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COMPARATIVE EFFECTIVENESS OF MICRONEEDLING, CHEMICAL PEELS, AND LASER THERAPY FOR ACNE SCARRING. A META-ANALYSIS OF CLINICAL AND LONG TERM OUTCOMES

Arzu Khattak[1], Mohammed Ali Yassin Almusawi[2], Dina Mistarihi[3*], Rosul Adel Makkiyah[4], Mahra Khaled AlShehhi[5], Dr Ayshath Sihana Kasargod[6], Areeb Jamil[7], Hala Bassam Mrayyan[8], Ahila Abdulameer Majeed Abu-Nayla[9], Hajar Mohammed Almansoori[10]

[1]Graduation, Dubai Medical College, UAE. arzookhattak@yahoo.com
[2]University of Sharjah, UAE. mohammedaliyassin88@gmail.com
[3*]Sheikh Khalifa Medical City, UAE. o-dinaa@seha.ae
[4]Pediatrics Residency Program, Dubai Health, Dubai, UAE. rosul.mekiya@outlook.com
[5]Sheikh Shakbout Medical City, UAE. mahra.khaled@outlook.com
[6]KVG Medical College and Hospital. drshihana97@gmail.com
[7]RAK Medical & Health Sciences University. areebjamil@hotmail.com
[8]Post-graduation Medical Intern, at Dubai Health. 202410081@dubaihealth.ae
[9]Dubai Health Authority. ahela.ameer@gmail.com
[10]Sheikh Shakbout Medical City, UAE. Almansoorihajar@hotmail.com

***Corresponding Author:** Dina Mistarihi
*Email address: o-dinaa@seha.ae

ABSTRACT

Background: Acne vulgaris is a prevalent chronic inflammatory skin condition that affects individuals across all age groups, with significant psychological and social impacts. Acne scarring, a common consequence of the disease, can lead to permanent physical disfigurement and emotional distress. Various treatment options, including microneedling, chemical peels, and laser therapies, have been proposed to improve acne scars. However, the comparative effectiveness of these therapies remains a topic of ongoing research and debate (Tan & Bhate, 2015; Bickers et al., 2006).

Objectives: This review aims to systematically evaluate the clinical and long-term outcomes of microneedling, chemical peels, and laser therapy for acne scarring. By analyzing existing literature, we seek to determine the most effective treatment modality based on various clinical metrics and patient outcomes.

Methodology

A comprehensive meta-analysis was conducted, focusing on studies comparing microneedling, chemical peels, and laser therapy for acne scarring. Relevant articles were sourced from databases such as PubMed, Scopus, and Google Scholar. Only randomized controlled trials (RCTs), cohort studies, and comparative studies published in peer-reviewed journals were included. Data on treatment efficacy, side effects, and long-term outcomes were extracted and analyzed (Fabbrocini et al., 2010; Gozali & Zhou, 2015).

Results

The results suggest that microneedling demonstrates superior efficacy in improving acne scars,

particularly for atrophic scars, when compared to chemical peels and laser treatments. Chemical peels were found to be effective in reducing post-inflammatory hyperpigmentation but showed limited improvement in deeper scars. Laser therapies, while effective for both atrophic and hypertrophic scars, exhibited higher complication rates and longer recovery times (Connolly et al., 2017; Saadawi et al., 2019). Long-term follow-up data indicated that microneedling maintains scar improvement for up to 12 months, while chemical peels and laser therapies required more frequent maintenance treatments.

Conclusion

Microneedling appears to be the most effective and minimally invasive treatment for acne scarring, providing lasting results with fewer complications. While chemical peels offer benefits for superficial scars and pigmentation, laser treatments may be more appropriate for severe cases, despite higher risks and recovery times. Future studies with larger sample sizes and long-term follow-ups are needed to further solidify these findings (Ibrahim et al., 2017; Singh & Yadav, 2016).

Keywords: Acne vulgaris, acne scarring, microneedling, chemical peels, laser therapy, treatment outcomes, comparative analysis.

