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REVIEW ARTICLE

Lasers and lights for the treatment of striae distensae

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Abstract Striae distensae (SD) or "stretch marks" are a common and well-recognized dermatologic entity affecting patients of all ages, genders, and ethnicities. The treatment of SD has long been plagued by disappointing outcomes and remains a frustrating entity for both physicians and patients. While striae may become less conspicuous over time, they rarely resolve without intervention. Inspired by the success of lasers for the treatment of scars and rhytides, these devices have been applied to the treatment of SD in the hopes of achieving similar efficacy.

Keywords Laser · Treatment · Striae distensae · Striae rubra · Striae alba · Stretch marks

Introduction

Striae distensae (SD) or "stretch marks" are a common and well-recognized dermatologic entity affecting patients of all ages, genders, and ethnicities. Clinically, striae are characterized by multiple, linear, red-to-violaceous, atrophic depressions. Striae most commonly involve the outer aspects of the thighs and the lumbosacral region in boys, and the thighs, upper arms, buttocks, and breasts in girls [7]. They are generally acquired after rapid changes in weight (loss or gain), height (e.g., a growth spurt during puberty), or muscle mass (e.g., weight lifting). Striae also commonly occur during pregnancy, and in this context are referred to as striae gravidarum (SG). Additionally, striae may be the result of endogenous or exogenous hypercortisolism, often complicating systemic and topical steroid administration.

Regardless of the context in which they appear, the evolution of striae follows a predictable clinical course. Early, active striae may be pruritic and appear pink to red to violaceous in color. Striae in this stage are referred to as "striae rubra". Over time, they become white or skin-colored depressions with fine wrinkling, closely resembling a scar. Striae in this stage are classified as "striae alba" and are considered permanent. It has been postulated that an early inflammatory response associated with vasodilation that subsides with time, underlies their clinical transformation from a pink raised lesion to their eventual scar-like appearance [32].

The histologic appearance of SD also varies depending on the age of the lesion. A deep and superficial perivascular lymphocytic infiltrate with occasional eosinophils and dilated venules with edema of the upper dermis are characteristic of newly acquired striae. Late-stage striae are significant for scant, elongated collagen bands concentrated within the upper third of the reticular dermis and arranged parallel to the surface of the skin. In the "terminal" stages of striae distensae, there is a thinning of the epidermis due to blunting of the rete ridges and a paucity of collagen and elastic fibers [1, 5].

Striae distensae are a known feature of several clinical conditions, both chronic and acute, with very distinct pathophysiology, making it difficult to determine their true etiology. While the pathophysiology of SD has yet to be fully elucidated, several theories have been proposed. It has been suggested that infection or inflammation trigger the release of a so-called "striatoxin" that damages tissue and creates linear atrophic depressions [10]. Mechanical forces from weight gain or growth that generate progressive stretch creating small intradermal tears have also been identified as a potential etiology; however, there is no consistent causal relationship between growth and the appearance of striae, thus challenging the so-called "skin-stretch hypothesis." Furthermore, gene analysis has revealed a diminished expression of collagen and fibronectin genes in involved tissue, suggesting a role for genetic susceptibility [21].

In the simplest of terms, striae are a form of dermal scarring and their clinical and histologic stages closely parallel those of scar remodeling. For whatever reason, dermal

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collagen ruptures or separates and the resulting gap is replaced with newly formed collagen that orients itself in the direction of local stress forces [5]. Irrespective of the underlying pathology that may incite a cascade of uncertain events, a final common pathway results in the breakdown and tearing of the dermal matrix, which manifests clinically as striae distensae.

The treatment of SD has long been plagued by disappointing outcomes and remains a frustrating entity for both physicians and patients. While striae may become less conspicuous over time, they rarely resolve without intervention. Even with intervention, improvement rather than complete resolution is a more realistic goal. As is true for most conditions, treatment of striae in the early, active phase seems to result in the greatest improvement. Once striae reach a mature, static phase, they are significantly more resistant to treatment and most interventions result in less than favorable outcomes.

To date, there remains no treatment that consistently offers improvement in the appearance of SD. The first treatment modality to provide reliable results was tretinoin cream, but other topical agents, radiofrequency devices, and laser and light therapies have also been employed, albeit with variable outcomes.

