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LITERATURE REVIEW

Exploring the clinical studies of surgical acne scar management: a 10-year systematic review of modalities and outcomes

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ABSTRACT

Acne scars are permanent sequelae of acne vulgaris, classified into hypertrophic, keloid, and atrophic types. Treatment strategies include non-invasive, minimally invasive, and invasive modalities. This systematic review evaluates clinical studies from the past decade on surgical and related interventions for acne scars. Using PRISMA guidelines, searches were conducted on PubMed, Scopus, and Epistemonikos with keywords related to "acne scar" and "surgical therapy." Twenty-four studies met the inclusion criteria out of 396 screened articles. The modalities examined encompass TCA CROSS, radiofrequency (RF) micro-needling, fractional microplasma RF, fractional bipolar RF, fractional CO_2 laser, erbium YAG (2940 nm), 1550 nm erbium, 1540 nm erbium glass, subcision, punch techniques, microdermabrasion, needling, platelet-rich plasma (PRP), hyaluronic acid fillers, hybrid energy devices, trifractional technology, and human adipose-derived stem cell exosomes (ASCE). Results demonstrated variable efficacy, with predominantly positive outcomes across modalities. Specific treatments showed better suitability for certain scar types; however, all carry potential risks of adverse effects, emphasizing the need for cautious application and patient management. Limitations include small sample sizes and heterogeneity among studies, which may affect the generalizability of findings. This review highlights the diversity of surgical and minimally invasive options for acne scar management, supporting tailored treatment approaches based on scar morphology and patient factors.

1. Introduction

Acne is a prevalent inflammatory disorder of the pilosebaceous glands, characterized by nodules, pustules, inflammatory papules, and comedones (Boen & Jacob, 2019). It typically begins at puberty, affecting 95–100% of teenage boys and 83–85% of adolescent girls, with 12–14% of cases persisting into adulthood (Fabbrocini *et al.*, 2010). Acne scars, which can affect up to 95% of patients, represent one of the most severe and distressing long-term consequences of the disease (Salameh *et al.*, 2022). These scars significantly impair quality of life, often leading to decreased self-confidence, social withdrawal, and depression, thereby impacting both personal and professional domains (Sadick & Cardona, 2018).

1Scarring primarily results from severe inflammatory nodulocystic acne but can also develop from superficial inflammation or by squeezing and traumatizing lesions with fingernails (Patel *et al.*,

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2010). Based on collagen hyperproliferation or loss, acne scars are classified as hypertrophic, keloid, or atrophic. Multiple scar types can coexist within the same individual and on the same skin area (Basta-Juzbašic, 2010; Maibach & Gorouhi, 2011). Approximately 80–90% of affected individuals develop atrophic scars, which appear as skin indentations caused by collagen loss and dermal destruction due to inflammation (Patel *et al.*, 2010; Abdel Hay *et al.*, 2016). These atrophic scars are further categorized into three primary types: ice pick (60-70%), rolling (15-25%), and boxcar (20-30%) (Jacob *et al.*, 2001).

Kannangara (2015) classified acne scar management into three categories: non-invasive (topical therapies, nonablative laser/radiofrequency, light therapy), minimally invasive (subcision, chemical peels, TCA CROSS, microdermabrasion, skin needling, fillers, intralesional steroids, fractional photo-thermolysis), and invasive procedures (punch techniques, laser resurfacing) (Kannangara, 2016). This systematic review aims to synthesize recent clinical studies from the past decade focusing on surgical and related modalities for acne scar treatment.

2. Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines. Articles were identified through searches of PubMed, Scopus, and Epistemonikos using the following strategy: ("Scar acne" AND ("Surgery" OR "Chemical Agent" OR "Laser" OR "Radiofrequency" OR "Subcision" OR "Punch" OR "Dermabrasion" OR "Needling" OR "JVR" OR "PRP" OR "LRP" OR "Filler")). Filters applied included Clinical Study, Clinical Trial, Phase I, Phase II, Phase III, Phase IV, Multicenter Study, Observational Study, and Randomized Controlled Trial, with publication dates from 2012 to 2023.

