

Modern techniques in addressing facial acne scars: A thorough analysis

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Abstract

Background: Facial acne scars are a prevalent concern, leading to the development of various treatment modalities.

Objectives: This review aims to explore the latest advancements in the treatment of facial acne scars, focusing on both surgical and non-surgical methods.

Methods: The non-surgical treatments reviewed include topical medications (such as retinoids and alpha hydroxy acids) and non-invasive procedures (like microdermabrasion and chemical peels). Surgical options discussed are punch excision, subcision, and fractional laser treatments.

Results: Combination therapy, integrating both surgical and non-surgical approaches, is frequently utilized to achieve optimal results in scar improvement.

Conclusion: Recent advancements in the treatment of facial acne scars provide promising options for individuals seeking improvement. However, these treatments have associated risks and potential adverse effects, highlighting the importance of consulting a dermatologist before beginning any treatment regimen.

KEYWORDS

acne scars, combined treatment, medical therapy, surgical therapy, treatment

1 | INTRODUCTION

Acne is a common chronic inflammation of hair follicles and sebaceous glands, affecting about 85% of adolescents.¹ and acne inflammation can lead to varying degrees of scar formation.² In the context of acne patients, the prevalence and risk factors associated with acne scarring are explored in-depth in the study conducted by Liu L et al.,³ shedding light on the commonality and contributing elements to acne scars in this population. Acne scars, an important aesthetic issue for patients, can cause various facial disfigurement and psychological disorders^{1,4} and affect their quality of life.⁶⁻⁸ Acne is a chronic inflammation of the hair follicle sebaceous gland caused by multiple factors (Figure 1), mainly related to androgens, increased sebum secretion, abnormal

keratinization of hair follicles and sebaceous glands, proliferation of Propionibacterium acnes, and inflammatory reactions of lymphocytes, macrophages, and neutrophils.⁹ Acne lesions are prone to occur on the cheeks and forehead. After healing, acne scars are often left on the face, which may be related to abnormal degradation of facial collagen. Acne scars can be divided into atrophic acne scars, hypertrophic acne scars, and keloids, among which atrophic acne scars are the most common.¹⁰

Innovations in acne grading are addressed in the study by Liu L et al.¹¹ with the development of "AcneGrader," an ensemble pruning of deep learning base models, offering a novel approach to effectively grade acne severity. Atrophic acne scars are caused by inflammation that destroys deep dermal structures, followed by abnormal synthesis

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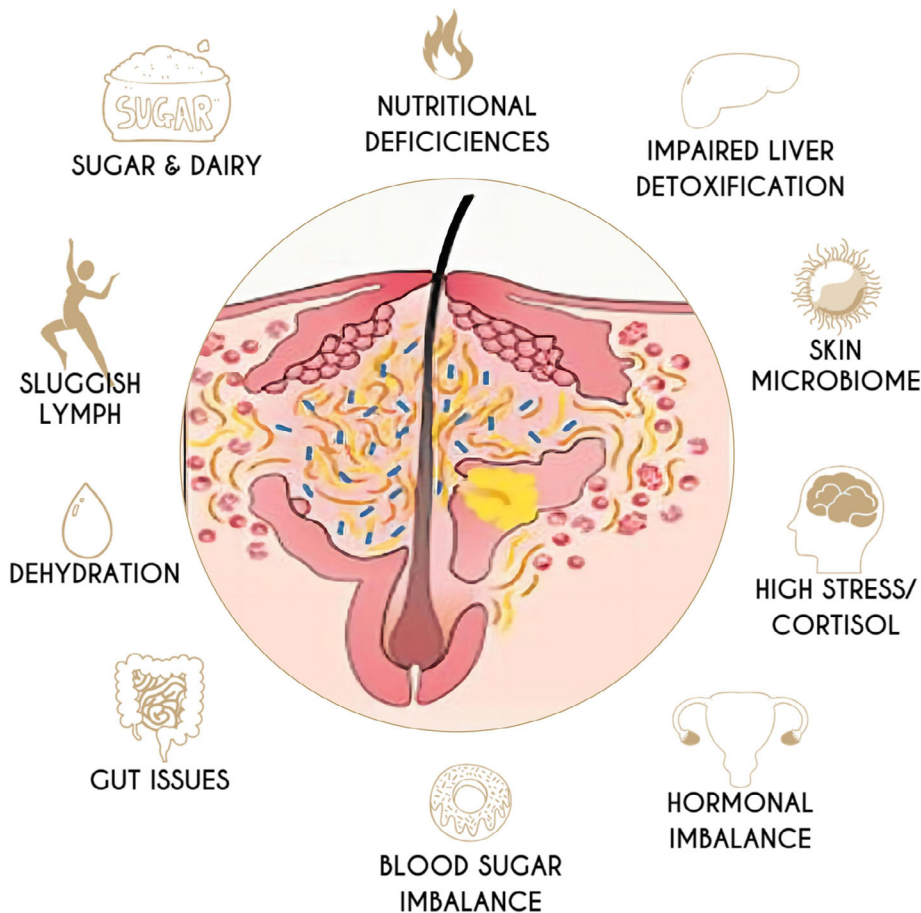


