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A Comparative Study on Efficacy of Microneedling with Platelet Rich Plasma & Microneedling with Tranexamic Acid in the Treatment of Melasma

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ABSTRACT

Introduction: Melasma is a chronic, relapsing acquired hyperpigmentary disorder characterized by hyperpigmented macules and patches, predominantly involving sun-exposed areas of the face. It is particularly common in individuals with Fitzpatrick skin types III–V and frequently poses a therapeutic challenge because of its recurrent nature. Microneedling can enhance transdermal delivery of therapeutic agents, including platelet-rich plasma (PRP) and tranexamic acid (TA), and has emerged as a useful treatment approach for melasma. To compare the efficacy and safety of microneedling with PRP versus microneedling with tranexamic acid in patients with melasma by assessing changes in the Modified Melasma Area and Severity Index (mMASI) score from baseline to 4, 8, and 12 weeks.

Methodology: A comparative study was conducted among 70 patients with melasma, who were divided into two treatment groups. Group A received microneedling with PRP, while Group B received microneedling with tranexamic acid (100 mg/mL). Treatment was administered in three sessions at 4-week intervals (baseline, 4 weeks, and 8 weeks), with final follow-up at 12 weeks. Treatment efficacy was assessed using serial mMASI scores. Adverse effects were also recorded. Appropriate statistical analyses, including t-tests and analysis of variance (ANOVA), were performed to assess within- and between-group differences.

Results: Both treatment groups demonstrated a progressive reduction in mMASI scores over the 12-week study period. At 12 weeks, Group A showed a 30.7% reduction in mMASI score, whereas Group B demonstrated a greater reduction of 47.9%. The difference in treatment response between the groups was statistically significant ($p=0.039$), indicating greater overall improvement with microneedling combined with tranexamic acid. A slightly higher proportion of patients in Group A achieved an excellent response (>75% reduction in mMASI). The most commonly observed adverse effects were transient erythema, burning, pain, and local swelling, and no serious adverse events were reported in either group.

Conclusion: Both microneedling with PRP and microneedling with tranexamic acid were effective and well tolerated in the treatment of melasma. However, microneedling with tranexamic acid (100 mg/mL) produced a greater overall reduction in mMASI score at 12 weeks (47.9%) compared with microneedling with PRP (30.7%). These findings suggest that microneedling with tranexamic acid may provide a more effective short-term therapeutic

option for reducing melasma severity, although larger studies with longer follow-up are required to assess long-term efficacy and recurrence.

Keywords*: Xanthelasma palpebrarum, Trichloroacetic acid, Fractional CO_2 laser, Chemical cauterization, Laser therapy.*

INTRODUCTION

Melasma is a common acquired hyperpigmentary disorder characterized by light-to-dark brown macules and patches, predominantly involving sun-exposed areas of the face, including the forehead, cheeks, nose, upper lip, and chin. It usually follows a chronic and relapsing course and can substantially affect quality of life because of its cosmetic and psychosocial impact, particularly among individuals with darker skin types.[1]

Melasma occurs considerably more frequently in females than in males, with a reported female-to-male ratio ranging from 9:1 to 39:1. It predominantly affects women of reproductive age, indicating an important hormonal contribution to its pathogenesis. Although melasma can occur across all ethnic groups, it is particularly prevalent among individuals with Fitzpatrick skin types III–V and in Asian, Hispanic, Middle Eastern, and Indian populations. Its higher prevalence in tropical and subtropical regions further emphasizes the important role of chronic ultraviolet (UV) radiation exposure in its development and persistence.[2]

Clinically, melasma is classified according to the distribution of pigmentation into centrofacial, malar, and mandibular patterns. Based on Wood's lamp examination and the presumed depth of melanin deposition, it may also be categorized as epidermal, dermal, mixed, or indeterminate.[3] These distinctions may have therapeutic implications because epidermal pigmentation generally responds more readily to superficial therapies, whereas deeper or mixed pigmentation may be more resistant and require combination or procedural approaches.

Microneedling is a minimally invasive procedure increasingly used in the management of melasma. It involves the creation of controlled microscopic injuries using fine needles, resulting in transient microchannels that facilitate transdermal delivery of therapeutic agents. In addition to enhancing drug penetration, microneedling initiates a controlled wound-healing response that promotes fibroblast activity, collagen remodeling, and tissue regeneration.[4] Unlike more aggressive ablative procedures, microneedling causes relatively limited epidermal disruption and may therefore reduce the risk of treatment-induced post-inflammatory hyperpigmentation. It has been used alone and in combination with several therapeutic agents, including platelet-rich plasma (PRP), tranexamic acid (TA), vitamin C, and glutathione, with encouraging clinical outcomes.

Platelet-rich plasma is an autologous preparation containing a platelet concentration above that normally present in peripheral blood and is obtained by centrifugation of the patient's blood.[5] Platelet alpha granules contain several biologically active growth factors, including platelet-derived growth factor (PDGF), transforming growth factor-β (TGF-β), vascular endothelial growth factor (VEGF), and epidermal growth factor (EGF). These mediators contribute to cellular proliferation, angiogenesis, collagen synthesis, tissue repair, and remodeling.[6] These regenerative and regulatory properties have led to increasing interest in PRP as an adjunctive treatment for melasma, particularly when combined with microneedling to facilitate its delivery.

Tranexamic acid is a synthetic lysine analogue that exerts antifibrinolytic activity by inhibiting the conversion of plasminogen to plasmin. Although originally developed for the management of bleeding, TA has emerged as a promising therapeutic option for melasma because of its effects on several pathways involved in melanogenesis. TA inhibits UV-induced plasmin activity in keratinocytes, thereby reducing the release of arachidonic acid and prostaglandins that stimulate melanocyte activity. It may also modulate melanocyte–keratinocyte interactions and reduce the vascular component associated with melasma.[7] TA has been administered through oral, topical, and intradermal routes, with clinical studies demonstrating improvement in melasma severity.