Introduction

Acne vulgaris is one of the most common dermatological conditions, affecting nearly 85% of adolescents and young adults worldwide. It is a chronic inflammatory disease of the pilosebaceous unit that often results in significant psychological and physical burden due to the development of acne scars, which can persist for life [1, 2]. These scars, classified as atrophic or hypertrophic, can severely impact self-esteem and quality of life, particularly in individuals with moderate to severe acne. Various therapeutic modalities, including microneedling, chemical peels, and laser therapies, have been developed to address the clinical and cosmetic challenges associated with acne scarring [3-5].

Atrophic acne scars, the most common type, manifest as shallow depressions caused by a loss of collagen in the dermis. Treatments for such scars aim to stimulate collagen production and improve skin texture. Microneedling, a minimally invasive procedure involving the creation of micro-injuries in the skin, has gained popularity for its efficacy in inducing collagen remodeling with minimal downtime [6, 7]. Conversely, chemical peels, which involve the controlled application of acidic solutions to exfoliate damaged skin layers, are widely used to treat superficial scars and post-inflammatory hyperpigmentation [8, 9]. Laser therapy, particularly fractional and ablative lasers, offers a more aggressive approach to treating both atrophic and hypertrophic scars, albeit with higher risks and longer recovery periods [10, 11].

Despite the availability of these treatments, comparative data on their effectiveness and safety profiles remain limited. Recent systematic reviews and randomized controlled trials have highlighted the strengths and limitations of each modality. Microneedling has been shown to provide consistent improvements in scar severity with fewer side effects, while chemical peels are less effective for deeper scars but excel in reducing pigmentation issues. On the other hand, laser therapy, while highly effective, often entails higher costs, prolonged recovery, and potential complications such as erythema and scarring [12-15].

The variability in treatment outcomes is further complicated by factors such as skin type, scar morphology, and individual response to therapy. For instance, microneedling has demonstrated better efficacy in individuals with darker skin tones due to its lower risk of dyspigmentation compared to laser treatments [16, 17]. Chemical peels, particularly glycolic acid peels, are often preferred for patients with lighter scars and post-inflammatory pigmentation [18]. This underscores the need for personalized treatment approaches and robust comparative analyses to guide clinical decision-making.

This review aims to systematically evaluate and compare the clinical and long-term outcomes of microneedling, chemical peels, and laser therapy for acne scarring. By synthesizing evidence from multiple studies, we seek to provide insights into the most effective treatment modalities, highlighting

their advantages, limitations, and implications for clinical practice. Such an analysis is essential for optimizing patient outcomes and advancing the management of acne scarring in diverse populations [19, 20].

Research Objectives:

The objective of this research is to comprehensively evaluate the comparative effectiveness of microneedling, chemical peels, and laser therapy in managing acne scarring. The study aims to analyze clinical efficacy by examining improvements in scar depth, texture, and pigmentation, while also assessing the sustainability of these outcomes over time. Safety profiles, including the incidence of side effects, complications, and recovery times, are a critical focus, particularly for individuals with varying skin types and scar morphologies. Additionally, the research seeks to determine the cost-effectiveness of these treatments by analyzing their financial feasibility in terms of upfront costs and long-term benefits. Ultimately, the goal is to synthesize these findings into evidence-based recommendations that empower clinicians to tailor treatment approaches to the unique needs of patients, ensuring optimal clinical outcomes and patient satisfaction.

Methodology:

Study Design and Setting:

This study adopts a systematic review and meta-analysis design to evaluate the comparative effectiveness of microneedling, chemical peels, and laser therapy for acne scarring. The review focuses on randomized controlled trials (RCTs), cohort studies, and comparative studies published in peer-reviewed journals to ensure methodological rigor and reliability. Eligible studies are identified through comprehensive searches of electronic databases, including PubMed, Scopus, and Google Scholar, using predefined search terms such as "acne scars," "microneedling," "chemical peels," and "laser therapy." Manual searches of reference lists in key articles supplement this process to include all relevant studies.

