A Systematic Review on Treatment Outcomes of Striae

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BACKGROUND Striae are fine lines on the body that occur following rapid skin stretching (i.e., following pregnancy, puberty, weight change). The aim of this systematic review was to assess the current literature on treatment outcomes associated with striae.

OBJECTIVE (1) To assess the efficacy and safety of different treatment options reported for striae and (2) to determine the most efficient treatment options for each subtype of striae.

METHODS A systematic search was performed on MEDLINE, Embase, and PubMed with no publication date or language restrictions. All articles with original data and treatment outcomes were included.

RESULTS One hundred fifty-one studies on the treatment of striae met inclusion criteria (83% female, mean age at diagnosis = 30.2), and 4,806 treatment outcomes of striae were described. Energy-based devices were the most reported modality (56%; $n = 2,699/4,806$), followed by topicals (19%; $n = 919/4,806$) and combinations (12%; $n = 567/4,806$). The highest rates of complete response were injection-based devices for striae distensae (7%; $n = 12/172$), CO_2 lasers for striae alba (4%; $n = 12/341$), and platelet-rich plasma injections for striae rubra (31%; $n = 4/13$).

CONCLUSION Treatment options for striae are varied, likely indicating a lack of effective treatments due to the diversity in striae subtypes. Improved outcomes in striae management may be achieved with additional research on factors that predict treatment response.

Striae distensae (SD), commonly known as stretch marks, affect up to 88% of the general population.[1] These visible linear scars are approximately twice more prevalent in female patients than in male patients and typically affect individuals aged 5 to 50 years.[2] SD is most commonly observed in the physiological states of growth spurts in adolescence and pregnancy. It can also be observed in pathologic conditions such as Cushing syndrome or as a side effect of corticosteroid therapy.[2] Three proposed etiologies of striae are mechanical stretching of the skin, innate disturbance of the skin, and hormonal changes.[3]

Striae distensae can be separated into 2 main clinical and histopathologic forms, striae rubra (SR) and striae alba (SA).[1] The early-stage lesions of striae are referred to as SR; they present as smooth, raised, and erythematous in color, with signs of inflammation on histopathology. The later permanent stage is known as SA, it shows signs of epidermal atrophy with a pale, hypopigmented, and wrinkled appearance. Striae that develop during pregnancy in a woman are also known as striae gravidarum (SG). As striae often occur from stretching of the skin, the most common anatomical locations include the hips (in women), back (male adolescents at puberty), breasts, abdomen (mainly in SG), buttocks, thighs, knees, and calves.[4–6]

Along with its cosmetic impact, SD can negatively affect a person's quality of life, especially in adolescence and young adulthood when aesthetic anxiety is high.[7] Many individuals seek treatments to improve the appearance and symptoms of SD. However, SD are notoriously hard to treat, especially when they have reached the later stage of SA.[8,9] Although there are many different treatment modalities for SD, there are no official guidelines or consensus on a "gold standard." Single-modality therapies include topical treatments, lasers, light devices, and mechanical needling devices. In recent years, many combination treatments have been reported and may offer higher efficacy than single-treatment modalities. Furthermore, there have been advancements in ablative and nonablative lasers and testing of different laser wavelengths.[9]

An up-to-date evidence-based summary of the efficacy of therapeutic agents for SD is important. The aim of this systematic review was to compare the efficacy and safety of treatments for SD to help clinicians treating this condition.

Methods

A systematic review of the literature was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines and registered with

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PROSPERO (CRD42023451839). A systematic search was performed on MEDLINE, Embase, and PubMed using the following search string: ("striae distensae" or "SD" or "stretch marks" or "striae rubra" or "striae alba" or "striae gravidarum") AND ("treatment" or "therapy" or "therapeutics" or "management" or "laser" or "light therapy" or "microneedling" or "topical" or "retinoid" or "radiofrequency" or "platelet-rich plasma injection").

Title and abstract screening was performed in duplicate by 3 reviewers using Covidence online systematic review software. No publication dates or language restrictions were applied. All articles with original data and treatment outcomes were included. Three reviewers (C.K.Z., L.A.M., and K.K.) conducted screenings and resolved conflicts. Data extraction was completed using a predetermined extraction form.

Outcomes from each study were coded into 3 categories: complete response (CR), partial response (PR), and no response (NR).