Combining microneedling with PRP or TA may provide complementary therapeutic benefits by enhancing transdermal delivery while simultaneously utilizing the regenerative effects of PRP or the antimelanogenic effects of TA. Such combination approaches are particularly relevant because the primary therapeutic objective in melasma is to suppress excessive melanogenesis and reduce existing pigmentation while minimizing inflammation and epidermal injury. Excessive irritation or injury to keratinocytes may paradoxically activate melanocytes and contribute to post-inflammatory hyperpigmentation or worsening of pre-existing melasma.

Previous clinical studies have demonstrated encouraging results with TA in melasma. Sharma et al. compared oral TA with local TA infiltration through microinjections and reported reductions in mMASI scores of 64.1% and 78%, respectively, at 12 weeks, demonstrating substantial improvement with both routes of administration.[8] Similarly, Seema et al. evaluated different PRP delivery techniques in a split-face comparative study involving 62 patients. PRP delivered with microneedling produced greater clinical improvement than intradermal PRP microinjections, with more than 50% reduction

in pigmentation observed in 73.33% of patients on the microneedling-treated side compared with 18.33% on the microinjection-treated side.[9]

Despite the availability of multiple therapeutic modalities, melasma remains difficult to treat because of its multifactorial pathogenesis, variable therapeutic response, and tendency to recur. Evidence directly comparing microneedling-assisted PRP with microneedling-assisted TA remains limited. Therefore, the present study was undertaken to **compare the** therapeutic efficacy and safety of microneedling with PRP versus microneedling with tranexamic acid in patients with melasma, with treatment response assessed primarily through serial changes in the Modified Melasma Area and Severity Index (mMASI) score.

To compare the therapeutic efficacy of microneedling with PRP and microneedling with Tranexamic acid in the treatment of melasma.

MATERIALS AND METHODS

Study Design and Setting

This comparative study was conducted among 70 patients with melasma attending the Dermatology Outpatient Department (OPD), Department of Dermatology, Venereology and Leprosy, Prasad Institute of Medical Sciences, Lucknow, Uttar Pradesh, India. Eligible patients were enrolled according to predefined inclusion and exclusion criteria and allocated into two treatment groups: Group A received microneedling with platelet-rich plasma (PRP), while Group B received microneedling with tranexamic acid (TA).

Inclusion and Exclusion Criteria

Patients aged 18–60 years, of either gender, with clinically diagnosed melasma were eligible for inclusion. Patients who had not previously received treatment for melasma were included. Patients with a history of topical treatment for melasma were also eligible after completing a washout period of six weeks.

Patients younger than 18 years, pregnant or lactating women, patients receiving oral contraceptives or hormone replacement therapy, and those with systemic or endocrinological illnesses were excluded. Patients with active herpes simplex infection, hypersensitivity to chemical peels or laser procedures, or an irregular follow-up pattern were also excluded from the study.

Group Allocation

Eligible patients were allocated to the two treatment groups using the sealed-envelope method. Group A comprised patients treated with microneedling combined with PRP, whereas Group B comprised patients treated with microneedling combined with tranexamic acid. Each participant selected a sealed envelope and was assigned to the treatment group indicated in the envelope.

Treatment Protocol

Patients in Group A underwent microneedling with PRP for three treatment sessions at 4-week intervals, administered at baseline (week 0), week 4, and week 8, followed by a final clinical assessment at week 12. Patients in Group B underwent microneedling with tranexamic acid at a concentration of 100 mg/mL following the same treatment schedule, with sessions at baseline, week 4, and week 8 and final follow-up at week 12.

Preparation of Platelet-Rich Plasma

For patients in Group A, approximately 10–15 mL of venous blood was collected under aseptic conditions into tubes containing acid citrate dextrose (ACD) as an anticoagulant. The collected blood was initially centrifuged at 1500 rpm for 10 minutes (soft spin) to separate the red blood cells, buffy coat, and platelet-containing plasma. The supernatant plasma was subsequently transferred into sterile tubes and subjected to a second centrifugation at 3500 rpm for 20 minutes (hard spin) to concentrate the platelets in the lower one-third of the tube. Approximately 4–5 mL of platelet-rich plasma was subsequently collected in sterile insulin syringes and used immediately for treatment.

Microneedling Procedure

Before the procedure, the treatment area was cleansed appropriately. The skin was stretched using the non-dominant hand, and microneedling was performed using a Dermapen in stamping mode over the affected facial areas. The procedure was continued until uniform pinpoint bleeding was achieved, which was considered the clinical endpoint of microneedling. Following microneedling, PRP was topically applied over the treated area in Group A, whereas tranexamic acid (100 mg/mL) was topically applied in Group B, allowing penetration through the microchannels created during microneedling. Patients were advised not to wash their face for the remainder of the day following the procedure.

Clinical Assessment

Clinical response was assessed using the Modified Melasma Area and Severity Index (mMASI) at baseline and subsequently at 4, 8, and 12 weeks. Serial clinical photographs were also obtained to document changes in pigmentation

during treatment and follow-up. Patients were monitored for treatment-related adverse effects, including pain, erythema, burning, swelling, and other local reactions.

For mMASI assessment, the face was divided into four anatomical regions: the forehead (30%), right malar region (30%), left malar region (30%), and chin (10%). The extent of the involved area (A) and darkness of pigmentation (D) were assessed for each region.