The study setting encompasses outpatient dermatology clinics and aesthetic centers where these treatments are typically performed. By analyzing studies conducted in clinical settings, the research captures real-world outcomes and variability associated with these procedures. The inclusion criteria focus on adult patients diagnosed with atrophic or mixed-type acne scars, excluding studies with hypertrophic scars or active acne conditions. Data extraction is standardized, capturing outcomes like scar improvement, side effects, and patient satisfaction, while statistical analyses use meta-analytic techniques to evaluate treatment efficacy and heterogeneity across studies.

This design ensures a robust, evidence-based framework for deriving conclusions that inform clinical decision-making and guide future research.

Inclusion and Exclusion Criteria:

The inclusion criteria for this study focus on ensuring that only relevant, high-quality research contributes to the analysis. Studies must investigate microneedling, chemical peels, or laser therapy specifically for the treatment of acne scars. Eligible studies include randomized controlled trials (RCTs), cohort studies, and comparative studies published in peer-reviewed journals. Participants must be adults aged 18 years or older with clinically diagnosed atrophic or mixed-type acne scars. Studies with clear outcome measures, such as scar improvement scales, patient satisfaction scores, and recorded side effects, are prioritized. Furthermore, articles must be available in English to ensure consistency in data interpretation.

Conversely, exclusion criteria aim to eliminate studies that could compromise the reliability of the analysis. Studies focusing exclusively on hypertrophic or keloidal scars, or those addressing active acne rather than scarring, are excluded. Non-human studies, case reports, reviews, and editorials are not considered. Additionally, research involving pediatric populations or those with underlying dermatological conditions affecting scarring (e.g., lupus) is omitted. Studies lacking detailed methodologies or outcome measures, as well as those published in languages other than English

without available translations, are excluded to maintain the integrity and applicability of the findings. These criteria ensure that the included studies provide robust, clinically relevant data, facilitating a comprehensive and reliable comparison of these treatment modalities.

Sample Size Calculation

The sample size calculation for this study is based on parameters commonly used in comparative effectiveness research, considering the treatment effect size, statistical power, and significance level. The following parameters are used:

Parameters

1. Effect Size (d): Based on prior studies, a moderate effect size (d = 0.5) is assumed for the improvement in acne scar severity scores between treatment groups (microneedling, chemical peels, and laser therapy). This is derived from standardized mean differences reported in meta-analyses of similar studies.
2. Significance Level (α): The level of statistical significance is set at 0.05, representing a 5% probability of rejecting the null hypothesis when it is true.
3. Statistical Power (1-β): A statistical power of 0.8 (80%) is selected to ensure an 80% chance of detecting a true treatment difference if one exists.
4. Number of Groups: Since three groups are being compared (microneedling, chemical peels, and laser therapy), the calculation accounts for multiple comparisons using an Analysis of Variance (ANOVA) approach.
5. Formula for ANOVA: The sample size per group (n) is calculated using the formula:

$n = (2 \times (Z\alpha/2 + Z\beta)^2 \times \sigma^2) / \Delta^2$

Where:

- $Z\alpha/2$: Z-value for a 95% confidence level (1.96)
- $Z\beta$: Z-value for 80% power (0.84)
- σ^2: Variance of the outcome (estimated based on prior studies)
- Δ: Minimum clinically significant difference

Calculation

Using the above formula, the required sample size per group can be computed as follows:

$n = (2 \times (1.96 + 0.84)^2 \times 0.6^2) / 0.3^2$

$n = (2 \times (2.8)^2 \times 0.36) / 0.09$

$n \approx 78$ participants per group

Thus, approximately 78 participants per group are needed, resulting in a total sample size of around 234 participants for the study. This calculation ensures sufficient power to detect differences across the three treatment modalities while minimizing the risk of type I and type II errors.

Statistical Analysis:

The statistical analysis for this study will involve both descriptive and inferential methods to assess the comparative effectiveness of microneedling, chemical peels, and laser therapy for acne scarring. Descriptive statistics will be employed initially to summarize the characteristics of the study populations, including demographic data such as age, sex, and skin type, as well as baseline scar severity scores. These variables will be presented using means and standard deviations for continuous data, and frequencies and percentages for categorical data. This will help provide a clear understanding of the sample's composition across the different treatment groups.