FIGURE 1 Etiology of acne.



FIGURE 2 The shape of atrophic acne scars.

and degradation of type I and type III collagen, and tissue contraction resulting in skin indentation. Atrophic acne scars can be classified into three types based on their shapes: ice-pick type, rolling type, and boxcar type (Figure 2). The ice-pick type scar is narrow and deep, with a

“V” shape, and the surface width is usually less than 2 mm, extending to the deep dermis or subcutaneous tissue; the rolling type scar is shallow and wide with a soft edge, with a diameter of more than 4 mm, and the dermis and subcutaneous tissue have a chaotic fibrous structure with



FIGURE 3 Treatments of acne scars.

a wavy “M” appearance; the boxcar type scar is round to oval, with a clear edge, and the surface opening is wider than that of the ice-pick type scar, with a wider bottom. The cross-section is similar to a “U” shape. Hypertrophic acne scars are formed by excessive proliferation of fibroblasts and collagen synthesis greater than degradation, a common acne sequela after healing.

At present, there are many methods for treating acne scars. Traditional treatment methods include skin abrasion, chemical peeling, scarring drill excision, tissue filling, micro-needle therapy, scarring drill elevation, thread lifting, and photodynamic therapy, while emerging therapies such as mesenchymal stem cells (MSCs) and their derivatives are also available (Figure 3). Currently, laser therapy is a first-line therapy for acne scars, with the advantages of good efficacy and a short recovery period. Still, after treatment, it may cause adverse reactions such as pain, erythema, edema, and inflammatory pigmentation.¹² In recent years, many studies have also used stem cells and their derivatives for treating acne scars, among which MSCs and their derivatives are the most commonly used. In addition, combination therapy with various methods is also possible, and combination therapy often achieves more satisfactory efficacy than a single treatment. This article aims to provide a brief overview of traditional and emerging treatments for acne scars and their advantages and disadvantages.

2 | NON-SURGICAL TREATMENT

2.1 | Photonic treatment

Photonic treatment mainly refers to laser treatment and radio frequency treatment. According to the different wavelengths of lasers, they are divided into ablative lasers and non-ablative fractionated lasers. Ablative lasers use high heat to vaporize the skin surface, accelerating the effect of tissue removal and creating scabs after treatment. Non-ablative fractionated lasers are a kind of laser emission mode which divides a beam of laser into several discontinuous weak light spots acting on the skin, causing the water in the tissue to absorb the laser energy and vaporize, forming multiple small columnar structures of microthermal injury zones called microthermal zones (MTZs), while the tissue between MTZs remains intact. It can quickly produce repair reactions, stimulate collagen regeneration and repair, and significantly improve scar tissue.¹³ Radiofrequency treatment involves inserting specific electrodes into unaffected skin and discharging them, producing both ablative and coagulative microthermal injury to the epidermis and dermis, stimulating fibroblasts in the dermis and causing collagen resynthesis, promoting tissue healing and repair, and significantly improving scars.

2.2 | Ablative lasers

Ablative lasers have been widely used in the surface repair and treatment of atrophic acne scars. Common ablative lasers for treating acne scars include 10600 nm CO₂ and 2940 nm pulsed Er: YAG lasers.² 10600 nm CO₂ lasers belong to the far-infrared spectrum and produce many microthermal treatment zones, which can activate the formation of new collagen proteins and epithelial regeneration.¹⁴