The mMASI score was calculated using the following formula:
mMASI = 0.3(A × D) Forehead + 0.3(A × D) Right Malar + 0.3(A × D) Left Malar + 0.1(A × D) Chin

The total mMASI score ranged from 0 to 24, with higher scores indicating greater severity of melasma. Changes in mMASI scores from baseline to subsequent follow-up visits were used to evaluate treatment response in both groups.

RESULTS

A total of 70 patients with melasma were included in the study and allocated into two treatment groups. Group A received microneedling with platelet-rich plasma (PRP), whereas Group B received microneedling with tranexamic acid (TA). The demographic and clinical characteristics and changes in mMASI scores during the 12-week study period were evaluated.

A. Demographic and Clinical Characteristics

Table 1. Comparison of Mean Age Between Group A and Group B

Group	N*	Mean age (years)	SD	*t*	*p*-value
Group A	30	35.41	6.90	2.05	**0.045**
Group B	30	31.84	7.68		

The mean age was 35.41 ± 6.90 years in Group A and 31.84 ± 7.68 years in Group B. The difference in mean age between the two groups was statistically significant (t=2.05, p=0.045).

Table 2. Age Distribution of Patients in Group A and Group B

Age group (years)	Group A, n	Group B, n
18–25	2	3
26–35	17	16
36–45	11	12
46–55	5	4
Total	**35**	**35**

Most patients were between 26 and 45 years of age in both treatment groups. The 26–35-year age group included 17 patients in Group A and 16 in Group B, while the 36–45-year group included 11 and 12 patients, respectively. Patients aged 18–25 years constituted the smallest age category in both groups.

Table 3. Sex Distribution of Patients in Group A and Group B

Sex	Group A, n	Group B, n
Female	35	34
Male	0	1
Total	**35**	**35**

A marked female predominance was observed in both groups. All 35 (100%) patients in Group A were female, whereas Group B included 34 (97.1%) females and 1 (2.9%) male.

Table 4. Fitzpatrick Skin Type Distribution in Group A and Group B

Fitzpatrick skin type	Group A, n	Group B, n
III	10	14
IV	19	15
V	6	6
Total	**35**	**35**

Fitzpatrick skin type IV was the most frequently observed skin type, occurring in 19 (54.3%) patients in Group A and 15 (42.9%) patients in Group B. Skin type III was observed in 10 (28.6%) and 14 (40.0%) patients, respectively, while skin type V was present in 6 (17.1%) patients in each group.

B. Assessment of Treatment Response

Table 5. Mean mMASI Scores at Different Follow-up Periods in Group A

Assessment period	Mean mMASI	SD	F	*p*-value
Baseline	8.07	2.46		

4 weeks	7.30	2.23	**18.26**	**0.031**
8 weeks	6.35	2.15		
12 weeks	5.59	2.06		

In Group A, treated with microneedling and PRP, the mean mMASI score showed a progressive decline from 8.07 ± 2.46 at baseline to 7.30 ± 2.23 at 4 weeks, 6.35 ± 2.15 at 8 weeks, and 5.59 ± 2.06 at 12 weeks. The overall change in mMASI scores across the assessment periods was statistically significant (F=18.26, *p*=0.031), demonstrating improvement in melasma severity over time.

Table 6. Mean mMASI Scores at Different Follow-up Periods in Group B

Assessment period	Mean mMASI	SD	F	*p*-value
Baseline	7.24	2.43		
4 weeks	5.76	2.14	**17.85**	**0.0010**
8 weeks	4.70	1.97		
12 weeks	3.77	1.90		

In Group B, treated with microneedling and tranexamic acid, mean mMASI decreased progressively from 7.24 ± 2.43 at baseline to 5.76 ± 2.14 at 4 weeks, 4.70 ± 1.97 at 8 weeks, and 3.77 ± 1.90 at 12 weeks. The overall change across the four assessment periods was statistically significant (F=17.85, *p*=0.0010), indicating substantial improvement in melasma severity during treatment and follow-up.

Table 7. Pairwise Comparison of Mean mMASI Scores in Group A (Tukey's Test)

Comparison	Mean difference	*p*-value	95% CI	Significant
12 weeks vs 4 weeks	1.37	0.165	−0.34 to 3.08	No
12 weeks vs 8 weeks	0.63	0.777	−1.08 to 2.34	No
12 weeks vs baseline	**1.84**	**0.029**	**0.13 to 3.55**	**Yes**
4 weeks vs 8 weeks	−0.74	0.674	−2.45 to 0.97	No
4 weeks vs baseline	0.48	0.886	−1.23 to 2.19	No
8 weeks vs baseline	1.22	0.254	−0.49 to 2.93	No

Post-hoc pairwise analysis in Group A demonstrated that the 12-week mMASI score differed significantly from baseline, with a mean difference of 1.84 (95% CI: 0.13–3.55; *p*=0.029). The remaining pairwise comparisons were not statistically significant (*p*>0.05). Thus, although mMASI declined progressively throughout follow-up, a statistically significant pairwise difference from baseline was demonstrated at 12 weeks.

Table 8. Pairwise Comparison of Mean mMASI Scores in Group B (Tukey's Test)

Comparison	Mean difference	*p*-value	95% CI	Significant
12 weeks vs 4 weeks	1.71	0.187	−0.49 to 3.91	No
12 weeks vs 8 weeks	0.66	0.862	−1.54 to 2.86	No
12 weeks vs baseline	**3.29**	**0.0009**	**1.09 to 5.49**	**Yes**
4 weeks vs 8 weeks	−1.04	0.607	−3.24 to 1.16	No
4 weeks vs baseline	**2.18**	**0.024**	**0.62 to 3.78**	**Yes**
8 weeks vs baseline	**2.62**	**0.012**	**0.42 to 4.82**	**Yes**

In Group B, significant differences from baseline were observed at 4 weeks (mean difference=2.18, 95% CI: 0.62–3.78; *p*=0.024), 8 weeks (mean difference=2.62, 95% CI: 0.42–4.82; *p*=0.012), and 12 weeks (mean difference=3.29, 95% CI: 1.09–5.49; *p*=0.0009). In contrast, differences between the post-treatment follow-up visits themselves were not statistically significant. These findings indicate that Group B demonstrated an earlier and sustained significant improvement from baseline.