Eligible articles were selected based on predefined inclusion and exclusion criteria. The research questions were formulated using the PICO framework: (P) patients with acne scars; (I) dermatologic surgical interventions; (C) placebo or pharmacologic therapies or no comparator; (O) improvements in acne, skin texture, enlarged pores, scar reduction, or side effects. Inclusion criteria comprised original research articles published in English within the last decade (2012–2023), including randomized controlled trials, clinical studies, and observational studies. Exclusion criteria included editorials, reviews, case reports, meta-analyses, and articles published before 2012.

After completing the literature search, the similar articles were de-duplicated. The first screening was based on titles and abstracts identified through the scientific database. Then, the screening after full-text retrieval was conducted using eligibility criteria. The selection process results were reported based on the PRISMA flowchart diagram. Data extraction was performed using the first author's name, year of publication, study design, number of participants, indication, study duration, acne scars surgery technique, and study outcomes. The studies that met the eligibility criteria were analyzed descriptively for each type of treatment for acne scars.

3. Results and Discussion

The literature search yielded a total of 396 articles from the specified databases. After removing duplicates, 317 articles were excluded. Screening titles and abstracts narrowed the pool to 79 articles, with 74 undergoing full-text review; among these, 47 were not retrieved, leaving 27 articles for eligibility. Ultimately, 24 studies met the inclusion criteria (Figure 1). These studies investigated various surgical and minimally invasive modalities, including TCA CROSS (3 studies); Radiofrequency (RF) micro-needling (3 studies); Fractional Microplasma RF (1 study); Fractional Bipolar RF (1 study); Fractional CO_2 laser (FCL) (6 studies); Fractional Erbium YAG (2940 nm) (2 studies); 1550 nm Erbium (2 studies); 1540 nm Erbium Glass (1 study); Subcision (6 studies); Punch technique (1 study); Microdermabrasion (1 study); Needling (1 study); Micro-needling (3 studies); Platelet-rich Plasma (PRP) (7 studies); Hyaluronic Acid (HA) Filler (2 studies); Hybrid energy (1 study); Trifractional technology (1 study); and Human Adipose Tissue Stem Cell-derived Exosomes (ASCE) (1 study).

3.1. Trichloroacetic Acid (TCA)

The TCA CROSS technique involves the focused application of high-concentration TCA on atrophic scars, especially ice-pick scars. Nofal *et al.* (2014) demonstrated significant scar reduction ($p < 0.001$) using 100% TCA with a frosting technique. Abdel-Magiud *et al.* (2020) reported increased serum collagen III and clinical improvement after 4 months. Mumtaz *et al.* (2021) observed a significant decrease in scar scores, improving from 38.70 ± 4.80 to 10.09 ± 3.58 following 50% TCA CROSS (Mumtaz *et al.*, 2021).

3.2. Radiofrequency (RF)

Radiofrequency (RF) therapy is widely utilized in skin rejuvenation and is particularly effective for treating atrophic acne scars, including ice pick, boxcars, and rolling scars (Simmons *et al.*, 2014). Several studies have demonstrated its benefits for these scar subtypes.

