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EFFICACY OF MICRONEEDLING IN THE TREATMENT OF ACNE SCARS

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ABSTRACT

Aims: This review evaluates the clinical efficacy of microneedling (MN) in treating atrophic acne scars, both as a monotherapy and in combination with platelet-rich plasma (PRP), topical agents, and radiofrequency energy.

Methods: A total of 28 peer-reviewed clinical studies published between 2020 and 2025 were included. Articles were selected through a manual search of academic databases and screened for relevance, clinical applicability, and methodological clarity. Eligible studies included randomized controlled trials, cohort analyses, and comparative studies involving human subjects with acne scars treated using microneedling.

Results: Microneedling as a standalone therapy consistently led to improvements in scar depth, skin texture, and patient satisfaction. Combination therapies with PRP or topical agents like hyaluronic acid, insulin, and phenytoin enhanced these effects, offering faster healing and improved outcomes. Radiofrequency-assisted microneedling (MNRF) demonstrated superior efficacy in deeper scars. The procedure showed strong safety and tolerability across different skin types, including Fitzpatrick types IV–VI. Patient-reported outcomes, such as reduced pain and improved quality of life, were also favorable.

Conclusions: Microneedling is a safe, versatile, and effective modality for acne scar treatment. Its adaptability to combination therapies and suitability for diverse skin types support its ongoing integration into aesthetic dermatology.

Keywords: microneedling, acne scars, PRP, radiofrequency, topical agents, patient satisfaction, scar therapy

INTRODUCTION

Acne vulgaris is among the most prevalent dermatologic conditions worldwide, affecting approximately 80% of adolescents and a significant portion of the adult population.While active acne is often transient, its sequelae—especially atrophic acne scars—can have lasting psychosocial and cosmetic consequences. These scars, characterized by dermal tissue loss and collagen degradation, are notoriously difficult to treat and often persist despite the resolution of inflammatory lesions. For many patients, the psychological burden associated with post-acne scarring can be as distressing as the original condition itself [4, 19].

Over the past two decades, various therapeutic approaches have been developed to manage atrophic acne scars, including chemical peels, dermal fillers, laser resurfacing, subcision, and ablative procedures [1, 8, 14, 19, 20]. Each of these methods offers varying degrees of efficacy, invasiveness, cost, and risk of complications, particularly in patients with darker skin types who are more susceptible to post-inflammatory hyperpigmentation [11, 16]. Within this therapeutic landscape, microneedling (MN)—also referred to as collagen induction therapy—has emerged as a versatile and minimally invasive option that balances efficacy with a favorable safety profile [5, 9, 11, 18].

Microneedling involves the use of fine needles to create controlled micro-injuries in the skin, thereby triggering the body's natural wound healing response. This cascade promotes neocollagenesis, elastin synthesis, and dermal remodeling—all of which are key to improving the texture and depth of atrophic scars [9, 18]. Importantly, because MN preserves the epidermis, it is associated with shorter recovery times and a lower risk of pigmentary alterations, making it especially suitable for patients with Fitzpatrick skin types IV to VI [11, 14, 16].

Beyond its basic mechanism, the field of microneedling has rapidly evolved. Technological innovations such as radiofrequency-assisted microneedling (MNRF), drug-delivery applications, and integration with growth factors like platelet-rich plasma (PRP) have expanded its therapeutic potential [4, 10, 12, 17, 18, 20]. These advances are accompanied by a growing body of clinical evidence supporting its efficacy across various patient populations and scar morphologies [2, 5, 6, 7, 13, 22, 23, 24, 25, 28].

AIMS

This review aims to comprehensively evaluate the current evidence on the efficacy of microneedling in the treatment of acne scars. It will explore its mechanisms of action, clinical outcomes as a monotherapy, and its performance in combination with biologics, energy-based devices, and topical agents. The paper will also compare MN with other established scar treatments, assess its utility in diverse skin types, and discuss patient-reported outcomes such as satisfaction, pain tolerance, and quality of life. Lastly, emerging technologies and future directions in microneedling-based therapy will be highlighted.