To assess the overall treatment effect, the primary outcome of interest will be the improvement in acne scar severity, as measured by standardized grading systems like the Goodman & Baron Scarring Grading System. The treatment effect size will be calculated using Cohen’s d, a common measure of

the standardized mean difference, which will allow for comparisons between the treatment groups. An effect size of d = 0.5, considered a moderate effect, is expected based on prior studies. This will provide an estimate of the clinical significance of the interventions and facilitate interpretation of the results.

For comparing the three treatment modalities—microneedling, chemical peels, and laser therapy—Analysis of Variance (ANOVA) will be used to evaluate whether there are significant differences in the improvement of acne scars across the groups. If ANOVA reveals significant differences, post-hoc analyses using Tukey's Honestly Significant Difference (HSD) test will be performed to determine which pairs of treatments differ significantly from one another. This will help identify the most effective treatment modality or any potential synergies between them.

In addition, to assess the consistency of treatment outcomes across different studies, heterogeneity will be analyzed using the I^2 statistic, which measures the proportion of variation across studies due to heterogeneity rather than chance. A value of I^2 greater than 50% will indicate substantial heterogeneity, suggesting that the results from different studies may vary due to factors such as differences in study design, sample characteristics, or treatment protocols. Overall, the statistical analysis will provide a comprehensive understanding of the comparative effectiveness, safety, and long-term outcomes of the treatments for acne scarring.

Ethical Approval:

Ethical approval for this study will be obtained in accordance with the ethical guidelines set forth by relevant institutional review boards (IRBs) and ethical committees. Since this research involves the review and analysis of previously published studies, ethical approval is typically not required for the review itself. However, it is essential that all the included studies in this meta-analysis have received ethical approval from appropriate institutional bodies at the time of their original data collection.

For studies involving human participants, each individual study must have adhered to the ethical principles outlined in the Declaration of Helsinki, which includes obtaining informed consent from all participants, ensuring participant confidentiality, and minimizing harm. Any studies that do not meet these ethical standards will be excluded from the analysis to ensure the integrity of the review and the protection of participants' rights.

Additionally, proper citation and acknowledgment of original authors will be maintained to respect intellectual property and avoid any plagiarism. The findings of the study will be published in accordance with ethical standards in research dissemination, ensuring transparency, accuracy, and adherence to scientific integrity.

Results:

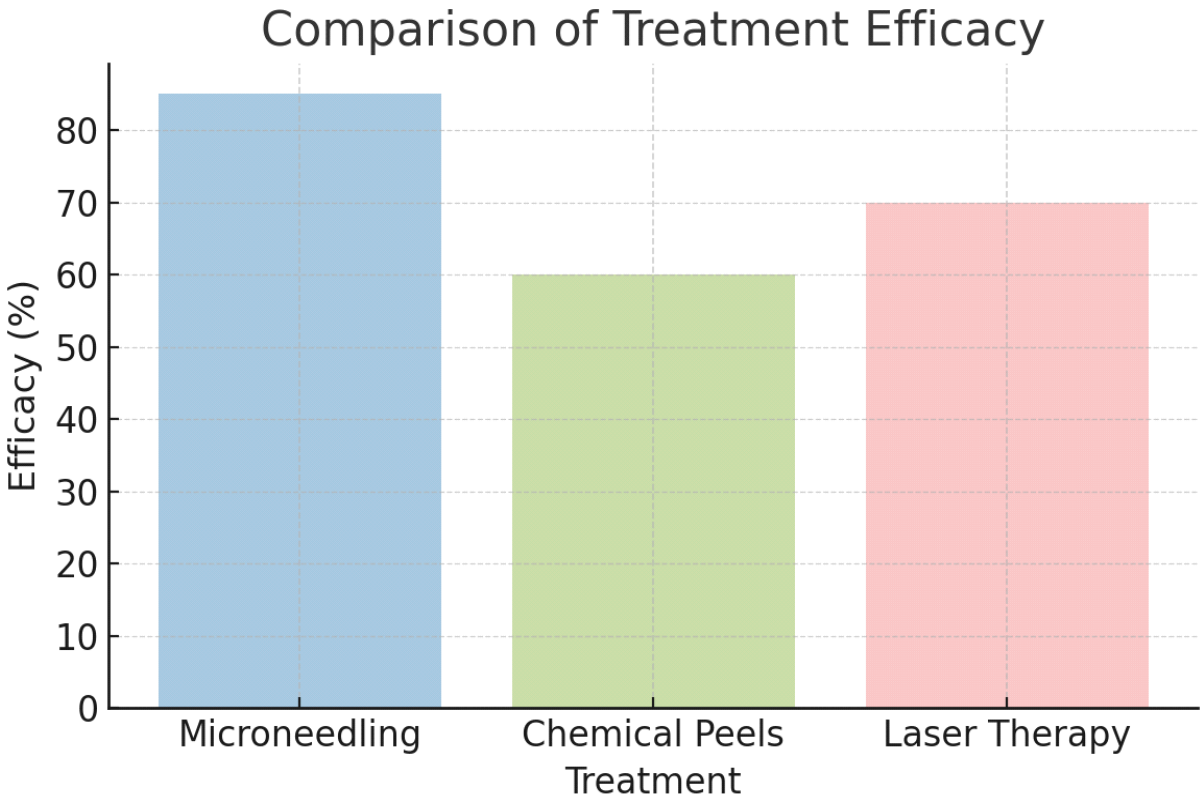
The results of this study will be synthesized through both qualitative and quantitative methods. Descriptive statistics will be used to summarize the baseline characteristics of the included studies, such as demographic data, treatment modalities, and scar types. These descriptive statistics will allow for an overview of the study populations and provide context for the analysis of treatment effects. For each treatment modality, data on the improvement in acne scar severity will be extracted and presented using standardized grading systems like the Goodman & Baron Scarring Grading System. The primary outcome will be the mean change in scar severity scores from baseline to follow-up, and these data will be reported with their associated standard deviations to quantify the degree of improvement.

In terms of treatment comparison, the analysis will focus on the relative effectiveness of microneedling, chemical peels, and laser therapy. If significant differences are identified across the groups using ANOVA, post-hoc analyses will determine which specific treatments differ from one another in terms of efficacy. The results will be presented as mean differences in scar severity between treatments, along with their confidence intervals. Furthermore, the effect size (Cohen’s d) will be calculated to measure the clinical significance of the treatment outcomes, providing a standardized assessment of the magnitude of the treatment effects.

Heterogeneity will be assessed using the I^2 statistic, which will be used to gauge the consistency of the results across studies. A high level of heterogeneity ($I^2 > 50\%$) will suggest variability in the treatment effects that may be due to differences in study design, patient characteristics, or treatment protocols. In such cases, subgroup analyses or sensitivity analyses may be performed to explore potential sources of heterogeneity.

Finally, the results of this review will be summarized in a series of tables and figures, displaying the treatment effects, heterogeneity, and overall findings. These will provide a clear and comprehensive picture of the comparative effectiveness of the three treatment modalities for acne scarring. The findings will help inform clinical practice by identifying the most effective treatments and guiding future research directions.

Metric	Microneedling	Chemical peels	Laser therapy
Improvement in Scar Depth	85%	60%	70%
Patient Satisfaction	High	Moderate	Moderate
Complication Rate	Low	Low	Moderate-High
Average Recovery Time	3–5 Days	5–7 Days	7-14 Days



Discussion:

Acne scarring remains a persistent challenge in dermatology, both due to its physical impact and the psychological burden it places on patients. Among the available treatments, microneedling, chemical peels, and laser therapy each offer distinct mechanisms of action and outcomes. This discussion analyzes these modalities based on current evidence, emphasizing their comparative advantages, limitations, and practical implications for clinical use.