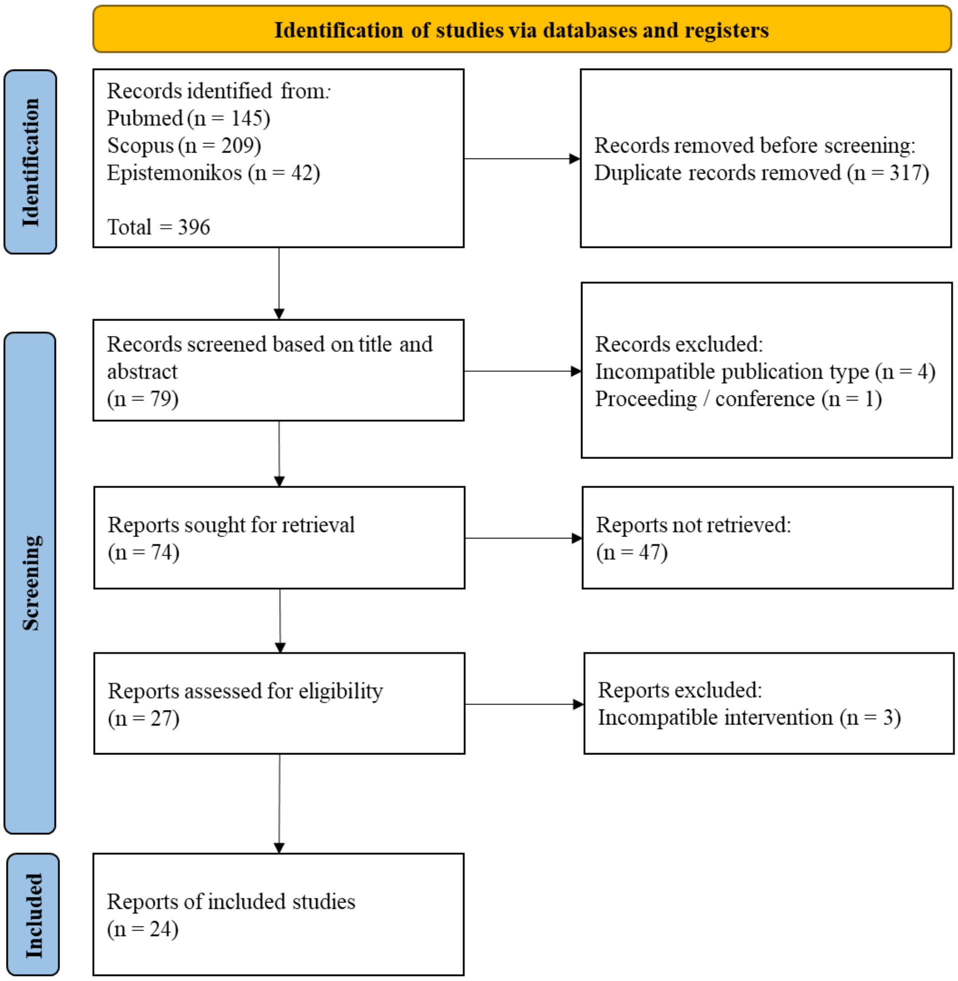

Figure 1. PRISMA Flowchart Diagram

Zhang *et al.* (2013) developed a fractional Microplasma RF device that delivers high-energy focused RF for facial treatment. Their findings indicated that fractional Microplasma RF achieved comparable scar reduction to fractional CO_2 laser but with higher patient satisfaction and fewer side effects, notably reducing post-inflammatory hyperpigmentation.

Similarly, Rongsaard and Rummaneethorn (2014) reported significant improvement in acne scars using fractional bipolar RF, with minimal epidermal disruption and side effects, leading to notable improvements in scar texture and severity. Kwon *et al.* (2017) found that combining fractional micro-needling RF with nonablative fractional laser (NAFL) yielded significantly faster and greater improvements in scar reduction than using NAFL alone.

Additionally, Faghihi *et al.* (2017) observed that pairing fractional micro-needling RF with subcision enhanced scar improvement and higher patient satisfaction compared to either modality alone. Kaçar *et al.* (2020) demonstrated that fractional RF and fractional CO_2 laser effectively improved atrophic scars, with laser therapy producing slightly better clinical outcomes, albeit with increased discomfort and oedema. Emam *et al.* (2022) suggested that micro-needling RF might be more effective at inducing skin thickening than laser therapy, reinforcing its suitability for improving scar texture.

3.3. Laser

Ablative laser techniques for skin resurfacing generally fall into two categories: fractional CO_2 laser (FCL) and erbium-doped yttrium aluminium garnet (Er: YAG) lasers (Keyal *et al.*, 2013). FCL has demonstrated significant improvement in atrophic acne scars after three sessions. However, temporary side effects such as erythema and scaling typically last around 10.2 and 12.3 days, respectively, affecting approximately 36.4% of patients (Zhang *et al.*, 2013). Gawdat *et al.* (2014) reported that FCL alone achieved an excellent response in 26.7% of patients, indicating its efficacy. In contrast, Abdelwahab *et al.* (2022) found that combining FCL with subcision yielded significantly better clinical outcomes but with an increased incidence of side effects.