A retrospective study by Fang et al. showed that the efficacy of 10600 nm CO₂ laser treatment for atrophic acne scars in Asians is positively correlated with treatment duration, and the duration of persistent post-treatment pigmentation is less than 3 months, often resulting in better prognosis.¹⁵ Gala et al. conducted a split-face study of 30 patients, using 10600 nm CO₂ lasers on one side of the face and intradermal injection of platelet-rich plasma (PRP) on the other. The therapeutic effects of both groups were satisfactory, but combined therapy could improve atrophic scars better.¹⁶ Zhou et al. used a 10600 nm CO₂ laser combined with allogeneic stem cells and found that this treatment could improve skin elasticity and hydration. Histological examination showed an increase in the density of dermal collagen and elastic fibers.¹⁷ Alaa et al. conducted a split-face study of 40 patients with different types of atrophic acne scars. Each group consisted of 20 patients. The first group received a subcutaneous incision and cross-linked sodium hyaluronate filler injection on one side of the face, the second group received a subcutaneous incision and 10,600 nm CO₂ lasers on the other side of the face, and the third group received simple subcutaneous excision. The results showed no statistically significant difference in efficacy between the first and second groups; both were better than the third group.¹⁸ Cheng et al. conducted three treatments of 10600 nm CO₂ lasers for 19 patients. They found that the final clinical effective rate was 68.4%, concluding that it could effectively improve mild to moderate acne scars.

10600 nm CO₂ laser is currently one of the most effective methods for treating acne scars, using photothermal energy to stimulate the regeneration of dermal collagen. Still, it is often accompanied by adverse reactions such as erythema, edema, and pigmentation within a short period.¹⁹⁻²¹

2.3 | Non-ablative lasers

Non-ablative lasers include pulsed dye lasers (PDL) with wavelengths ranging from 585 to 600 nm, 1320 nm ND: YAG lasers, 1450 nm diode lasers, and 1550 nm erbium glass lasers, which help to reduce boxcar-type atrophic acne scars.¹³ At the histology and cellular tissue level, 675 nm lasers can stimulate collagen resynthesis, especially significantly increasing the number of fine and new collagen fibers.¹³ Cannarozzo treated 24 acne scar patients with three treatments of 675 nm lasers, significantly improving all patients' scars with no adverse reactions.^{22,23}

Rogachefsky et al. studied using 1320 nm Nd: YAG lasers to treat atrophic or mixed acne scars²⁴ and found that the scars improved.

Sadick et al. used 1320 nm Nd: YAG lasers to treat acne scars and concluded the same.²⁵ Soo Ran Lee et al. used 1550 nm erbium glass lasers to treat atrophic acne scars and found that the scars improved significantly, especially in patients aged 25 or younger. In addition, they found that combining 1550 nm fractionated lasers with tretinoin was more effective than laser monotherapy for ice-pick-type scars.²⁶

2.4 | Chemical peel therapy

Chemical peeling, chemexfoliation, or chemosurgery is a popular skin beauty treatment for rejuvenation. The most commonly used chemical peeling agents are acid substances, including alpha-hydroxy acids (AHAs) such as glycolic acid and lactic acid; beta-hydroxy acids (BHAs) such as salicylic acid; trichloroacetic acid (TCA); Jessner's solution; and full-trans retinoic acid. Emerging chemical peel agents such as pyruvic acid, esterified beta-hydroxy acids, salicylic acid, mandelic acid, and amino fruit acids are also gradually used in clinical practice. These peeling agents can dissolve keratinocytes, reduce the adherence of corneocytes, promote exfoliation of the epidermis, and induce the production of new collagen fibers.²⁷ Depending on the strength of the chemical peel, it can improve various skin problems, including acne and acne scars, photoaging, dyschromia, and precancerous lesions.

A previous study has shown that regular use of these chemical peeling agents can improve the appearance of shallow acne scars and treat pigmentation disorders.²⁸ The use of combination acids, such as salicylic, mandelic peels (SMPs), and retinoic acid-glycolic acid (RAGA), is more effective for the treatment of acne scars.²⁹ Combining glycolic acid or ethanol peels with 35% TCA can further enhance penetration and treat more severe acne scars by strengthening the middle-depth skin.^{30,31} However, due to limited penetration depth, superficial and medium-depth peeling is mostly limited to mild atrophic scars or acne-related pigmentation disorders.³²

For deeper atrophic scars, especially ice-pick scars, deeper peeling agents like TCA (>50%) are required, which destroy the epidermal cells, cause necrosis of the epidermal and upper dermal cells, penetrate the reticular dermis, and coagulate proteins. When applied to the skin, it will produce typical white frost, indicating the precipitation and necrosis of proteins. Within a few days after treatment, the necrotic skin layer will fall off, and the treatment area will be re-epithelialized with surrounding healthy skin. From a long-term perspective, TCA treatment can stimulate the production of new collagen fibers.¹³