Overall, both groups showed progressive reductions in mMASI scores. However, the decline was greater in Group B, with the mean mMASI decreasing from 7.24 to 3.77, compared with a reduction from 8.07 to 5.59 in Group A.

C. Adverse Effects

No serious adverse effects were observed in either treatment group during the study period. The reported treatment-related adverse effects were predominantly mild and transient and included local pain, erythema, burning sensation, and swelling at the microneedling site. No serious treatment-related complications were reported.

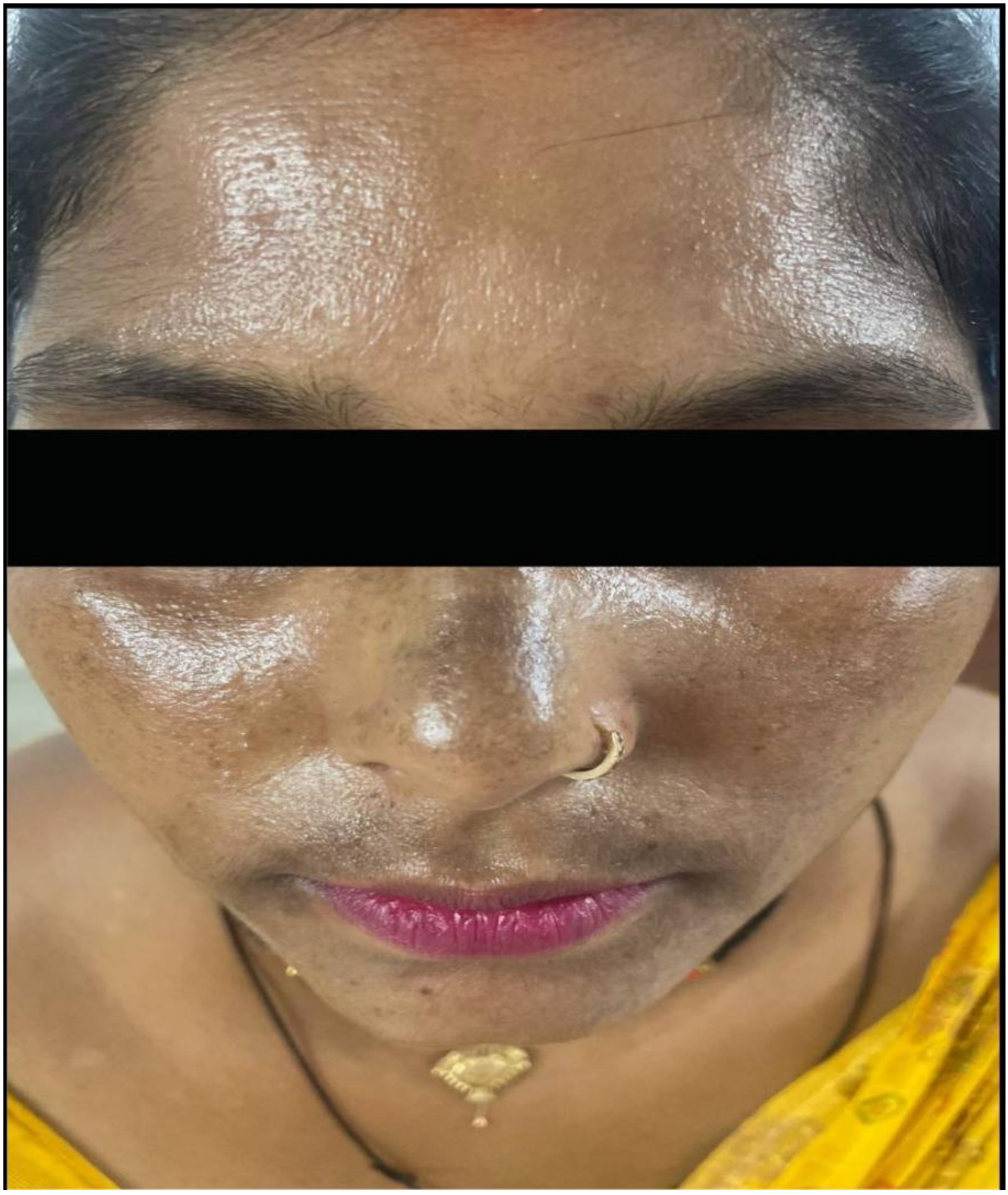
D. Clinical Photographs

Figure 1. Clinical Response to Microneedling with PRP

Case 1: Representative clinical photographs of a patient treated with microneedling and PRP: **(a) baseline, (b) 8 weeks, and (c) 12 weeks**. Serial photographs demonstrated progressive clinical reduction in facial pigmentation during treatment and follow-up.