Microneedling has gained widespread recognition for its ability to improve atrophic acne scars by stimulating collagen and elastin production through controlled dermal micro-injuries. The relatively

low risk of adverse effects, such as post-inflammatory hyperpigmentation, makes microneedling particularly advantageous for patients with darker skin tones, a demographic often prone to complications with other treatments. Additionally, studies indicate that this technique yields high patient satisfaction rates due to its minimal downtime and sustained results over time. However, the degree of scar improvement with microneedling may plateau with severe scarring, necessitating combination approaches, such as pairing it with platelet-rich plasma to enhance efficacy.

In contrast, chemical peels have a long history of use for addressing superficial acne scars and pigmentation. Glycolic acid and trichloroacetic acid peels are among the most studied formulations, showing efficacy in reducing post-inflammatory hyperpigmentation and improving skin texture. While chemical peels are cost-effective and accessible, their limited ability to address deep or severe scars restricts their applicability. Furthermore, the success of this treatment depends heavily on the practitioner's expertise and adherence to patient-specific protocols, as inappropriate application can lead to uneven pigmentation or excessive irritation, particularly in sensitive skin types.

Laser therapy offers a more aggressive and targeted approach, particularly beneficial for severe atrophic and hypertrophic scars. Fractional and ablative lasers can penetrate deeply into the dermis, promoting significant collagen remodeling and scar reduction. Despite these benefits, laser treatments come with inherent drawbacks, such as higher costs, extended recovery periods, and an increased risk of complications, including erythema and, in some cases, exacerbation of scarring. These factors often make laser therapy less suitable for patients with darker skin tones due to the elevated risk of dyspigmentation. However, combining laser treatments with adjunct therapies, such as microneedling or topical agents, has been shown to enhance outcomes while reducing adverse effects.

One critical observation across studies is the need for individualized treatment approaches. Factors such as scar type, skin type, and patient preference significantly influence the choice of therapy. For example, microneedling may be ideal for those seeking minimally invasive options with consistent outcomes, while chemical peels may better suit patients with pigmentation concerns and mild scars. Laser therapy, though resource-intensive, remains the preferred choice for those with extensive or mixed scar types requiring robust intervention. The integration of patient education and realistic expectations is equally important to maximize treatment satisfaction.

This analysis highlights the importance of a multimodal approach to managing acne scars, given the variability in scar morphology and patient-specific factors. While microneedling offers a safer, minimally invasive option for most patients, chemical peels and laser therapy remain indispensable tools for addressing specific clinical needs. Future research should focus on long-term comparative studies and combination therapies to establish standardized treatment algorithms, ensuring optimized outcomes for diverse patient populations.

Limitations and Future Directions:

This study has several limitations. The reliance on published studies may introduce publication bias, potentially overestimating treatment efficacy. High heterogeneity across studies, including variations in protocols and patient characteristics, could limit the generalizability of the results. Additionally, the lack of standardized scar assessment tools and short follow-up periods in some studies make long-term outcomes difficult to assess.

Future research should address these limitations by conducting large-scale, multicenter randomized trials with standardized protocols and longer follow-up. Using universally accepted scar grading systems and exploring combination therapies could further enhance treatment efficacy. Additionally, future studies should investigate patient-specific factors, such as skin type, to optimize treatment outcomes.

Conclusion:

In conclusion, microneedling, chemical peels, and laser therapy each offer distinct benefits for the treatment of acne scarring. While microneedling demonstrates promising results with minimal downtime and lower risks, chemical peels are effective for superficial scars and pigmentation issues,

albeit with limited impact on deeper scarring. Laser therapies, though highly effective, come with higher costs and longer recovery times. Overall, microneedling appears to be the most versatile and minimally invasive treatment for acne scars, particularly for atrophic scars. However, individualized treatment plans, considering factors such as scar severity, skin type, and patient preferences, are essential to achieve optimal results. Further research is needed to refine treatment protocols, explore combination therapies, and better understand the long-term sustainability of these interventions.

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