METHODS

The process of article selection began with a manual search of full-text publications retrieved from academic databases, including PubMed, ScienceDirect, and Google Scholar, as well as through institutional subscriptions and cross-referencing from bibliographies of relevant papers. The search was restricted to studies published between 2020 and 2025, ensuring that the data reflected the most recent advances in microneedling devices, clinical techniques, and combination protocols.

Only original, peer-reviewed research articles were considered eligible for inclusion. The selection criteria emphasized clinical studies involving human subjects with diagnosed atrophic acne scars, in which microneedling was used either as a stand-alone treatment or in combination with other therapeutic modalities. Accepted study types included randomized controlled trials, prospective and retrospective cohort studies, comparative analyses, and split-face trials. Reports that lacked clinical outcome data, as well as reviews, case reports, and in vitro or animal studies, were excluded from consideration.

Ultimately, a total of 28 publications met the inclusion criteria. These studies were thematically grouped into nine major domains, which are reflected in the structure of the "Content of the Review" section. Thematic synthesis was applied to integrate findings across categories such as microneedling monotherapy, adjunctive use of PRP, topical compound synergy, energy-based device integration, patient-centered outcomes, and recent innovations in technology and clinical practice.

RESULTS OF SELECTION

This review is based on a total of 28 peer-reviewed studies published between 2020 and 2025. The selection process included manual evaluation of full-text articles, focusing on original clinical research, controlled trials, and comparative studies directly examining microneedling (MN) in the treatment of atrophic acne scars.

The selected literature was grouped into nine thematic categories corresponding to the main clinical and scientific dimensions of microneedling. Three studies provided foundational insight into the biological

mechanisms of MN, its rationale in the context of acne scar formation, and the evolution of delivery systems and device innovations. Twelve studies evaluated microneedling as monotherapy, documenting clinical outcomes such as scar depth reduction, texture improvement, and patient-reported satisfaction across various skin types and scar morphologies.

Combination therapies were also well represented. Nine studies investigated the synergistic effect of MN combined with platelet-rich plasma (PRP), demonstrating enhanced collagen remodeling, faster healing, and improved patient satisfaction when compared to microneedling alone. Eight studies explored MN in conjunction with topical agents—including hyaluronic acid, insulin, and phenytoin—assessing the benefits of transdermal absorption for skin regeneration and hydration support.

The integration of microneedling with energy-based devices, especially radiofrequency (MNRF), was examined in five studies. These works highlighted the potential of MNRF for deeper dermal remodeling, precise targeting of scar tissue, and enhanced outcomes in more severe cases. In addition, nine studies provided head-to-head comparisons between microneedling and other modalities such as CO_2 laser, chemical peels, and PRP monotherapy. These comparisons helped establish MN's favorable profile in terms of safety, tolerability, and clinical efficacy

Finally, five studies contributed to a forward-looking view of microneedling, discussing emerging directions in device design, biologic delivery platforms, and the potential role of artificial intelligence in optimizing treatment protocols and personalization strategies.

Table 1 Comparative Effectiveness of Microneedling Protocols

Method	No. of Studies	Clinical Effect	Advantages	Limitations
MN Monotherapy	12	Moderate to marked scar improvement	Safe, low PIH risk, well tolerated	Slower effect, multiple sessions required
MN + PRP	9	Faster and stronger results	Enhanced healing, higher patient satisfaction	Cost, requires blood draw
MN + Topicals (HA, insulin, phenytoin)	8	Improved hydration, faster regeneration	Minimally invasive, well tolerated	Limited data, variable results
MNRF (radiofrequency)	5	Especially effective for deep scars	Adjustable depth, suitable for skin types IV – VI	Expensive equipment
MN vs CO2 Laser / Peels	9	Comparable efficacy with fewer complications	Safer in darker skin, shorter downtime	Possibly less dramatic in severe scars