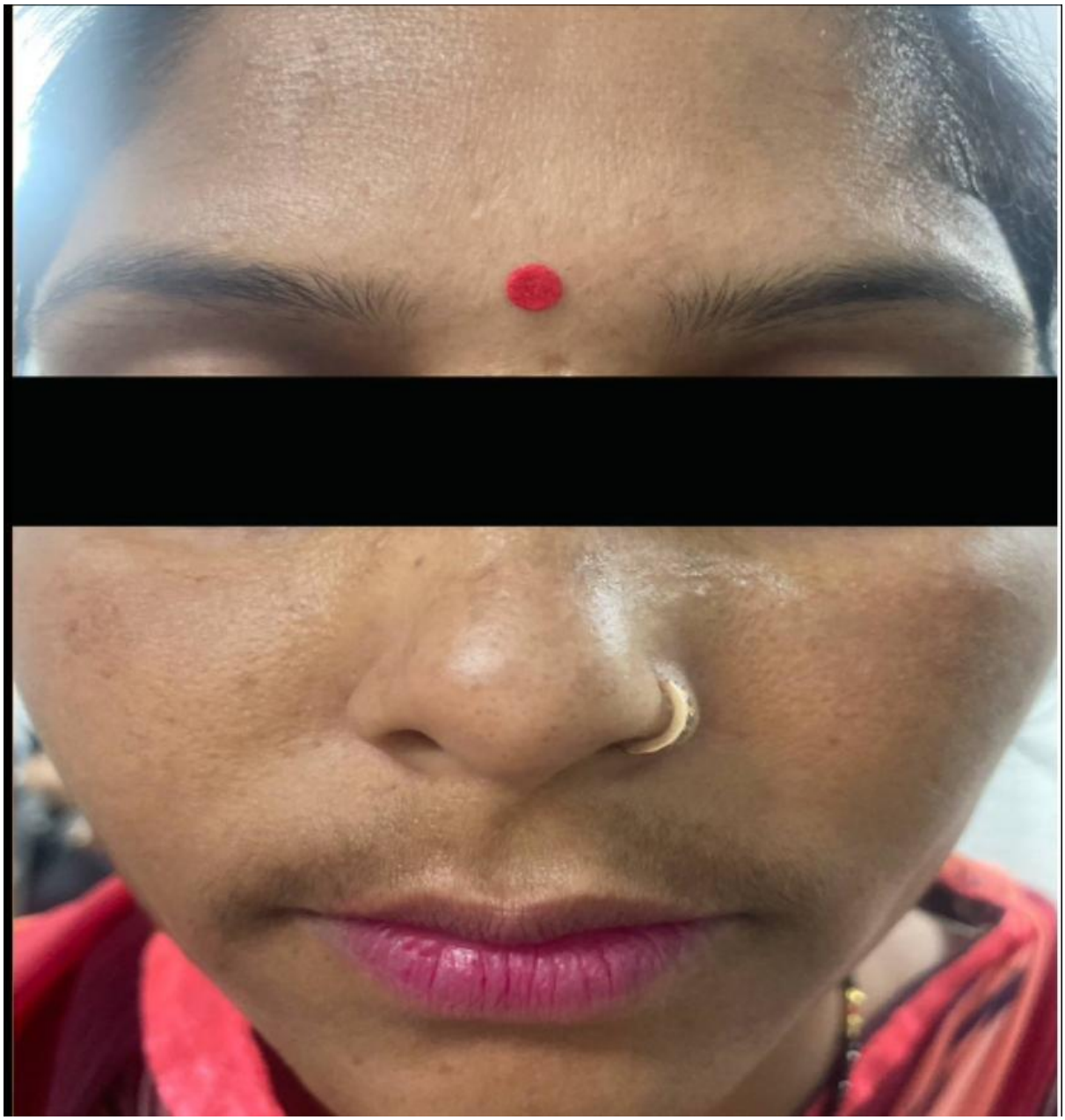
Figure 2. Clinical Response to Microneedling with Tranexamic Acid

Case 2: Representative clinical photographs of a patient treated with microneedling and tranexamic acid: **(a) baseline, (b) 4 weeks, and (c) 12 weeks**. Serial photographs demonstrated progressive improvement in melasma pigmentation over the study period.