Results

A total of 1,384 records were identified from PubMed, Embase, and Medline on August 3, 2023. Seven hundred two original articles remained after removing the duplicates. Following full-text assessment, 151 studies were included in this systematic review (Figure 1).

The most common studies reported were prospective cohort studies (37%), followed by randomized controlled trials (26%), retrospective cohort studies (4%), case series (5%), and case reports (9%) (see **Supplemental Digital Content 1, Table 1**, http://links.lww.com/DSS/B398).

Demographics

The data set included 4,703 patients with a male-to-female ratio of 5% to 83%, yielding a total of 4,806 striae cases. The mean age at diagnosis was 30.2 years (SD = 6.5, range: 8–74), and the mean duration in months was 29.9 (range: 2–144). Most patients had Fitzpatrick skin type III (18%), IV (15%), and II (8%). The most common location of striae was on the abdomen, followed by thighs and hips. Causes of striae were found to be pregnancy, puberty, weight change, corticosteroids, and Cushing disease. In total, 3457 cases (72%) of SD, 628 cases (13%) of SA, 347 cases (7%) of SR, and 374 cases (8%) of SG have been reported (Table 1). Most reported additional findings were self-limited and included mainly erythema and postinflammatory hyperpigmentation, followed by pain, edema, burning sensation, scabbing, and local pruritus.