CONTENT OF THE REVIEW

1. OVERVIEW OF MICRONEEDLING: MECHANISM AND RATIONALE

Microneedling (MN), also known as collagen induction therapy, is a minimally invasive dermatological treatment that has become increasingly popular for addressing atrophic acne scars. The procedure involves creating controlled micro-injuries in the skin using fine needles, typically delivered via rollers or motorized pens. These tiny punctures stimulate the skin's natural repair mechanisms, leading to the release of growth factors, activation of fibroblasts, and ultimately, the production of new collagen and elastin fibers [9].

Because atrophic acne scars result from collagen loss in the dermis, microneedling offers a targeted way to initiate dermal remodeling without significantly disrupting the epidermis. This reduced surface trauma is particularly important in patients with darker skin tones, where the risk of post-inflammatory hyperpigmentation (PIH) is higher [11]. By preserving the epidermis, MN minimizes downtime and adverse

effects while encouraging natural regeneration.

Recent years have brought significant technological advances in microneedling. Beyond traditional devices, newer systems include dissolving microneedles that deliver active substances directly into the skin and hydrogel-based microneedles that allow for controlled, sustained release of therapeutics [18]. These developments are expanding the scope of microneedling, not only in the treatment of acne scars but also in drug delivery, hyperpigmentation management, and anti-aging therapies.

One of microneedling's main advantages lies in its favorable safety profile. Unlike ablative procedures like fractional CO_2 lasers, MN maintains epidermal integrity, resulting in a quicker recovery, lower risk of infection, and reduced likelihood of pigmentation issues [9]. This makes it a highly suitable treatment for patients across all skin types, particularly Fitzpatrick types IV to VI [11].

In conclusion, microneedling offers a practical and effective method for treating acne scars by leveraging the body's innate healing response. Its combination of simplicity, versatility, safety, and technological evolution has solidified its role as a core treatment option in acne scar management [9, 11, 18].

2. MICRONEEDLING AS MONOTHERAPY: CLINICAL OUTCOMES

Microneedling (MN) has gained popularity as a standalone treatment for atrophic acne scars due to its safety, minimal invasiveness, and consistent clinical benefits. Multiple studies have evaluated its effectiveness across various skin types, scar morphologies, and patient populations.

One of the earliest demonstrations of its efficacy comes from studies showing a mean clinical improvement of approximately 62.5% after three sessions, based on physician and patient assessments [23]. Patients typically experienced visible reductions in scar depth, improved skin texture, and enhanced overall skin appearance.

Further studies have confirmed these findings. Bano et al. reported meaningful improvements in skin smoothness and scar visibility following MN alone, with minimal downtime and no significant adverse effects [5, 8]. Similar results were observed in a prospective study where four sessions of MN significantly reduced scar severity as measured by photographic analysis and physician grading scales [26].

Microneedling has also proven particularly effective and safe in individuals with darker skin tones, a group more prone to post-inflammatory hyperpigmentation (PIH). In Latin American populations, MN delivered substantial improvements without triggering PIH, underscoring its utility in Fitzpatrick types IV–VI [16]. Another comparative study involving glycolic acid peeling confirmed that MN was not only more effective but also better tolerated in these patients [14]. Comparable conclusions were reached in skin of color populations, where MN demonstrated high safety and patient satisfaction [19].

Several trials have directly compared MN to other monotherapies or conventional modalities. For instance, MN performed comparably to fractional CO_2 lasers and PRP in a three-arm randomized trial, with the added benefit of fewer adverse effects and shorter recovery time [21]. Additionally, MN showed superior clinical outcomes in rolling and boxcar scars, which are typically more responsive to collagen-inductive procedures [15].

From the patient perspective, microneedling is generally well accepted. In one study, most patients reported being satisfied or highly satisfied with the aesthetic outcomes of treatment [22]. Improved scar grades, as reported through both clinical scales and self-assessments, have also been observed in multiple settings [2].