The second modality, Er: YAG laser, involves several wavebands, with notable results reported at

Table 1. Data extraction of eligible studies.

No	Author, year	Disease	Populations	Surgical procedures
1.	Zhang *et al.*, 2013	Atrophic acne scars	10 patients (ages range 21 – 35 years) with Fitzpatrick skin type III	Fractional Microplasma RF and FCL
2.	Alam et al., 2014	Acne scar	20 healthy adults (age range, 20-65 years)	Needling
3.	Gawdat *et al.*, 2014	Atrophic acne scars	Thirty patients (14 males and 16 females, Fitzpatrick skin types III–V)	PRP and FCL
4.	Rongsaard & Rummaneethorn, 2014	Atrophic acne scars	20 patients (age range, 18–55 years) with Fitzpatrick skin types III to V	Fractional Bipolar RF Device and Fractional Erbium-Doped Glass 1,550-nm Device
5.	Nofal *et al.*, 2014	Atrophic acne scars	45 patients with atrophic acne scars of different durations, types, and severities.	PRP, TCA CROSS, and PRP combination with needling
6.	Nilforoushzadeh *et al.*, 2015	Rolling scars	8 patients with rolling scars caused	Subcision with cannula
7.	Al-Dhalimi & Jaber, 2015	Atrophic acne scars	21 patients (age range, 20 – 45 years)	Fractional 1540 nm erbium glass laser
8.	Cachafeiro *et al.*, 2016	Atrophic acne scars	Forty-two patients (age range, 16 – 50 years)	Fractional Erbium Laser 1,340 nm and micro-needling
9.	Yu & Abat, 2016	Acne scars	13 patients with Fitzpatrick skin type IV and V	Hybrid energy and Trifractional technology
10.	Anupama & Wahab, 2016	Acne scars	40 patients (mean age, 22.63±3.32 years)	Micro-dermabrasion
11.	Kwon *et al.*, 2017	Atrophic acne scars	25 patients (18 men and 7 women, age range 19–54 years), 12 with Fitzpatrick skin type III and 13 with type IV	Laser 1,550-nm Erbium-glass and Micro-needling RF
12.	Faghihi *et al.*, 2017	Atrophic acne scars	25 patients (age means 30.08±4.94 years) with Fitzpatrick skin type II-IV	Fractionated microneedle RF with and without Subcision
13.	Kotb *et al.*, 2018	Atrophic acne scars	35 patients (age mean, 24.7±6.8) with Fitzpatrick skin type I – IV	Micro-needling and PRP
14.	Bhargava *et al.*, 2019	Atrophic acne scars grade IV	30 patients (age range, 21 – 37 years) with Fitzpatrick skin type III – V	Subcision, needling, and PRP
15.	Mahamoud *et al.*, 2020	Atrophic acne scars	30 patients (age range, 25 – 44 years) with Fitzpatrick skin types III–V	FCL combined with injection of intradermal PRP and HA non-cross-linked
16.	Kwon *et al.*, 2020	Atrophic acne scars	25 patients (18 men and 7 women, age range 19–54 years), 12 with Fitzpatrick skin type III and 13 with type IV	FCL and ASCE
17.	Arsiwala *et al.*, 2020	Atrophic acne scars	33 patients (age mean, 24.36±4.37) with Fitzpatrick skin type III – V	FCL and combined with topical PRP
18.	Abdel-Magiud *et al.,* 2020	Acne scars	70 patients (age mean 23.93±5.51)	Micro-needling Dermaroller, chemical reconstruction using TCA, punch excision, Subcision
19.	Nilforoushzadeh *et al.*, 2020	Rolling scars	100 patients	Subcision with cannula