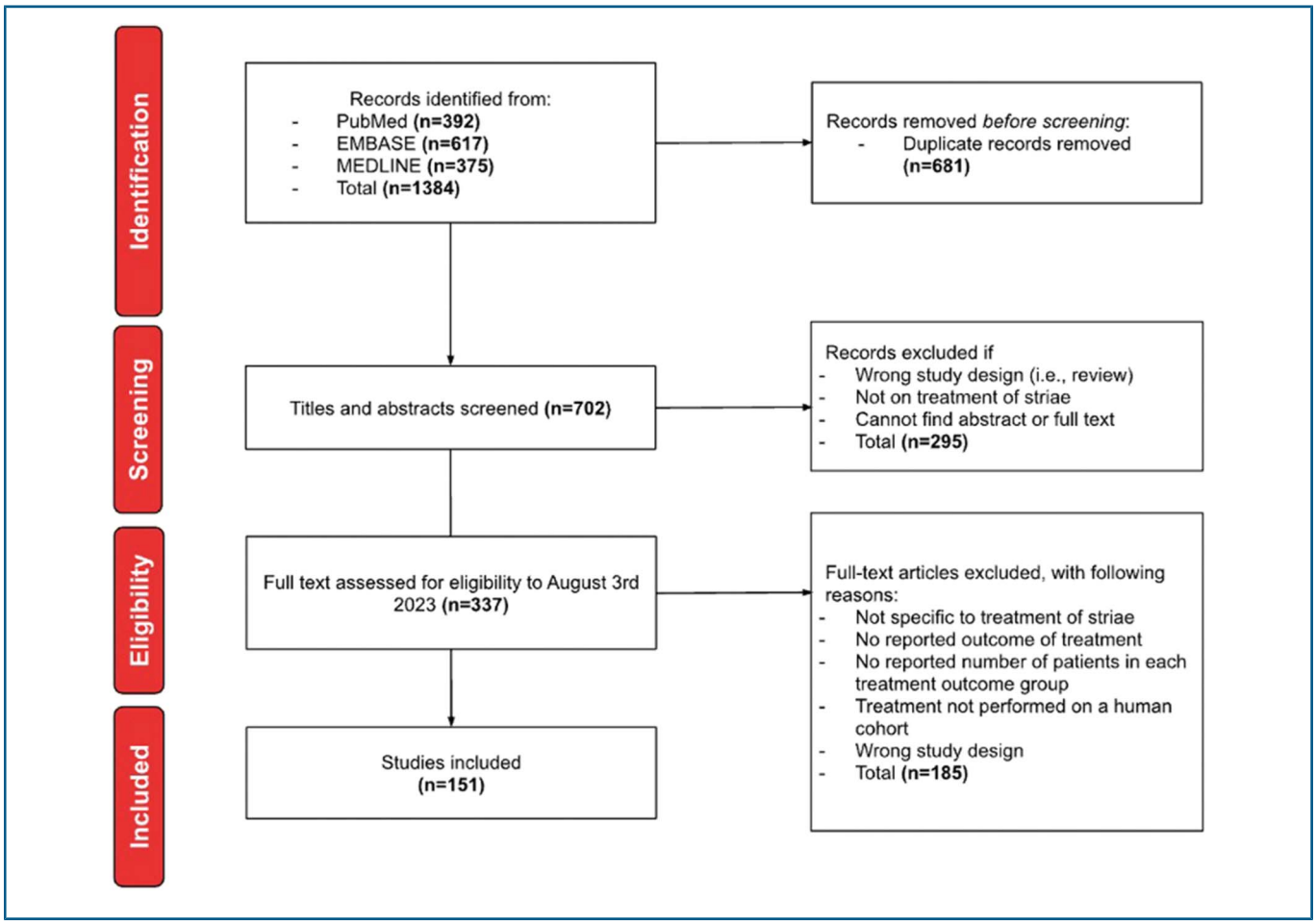

Figure 1. Preferred reporting items for systematic reviews and meta-analysis.

TABLE 1. Patient Demographics	
Demographics	***N* (%) or Mean ± StD (Range)**
Total patients	4,703
Total cases of striae	4,806
Sex (male: female), unspecified	241 (5%): 3890 (83%), 572 (12%)
Age at diagnosis, yr, mean ± StD (range)	30.2 ± 6.5 (8–74)
Fitzpatrick skin type (%)	
Type I	27 (1)
Type II	396 (8)
Type III	824 (18)
Type IV	712 (15)
Type V	110 (2)
Type VI	47 (1)
Unspecified	2,587 (55)
Duration of striae (mo)	29.9 (2–144)
Type of striae (%)	
SD*	3,457 (72)
SR	347 (7)
SA	628 (13)
SG†	374 (8)

* Manuscripts that only used the term "stretch marks" were included in "SD."
† Cases in which the cause of striae was confirmed to be pregnancy were included in "SG."
SA, striae alba; SD, striae distensae, SG, striae gravidarum; SR, striae rubra; StD, standard deviation.

Treatment Outcomes by Type of Striae

Data on treatment outcomes were available for 4,806 cases. Of these, 2,699 (56%) were treated with energy-based devices, 919 (19%) with topical treatments, 567 (12%) with combinations of treatments, 396 (8%) with mechanical devices, and 225 (5%) with injection-based devices (Table 2). When comparing subtypes of striae, the most common treatment modality for SD was energy-based devices (61%; n = 2,116/3,457) similar for SA (54%; n = 341/628), and SR (33%; n = 113/347), and topicals for SG (66%; n = 245/374). In general, the most common treatment response was partial (90%; n = 4,331/4,806), with a very small number of cases achieving CR (3%; n = 142/4,806) and NR (7%; n = 333/4,806). Looking at rates of CR of different treatment courses for all striae (SD, SA, SR, and SG), injection-based devices had the highest complete response rate (CRR) (7%; 16/225), followed by energy-based devices (4%; 107/2,699), mechanical devices (3%; 13/396), and combinations (1%; 6/567).

Treatment Outcomes for Striae Distensae

A total of 3,457 treatment outcomes were reported for SD with the most common treatment course being energy-based devices (61%; n = 2,116/3,457), followed by topicals (14%; n = 491/3,457, combination treatments (10%; n = 336/3,457) and injection-based treatments (5%; n = 172/3,457). Commonly reported energy-based devices included combinations of different lasers (e.g., Nd:YAG and CO_2 lasers) (49%; n = 1,029/2,116) and CO_2 lasers alone (21%; n = 443/2,116). The most common subtype of injection device was standard platelet-rich plasma (PRP) injections (80%; n = 137/172), the most common mechanical device was microneedling (36%; n = 123/342), the most common topical were "natural extract" creams (i.e., *Centella asiatica*, bio-oil, and cocoa butter) (38%; n = 188/491), and the most common combination was energy device with injection-based device (42%; n = 142/336).

The treatment course with the most CRR were injection-based devices (7%; n = 12/172) with all of them being standard PRP (9%; n = 12/137), followed by treatment with energy-based devices (4%; n = 86/2,116) and mechanical devices (4%; n = 13/342). The highest rate of CR was achieved by Nd:YAG laser for energy-based devices (66%; n = 45/68) and microneedling (11%; 13/123) for mechanical devices (see **Supplemental Digital Content 1, Table 2**, http://links.lww.com/DSS/B398).