Chemical Reconstruction of Skin Scars (CROSS) is another type of chemical peeling that applies high-concentration acid to the bottom of scars using a sharp applicator tool while protecting the surrounding skin.³³ This method can maximize the effect of high-concentration acid and minimize its complications by avoiding adjacent normal skin tissue and appendages.³⁴ Chemical peeling is a relatively safe and practical treatment method. Different depths of chemical peel agents can treat different types of acne scars.³⁵ It can be used alone or with other treatments.³⁶ Superficial chemical peel agents are suitable for shallow acne scars,³⁷ while medium-depth and deep peel agents,³⁸ as well as

combination therapies, are more advantageous in treating deeper acne scars.^{28,39}

Chemical peeling is convenient to operate, cost-effective, and has a fast recovery time. The postoperative care of the affected area is simple, and patients generally have good acceptance.⁴⁰ In summary, chemical peeling is a safe and effective method of treating acne scars.³⁰ Practitioners should be proficient in the concentration and scope of application of chemical peel agents and possible complications and inform patients about the importance of sunscreen and appropriate skin care programs.

2.5 | Skin fillers

Skin-filling treatment is another mainstream method used to treat atrophic acne scars. It involves injecting medical materials into the scarred area to raise the depressed part to the level of the normal surrounding skin. Different skin fillers have different durations and can be divided into short-acting, semi-permanent, and permanent fillers. In addition, different fillers have different durability due to variations in their biodegradability.⁴¹

Common short-term fillers include hyaluronic acid (HA) and exogenous collagen fillers. HA is a highly biodegradable substance that can be naturally decomposed by hyaluronidase in the body.⁴² With the advancement of technology, HA can now be stabilized through cross-linking, extending its clinical life to 6 to 18 months or more.⁴³ HA has both short-term and long-term effects. In the short term, its hydrophilicity can immediately increase the volume of subcutaneous tissue by retaining water in the dermis after injection. The long-term effect is that HA activates fibroblasts to increase collagen synthesis in the following months, promoting additional soft tissue growth.⁴⁴ HA can be classified as monophasic (a uniform mixture of low and high molecular weight HAs) or biphasic (cross-linked HAs in a non-cross-linked HA suspension). Another short-term filler is exogenous collagen filler, which can come from pigs or cows. It is directly injected into the deep dermis to restore volume loss caused by facial acne scars. The main disadvantage of collagen fillers is their potential allergenicity, which must be tested for each patient several weeks before injection.⁴⁵ Later, a more durable glutaraldehyde collagen filler was developed, which, unlike previous bovine-derived collagen fillers, not only corrected facial acne scars better but also did not cause allergic reactions at the injection site.⁴⁶

Semi-permanent fillers: Poly-L-lactic acid (PLLA) and Calcium Hydroxylapatite (CaHA). PLLA has a semi-permanent biological stimulating effect,⁴⁷ which can directly stimulate fibroblasts in the dermis to produce collagen.⁴⁸ Unlike HA, the effect of PLLA does not appear immediately, and it takes several weeks to several months to achieve optimal collagen production and ECM remodeling.⁴⁷ It has been reported that PLLA can maintain the correction of rolling acne scars for up to 4 years.⁴⁹ However, the correction effect of PLLA on ice-pick scars is very small.³² In addition, PLLA also carries risks of bruising, erythema, pain, and nodule formation, especially when improperly administered.⁵⁰

CaHA is another type of semi-permanent filler that stimulates collagen production and the formation of fibrous tissue. CaHA filler consists of microspheres suspended in a carboxymethylcellulose gel. Unfortunately, research has found that CaHA fillers can cause transient erythema, bruising, hematomas, and occasional nodule formation as adverse reactions.⁵⁰ Permanent fillers: to improve the effectiveness, safety, and lifespan of collagen fillers, researchers have developed polymethylmethacrylate (PMMA) fillers. PMMA is an indecomposable synthetic polymer that can be used as subcutaneous fillers to enhance local soft tissue.⁴¹ In a study, 90% of patients reported satisfaction after treatment with PMMA fillers, despite experiencing transient bruising, erythema, and pain in some injection sites.⁵¹ However, since foreign body granuloma is delayed, long-term follow-up is still needed to assess the safety of PMMA fillers.