Lasers and light therapies

Inspired by the success of lasers for the treatment of scars and rhytides, these devices have been applied to the treatment of SD in the hopes of achieving similar efficacy (Table 1). The usefulness of these laser and light sources may lie in their ability to produce energy that selectively targets oxyhemoglobin in the dilated vessels of striae rubra, or possibly through the effects of laser-induced changes in collagen and elastin formation.

The 308-nm excimer laser

The 308-nm xenon chloride excimer laser emits light energy close to that of narrow-band ultraviolet-B (UVB) light and is used primarily for the treatment of psoriasis and disorders of hypopigmentation. The excimer laser offers increased efficacy over traditional phototherapy through its ability to deliver higher fluences with greater precision in less time [9]. Additionally, excimer light can exclusively target the area of hypopigmentation, thus limiting the inadvertent cutaneous UVB exposure that is of concern with narrow-band UVB light therapy. The 308-nm excimer laser has been used successfully in a handful of studies for temporary repigmentation of late-stage hypopigmented striae alba.

Goldberg et al. investigated the use of the 308-nm excimer laser for treatment-naïve hypopigmented striae alba in 75 patients with Fitzpatrick skin types II–IV. All patients achieved 76 % or greater increase in pigment after a mean of 8.4 treatment sessions. Increased pigmentation beyond the treated area, or splaying, was observed in 31 % of patients. Mild-to-moderate erythema occurred in every patient at some point during treatment; however, there was no correlation between degree of erythema and extent of repigmentation [15]. Similar efficacy data was documented by Alexiades-Armenakas and colleagues who revealed pigment correction rates relative to control of 60–70 % after nine treatments with the excimer laser administered at biweekly intervals [3].

Histologically, the treated striae demonstrated increased melanin content and hypertrophy of melanocytes; however, no improvement in skin atrophy was documented [13, 15]. The 308-nm excimer laser may therefore be considered for temporary re-pigmentation of striae alba with an acceptable success rate and a low incidence of adverse effects. This modality is largely limited by the need for regular maintenance treatments.

The 577-nm copper-bromide laser

The copper bromide laser emits light energy at 577 nm, closely approximating the 585-nm pulsed dye laser. The wavelength of the copper bromide laser also coincides with the maximum absorption peak of hemoglobin, theoretically proffering an advantage over other vascular-specific lasers for the treatment of striae rubra.

In a study of 15 female patients (Fitzpatrick skin types II–III) treated over one to five sessions, five patients achieved complete clearance of their striae while the remaining patients displayed a 50–90 % improvement in depth, width, and color. According to the authors, these favorable results were maintained in 13 out of 15 patients at both 1- and 2-year follow-up [23].

While the results reported by Longo and colleagues suggest that the copper bromide laser is a safe, efficacious, and potentially long-term solution to striae distensae, this remains the only published data reporting on this laser system specifically for the treatment of SD. Further studies are need to replicate and substantiate these findings.

The 585-nm pulsed dye laser

Early in their clinical course, striae rubra are characterized by dilated vessels, which may serve as a selective target for the pulsed dye laser (PDL). Treatment with the PDL has also been shown to increase the amount of elastin in the papillary and reticular dermis of striae distensae [25]. McDaniel and colleagues proposed that the 585-nm PDL may increase fibroblast activity resulting in an increased production of collagen and elastin, thus promoting favorable scar remodeling [24].