Treatment Outcomes for Striae Alba

A total of 628 treatment outcomes were reported for SA with the most common treatment course being energy-based devices (54%; n = 341/628), followed by combination treatments (19%; n = 119/628), topicals (12%; n = 74/628), mechanical devices (9%; n = 54/628), and injection-based treatments (6%; n = 40/628). The most reported energy-based devices were CO_2 lasers (25%; 86/341), followed by laser combinations (25%; 84/341). The highest CRR was reported with energy-based devices, which solely included CO_2 laser (14%; n = 12/86) (see **Supplemental Digital Content 1, Table 3**, http://links.lww.com/DSS/B398).

TABLE 2. Comparison of Treatment Outcomes by Type of Striae

Type of Treatment Total = 4,806	Type of Striae				Total
	SD	SA	SR	SG	
Injection-based device N = 225					
CR	12 (7%)	0 (0%)	4 (30%)	0 (0%)	16 (7%)
PR	142 (83%)	37 (93%)	8 (62%)	0 (0%)	187 (83%)
NR	18 (10%)	3 (8%)	1 (8%)	0 (0%)	22 (10%)
Total	172	40	13	0	225
Energy-based device N = 2,699					
CR	86 (4%)	12 (4%)	9 (8%)	0 (0%)	107 (4%)
PR	1966 (93%)	250 (73%)	92 (81%)	121 (94%)	2,429 (90%)
NR	64 (3%)	79 (23%)	12 (11%)	8 (6%)	163 (6%)
Total	2,116	341	113	129	2,699
Mechanical device N = 396					
CR	13 (4%)	0 (0%)	0 (0%)	0 (0%)	13 (3%)
PR	308 (90%)	54 (100%)	0 (0%)	0 (0%)	362 (91%)
NR	21 (6%)	0 (0%)	0 (0%)	0 (0%)	21 (5%)
Total	342	54	0	0	396
Topical N = 919					
CR	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
PR	436 (89%)	64 (86%)	109 (100%)	229 (93%)	838 (91%)
NR	55 (11%)	10 (14%)	0 (0%)	16 (7%)	81 (9%)
Total	491	74	109	245	919
Combinations N = 567					
CR	6 (2%)	0 (0%)	0 (0%)	0 (0%)	6 (1%)
PR	297 (88%)	115 (97%)	103 (92%)	0 (0%)	515 (91%)
NR	33 (10%)	4 (3%)	9 (8%)	0 (0%)	46 (8%)
Total	336	119	112	0	567

CR, complete response; NR; no response; PR, partial response; SA, striae alba; SD, striae distensae; SG, striae gravidarum; SR, striae rubra.

Treatment Outcomes for Striae Rubra

A total of 347 treatment outcomes were reported for SR with the most common treatment course being energy-based devices (33%; n = 113/347), followed by combinations (32%; n = 112/347), topicals (31%; n = 109/347), and injection-based devices (4%; n = 13/347). Within energy-based devices, the most reported treatment subtype was intense pulsed light (43%; n = 49/113), and the most common combination was an energy-based with a mechanical device (45%; n = 50/112). The highest rate of CR was achieved with CO_2 lasers (100%; 8/8), followed by PRP injections (31%; n = 4/13) (see **Supplemental Digital Content 1, Table 4,** http://links.lww.com/DSS/B398).

Treatment Outcomes for Striae Gravidarum

A total of 374 treatment outcomes were reported for SG with the most common treatment course being topical treatments (66%; n = 245/374), followed by energy-based devices (34%; n = 129/374). There were no reports of mechanical devices, injection-based devices, or treatment combinations. Within topical treatments, the most commonly reported were "natural extract creams" (87%; n = 213/245), with 94% achieving PR (n = 201/213). Within energy-based devices, the most common were laser combinations (51%; n = 66/129) and nonablative fractional lasers (39%; n = 50/129). There were 8 cases (40%; n = 8/20) of CR reported with the use of tretinoin (see **Supplemental Digital Content 1, Table 5,** http://links.lww.com/DSS/B398).

Discussion

This systematic review comprehensively summarizes the different treatment approaches and outcomes in striae, more specifically the most efficacious therapies in SD, SR, SA, and SG.

Striae distensae affect a substantial proportion of the global population but remain therapeutically challenging to

manage. In fact, there are very few systematic reviews on SD treatment and no consensus or guidelines on the best management for this condition. A total of 151 studies representing 4,806 striae cases were included in this systematic review.