Atrophic acne scars can be filled with HA, polylactic acid, or hydroxylapatite calcium.¹⁸ Although many fillers are effective in treating acne scars, clinical decision-making about which filler to use needs to consider important factors such as patient needs, cost budgets and economic conditions, and patient concerns or choices regarding different durations and side effects of fillers.

2.6 | Micro-needling (MN) therapy

MN therapy is commonly used in cosmetic treatments. It is widely used for treating facial scars such as acne, fine lines, wrinkles, crow's feet, age spots, and other age-related skin diseases.^{52,53} Common MN devices include handheld roller devices with needles, automated needle pens, and micro-needle matrix radiofrequency devices.⁵⁴ MN therapy involves creating hundreds of tiny pin-sized holes in the skin to stimulate the regeneration of healthy skin. Many studies have reported increased epidermal thickness, upregulation of elastic protein fibers and collagen lattice formation, and the release of various regenerative growth factors in the days or weeks following treatment.^{18,52,55,56} The tiny damage caused by the needle in the dermis can promote the synthesis of cell growth factors, increase collagen deposition, and reduce local inflammatory reactions. These changes in the dermis can improve the appearance of acne scars.^{54,57,58} Additionally, MN therapy does not cause pigment deposition, so it is often used as an alternative to laser therapy for IV and V-type skin.⁵⁹ Because MN therapy is relatively simple, has a quick recovery time, and low complication rate, MN is considered a practical and effective method of treating acne scars.

Studies have shown that MN therapy increases type I collagen expression.^{60,61} In El-Domyati's study, 10 patients received skin MN therapy every 2 weeks for six treatments. Skin biopsies were taken before the first treatment and 3 months after the last treatment, showing improvement in acne scars and a significant increase in type I, III, and VII collagen.⁶² Tirmizi SS and others treated 50 patients with moderate to severe atrophic acne scars using MN therapy. They concluded that the appearance and grade of scars improved, indicating that MN effectively improves acne scars.⁶³

As a single treatment method, MN therapy is most effective for rolling scars, followed by boxcar scars, and has some

improvement in ice-pick scars.^{64–67} Most studies show little improvement in ice-pick scars, but Gupta and colleagues' study shows significant improvement.⁶⁶ These two results may be related to using different types of needles.⁶⁸ In addition, MN is also an effective transdermal drug delivery adjunct, with studies most commonly combining MN therapy with PRP. Numerous randomized controlled trials have reported mixed results on this combination therapy, with reports of significant improvements after adding PRP, while others report no significant differences.^{69,70} By comparing these studies, the frequency, application, and duration of combination therapy vary, leading to significant differences in study results. Some have explored alternative products to PRP, such as insulin and amniotic fluid. Pawar and others found that boxcar scars responded better to insulin than PRP.^{71,72} El-Domyati and others found that local application of amniotic fluid using MN can increase epidermal thickness and new collagen formation.⁷² In addition, many studies have shown that combining MN with chemical peels, such as TCA and glycolic acid, can improve patient outcomes.^{62,67} However, one study has shown that Jessner's solution does not enhance the effectiveness of MN.⁶⁵ In these studies of MN therapy, erythema, edema, and pain are the most commonly reported side effects of MN, but they typically resolve on their own.⁷³

The effect of MN therapy is best for rolling and boxcar scars, but there is almost no improvement for ice-pick scars. However, it can promote local transdermal drug delivery, increasing its versatility and making it a safe and effective method of combining with other treatment methods to improve and treat acne scars. In addition, patients are more satisfied with a combination of PRP and MN therapy than with MN alone.^{62,67} Other combination therapies with higher patient satisfaction than MN alone include: MN with glycolic acid⁶⁷ and trichloroacetic acid.⁶²

2.7 | Thread lifting surgery

Thread lifting is a simple, minimally invasive facial lifting surgery. In this process, barbed threads are inserted under the facial skin. The implanted threads can suspend the underlying tissues, lifting the skin and stimulating collagen synthesis by activating fibroblasts. Initially, non-absorbable medical sutures were used for this method, which provided long-term cosmetic improvement due to their biodegradability resistance and high tensile strength, but with potential infection risks and rejection reactions. Therefore, although the clinical efficacy duration of non-absorbable threads is longer, they have been replaced by semi-permanent absorbable threads. Although absorbable threads have a shorter correction time, they have greater biological compatibility and lower infection risk.²⁷ Donnarumma et al. used absorbable polydioxanone (PDO) barbed sutures to perform thread-lifting surgery on five patients with boxcar scars as the main complaint. The results showed that the scars of all five patients were improved. After six months, the skin fibers appeared to have a more regular fibrous network in observation with reflectance confocal microscopy. The study did not report any adverse events.⁷⁴ However, the study's sample size

needed to be bigger and more representative, and more research is needed to evaluate the efficacy and safety of thread lifting for acne scars. Additionally, different types of available threads and surgical techniques should be further analyzed for their reactions to different acne scars.