Table 1 Summary of lasers and lights used to treat striae distensae

Laser	Study	Parameters	Number of treatments (intervals)
308-nm xenon chloride excimer	Goldberg et al.	Fluence: minimal erythema dose specific to each patient was used (200–900 J/cm^2) Pulse duration, 30 ms Spot size, 0.2–1.8 cm^2	1–9
	Alexiades-Armenakas et al.	Fluence: performed at the minimal erythema dose specific to each patient (100–350 mJ/cm^2) Pulse duration, 30 ns Spot size, 3.2 cm^2	1–10 (2 weeks)
577-nm copper bromide	Longo et al.	Fluence, 4 J/cm^2 (breasts) 8 J/cm^2 (other) Pulse duration, 20–70 ms Spot size, 1.5–nm Overlap, 1/3	1–5 sessions (1 month)
585-nm pulsed dye	Jimenez et al.	Fluence, 3.0 J/cm^2 Pulse duration, 450 μs Spot size,10 mm 10 % overlap	2 (6 weeks)
	Nehal et al.	Fluence, 4.25 J/cm^2 Pulse duration, 450 μs Spot size, 10 mm Overlap, minimal	5–9 (2 months)
	McDaniel et al.	Fluence, 2.0, 2.5, 3.0, or 4.0 J/cm^2 Pulse duration, 450 μs Spot size, 7 or 10 mm	1
	Nouri et al.	Fluence, 3.0 J/cm^2 Spot size, 10 mm	1
1,064-nm Nd:YAG	Goldman et al.	Fluence, 80–100 J/cm^2 Frequency, 2.0 Hz Spot size, 2.5 mm No overlap	Average 3.45 (3–6 weeks)
1,450-nm diode	Tay et al.	Fluence, 4, 8, or 12 J/cm^2 Spot size, 6 mm 1 non-overlapping pass	3 (6 weeks)
Intense pulsed light	Hernandez-Perez et al.	Wavelength, 515–1,200 nm (645 nm used in 80 %) Energy output, 10 at 90 J/cm^2 Fluence: initial 30 J/cm^2 with 10–20 % increase in subsequent sessions guided by skin response Pulse duration, 2 pulses at 2.7 and 4 ms with a 20-ms delay	5 (2 weeks)

McDaniel et al. treated 39 mature striae (average age of 14 years) using varying energy densities and spot sizes. Striae were treated with four different protocols and compared to site-matched controls based on both subjective and objective criteria. Upon subjective evaluation, all protocols resulted in the return of treated striae toward the appearance of normal skin; however, the protocol utilizing a 10-mm spot size and a lower fluence energy, specifically 3.0 J/cm^2, resulted in the greatest improvement. These findings were confirmed histologically with striae treated at lower energy densities displaying elastin content comparable to that of normal skin [25].

Jimenez et al. attempted to discern a difference in the efficacy of the 585-nm PDL for the treatment of striae rubra

versus striae alba by treating 20 patients with skin phototypes II–VI with two treatments, 6 weeks apart. Untreated striae were used as control and clinical parameters were assessed and compared before the first and after the last treatment. A moderate clinical improvement in striae rubra was documented while no apparent clinical change could be observed in mature striae alba. Additionally, the authors strongly recommended against the use of the 585-nm PDL, even at low fluences, in patients with skin phototypes V to VI due to possible permanent dyspigmentation [18].

Pulsed dye lasers have recently been used in conjunction with radiofrequency (RF) devices due to a reported synergistic effect on neocollagenesis [34]. Preliminary studies have shown significant improvement in the overall appearance of SD in the majority of patients who underwent RF ablation with subsequent PDL therapy. Furthermore, all 37 subjects treated using this modality had darker skin phototypes with only one case complicated by transient hyperpigmentation [30].

Despite the success encountered by McDaniel et al. for the treatment of mature striae, subsequent studies have failed to reproduce similar efficacy rates. Therefore, while PDL may effectively reduce the erythema of early, active striae rubra, striae alba fail to consistently demonstrate any clinically apparent change after treatment with PDL [18, 24, 26, 27]. While further studies are needed, RF may also be a useful adjunct to PDL treatment of SD.

The 1,064 nm neodyium:yittrium–aluminum–garnet laser (Nd:YAG)

The 1,064-nm Nd:YAG laser is well-established for the treatment of vascular lesions and has also demonstrated the ability to induce dermal collagen formation when used to treat facial rhytides [14]. The combination of vascular selectivity and collagen induction has proven beneficial in the treatment of immature striae rubra in patients with skin phototypes II–IV [16]. A total of 20 patients successfully underwent treatment with a long-pulsed Nd:YAG laser, with the best results obtained after three treatment sessions. Both patients and physicians were asked to rate improvement of striae as poor, good, or excellent. In 16 patients, the physician and patient rated post-treatment improvement as either good or excellent indicating 30 % to greater than 70 % improvement. Adverse effects were transient and mild [16].

The longer wavelength of the 1,064-nm Nd:YAG effectively lowers the laser's selectivity for melanin, resulting in less epidermal damage when compared to other devices. This translates into an overall more favorable side effect profile and, importantly, allows this laser to be safely and effectively used in darkly complexioned patients when the appropriate settings and epidermal cooling is employed.