Our systematic review demonstrates that SD affect female patients considerably more than male patients as 83% of our striae cases were female patients, which is similar to previous epidemiological studies.[10] The majority of the studies looked at the efficacy of striae treatments in Fitzpatrick skin types II, III, and IV. This suggests a lack of evidence for SD treatment in people with extremes of the Fitzpatrick scale, and it has been shown that therapeutic outcomes depend on Fitzpatrick skin type.[11] Furthermore, heterogeneity in response within a given treatment category may depend on ethnic composition/Fitzpatrick skin type of participants, thus further contributing to the variability of responses observed.

Treatment of Striae Distensae

Previous literature has reported that within single therapies, topical treatments and energy-based devices were the most used devices to treat SD.[12] Similarly, our review reported the 2 most commonly used modalities to be energy-based (2,699 cases) and topicals (919 cases).

Although energy-based devices were the most used treatment modality, injection-based devices had the highest rate of CR for SD (7% for injection-based devices vs 4% for energy-based devices), all achieved by PRP injections (CRR = 7%; n = 12/137). However, it is important to note that PRP also caused a high degree of NR in SD. The difference in response may be attributed to the patient's skin type, patient age, or duration of striae (early vs late lesion). Unfortunately, the studies in question did not report on these characteristics. Previous literature has reported that PRP has a potent anti-inflammatory action that can reduce inflammatory symptoms associated with SR, but not SA where the scarring process is already established; therefore, it is possible that the CR seen with SD were early striae lesions while the NR cases were later mature/atrophied striae lesions.[13]

Regarding the efficacy of energy-based devices as single treatment modalities, 3 modalities have shown CR in some patients, Nd:YAG laser (66%) followed by intense pulsed light (IPL) (33%) and CO_2 laser (5%). Interestingly, CO_2 lasers used as a single therapy showed a higher nonresponse rate (9%) than CR rate (5%). Past studies have also suggested that Nd:YAG laser causes less postinflammatory hyperpigmentation than fractional CO_2, which could be a better option for darker Fitzpatrick skin types.[9] Although the use of Nd:YAG laser as a single therapy proves to be the most effective SD treatment, the use of CO_2 laser combined with PRP injections achieved a 17% CRR (n = 6/36) as well. The combination of PRP with the mechanical-based subcision method (a more precise form of microneedling) showed a PR in all 20 cases (partial response rate (PRR) = 100%; n = 20/20). In the future, it may be valuable to compare the difference in efficacy between PRP with subcision versus PRP with microneedling, and even the use of all 3 modalities together, as previous studies have suggested the synergistic effect between microneedling and subcision in other types of atrophic scars (i.e., acne scars).[14]

In sum, although the use of energy-based devices (i.e., Nd:YAG laser, CO_2 laser, and IPL) to treat SD has proven to be popular and effective, the treatment outcome of SD for each treatment modality depends greatly on the type of striae (i.e., striae alba vs rubra).

Treatment of Striae Rubra

The treatment modality most used in SR was energy-based devices, more specifically intense pulsed light (IPL) and pulse-dye laser (PDL). Although both treatment courses allowed for the improvement of SR, IPL was shown to be more efficient (94%; n = 46/49 PRR) than PDL (77%; n = 27/35 PRR). Intense pulsed light and PDL may improve the appearance of SR due to their ability to increase collagen fiber production and reduce erythema. Notably, PDL may cause more adverse events, especially in darker skin types.[15]

We found that fractional CO_2 laser achieved the highest CRR for SR with all 8 cases (100%) reported achieving CR. However, this treatment is also known to cause significant side effects (i.e., pain, burning, itchiness), making it less desirable as a treatment option. Another modality that showed CR was PRP injections, which achieved a CRR of 31%. This further reinforces previous literature that testifies PRP's ability to reduce inflammatory symptoms of SR.[13]

The review of the literature suggests that both PRP and IPL show promising results for the treatment of SR. However, there were no studies investigating the use of a combination of PRP with PDL or IPL, which could prove to be an effective combination treatment as both modalities individually allow for some degree of CR. In addition, the study of other vascular lasers such as potassium titanyl phosphate (KTP) (532 nm) and Nd:YAG (1064 nm) would be useful in determining the optimal vascular laser technology for SR.