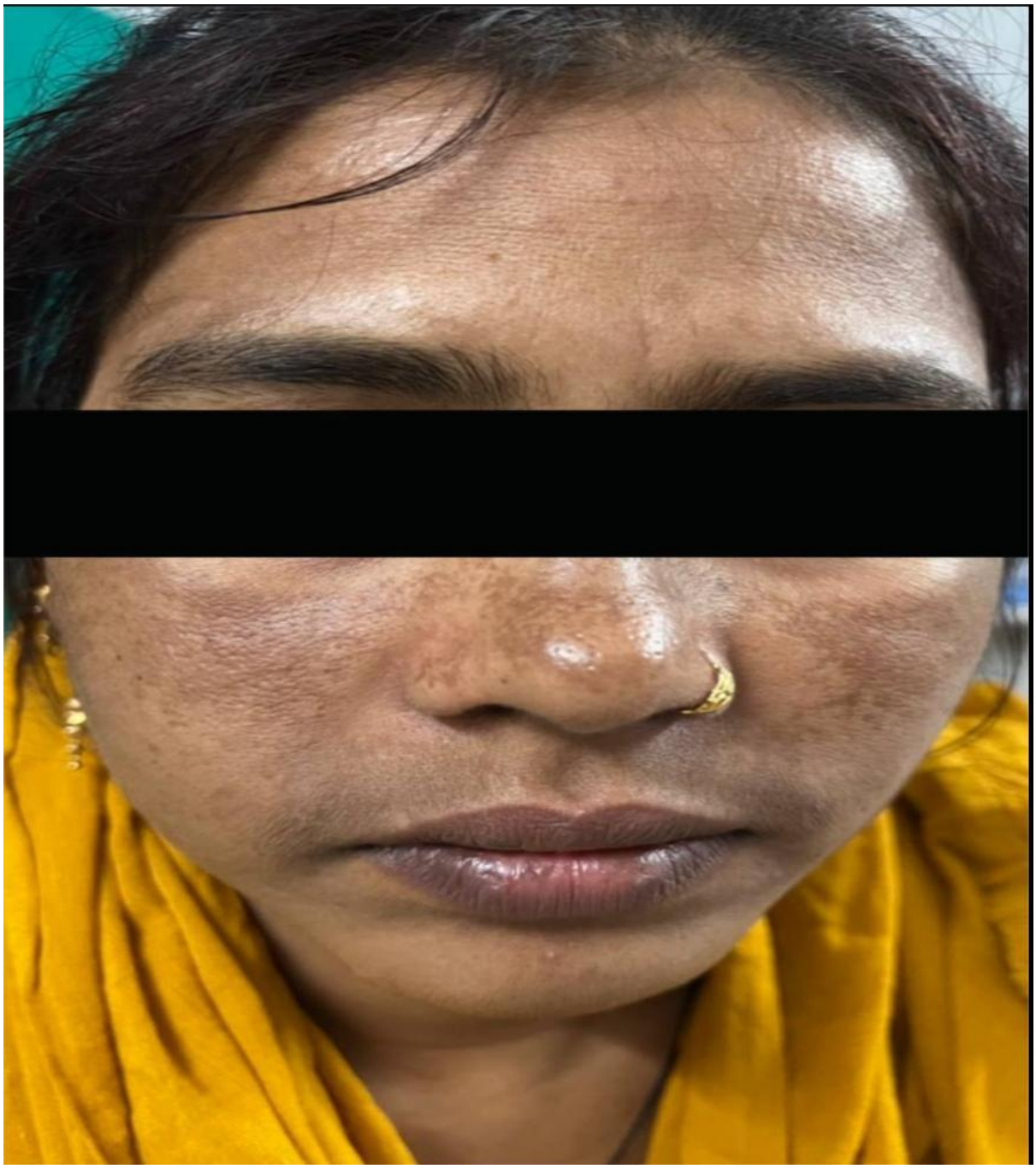
(a)

(b)



(C)

CASE 2: Microneedling With TA: (a) At baseline (b) At 4 weeks (c) At 12 weeks



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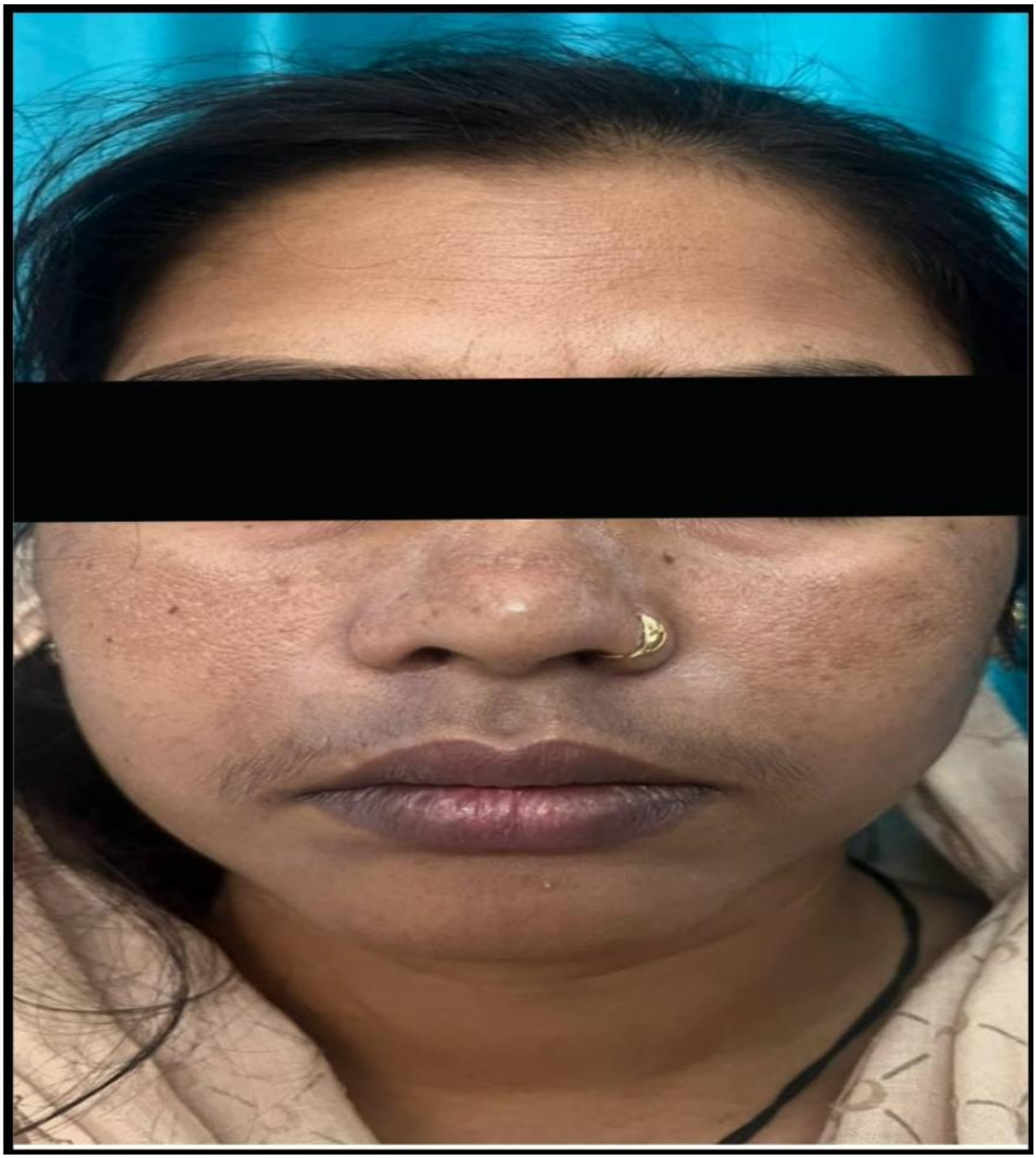