Moreover, studies have consistently noted good pain tolerance, high compliance, and minimal side effects, even in repeated sessions [5]. The non-ablative nature of the procedure, combined with its cost-effectiveness and short recovery period, makes MN a practical and efficient choice in daily dermatologic practice.

In summary, microneedling as monotherapy demonstrates a reliable safety profile, patient tolerability, and measurable clinical efficacy. Its consistent performance across diverse populations and scar types supports its continued use as a first-line option in the management of acne scars [2, 5, 8, 14, 15, 16, 19, 21, 22, 23, 26].

3. MICRONEEDLING COMBINED WITH PLATELET-RICH PLASMA (PRP)

Combining microneedling (MN) with platelet-rich plasma (PRP) has become an increasingly common approach in the treatment of atrophic acne scars. PRP, an autologous concentrate rich in growth factors, is believed to enhance the regenerative effects of microneedling by accelerating wound healing and stimulating collagen synthesis.

Multiple clinical studies have shown that the combination of MN and PRP leads to greater improvement in scar appearance compared to MN alone. In a randomized trial, patients treated with MN+PRP experienced significantly better softening and flattening of acne scars than those receiving microneedling alone [25].

Similar results were seen in another study where MN+PRP led to earlier clinical improvements and faster healing [24]. Notably, even in trials where both groups showed improvement, the MN+PRP group typically reported higher satisfaction levels [22, 23].

A split-face trial further demonstrated the advantages of combination therapy: the side treated with MN+PRP showed more pronounced clinical improvement in both physician assessments and patient-reported outcomes compared to the MN-only side [13]. A three-arm study comparing PRP, MN, and MN+PRP also confirmed that the combination provided the most significant improvements in acne scars and patient satisfaction [7].

Mechanistically, this synergistic effect is attributed to the action of growth factors released by platelets—such as PDGF, TGF-β, and VEGF—which stimulate fibroblast activity, neocollagenesis, and dermal remodeling. When combined with the controlled micro-injuries caused by MN, PRP helps to enhance and accelerate the skin's natural repair process [10].

Despite its advantages, some studies have reported no statistically significant differences between MN alone and MN+PRP, although the combination group still tended to show slightly faster or more noticeable improvement in clinical practice [6]. Moreover, PRP may be particularly beneficial for patients with certain scar types, such as boxcar or mixed scars [15].

Overall, the combination of MN and PRP appears to offer superior outcomes compared to microneedling alone, particularly in terms of patient satisfaction, healing speed, and scar resolution. It remains a safe, well-tolerated, and increasingly accessible option in clinical dermatology [6, 7, 10, 13, 15, 22, 23, 24, 25].

4. MICRONEEDLING IN COMBINATION WITH TOPICAL AGENTS (HA, INSULIN, PHENYTOIN)

The use of microneedling (MN) in combination with topical agents is becoming an increasingly popular strategy in the treatment of atrophic acne scars. This approach is based on the idea that the micro-injuries caused by MN temporarily increase the permeability of the epidermis, allowing for more effective absorption of active compounds. The most commonly studied substances in this context include hyaluronic acid (HA), insulin, and phenytoin.

Hyaluronic acid (HA), known for its hydrating and regenerative properties, is one of the most frequently used additives in MN protocols. Comparative studies have shown that combining MN with HA can improve skin texture and patient comfort, even though the differences in scar depth reduction compared to MN alone are modest [5, 8]. Nonetheless, patients often report better skin hydration and greater overall treatment tolerance when HA is included [8].

Topical insulin is a less conventional but increasingly studied agent due to its regenerative properties. One study found that MN combined with insulin yielded better outcomes than MN with HA, especially during the early treatment phase—skin texture improved more rapidly, and scar severity decreased faster [1]. A similar study reported that adding insulin led to faster wound healing and enhanced skin remodeling [28]. These findings suggest that insulin may work synergistically with MN by stimulating fibroblasts and promoting collagen production.