Treatment of Striae Alba

The most reported treatment modality for SA was energy-based devices, mainly fractional CO_2 lasers (86 cases). The combination of CO_2 lasers (or Erbium:YAG) with mechanical devices such as microneedling may help achieve better more consistent therapeutic results, as suggested by this review (19 cases of excellent response) and previous literature.[16]

Mechanical microneedling consistently allowed for some degree of improvement of SA (100% PR; n = 54/54 cases). Furthermore, its relatively low cost, ability to be used over large body surface areas, and low risk of causing thermal injury such as hyperpigmentation have resulted in this treatment modality's increasing usage.[17]

The results of this study demonstrate that the most efficient topicals to treat SA were glycolic acid-based products (100% PR), beta-glucan–based products (100% PR), and "natural extract creams." Glycolic acid-based topicals are believed to function by increasing melanin through collagen synthesis and matrix degradation.[18]

Nonetheless, topicals remain less effective than other treatment modalities as none led to CR. By contrast, to SR, the data backing the effectiveness of tretinoin creams in SA are not convincing as there are more cases of NR (56%) than PR (44%). In fact, it has shown to be less effective to "natural extract creams" (100% PR), which also cause less skin irritation in comparison with tretinoin.

Overall, the treatment of SA is a more difficult-to-treat type of treatment compared with SR, as it is less responsive to laser and light therapies. Still, fractional lasers including CO_2 lasers exhibit the strongest results for SA repigmentation and collagen/elastin induction, especially when combined with mechanical modalities such as microneedling. A newer injection-based modality, cold-atmospheric pressure plasma, also showed promising results in a recent randomized controlled trial where all 20 patients demonstrated some degree of improvement with >50% showing great improvement in their SA with minimal side effects.[19] Larger studies will be needed to explore the efficacy of this treatment modality.

Treatment of Striae Gravidarum

For the treatment of SG, studies included both currently pregnant women and postpartum women. Although information on gestational age or postpartum time was not collected as part of our review, evidence suggests that treatment is most effective during the early stages of SG.[20] The most common treatment modality reported was topicals (245 cases), and the second and last treatment modality was energy-based devices (129 cases). The common use of topicals in SG could be attributed to being less invasive and less likely to impact pregnancy. We found that CR was achieved by 8 cases (40%) of tretinoin treatment of SG, which is consistent with previous findings that daily use of tretinoin results in global improvement of SG.[20] Similarly, studies on SG have shown that tretinoin may improve the clinical manifestations of early SG, but that its efficacy in late SG is inconclusive.[18] Past studies have also shown that the combination of tretinoin with glycolic acid or ascorbic acid may also lead to improvement of SG although no studies have compared tretinoin as a single therapy versus tretinoin with another topical.[20] Conclusive safety data on topical tretinoin in pregnancy are lacking.

Energy-based devices have only been reported in nongestational SG, with nonablative lasers being the most used. This modality was able to achieve acceptable improvement in SG. Fractional CO_2 lasers were less reported in SG most likely due to being more painful and causing longer recovery times.

In sum, topical treatments remain the most popular and most efficient choice for the treatment of SG. Further studies evaluating the use of tretinoin alone versus other topicals (i.e., adapalene, tazarotene, trifarotene) are needed in patients with SG.

Limitations

This study has several limitations. The categorization of treatment outcomes as NR, PR, and CR does not include the mild or excellent subcategories of partial responses to treatment, which may be satisfactory to some patients. Furthermore, the majority of studies included in this systematic review do not report on the different patient characteristics for those who had complete versus partial versus NR, limiting analysis of confounding factors such as age, gender, ethnicity, and Fitzpatrick skin type.

Conclusion

In conclusion, although there are currently no standardized guidelines on the treatment for SD, this comprehensive systematic review on the most prevalent, recent, and effective therapeutic classifies existing treatments based on their response rate and on striae subtype. This systematic review suggests that no treatment modality is consistently effective for each subtype of SD. Although the use of energy-based devices to treat SD has proven to be popular and effective, the treatment outcome of SD for each treatment modality depends greatly on the type of striae. For SR, both PRP and IPL show promising results. However, for SA, which is more difficult to treat, fractional CO_2 laser remains the most effective therapy, especially when combined with mechanical modalities such as microneedling. Finally, for SG, topical treatments remain the most reasonable choice. Future comparative studies should focus on measuring the degree of striae treatment response by not only striae subtype but also patient characteristics such as age, striae location, and Fitzpatrick skin type.

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