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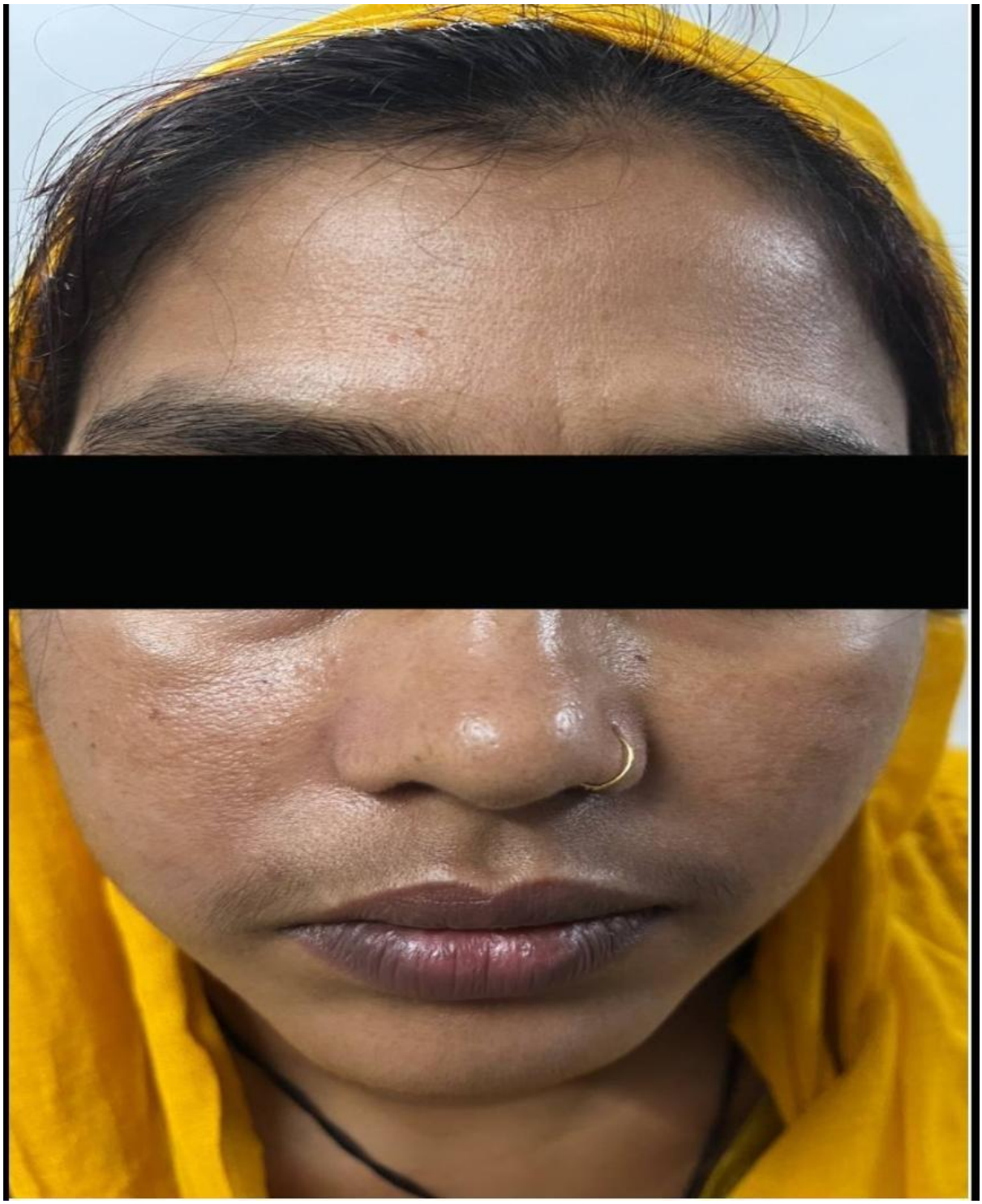

(C)

DISCUSSION

Melasma is a chronic and frequently relapsing pigmentary disorder for which satisfactory and sustained therapeutic responses remain challenging. In the present study, both microneedling with platelet-rich plasma (PRP) and microneedling with tranexamic acid (TA) resulted in progressive improvement in melasma severity during the 12-week study period. However, the magnitude and timing of improvement differed between the two groups, with the TA group demonstrating an earlier and greater reduction in Modified Melasma Area and Severity Index (mMASI) scores.

In Group A (PRP group), the mean mMASI score progressively decreased from 8.07 ± 2.46 at baseline to 7.30 ± 2.23 at 4 weeks, 6.35 ± 2.15 at 8 weeks, and 5.59 ± 2.06 at 12 weeks. The overall change across the study period was statistically significant ($F=18.26$, $p=0.031$), indicating a beneficial effect of microneedling with PRP on melasma severity. However, post-hoc analysis demonstrated that the difference from baseline became statistically significant only at 12 weeks, with a mean difference of 1.84 (95% CI: 0.13–3.55; $p=0.029$). Differences between baseline and 4 weeks ($p=0.886$) and between

baseline and 8 weeks (p=0.254) were not statistically significant. These findings suggest that PRP produced a gradual therapeutic response, with a significant effect becoming evident later during follow-up.