3 | SURGICAL EXCISION

3.1 | Dermabrasion

Dermabrasion is a common medical cosmetic technique used for skin resurfacing. It involves controlled mechanical abrasion of the superficial layers of the epidermis and dermis using a grinding wheel. It mainly induces reepithelialization, repigmentation, and neocollagenesis in the basal cells, spinous cells, and the remaining skin appendages such as hair follicle walls, sweat gland duct walls, and sebaceous gland duct walls.²⁷ Initially, the purpose of dermabrasion was to induce damage in the dermis above the reticular layer in a controlled manner. Therefore, it is particularly effective in treating shallow rolling and boxcar scars but has minimal clinical improvement in deeper ice pick scars. Usually, significant correction of acne scars can be achieved with a single dermabrasion procedure. However, the depth of dermabrasion should not be too deep, as penetrating the reticular layer of the dermis may lead to new scars. Therefore, the operator needs to be extra cautious during the operation. In addition, numerous reports of dermabrasion complications, such as persistent pain, erythema, and permanent dyschromia.³² Although dermabrasion is still a simple and effective method for treating acne scars, it is gradually being replaced by other treatment methods due to its numerous complications and poor tolerability. Therefore, it is not the best choice among the various treatments for facial acne scars.

4 | PUNCH EXCISION TREATMENT

Punch excision treatment includes punch elevation, punch excision, and punch grafting. Punch elevation is a method developed for sharp-edged and flat-bottomed boxcar scars. It is a technique of punching the scar to the subcutaneous tissue without causing tissue damage. The punctured scar is then lifted and sutured slightly higher than the surrounding skin to alleviate the contraction of scars after formation.⁷⁵ Punch elevation is suitable for ice pick and narrow boxcar scars. The operator uses a punch slightly larger than the scar to cut from the outer edge of the scar to the subcutaneous fat and then sutures the skin along the tension lines of the skin, thus transforming the more obvious ice pick and boxcar scars into less noticeable linear scars. Laser treatment can also be combined to improve scars⁶⁶ further. The punch excision method is the simplest punching technique and most effective for ice-pick scars.⁶⁷ First, the ice pick scar needs to be found, and then it is removed with a punch slightly larger than the diameter of the scar, followed by suturing of the 2–3 mm hole.⁷⁶ For scars with a diameter greater than 3–3.5 mm,

an elliptical or fusiform closure should be performed to ensure the skin is flat and smooth. Although this method can remove multiple scars simultaneously, the distance between each scar should be at least 4–5 mm. It can prevent excessive tension on the skin after repairing the puncture site. If there is any residual scar, the next excision can be performed after the previous excision site has completely healed.

Similarly, linear scars after punch excision can be improved by laser treatment.²⁷ Although punch excision treatment is an effective technique for treating ice-pick scars, it can result in a less conspicuous linear scar than the original acne scar.²⁷ Punch grafting can solve this problem using skin grafts, most commonly taken from behind the ear and tightly inserted into the puncture site. Ensuring that the graft is appropriate for a better fit is essential. However, some studies have reported graft suppression 4–6 weeks after punch excision, leading to irregular skin texture, which can be corrected by skin filling (such as collagen) or laser treatment.²⁷ Punch elevation elevates the cylindrical skin at the affected site without complete removal, so no irregular skin texture is observed in the graft. However, the disadvantage is that the scar will shrink and affect the healing of the edge of the punched tissue, leaving a conspicuous ring-shaped scar. Nevertheless, punch techniques can be a last option for deep ice pick and boxcar scars that are difficult to treat with other methods.