No	Author, year	Disease	Populations	Surgical procedures
20.	Kaçar *et al.*, 2020	Acne scars	27 patients (age range, 17 – 33 years)	FCL and fractional RF
21.	Chen *et al.*, 2021	Concave acne scars	90 patients (age range, 18 – 35 years) with Fitzpatrick skin type III and IV	2940 nm Er YAG laser with Microlaser-peeling mode (MM) and laser fractional ablative mode (FM)
22.	Mumtaz *et al.*, 2021	Atrophic acne scars	92 patients (age range, 20 – 40 years)	Intradermal PRP and 50% TCA CROSS
23.	Abdelwahab *et al.*, 2022	Atrophic acne scars	40 patients (age range, 18 – 40 years) with Fitzpatrick skin type II-IV	Subcision, with FCL or cross-linked HA
24.	Emam *et al.*, 2022	Atrophic acne scars	21 patients (age range, 20 – 41 years) with Fitzpatrick skin type II-IV	Fractional Laser Er: YAG and micro-needling RF

different wavelengths. A 1340 nm fractional Er: YAG laser demonstrated significant scar improvements, with nearly all patients showing positive outcomes; however, post-treatment erythema lasted an average of 3 days per session (Cachafeiro *et al.*, 2016). The 1540 nm erbium glass laser, administered at two-week intervals, resulted in moderate scar improvement in 58% of patients, with a statistically significant reduction in severity (Al-Dhalimi & Jaber, 2015). The 1550 nm erbium glass laser also showed promising results; both Rongsaard *et al.* (2014) and Kwon *et al.* (2017) documented significant improvements in scar texture and severity, though side effects such as pain and dry skin could occur. The 1550 nm laser is particularly valued for its collagen-stimulating effects and scar-type-specific benefits.

Additionally, a 2940 nm erbium laser used in combination mode achieved the best scar reduction but was associated with more pain and pigmentation changes than microlaser-peeling and fractional modes (Chen *et al.*, 2021). Another study demonstrated significant scar improvement, measured visually and through increased epidermal and dermal thickness, after treatment with Er: YAG laser compared to microneedling (Emam *et al.*, 2022). FCL and Er: YAG lasers are especially effective for atrophic scars, with optimal results in rolling, superficial boxcars, and ice-pick scars. FCL is particularly effective for dotted, ice pick, and V-shaped scars, whereas Er: YAG lasers show good to excellent results in ice pick and shallow boxcar scars, with moderate outcomes for deeper boxcar and rolling scars (Petrov & Pljakovska, 2016).

3.4. Subcision

Scalpel subcision may be an excellent candidate for managing acne scars, particularly for treating rolling scars. Six studies evaluated the subcision technique for acne scars in this systematic review. Modified subcision with a metal spinal needle cannula proved highly effective in improving acne scars. Studies by Nilforoushzadeh *et al.* showed nearly 90% of patients experienced significant scar reduction in depth, texture, and overall appearance. Cannula subcision also offered a safer alternative to needle subcision, significantly less bruising, swelling, and scar formation. (Nilforoushzadeh *et al.*, 2015; Nilforoushzadeh *et al.*, 2020)

Faghihi *et al.* (2017) proved that combining the subcision technique with Fractional Micro-needling RF can significantly improve acne scars. Bhargava *et al.* (2019) also combined the subcision technique with needling and PRP. On the other hand, Abdel-Magiud *et al.* (2020) discussed various modalities, including subcision. A total of 18 patients were given subcision management and showed significant improvement in acne scars four months after the last therapy session. Mean serum collagen III was significantly higher in all patients of the subcision therapy group compared to the control group ($p < .001$). Combined subcision with either cross-linked HA or FCL also significantly outperformed subcision alone for improving facial atrophic acne scars, with both options showing superior clinical outcomes compared to subcision alone (Abdelwahab *et al.*, 2022).