In comparison, Group B (TA group) demonstrated an earlier and more pronounced reduction in mMASI scores. The mean mMASI decreased from 7.24 ± 2.43 at baseline to 5.76 ± 2.14 at 4 weeks, 4.70 ± 1.97 at 8 weeks, and 3.77 ± 1.90 at 12 weeks. The overall change was statistically significant (F=17.85, p=0.0010). Post-hoc analysis further demonstrated significant reductions from baseline at 4 weeks (mean difference 2.18, 95% CI: 0.62–3.78; p=0.024), 8 weeks (mean difference 2.62, 95% CI: 0.42–4.82; p=0.012), and 12 weeks (mean difference 3.29, 95% CI: 1.09–5.49; p=0.0009). Thus, unlike PRP, TA produced a statistically significant response as early as 4 weeks, which was maintained throughout the subsequent follow-up period.

Although improvement continued numerically between successive visits in the TA group, differences between the post-treatment time points were not statistically significant. The differences between 12 and 4 weeks (p=0.187), 12 and 8 weeks (p=0.862), and 4 and 8 weeks (p=0.607) did not reach statistical significance. This may indicate that a substantial component of the therapeutic response to TA occurred relatively early, followed by continued but more gradual improvement.

At the end of 12 weeks, the overall percentage reduction in mMASI was greater in the TA group than in the PRP group. Group B demonstrated a 47.9% reduction compared with 30.7% in Group A, indicating a greater magnitude of clinical improvement with microneedling-assisted TA. These findings support the potential advantage of TA for achieving a relatively rapid and greater reduction in pigmentation severity. Nevertheless, both treatment modalities produced progressive clinical improvement, suggesting that PRP also represents a potentially useful therapeutic option for melasma.

The greater response observed with TA may be explained by its direct effects on melanogenesis. Tranexamic acid is a synthetic lysine analogue that inhibits the conversion of plasminogen to plasmin. By suppressing UV-induced plasmin activity in keratinocytes, TA decreases arachidonic acid and prostaglandin production and thereby reduces melanocyte stimulation. It may additionally influence melanocyte–keratinocyte interactions and the vascular component of melasma. Microneedling creates transient microchannels in the epidermis, potentially facilitating penetration of TA into the skin and enhancing its local therapeutic activity.

The present findings are broadly consistent with the observations of Sharma et al., who compared oral TA with local TA infiltration through microinjections in patients with melasma. They reported reductions in mMASI scores of 64.1% with oral TA and 78% with local TA at 12 weeks, demonstrating substantial improvement with both routes of administration.[8] Although the magnitude of improvement in the present study was lower, the significant and progressive decline in mMASI scores supports the therapeutic potential of locally delivered TA in melasma.

The concentration of TA may also influence the magnitude and speed of the clinical response. Previous studies using lower concentrations, including 4 mg/mL and 10 mg/mL, have reported improvement in melasma. In the present study, TA at a concentration of 100 mg/mL was used in combination with microneedling, and a significant reduction from baseline was already evident at 4 weeks. Previous observations with 100 mg/mL TA have similarly suggested a favorable clinical response. However, direct comparisons across studies should be interpreted cautiously because treatment technique, TA concentration, treatment frequency, baseline disease severity, follow-up duration, and outcome assessment may differ considerably.

PRP may improve melasma through mechanisms distinct from those of TA. Platelet-derived growth factors, including PDGF, TGF-β, VEGF, and EGF, participate in tissue repair, extracellular matrix remodeling, and regulation of cellular activity. When combined with microneedling, PRP may additionally benefit from enhanced penetration through the microchannels created during the procedure. In the present study, the progressive decline in mMASI from 8.07 at baseline to 5.59 at 12 weeks supports a therapeutic effect, although the response appeared slower than that observed with TA.

The beneficial role of microneedling-assisted PRP is also supported by Seema et al., who compared PRP delivered through microneedling with intradermal PRP microinjections in a split-face study. They reported that 73.33% of patients achieved more than 50% pigmentation reduction on the microneedling-treated side compared with 18.33% on the microinjection-treated side.[9] These findings suggest that microneedling may enhance the therapeutic effectiveness of PRP and support its use as a delivery technique in patients with melasma.

With regard to safety, no serious adverse effects were observed in either treatment group. The adverse effects were predominantly mild and transient and included local pain, erythema, burning, and swelling at the microneedling site. This favorable short-term safety profile is particularly relevant in patients with darker Fitzpatrick skin types, in whom aggressive procedures may increase the risk of post-inflammatory hyperpigmentation.

Overall, the present study demonstrates that both microneedling with PRP and microneedling with TA are effective and well-tolerated approaches for melasma, but TA produced an earlier and greater improvement in mMASI scores during the 12-week observation period. The 47.9% reduction with TA compared with 30.7% with PRP, together with significant improvement from baseline as early as 4 weeks in the TA group, suggests a potential therapeutic advantage of microneedling with TA. However, the relatively short follow-up period limits assessment of long-term durability and recurrence. Further studies involving larger populations, standardized TA concentrations and microneedling protocols, and longer follow-up periods are required to establish the optimum treatment regimen and long-term comparative effectiveness of these approaches.

CONCLUSION

Both microneedling with platelet-rich plasma (PRP) and microneedling with tranexamic acid (TA) were effective and well tolerated in the treatment of melasma. However, TA at a concentration of 100 mg/mL produced a faster and greater reduction in mMASI scores, with a 47.9% reduction at 12 weeks compared with 30.7% in the PRP group. No serious adverse effects were observed in either group. Microneedling with TA may therefore represent an effective, practical, and comparatively convenient treatment option for melasma. Larger studies with standardized treatment protocols and longer follow-up are required to determine the optimal TA concentration, treatment frequency, long-term efficacy, and recurrence rate.

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