4.1 | Subcutaneous excision

Subcutaneous excision, or subcutaneous surgery without incisions, is commonly used to treat atrophic acne scars, depressed scars, wrinkles, and other similar conditions. The main improvement achieved through subcutaneous incision treatment is for rolling scars, and some research reports show that the effective improvement rate using standardized acne scar grading assessment tools (such as the Goodman and Baron qualitative grading system) is 100%.⁷⁷ However, isolated subcutaneous excision has proven ineffective for boxcar scars.^{78,79} Some studies have reported that subcutaneous surgery without incisions can also improve scars caused by car accidents and ice picks.^{79–82} Still, in these studies, subcutaneous surgery without incisions was combined with other non-energy treatments, making it difficult to assess the efficacy of isolated subcutaneous excision for these types of scars. In addition, due to the nature of the surgery and the surgical tools used, there is a certain risk of nerve and blood vessel damage associated with subcutaneous excision, which may cause side effects such as hematoma formation, bruises, erythema and excessive pigmentation.^{80,83} For example, Taylor et al. developed a new surgical instrument composed of a long metal rod with a “W” shaped blunt end and a sharp notch at the tip, which could effectively capture the fiber strands in rolling scars and cut them off as the rod advances through the subcutaneous plane,^{84,85} improving the overall effectiveness of subcutaneous excision, but with a higher risk of damage to deep facial structures.⁸⁴ Most studies on isolated or combined subcutaneous excision with other therapies are more likely to have complications such as hematoma formation, bruises, erythema, and excessive pigmentation.⁸³ However, in recent years, metal wires and blunt cannulas have replaced the previously used Nokor nee-

dles and hollow needles, reducing the incidence of complications and achieving similar or even better outcome results.^{77,80,86}

Subcutaneous excision surgery can also be combined with other commonly used scar treatment methods, such as microneedle therapy, laser therapy, etc. A randomized split-face study conducted by Alaa et al. showed that combining subcutaneous excision surgery with CO2 fractional laser or HA subcutaneous injection had better therapeutic effects on facial atrophic acne scars. Their study also showed no statistically significant difference in treatment effects between the HA injection and CO2 laser groups.¹⁸ Some studies have found that combining subcutaneous excision surgery with microneedling and platelet-rich plasma (PRP) can improve acne scars.^{79,81,87} Moreover, PRP can improve the therapeutic effects of acne scars and reduce the incidence of complications.⁸⁷ It should be noted that only by carefully operating the surgical tools and fully understanding the facial anatomy can the maximum clinical efficacy and safety of patients be achieved, which places higher demands on operators. Subcutaneous excision surgery is still a good option for rolling or box scars patients.

5 | COMBINED THERAPY

Combined therapy for acne scars uses two or more treatment methods to improve acne scars. This approach can improve acne scars from multiple angles and achieve a “1+1 > 2” effect by utilizing the complementary effects of different treatment methods. Currently, the most researched combined therapies include laser and platelet-rich plasma (PRP) injections. PRP is an autologous blood derivative rich in platelets, growth factors, and cell signaling molecules. When delivered in the form of plasma, PRP has the potential to transport high concentrations of growth factors to target tissues.⁸⁸ In a study by Lee et al., two groups of subjects received lattice laser treatment in combination with either PRP or saline. The results showed a greater improvement in the PRP group than in the saline group.⁸⁹ Mumtaz et al. compared the efficacy of PRP with 50% TCA (trichloroacetic acid) using the CROSS method and found that PRP was significantly superior to 50% TCA in improving atrophic acne scars.⁵⁵ Bhargava et al. conducted a study using PRP as an adjunct therapy to subcision and microneedling for severe atrophic acne scar formation. One group received subcision and MN treatment; the other group received subcision, MN, and local PRP application. The results showed that the group with PRP had better efficacy.⁸¹ Nilforoushzadeh et al. treated atrophic acne scars using autologous adipose-derived stem cells, matrix vascular stem cells, and PRP. Nine patients received adipose-derived stem cell transplantation, PRP, and matrix vascular stem cells. After six months, improvements were observed in skin brightness, skin elasticity, transepidermal water loss, pigmentation, and skin pores.⁹⁰ In the treatment of atrophic facial acne scars, Lotfi L. conducted a preliminary investigational study demonstrating the potential efficacy of adjunct radiofrequency microneedle stimulation combined with poly-caprolactone-based dermal filler.⁹¹ In a split-face study, Chawla et al. compared the use of MN with PRP on one side and MN with vitamin C on the other, with a treatment interval

of one month. The results showed that the PRP group responded better than the MN+vitamin C group.⁹² Overall, combined therapy is superior to a single therapy, but further exploration is needed to select the optimal treatment combination from a wide range of treatment options.

