

Microneedling with Vitamin C, Soft-tissue Laser and Scalpel Technique in the Management of Gingival Pigmentation: A Prospective Interventional Study

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ABSTRACT

Introduction: Gingival hyperpigmentation is a common aesthetic concern caused by excessive melanin deposition in the gingival epithelium. Various treatment modalities have been proposed for depigmentation, including conventional scalpel surgery, soft-tissue lasers, and newer minimally invasive approaches such as microneedling with topical agents. Microneedling combined with vitamin C has recently gained attention for its potential to enhance drug delivery, promote healing, and reduce recurrence.

Aim: To comparatively evaluate the clinical efficacy of gingival depigmentation using microneedling with a derma pen and topical vitamin C, soft-tissue laser and the conventional scalpel technique.

Materials and Methods: The present prospective interventional study was conducted in the Department of Periodontics and Oral Implantology at Santosh Dental College and Hospital, Ghaziabad, Uttar Pradesh, India, from October 2024 to November 2025, with follow-up assessments at 24 hours, one week, one month and six months. Eleven systemically healthy patients, predominantly females, aged 18-40 years with physiologic gingival hyperpigmentation participated in the study. Of 23 patients screened, 33 hyperpigmented gingival sites in these 11 patients were included and randomly allocated to three groups: Group 1 (conventional scalpel technique), Group 2 (soft-tissue laser), and Group 3 (microneedling with derma pen and topical vitamin C). Clinical parameters-Dummett Oral Pigmentation

Index (DOPI), Takashi's Oral Pigmentation Index (TOPI), Visual Analogue Scale (VAS) for pain, and Wound Healing Index (WHI)-were recorded at baseline, 24 hours, one week, and six months, as applicable to each parameter. Intergroup comparisons were performed using one-way Analysis of Variance (ANOVA), and intragroup comparisons across time were performed using the paired t-test.

Results: All three techniques produced a significant reduction in gingival pigmentation from baseline (DOPI and TOPI, $p<0.001$ within each group), with pigmentation scores falling to near zero in all groups by one month. By six months, however, a significant intergroup difference emerged for DOPI ($p=0.013$), with pigment recurrence in the scalpel (0.909 ± 0.944) and laser (0.727 ± 0.786) groups, whereas the microneedling group maintained a complete absence of pigmentation (0.000 ± 0.000). Postoperative pain at 24 hours (VAS) was significantly higher after scalpel surgery (3.636 ± 0.924) than after microneedling (1.364 ± 0.505) or laser (0.273 ± 0.467 ; $p<0.001$). Wound healing at one week was most favourable in the microneedling group (1.000 ± 0.000 , uneventful in all cases) compared with laser (1.545 ± 0.522) and scalpel (1.818 ± 0.405 ; $p<0.001$).

Conclusion: Microneedling with derma pen and topical vitamin C achieved depigmentation outcomes comparable to laser and scalpel techniques, with the least postoperative discomfort, the most uneventful early wound healing, and the greatest resistance to pigment recurrence at six months-supporting its use as a minimally invasive alternative for gingival depigmentation.

Keywords: Aesthetics, Ascorbic acid, Dermapen, Hyperpigmentation, Melanin, Neodymium-doped: Yttrium Aluminium Garnet laser

INTRODUCTION

A flawless smile has recently become a key target for patients in their aesthetic pursuit. The harmony of a smile is not solely determined by the shape, alignment and shade of the teeth, but also by the clinical characteristics of the gingiva. Gingival colour is especially important in creating an attractive smile [1]. The best colour of the gingiva is salmon or coral pink. Gingival colour is affected by the presence of melanin, carotene, a decrease in haemoglobin and oxyhaemoglobin, keratinisation, and the number and size of blood vessels [2]. Oral pigmentation may be physiological or pathological and results from excess deposition of melanin in the basal and suprabasal epithelial layers [3]. It can be due to systemic disease, tobacco habits, exposure to heavy metals, and certain medications [4]. Melanin, the most common endogenous pigment, is a non haemoglobin brown pigment synthesised by melanocytes present in the basal layer of the epithelium [5]. Physiological pigmentation is a genetic trait, most often found in

the attached gingiva, and to a lesser extent involving the interdental papilla and marginal gingiva, as reported by Ponnaiyan D et al., [6].

Gingival depigmentation is one of the aesthetic procedures of modern dentistry. Many treatment modalities are available like surgical, laser, chemical and grafting with varying success [7]. Surgically removing the pigmentation is one of the earliest and still remains a popular technique, achieved directly with scalpel surgery, which involves removal of the gingival epithelium along with the underlying connective tissue. Dummett CO and Barends G (1967) concluded that scalpel surgery is simple, inexpensive, and requires no special instruments [8], although it may cause bleeding and requires a periodontal dressing.