The 1,450-nm diode laser

Due to its reported success in the treatment of atrophic facial scars, the nonablative 1,450-nm diode laser was evaluated for its safety and efficacy in a small, cohort of patients with skin phototypes IV–VI. Eleven subjects with striae rubra and striae alba underwent three treatments, receiving either 4, 8, or 12 J/cm^2 at 6-week intervals for half of their lesions while the untreated half served as a control. Dynamic cooling with cryogenic spray was also utilized. While the procedure was well tolerated, with only mild-to-moderate peri-operative discomfort and post procedural erythema, 2 months after the final treatment, physician assessment revealed no improvement in any lesions at any fluence for any of the subjects. Furthermore, transient post-inflammatory hyperpigmentation was observed in 64 % of cases. The authors concluded that the nonablative 1,450-nm diode laser should not be utilized for the treatment of SD in patients with skin phototypes IV–VI [31].

Fractional photothermolysis

Fractional photothermolysis (FP) is a fairly new concept in laser therapy that was developed to overcome the adverse effects associated with traditional ablative laser resurfacing and the diminished efficacy of nonablative lasers [12]. Fractional laser resurfacing can be delivered in either an ablative or nonablative mode. These laser devices generate focused laser energy that is delivered in a microarray pattern, producing small columns of tissue destruction in the epidermis and dermis, termed microscopic treatment zones (MTZs), with intervening islands of healthy tissue. Within these cones of destruction, the induction of tissue remodeling and synthesis of new collagen and elastic fibers occurs. The surrounding unaffected, healthy tissue serves as a structural scaffolding as well as provides nutritional support for the treated zones, offering the advantage of significantly reduced healing times [11].

The difference between ablative and nonablative FP lies in the variable degree of complete vaporization of columns of tissue (ablative) versus thermal injury with residual epidermal necrotic debris (nonablative). The nonablative technique achieves only minimal efficacy and requires multiple treatment sessions over an extended period of time while the fractional ablative technique boasts superior efficacy, albeit with more procedure-related discomfort, post-operative erythema, and recovery time [2].

Fractionated delivery devices demonstrate superior efficacy over other modalities and treatment techniques for photorejuvenation and have proven particularly effective for acne scars, deep facial rhytides, and atrophic scarring. Given the clinical and histologic similarity of

striae to the dermal scarring characteristic of these conditions, comparable outcomes could theoretically be achieved in SD.

Fractional ablative devices vs. nonablative devices

The three ablative wavelengths used for fractional ablative laser resurfacing are the 10,600-nm CO_2 laser, the 2,940-nm erbium:yttirum–aluminum–garnet (Er:YAG) laser, and the 2,790-nm yttrium: sapphire; garnet (YSSG) laser. The difference between these three devices is the ratio of thermal injury to ablation achieved [2]. Studies show that both ablative and nonablative fractional laser resurfacing are safe and effective for the treatment of striae rubra and striae alba, with some studies suggesting greater efficacy in striae alba. However, to date, neither modality has been distinguished as superior to the other (Table 2) [33].

Adverse effects associated with FP, ablative or nonablative, are generally mild and most commonly include transient erythema and edema as well as post-inflammatory hyperpigmentation. Dyschromia is more frequently a complication of the ablative technique, particularly the CO_2 fractional ablative laser, and should therefore be avoided in patients with Fitzpatrick skin types IV through VI [33].

Fractional nonablative

The 1,540-nm erbium:glass laser The 1,540-nm erbium:glass laser is currently the only fractionated laser device that is approved by the United States Food and Drug Administration (FDA) for the treatment of SD. This laser system is equipped with a stamping compression mode of light delivery and therefore offers a deeper and more uniform transmission of energy to the dermis, regardless of an individual's skin topography, conferring a serious technical advantage over its predecessors [8].

De Angelis and colleagues examined the clinical and histologic effects of treatment with the fractioned 1,540-nm erbium:glass laser in 51 patients with SD of various stages. Post-treatment, non-blinded reviewers reported an overall improvement of 50 % or greater for all 51 subjects, while blinded reviewers assessed a subset of 14 images and reported mean improvement of 50–75 %. Side effects were predictable and mild with eight cases of post-inflammatory hyperpigmentation (PIH) observed that completely resolved over days to months. At 18 and 24-months follow-up, no patients experienced a recurrence of their striae.