6 | EMERGING THERAPIES

Emerging therapies mainly refer to certain stem cells and cytokines, such as MSCs, growth factors, exosomes, etc. MSCs are a kind of adult stem cells that originate from the mesoderm with self-renewal, self-repair, and differentiation potential, which can be derived from various tissues, including bone marrow, adipose tissue, amniotic fluid, umbilical cord blood, dental pulp, peripheral blood, hair follicles, etc. Currently, they have been applied in the field of plastic and reconstructive surgery.^{93,94} Epidermal growth factor ointment (EGFO) can accelerate skin healing by stimulating, migrating, and proliferating mesenchymal and epidermal cells.⁹⁵ Dong Hyo Kim et al. have demonstrated that EGFO effectively improves acne vulgaris and scars clinically and histologically. In addition, they found that EGFO can reduce inflammation and abnormal keratinization and promote scar regeneration through immunohistochemical analysis.⁹⁶

Recent studies have shown that exosomes derived from human adipose tissue stem cells (ASCE) have stem cell key features and are as effective as MSCs in repairing various organ injuries.^{97,98} Hyuck Hoon KWON et al. studied the efficacy of carbon dioxide fractional laser combined with exosomes (derived from adipose tissue stem cells) in treating acne scars. The results showed that the exosome group had a significantly higher improvement rate (32.5% vs. 19.9%), the redness was lighter, and the recovery was faster.⁹⁹ Traditional therapies for acne scars, such as chemical peeling, phototherapy, and microneedling, mostly cause slight skin damage,^{2,32,100} which may lead to related complications during treatment.

7 | DISCUSSION

The efficacy of phototherapy for acne scars is lower for patients with darker skin tones compared to those with lighter skin tones. It poses higher risks of pigment loss and even hypopigmentation and can cause redness, swelling, and hyperpigmentation in people with darker skin tones. In addition, it must be combined with topical medication to promote wound healing, limiting its use. Microneedling therapy is a common technique for improving acne scars, and many studies have shown that it can improve the appearance of acne scars. However, these studies have yet to achieve uniform results in the degree of improvement consistently, and the results of studies comparing microneedling monotherapy with combination therapy are also inconsistent. However, most studies have shown that microneedling combined with other therapies such as TCA (trichloroacetic acid), glycolic acid, or CO₂ laser spot irradiation is better than microneedling monotherapy.⁹⁸ Although dermal filling treatment has some effect on improving acne scars, it requires repeated injections over time. Thread lifting,

conversely, does not have an immediate effect after treatment and may take a long time to observe its efficacy. In addition, if absorbable sutures are used in the thread lifting procedure, the durability is poor, while non-absorbable sutures pose a risk of foreign body infection, and therefore, this method is now rarely used. Dermabrasion for acne scar treatment is now rarely used due to its high operator demands, high degree of difficulty, prominent complications, and poor treatment experience. Subcutaneous excision surgery as an invasive operation has potential risks of nerve and vascular damage, subcutaneous hematoma formation, and ecchymosis and has been gradually replaced by other treatment modalities. Although punch grafting can solve more challenging ice-pick scars, residual linear scars may still exist. Punch elevation surgery may leave less obvious circular scars, but the effectiveness of these two methods still needs to be improved when used alone.

Emerging treatment methods mainly rely on some biologically active substances to exert anti-inflammatory, anti-fibrotic, and regulate extracellular matrix remodeling effects to improve acne scars. However, the preparation methods of stem cells and their derivatives could be more convenient, the treatment dosage has no unified standard, the transplantation routes and efficacy cannot be determined, and the use of stem cells still raises ethical controversy, which limits their clinical application. Although extracellular vesicles have fewer restrictions in clinical use, the preparation process could be more convenient, and there may be biological contamination risks during cell separation and in vitro culture, which also limit their clinical use. In addition, a patient's physical condition, genetics, age, and Fitzpatrick skin type can all affect their response to treatment and their ability to produce collagen in the skin, thus affecting treatment outcomes.

8 | CONCLUSION

Currently, acne scars remain a challenge for dermatologists as a common sequela of acne vulgaris. Scientific research and clinical trials to improve acne scars are still hot research topics in medicine. There are now many effective ways to improve acne scars. Still, each acne treatment method has its advantages and disadvantages, which can be optimized by combination therapy to achieve better results. The specific treatment plan should be individualized according to the patient's situation. Before implementing a treatment plan, experimental treatment of scars can be conducted on a small scale to evaluate efficacy and safety. At the same time, the design of treatment plans should also consider other factors such as patient expectations, recovery time, and economic costs. In summary, proper treatment methods, correct skin care, and timely medical attention can help achieve the best treatment outcome.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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