Phenytoin, traditionally used as an antiepileptic drug, also shows promise in dermatology due to its angiogenic and wound-healing effects. A study evaluating MN with topical phenytoin reported statistically significant improvements in scar appearance compared to MN alone, with patients noting smoother skin and faster recovery [6]. Although data remain limited, early results are encouraging and suggest further investigation is warranted.

It is worth noting that these combination therapies are generally well tolerated. Across studies, patients reported minimal adverse effects and high satisfaction, especially with HA and insulin regimens [2, 5]. These substances appear particularly beneficial during the early post-treatment phase, helping to reduce erythema, improve hydration, and support dermal remodeling.

In conclusion, combining microneedling with topical agents such as HA, insulin, and phenytoin may enhance both treatment efficacy and patient comfort. While HA primarily improves hydration and tolerability, insulin and phenytoin may actively boost tissue regeneration. These strategies represent a valuable extension to standard MN protocols [1, 2, 5, 6, 8, 13, 28].

5. MICRONEEDLING WITH ENERGY-BASED DEVICES: RADIOFREQUENCY (MNRF)

Microneedling combined with radiofrequency (MNRF) represents an important evolution in acne scar treatment. By integrating thermal energy with the traditional mechanical action of microneedling, MNRF enhances dermal remodeling and stimulates collagen production at deeper skin layers. This dual mechanism makes it especially effective for patients with moderate to severe atrophic scars.

Unlike standard microneedling, which relies solely on mechanical microinjuries, MNRF delivers controlled radiofrequency energy through tiny insulated or non-insulated needles directly into the dermis. This induces heat-mediated collagen denaturation and triggers neocollagenesis, all while sparing the epidermis. Studies have confirmed that MNRF can achieve greater scar depth reduction and smoother skin texture compared to microneedling alone, particularly in rolling or boxcar-type scars [20].

One clinical study focusing on the Wosyet technique—an insulated RF microneedling method—demonstrated its effectiveness in treating moderate to severe acne scars, with patients reporting substantial improvement and minimal post-treatment downtime [4]. The technique was also found to be safe for darker skin types, with no observed post-inflammatory hyperpigmentation.

Another key benefit of MNRF lies in its flexibility. Parameters such as needle depth, pulse duration, and energy intensity can be tailored to the specific needs of each patient. A head-to-head trial comparing MNRF with fractional CO_2 laser therapy revealed comparable scar improvement between both modalities. However, patients who underwent MNRF reported less redness, faster recovery, and greater overall comfort during the healing process [27].

Patient satisfaction with MNRF is consistently high. In split-face trials and comparative studies, individuals tended to prefer the side treated with MNRF, citing faster healing, better cosmetic outcomes, and less discomfort [17]. Some researchers have also begun exploring the potential of combining MNRF with topical agents like insulin, which may further enhance regenerative effects through synergistic pathways [28].

In conclusion, MNRF merges the mechanical stimulation of microneedling with the thermal benefits of radiofrequency, offering an advanced, customizable, and well-tolerated option for treating acne scars. It shows particular promise in more challenging scar types, offers a favorable safety profile in diverse skin tones, and is gaining traction as a valuable addition to modern acne scar management strategies [4, 17, 20, 27, 28].

6. MICRONEEDLING VERSUS OTHER MODALITIES (E.G., CO_2 LASER, CHEMICAL PEELS)

Microneedling (MN) has been increasingly compared with other established acne scar treatments, particularly fractional CO_2 lasers, chemical peels, and PRP monotherapy. While these modalities have been long used in dermatology, microneedling stands out as a less invasive option that offers comparable efficacy with fewer complications—especially in individuals with darker skin tones.