3.5. Punch Technique

Punch excision is a technique commonly used for deep ice-pick or boxcar acne scars, leveraging methods like punch biopsy, which is typically employed for diagnosing inflammatory dermatoses (Kannangara, 2016). This approach is practical for scar removal, providing precise excision of the targeted tissue. A study involving 18 patients showed significant improvements in acne scars four months post-treatment. These patients exhibited significantly higher mean serum collagen III levels compared to the control group ($p < .001$), indicating improved collagen formation and scar healing (Abdel-Magiud *et al.*, 2020).

3.6. Microdermabrasion

Microdermabrasion is a superficial, minimally invasive technique that utilizes pressurized particles, such as aluminium oxide crystals, to abrade the skin mechanically. This procedure is primarily indicated for atrophic acne scars of mild to moderate severity and is less effective for more profound or severe scar types. It offers a safe and gentle method for scar improvement, with 22% of patients achieving good results and 30% reporting satisfaction (Anupama & Wahab, 2016).

3.7. Platelet-rich Plasma (PRP)

Platelet-rich plasma (PRP) is a concentration of autologous human platelets suspended in a small plasma volume. It contains high growth factors such as platelet-derived growth factor, transforming growth factor-β, vascular endothelial growth factor, and epidermal growth factor, which play key roles in tissue regeneration and collagen synthesis. PRP has been used to treat acne scars, notably showing benefits for rolling and boxcar scars, with some improvement observed in ice-pick scars (Betaubun *et al.*, 2020; Nofal *et al.*, 2014). In this systematic review, with seven studies, PRP was the most studied modality for acne scars.

Microneedling combined with PRP has demonstrated promising results, especially for deep scars (Nofal *et al.*, 2014). Gawdat *et al.* (2014) reported that combining fractional CO_2 laser (FCL) with PRP yielded superior scar improvement compared to FCL alone, and both topical and intradermal PRP showed similar efficacy. Kotb *et al.* (2018) observed that PRP with micro-needling significantly reduced scar severity, decreasing scores from 3.2±0.7 to 1.8±0.6 ($p < 0.001$). Additionally, combining subcision, needling, and topical PRP improved outcomes by ≥50%, surpassing results achieved with subcision and needling alone (Bhargava *et al.*, 2019). Arsiwala *et al.* (2020) found that FCL combined with topical PRP resulted in significantly greater scar reduction than FCL alone. Mahamoud *et al.* (2020) reported that adding PRP to treatment protocols significantly reduced scar severity by approximately 33% and enhanced collagen and elastin production. Moreover, intradermal PRP was more effective than 50% TCA CROSS in reducing atrophic scars (Mumtaz *et al.*, 2021).

3.8. Hyaluronic Acid (HA) Temporary Filler

Hyaluronic acid (HA) is a high molecular weight, non-sulfated glycosaminoglycan vital in maintaining tissue structure supporting cell motility, adhesion, proliferation, and skin hydration. Non-cross-linked HA contributes to wound healing by stimulating dermal fibroblasts enhancing collagen deposition. Combining fractional carbon dioxide (FCL) laser with non-cross-linked hyaluronic acid injections has effectively increased collagen and elastin production, thereby improving atrophic acne scars (Mahamoud *et al.*, 2020). While HA alone offers some scar improvement, combining fractional CO_2 laser with HA provides superior and more durable clinical outcomes in treating atrophic scars (Abdelwahab *et al.*, 2022).

3.9. Needling

Needling has been extensively studied as a treatment for acne scars, particularly atrophic types such as ice pick, boxcar, and rolling scars (Alam *et al.*, 2014). Percutaneous collagen induction (PCI) via needling creates perforations in the papillary dermis, activating fibroblasts and subsequent collagen synthesis. This minimally invasive procedure has demonstrated effective scar reduction. Alam *et al.* (2014) reported a 41% improvement in appearance at six months, with minimal pain and no significant side effects. Bhargava *et al.* (2019) further showed that combining needling with subcision and platelet-rich plasma (PRP) enhances treatment outcomes.