While there is an obvious need for further studies to corroborate these findings, it appears as though the 1,540-nm fractionated erbium:glass laser is a safe and effective treatment for both striae rubra and alba.

Table 2 Summary of fractional lasers used for the treatment of striae distensae

	Laser	Study	Parameters	Number of treatments (intervals)
Nonablative	1,540-nm erbium:glass laser	de Angelis et al.	Fluence, 35–55 mJ/μb with a 10-mm tip OR 12–14 mJ/μb with the 15-mm tip	2–4 (4–6 weeks)
	1,550-nm erbium-doped laser	Kim et al.	Fluence,15 mJ/MTZ Density,125 MTZ/pass	1
			Pulse Duration, 10-ms pulse duration	
			8 passes were performed for a cumulative energy density of 1,000 MTZ/cm^2.	
		Stotland et al.	Fluences ranging 12–18 J/cm^2 Density, 125–250 MTZs/cm^2	6 (2–3 weeks)
			8–12 passes for total energy of 1.4 to 3.5 kJ per session	
		Bak et al.	Fluence, 30 mJ 8 passes	2 (4 weeks)
		Katz et al.	Fluence, 20–70 mJ 8 passes for a total energy density of 384–1,344 MTZs/cm^2	3–5 (4 weeks)
Ablative	10,600-nm carbon dioxide laser	Lee et al.	Pulse energy, 10 mJ Density, 2 (10 % coverage) 300 Hz	1
			Spot diameter, 1–10 mm	
			1 pass	
		Cho et al.	Fluence, 15 mJ Density, 2, 300 Hz	2 (4 weeks)
			Spot diameter, 0.12 mm	

The 1, 550-nm erbium-doped laser One study investigated the safety and efficacy of the fractionated 1,550-nm erbium-doped laser in six female volunteers, skin phototypes III–IV, for atrophic striae alba on the bilateral buttocks. Topical anesthetic cream and forced-air cooling was used during irradiation. One treatment was administered with two follow-up visits occurring 4 weeks apart.

Improvements in overall appearance were noted in all subjects at 8-weeks follow-up, specifically, in pigmentation and texture. Increased skin elasticity was also observed in FP-treated striae at both 4- and 8-week follow-up; however, these changes failed to achieve statistical significance. Upon histologic examination, treated striae displayed statistically significant thickening of the epidermis as well as enhanced quality and quantity of collagen and elastin fibers, with an overall microscopic appearance closely resembling normal skin. Treatment was well-tolerated by all patients with mild treatment-related pain reported in all six cases and transient hyperpigmentation noted during evaluation of three patients at 4 weeks; however, complete resolution was noted by 8 weeks [19].

Another study evaluating the safety and efficacy of the fractionated 1,550-nm erbium-doped laser was performed by Stotland and colleagues [29] on 14 female patients with Fitzpatrick skin phototypes I–IV, affected by both striae rubra and striae alba of varying etiologies on the abdomen, thighs, and buttocks. Half of each patient's striae were randomized to receive treatment while the remaining untreated lesions served as a site-matched control. A total of six treatments were administered at 2- to 3-week intervals. Striae were evaluated at each visit as well as 1-, 2-, and 3-months post-treatment. Assessment was conducted using a quartile grading scale by four independent dermatologists. Seven of the 14 patients reported a less than 25 % improvement in treated lesions at 3-months and one patient noted improvement greater than 75 % from baseline. The patient who noted the greatest improvement was the only patient of the 14 with striae rubra as opposed to sriae alba. Physician evaluation of eight randomly selected patients at follow-up revealed 26–50 % overall improvement in five out of the eight. However, improvement in wrinkling and dyschromia was less impressive.

Post-treatment edema and erythema was documented in all patients and four cases of papules and one case each of blistering and PIH complicated the 84 total sessions. All adverse effects reported were transient and required no additional intervention. Notably, no patients with Fitzpatrick skin phototype IV experienced PIH. The greater degree of improvement achieved in the one patient with striae rubra is consistent with previous reports that early striae respond more favorably to treatment than late-stage striae alba.