Head-to-head studies consistently show that MN is at least as effective as CO_2 laser therapy in improving the appearance of atrophic scars, particularly boxcar and rolling types. In one study, both treatments led to visible clinical improvement, but patients treated with lasers experienced more post-treatment redness, longer downtime, and a higher risk of post-inflammatory hyperpigmentation [27]. A similar trend was observed in another comparison, where MN achieved results comparable to CO_2 while being better tolerated overall [19].

Skin type plays an important role in determining the safety of these treatments. In patients with Fitzpatrick types IV–VI, MN demonstrated a significantly lower risk of pigmentation issues compared to both lasers and medium-depth chemical peels [11, 16]. These findings make microneedling an appealing alternative for treating acne scars in individuals with skin of color.

When compared to chemical peels, particularly glycolic acid, MN has also performed favorably. In a randomized study, patients treated with MN reported greater improvements in scar texture and depth than those who received 35% glycolic acid peels. This effect was even more pronounced among patients with darker skin tones [14]. Another split-face study confirmed that MN achieved deeper dermal remodeling and longer-lasting results compared to peels [25].

Microneedling has also been evaluated alongside PRP monotherapy. In a triple-arm study comparing MN, PRP, and their combination, microneedling alone produced better outcomes than PRP, while the combination achieved the best overall results [7]. Similar observations were made in a trial comparing MN, PRP, and CO_2 laser: MN was found to be just as effective as laser and PRP, with fewer adverse effects [21].

Some reports suggest that although CO_2 lasers may lead to slightly more dramatic tissue remodeling in certain cases, the risk-benefit balance often favors microneedling, especially when safety, downtime, and cost are taken into account [20].

In conclusion, while traditional modalities like CO_2 lasers and chemical peels remain effective, microneedling provides a compelling alternative. It combines proven efficacy with a high safety profile, short recovery times, and better tolerance across a wide range of skin types, making it a versatile and patient-friendly treatment option [7, 11, 14, 16, 19, 20, 21, 25, 27].

7. MICRONEEDLING IN DIFFERENT SKIN TYPES AND PATIENT POPULATIONS

The safety and effectiveness of microneedling (MN) across various skin types and clinical populations is one of the key reasons for its growing popularity in the treatment of acne scars. Unlike ablative therapies, MN is typically well tolerated by individuals with darker skin tones (Fitzpatrick types IV–VI), who are more prone to pigmentary side effects such as post-inflammatory hyperpigmentation (PIH).

Several studies have confirmed the suitability of MN for patients with more pigmented skin. In a clinical trial conducted in a Latin American population with Fitzpatrick skin types IV and V, MN significantly improved acne scars without causing PIH or other pigment disturbances [16]. Another study found that MN was more effective and better tolerated than a 35% glycolic acid chemical peel in patients with darker skin, with a lower risk of discoloration and higher overall satisfaction [14].

The safety and efficacy of MN have also been validated in energy-based approaches such as microneedling with radiofrequency (MNRF). In a study using insulated RF microneedles, treatment not only improved acne scar severity but was also entirely safe for patients with Fitzpatrick types IV–V, with no cases of pigmentary side effects reported [4].

Microneedling also proves effective across a range of patient profiles, not only with respect to skin type but also in terms of scar morphology and comorbid skin conditions. For example, the combination of MN with topical insulin was well tolerated among different patient groups and showed positive outcomes regardless of skin phototype [28].

In a study comparing MN with CO_2 laser therapy in individuals with skin types IV and V, both methods proved effective. However, MN was associated with shorter downtime and fewer side effects, reinforcing its advantage in treating darker skin tones [19].

In summary, microneedling is a versatile and safe technique that offers significant scar improvement across a range of skin types and patient populations. Thanks to its non-ablative mechanism of action, low risk of pigmentation changes, and good treatment tolerance, MN is especially valuable for individuals with darker skin and for those seeking a safe, minimally invasive approach to acne scar therapy [4, 14, 16, 19, 28].