Micro-needling, a specific needling, has shown promising results due to its cost-effectiveness, rapid healing, and low risk of post-inflammatory hyperpigmentation (PIH). Cachafeiro *et al.* (2016) highlighted micro-needling as a safe, efficient, and affordable option for scar reduction. Micro-needling achieves even greater improvements when combined with hyaluronic acid (HA) or PRP. Kotb *et al.* (2018) demonstrated that micro-needling with PRP significantly reduced scar severity compared to microneedling alone, indicating an additive benefit. Similarly, Abdel-Magiud *et al.* (2020) reported that microneedling dermarollers promoted collagen synthesis and facilitated gradual scar improvement.

3.10. Other modalities

Beyond the previously discussed treatments, this review identified additional surgical approaches for acne scars, including hybrid energy (HE), trifractional technology (TF), and Human Adipose Tissue Stem Cell-derived Exosomes (ASCE). Yu *et al.* (2016) investigated the effects of HE and TF on acne scars. Their results showed that 58.3% of subjects experienced mild to moderate improvement, 8.3% achieved significant progress, and 33.3% showed no change after HE therapy. After two additional TF sessions, improvements were noted in 37.5% of patients with mild to moderate responses, another 37.5% with significant responses, and 25% unchanged. 75% of patients showed improvement after four HE sessions, and 100% improved after the last TF session (Yu & Abat, 2016).

Kwon *et al*. (2020) conducted a comparative study of fractional CO_2 laser (FCL) and human ASCE therapy on atrophic scars. The findings indicated a significant reduction in ECCA scores from baseline in both groups, with a greater percentage reduction observed in the ASCE group. Specifically, the ECCA score decreased by 32.5% in the ASCE group, significantly more than the 19.9% reduction in the FCL group at the final follow-up ($p < 0.01$). Both treatments resulted in significant score reductions for V- and U-shaped scars, but differences between groups were not statistically significant. Both groups showed substantial improvements in M-shaped scars, with the ASCE group demonstrating more pronounced benefits at the last follow-up (Kwon *et al*., 2020).

3.11. Advantages and Limitations

This systematic review comprehensively synthesizes the most recent clinical evidence on various surgical modalities for acne scar management. It facilitates the comparison of efficacy and safety profiles across different techniques, supporting clinicians in tailoring individualized treatment plans. However, the review has several limitations. Many included studies feature small sample sizes and exhibit heterogeneity in study designs and outcome measures, which may limit the comparability and generalizability of the findings. Additionally, limited access to some references may affect the completeness of the analysis.

As highlighted in the review, potential risks associated with these procedures include procedural discomfort, downtime, and adverse effects such as erythema, swelling, hyperpigmentation, infection, and, rarely, scarring or dyspigmentation. These factors underscore the importance of careful patient selection, thorough pre-treatment counselling, and proactive management of side effects to optimize outcomes and minimize complications.

4. Conclusion

Acne scars are a prevalent and challenging condition. Various treatment modalities—including trichloroacetic acid, radiofrequency, laser therapy, subcision, punch techniques, microdermabrasion, platelet-rich plasma, hyaluronic acid fillers, needling, hybrid energy, tri fractional technology, and human adipose tissue stem cell-derived exosomes—have demonstrated varying degrees of efficacy, generally with positive outcomes. Each technique has unique advantages and limitations; some are better suited for specific scar types. However, all treatments carry potential risks of adverse reactions, underscoring the need for careful patient selection and proactive management.

This systematic review is limited by the scope of accessible references, indicating that further research with larger sample sizes is necessary to strengthen evidence. Clinicians are encouraged to adopt a patient-centred approach, tailoring therapies to individual scar characteristics and skin features. Combining modalities—such as fractional CO_2 laser with PRP or subcision with microneedling—often yields superior results compared to single treatments, but practitioners must remain vigilant of potential side effects.

For future research, large-scale, well-designed, randomized controlled trials with standardized outcome measures are essential to evaluate treatment efficacy better. Additionally, studies should explore long-term safety, the psychosocial impact of acne scarring, and the benefits of combined therapies, aiming to provide a comprehensive understanding of treatment outcomes and improve patient quality of life.

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Conflict of interest

The authors have no conflicts of interest to declare concerning this article.

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