An investigation into the safety and efficacy of FP on Asian skin was also conducted by treating 22 women with SD for a total of two treatments, 4 weeks apart with clinical and histologic evaluation at 1 month post-treatment. Six patients displayed marked improvement in overall appearance, while the remaining 16 patients experienced mild improvement. Surprisingly, the majority of lesions that achieved the greatest overall improvement were clinically defined as striae alba. In these patients, histologic assessment was significant for increased epidermal and dermal thickness 1 month after treatment compared to baseline samples. The authors explained their unusually high efficacy for striae alba from a histologic standpoint. While late-stage striae alba display thinning of the epidermis with flattening of the rete ridges and diminished collagen and elastin in the dermal matrix, striae rubra early in their clinical course have not yet developed these characteristic changes. Thus, hypothetically, only striae alba would benefit from epidermal and dermal collagen regeneration induced by FP devices [6].

Katz et al. reported two cases of patients affected by striae rubra treated with the 1,550-nm erbium-doped laser for three to five sessions performed at 4-week intervals. At 6 to 8 weeks after treatment a more than 75 % improvement in overall appearance was noted in both patients.

Striae are notoriously difficult to treat and arguably more so in ethnic skin where inadvertent epidermal thermal injury is a real concern due to chromophore competition by increased epidermal melanin. The fractionated 1,550-nm Er:Glass laser may therefore provide a safe and effective alternative for darker skin phototypes that are not amenable to treatment with PDL or other systems.

Although there seems to be conflicting evidence on the true level efficacy of the fractionated 1,550 nm erbium-doped laser for striae alba, there has been consistent evidence to support its safe and successful use for the treatment of striae rubra and all investigations have concluded that this fractionated device offers a safe and efficacious therapeutic option for SD, even in moderately complexioned individuals.

Fractional Ablative

The 10, 600-nm carbon dioxide (CO_2) Laser The 10,600-nm CO_2 laser has been shown to be highly efficacious for resurfacing as well as for the treatment of scars due to its ability to stimulate collagen and elastin regeneration and remodeling. Additionally, it has been documented that the fractional CO_2 laser induces neocollagensis to a greater degree than the nonablative lasers [28].

Due to the high risk of pigmentary alteration in ethnic skin, the use of the CO_2 laser in patients with phototypes IV and higher has largely been discouraged; however, when used with appropriate caution, it appears that the fractionated CO_2 systems are safe and efficacious for the treatment of SD with no appreciable increase in risk for PIH.

Twenty-seven female patients, skin phototype IV, were treated using a fractionated CO_2 laser for striae alba in a variety of anatomic sites. All patients were treated with a

single session and at 3-month post-treatment evaluation, 59 % of the patients displayed marked or near total improvement in the clinical appearance of their striae and 74 % of the subjects reported that they were "satisfied" or "very satisfied" with their outcome. The treatment session was mostly without complication; however, post-procedure erythema, transient pruritus, crusting or scaling, and oozing from the treated sites was documented in most patients. Hyperpigmentation was also noted in several patients but resolved within 4 weeks [22].

A split-lesion study comparing the nonablative fractional 1,550-nm Er:Glass laser to the ablative fractional 10,600-nm CO_2 laser was conducted by Yang and Lee [33] on 22 Korean female volunteers (Fitzpatrick skin type IV) with abdominal atrophic striae alba. Each lesion underwent treatment with both lasers for a total of three treatments, 4 weeks apart. The width of the widest striae and skin elasticity were evaluated at baseline and 4 weeks after the last treatment (Table 3). Results revealed that both the nonablative fractional laser and the ablative fractional laser produced statistically significant improvement in overall clinical appearance, skin elasticity, and width of the widest striae over baseline measurements. Assessment by blinded physicians and scoring by the subjects themselves revealed a trend favoring the fractional ablative CO_2 laser over the fractional nonablative Er:Glass laser; however, the difference was not statistically significant. Further studies with larger cohorts are needed to reveal a statistically significant difference between the two modalities, if one does indeed exist, as well as to establish the optimal laser parameters, number of treatments, and treatment intervals for each device.

Intense pulsed light

Intense pulsed light (IPL) is a form of noncoherent, polychromatic light energy delivered in wavelengths between 400 nm and 1,200 nm. The broad spectrum available with IPL makes it an ideal device for the treatment of various dermatologic conditions such as telangiectasia, vascular malformations, lentigines, acne, poikiloderma of Civatte, as well as photoaging and the removal of unwanted hair.