8. PATIENT SATISFACTION, PAIN TOLERANCE, AND QUALITY OF LIFE

The effectiveness of acne scar treatments extends beyond clinical outcomes. Increasing attention is being paid to how patients perceive their treatment experience—especially satisfaction with results, pain tolerance, and improvements in quality of life. As a minimally invasive and well-tolerated procedure, microneedling (MN) consistently receives positive feedback in all of these domains.

In a study specifically focused on patient satisfaction and quality of life after MN treatment, 76.5% of participants described themselves as "very satisfied" with the results. Patients reported not only visible improvements in scar appearance but also greater self-confidence and ease in social situations. A significant increase in Dermatology Life Quality Index (DLQI) scores was also observed, confirming that MN has a measurable positive effect not just on the skin, but on patients' psychological well-being as well [3].

Pain tolerance was also rated favorably. Most patients described the discomfort as moderate, with an average pain score of 3–4 out of 10 on the Visual Analogue Scale (VAS), and no participants discontinued treatment due to pain [3]. These findings are supported by other studies in which pain was described as mild to moderate and easily managed with topical anesthesia [4, 28].

Notably, many patients prefer MN over more invasive procedures like fractional CO_2 lasers. In comparative trials, MN was associated with shorter recovery times, fewer side effects, and a greater willingness among patients to repeat the treatment [19, 20].

Patients also highlighted the psychological dimension of MN—its visible effects combined with minimal disruption to daily life helped them feel more in control and boosted their self-esteem [3, 19].

Thus, microneedling is not only a clinically effective treatment for acne scars, but also one that is highly rated by patients. Its strong satisfaction scores, good pain tolerance, and positive impact on quality of life make MN a well-rounded and patient-friendly therapeutic option [3, 4, 19, 20, 28].

Table 2 Safety and patient satisfaction

Parameter	MN	MN + PRP	MN + HA/ Insulin	MNRF
Pain (VAS 0-10)	3-4	3-4	2-3	4-5

Recovery time	1-3 days	2-4 days	1-3 days	2-5 days
PIH frequency (types IV – VI)	Rare	Rare	Very rare	Extremely rare
Patient satisfaction (>70%)	Yes	Up to 80-90%	High	Very high
Willingness to repeat the procedure	High	Very high	High	Very high

9. INNOVATIONS AND FUTURE DIRECTIONS IN MICRONEEDLING THERAPY

As microneedling (MN) becomes more firmly established in dermatological practice, a wave of new technologies and clinical approaches is emerging to enhance its effectiveness, safety, and adaptability. Key innovations include the use of radiofrequency energy, the development of smart delivery systems for active compounds, and the implementation of AI-assisted diagnostics and treatment personalization.

One of the most impactful advancements in recent years is the integration of microneedling with radiofrequency (MNRF). This technique allows for deeper, more controlled collagen remodeling while minimizing surface damage. Modern RF devices enable precise adjustment of needle depth and energy levels based on the scar type and skin thickness. A notable example is the Wosyet technique, which uses insulated RF microneedles to achieve effective results with minimal downtime [4]. MNRF has also demonstrated a strong safety profile across various skin types, increasing its versatility [20].

Another promising direction is the use of microneedling as a platform for targeted transdermal delivery of bioactive substances—such as growth factors, peptides, PRP, or exosomes. The temporary microchannels created by MN can facilitate deep penetration of these compounds, enhancing tissue regeneration and collagen synthesis [12]. This approach is shifting microneedling from a mechanical technique to a precision-based, biologically active therapy.

Device innovation is also progressing rapidly. New-generation MN devices now feature thinner needles, ergonomic handpieces, and built-in calibration systems to improve comfort and ensure procedural safety [17]. In addition, real-time skin assessment tools are being developed, enabling clinicians to adjust treatment parameters dynamically during the procedure for better outcomes [18].

Looking forward, personalized treatment protocols tailored to scar type, skin phototype, and individual preferences are expected to play an increasingly central role. Current studies are exploring the integration of artificial intelligence to assist in scar classification, treatment planning, and monitoring therapeutic progress more objectively [18, 20].

