reduces striae (2,34).

A variety of different forms of RF were used in the literature, often in combination with other treatment methods.

By utilizing bipolar RF in combination with IL, Harmelin et al. (12) achieved significant improvement in the depth of SD and in skin texture and laxity. Interestingly, the treatment regime was effective on both SA and SR. The effect of RF on mature striae is vindicated further by the results of Issa et al. (11) who achieved statistically significant improvement against mature striae by using a combination of fractional ablative RF and topical retinoic acid.

Between the different RF techniques reviewed, fractional RF appears to be the most efficacious, with some combination treatments such as platelet-rich plasma (PRP) and topical retinoic acid offering further synergistic benefits (5,9,11). Interestingly, the combination of fractional RF with bipolar RF and IR light significantly reduces the depth of striae in both immature and mature striae. However, improvement in striae width with this treatment was only mild and statistically non-significant (12).

Even though side effects were mild and transient, pain remains a significant limitation to the use of fractional RF, especially in sensitive areas such as the abdomen (12). The incidence of hyperpigmentation is reported to be lower than that of lasers, especially in darker skin phototypes (7,9).

- Narrow band UVB

Treatment with narrow band UVB has been widely used against psoriasis for many years (27). Against SD, it was utilized in two studies and lead to variable results, with a significant number of patients failing to achieve a meaningful response. Furthermore, no relationship between the type of striae or skin type and efficacy were observed (8).

This method has the advantage of not causing any discomfort at the time of treatment. However, transient hyperpigmentation has been noted to occur in as high as 50% of treated patients (8). Finally, and despite lack of evidence in the literature, the use of ultraviolet light is thought to carry a small theoretical risk of increased skin cancer (8,27).

- IR light

Non-fractional broadband IL is a painless and safe treatment method with promising effects on skin rejuvenation and tightening. Against striae, it was utilized by only one study and lead to poor subjective patient satisfaction scores but with measurable improvement in the 3D skin surface analysis, and histological architecture of striae. Further studies would be required in order to evaluate this modality's true impact against SD (33).

Conclusion

Striae are very common and can be challenging to treat given the fact that no definitive treatment is available that gives consistently good results. Several energy-based devices have been used with various levels of efficacy and adverse reaction profiles.

RF was found to be the most widely researched modality.

A large number of papers did not differentiate between the different types of striae. Furthermore, an absolute comparison between the efficacies of different modalities is difficult due to dissimilar study designs and outcome measures. Keeping this in mind, we found that consistently good results against SA were achieved with RF, the CO_2 laser, and Er:Glass FP. Similarly, in the treatment against SR the best outcomes were achieved after treatment with either the Nd:YAG or Er:Glass lasers.

Cost and availability remain a limitation to the use of energy devices. However, the results from the above review show that certain modalities have a significant role to play in the management of SD, either in isolation or in combination with other energy devices and topical interventions.

Disclosure statement

The authors have no conflicts of interest to declare.

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