Previous studies have demonstrated that IPL induces neo-collagen formation and potentially improves epidermal atrophy and dermal elastosis, a feature that has recently been exploited for the treatment of SD [17]. Investigation of this modality demonstrated that five IPL treatments at 2-week intervals could result in both clinical and microscopic improvement of abdominal striae alba. While IPL offers the advantage of little to no downtime after treatment, PIH complicated up to 40 % of cases and therefore larger studies are needed to corroborate the safety in striae distensae [17].

Table 3 Yang and Lee split-lesion study: non-ablative vs. ablative

Laser device	Parameters	Number of treatments (interval)
1,550 nm Er:glass	Fluence, 50 mJ Density, 100 MTZs/cm^2 Spot size, 5×10 mm 1 pass non-overlapping	3
10,600 nm CO_2	Fluence, 40–50 mJ Density, 75–100 MTZs/cm^2 Spot size, 8×8 mm	3

Special considerations in ethnic skin

Unfortunately, the use of lasers for scars or striae in patients with skin phototypes IV–VI may result in an

Table 4 Summary of adverse effects associated with laser treatment of striae distensae

Laser	Adverse effects
308 nm XeCl excimer	Pigment splaying (use of an iris handpiece may reduce incidence) Potential for blistering or dyspigmentation; however, this risk is negligible if minimal erythema dose is found prior to the initiation of treatment Erythema is expected and the desired clinical endpoint
577 nm CuBr	Sensation of heat, swelling, and scabbing that resolved within 1 week
585 nm PDL	Purpura (7–10 days) PIH in darker skin phototypes
1,064 nm Nd:YAG	Minimal edema and erythema that resolved within a few hours to a few days
1,450-nm diode	PIH (do not use in skin phototypes IV–VI)
1,540-nm Er:glass	Transient erythema and edema (resolved generally within 2–7 days) Mild and transient PIH (resolved within 1–4 months) has been observed in a minority of patients
1,550-nm Er-doped	Mild procedure-related pain Post-treatment edema and erythema Transient hyperpigmentation Blistering in rare cases
10,600 nm CO_2	Erythema lasting ~4 weeks Transient pruritus, crusting, scaling, or oozing from the treatment site Transient hyperpigmentation (resolved within 4 weeks)
IPL	PIH

unacceptable potential for persistent erythema, scarring, and hyperpigmentation and should therefore be avoided or used with great caution [27]. Jimenez and colleagues suggested that the use of PDL to treat striae rubra should be limited to patients with Fitzpatrick skin phototypes II to IV [18]. Another study comparing the 585-nm pulsed dye laser and the short-pulsed CO_2 laser reported a high incidence of persistent erythema, scarring and hyperpigmentation and recommended that both lasers should be used with extreme caution or avoided altogether in patients with phototypes IV to VI [27]. Furthermore, treatment of striae with the 1,450-nm diode laser should be avoided in similarly complexioned individuals [31].

Future directions

Combined platelet-rich plasma and intradermal radiofrequency

Intradermal RF devices have recently been developed that are capable of delivering high fluences directly to the dermis. These devices were initially developed as a way to enhance filler delivery by passing the filler material through a needle electrode. A small cohort of Asian patients with late-stage SD (duration between 5 and 22 years) were treated with this same device. In place of filler material, autologous platelet-rich plasma was injected into the dermis.

Platelet-rich plasma has a well-documented favorable effect on wound healing through platelet-mediated secretion of growth factors and other metabolites that positively influence wound regeneration and repair [4]. After three sessions of intradermal RF combined with autologous platelet-rich plasma, all patients showed a satisfactory clinical response with 42 % experiencing excellent or marked improvement. The procedure was well tolerated and transient bruising was the only significant adverse effect reported [20].

Conclusion

Disappointing outcomes, regardless of the modality chosen, have long complicated the treatment of SD; however, laser and light systems have recently shown promise for the improvement of these aesthetically distressing lesions. While certain precautions must be made in darker skin phototypes, the adverse effects associated with laser treatment of SD are fairly mild, predictable, and mostly short-lived (Table 4). Larger, controlled studies are still needed to support their safety and efficacy as well as the duration of response. Based on current evidence, it appears that certain devices may be more suited for the treatment of striae rubra versus mature striae alba, with primarily clinical appearance and stage in evolution dictating appropriate treatment.

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