In summary, microneedling is undergoing a transformation—from a purely mechanical approach to a multi-dimensional, customized regenerative therapy. Technological innovation, biologically active agents, and personalized care models are not only enhancing treatment outcomes but also redefining the future potential of MN in acne scar management [4, 12, 17, 18, 20].

DISCUSSION

Microneedling has emerged as a cornerstone in the management of atrophic acne scars, offering a compelling combination of safety, efficacy, accessibility, and adaptability. Across the reviewed literature, microneedling consistently demonstrated clinically significant improvements in scar depth, skin texture, and patient satisfaction—both as a monotherapy and in combination with other treatments [2, 5, 8, 14, 15, 16, 19, 22, 23]. Its ability to stimulate dermal remodeling while preserving the epidermis makes it a particularly valuable option in individuals with darker skin types, where conventional ablative therapies may pose a higher risk of pigmentary complications [11, 14, 16, 19].

As a standalone treatment, microneedling has proven effective across various scar morphologies and skin phototypes, with consistent improvements documented in both objective assessments and patient-reported outcomes [2, 5, 8, 14, 16, 19]. Compared to more invasive procedures like fractional CO_2 laser or medium-depth peels, microneedling offers a more favorable side-effect profile and shorter recovery time [19, 20, 27], making it especially well-suited for outpatient and low-downtime treatment settings.

The addition of platelet-rich plasma (PRP) to microneedling protocols has shown promise in accelerating healing and enhancing clinical outcomes, particularly in patient satisfaction and early response [6, 7, 10, 13, 15, 22, 23, 24, 25]. Similarly, combining MN with topical agents such as hyaluronic acid, insulin, or phenytoin appears to improve hydration, healing speed, and collagen induction—though further comparative

studies are needed to determine optimal agents and regimens [1, 2, 5, 6, 8, 13, 28].

Moreover, the evolution of energy-based devices, particularly radiofrequency-assisted microneedling (MNRF), marks a notable advancement in targeting deeper scars with precision and customization [4, 17, 20, 27, 28], further broadening the therapeutic scope.

Despite these advantages, several limitations must be acknowledged. First, heterogeneity in study protocols —including treatment intervals, needle lengths, outcome measures, and combination strategies—makes direct comparison across studies difficult [9, 23]. Additionally, most studies had relatively small sample sizes and short follow-up periods, limiting the ability to assess long-term efficacy and recurrence of scarring [23]. Moreover, the subjective nature of scar assessment and limited blinding in many trials may introduce bias in outcome interpretation [9, 23].

Another gap in the literature is the limited exploration of microneedling in real-world clinical settings, including treatment adherence, cost-effectiveness, and accessibility in resource-limited environments [3, 4]. Furthermore, while microneedling is generally well tolerated, pain perception and post-treatment discomfort vary among individuals and are rarely quantified beyond basic scales [3, 4, 28]. More rigorous, standardized research is needed to optimize treatment parameters, explore novel adjuncts, and establish long-term safety data [9, 23, 27].

Looking ahead, future directions in microneedling therapy will likely focus on personalization—developing individualized protocols based on scar type, skin phototype, and patient preferences [18, 20]. The integration of AI-driven diagnostics, real-time imaging, and biologic agents (e.g., growth factors, stem cell-derived products, exosomes) offers exciting opportunities for precision medicine approaches [12, 17, 18]. As device technologies continue to evolve, microneedling is poised to become not just a supportive therapy but a central, customizable platform in regenerative dermatology [4, 18, 20].

CONCLUSION

In conclusion, microneedling represents a safe, effective, and versatile treatment for acne scars, with strong support in the current literature for its use both alone and in combination with adjunctive modalities. While further research is warranted to refine protocols and expand indications, the available evidence supports its continued and expanded use as a core strategy in acne scar management.

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