Laser gingival depigmentation is dependable and efficient. Soft-tissue lasers are classified into Diode, Neodymium-doped:Yttrium Aluminium Garnet (Nd:YAG), Erbium-Doped Yttrium Aluminium Garnet (Er:YAG) and CO₂ lasers based on wavelength, which determines the absorption of energy in tissue chromophores such

as melanin, haemoglobin or water. Shorter wavelengths penetrate to the basal layer and target melanin, while longer wavelengths ablate the tissue layer by layer until the pigment is removed. Laser depigmentation allows precise removal with minimal damage to surrounding tissues, and healing occurs by secondary intention with good tissue recovery [9].

Microneedling with a derma pen and vitamin C is a recent, minimally invasive technique for gingival depigmentation [10]. It creates micro-conduits that increase tissue permeability and blood flow, enhancing vitamin C penetration. Vitamin C then inhibits tyrosinase activity by interacting with copper ions at its active site, reducing melanin production and helping eliminate hyperpigmented spots [11]. As no consensus exists on the ideal gingival depigmentation method and traditional methods-though well documented-carry drawbacks such as bleeding, pain, delayed healing, cost, and recurrence [12], a comparative study of microneedling versus scalpel and laser techniques is needed.

Therefore, a comparative study is required to evaluate whether microneedling, a minimally invasive and emerging technique, can deliver clinical outcomes comparable to or superior to conventional scalpel and laser methods in terms of depigmentation efficacy, patient comfort, healing, and aesthetics, while minimising the drawbacks associated with traditional techniques. The present study aimed to compare the effectiveness of microneedling with a derma pen, soft-tissue laser and conventional scalpel in the management of gingival pigmentation.

MATERIALS AND METHODS

The present prospective interventional study was carried out in the Department of Periodontics and Oral Implantology at Santosh Dental College and Hospital, Ghaziabad, Uttar Pradesh, India, from October 2024 to November 2025, with follow-up assessments at 24 hours, one week, one month and six months. The study protocol was approved by the Institution's Ethical Committee {SU/2024/1349(13)} and conducted in accordance with the Declaration of Helsinki (2013). Each patient was informed of the limitations and benefits of treatment, and written consent was obtained prior to the procedure.

Inclusion criteria: Patients aged 18-40 years with pigmentation of score 1 to 3 on the DOPI and score 2 on TOPI in the aesthetic zone, and with no history of periodontal disease [13,14].

Exclusion criteria: Patients with systemic disease, bleeding disorders, or on medications known to cause gingival pigmentation; pregnant or breastfeeding women; smokers or users of smokeless tobacco; and individuals with gingival thickness less than 2 mm were excluded from the study.

Patients were randomly divided into three groups:

Group 1- Scalpel technique;

Group 2- Laser technique;

Group 3- Microneedling with derma pen and topical vitamin C.

For the present study, a surgical site was defined as a single hyperpigmented gingival unit corresponding to one tooth (extending from the mesial to the distal papilla) within the maxillary and/or mandibular anterior aesthetic zone. Each patient contributed multiple such pigmented sites, which were randomly and equally distributed among the three treatment groups, yielding a total of 33 sites (11 sites/group) across the 11 participating patients.

Sample size calculation: Sample size was calculated a priori using nMaster 2.0 software, based on the wound-healing index effect size ($f=0.65$) reported by Morsy S for the overall sample size calculation for their microneedling-versus-scalpel depigmentation trial [15], at 80% power and a 95% confidence interval; the minimum required sample size was estimated at 11 sites per group. Randomisation

of sites to the three treatment groups was performed using block randomisation.

Study Procedure

Clinical parameters: The following clinical parameters were recorded.

- 1) **Dummett Oral Pigmentation Index (DOPI) [13]:** measures the intensity and severity of gingival pigmentation.

Score 0: no clinical pigmentation (pink tissue); Score 1: mild pigmentation (light brown colour); Score 2: moderate pigmentation (medium brown or mixed pink and brown colour); Score 3: heavy pigmentation (deep brown or bluish-black tissue).

- 2) **Takashi's Oral Pigmentation Index (TOPI) [14]:** measures the extension of the band of gingival hyperpigmentation.

Score 0: no pigmentation; Score 1: solitary unit(s) of pigmentation in the papillary gingiva without extension between neighbouring units; Score 2: formation of a continuous ribbon extending from neighbouring units.

- 3) **Visual Analogue Scale (VAS) [16]:** a simple scale measuring pain intensity during and after surgery, recorded at 24 hours and one month postoperatively. Scores were interpreted using the widely adopted cut-offs of Collins SL et al., [16]: It used to assess the intensity of postoperative pain. The scale consists of a 10-cm horizontal line, with 0 representing "no pain" and 10 representing "worst pain imaginable." Patients were asked to mark a point on the line corresponding to the intensity of pain experienced. The distance from the zero point to the patient's mark was measured in centimetres and recorded as the VAS pain score, with higher scores indicating greater pain intensity. The VAS was assessed at the predetermined postoperative follow-up period.

- 4) **Wound Healing Index (WHI) [17]:** It is a 3-point clinical index for assessing periodontal soft-tissue healing. Importantly, the original WHI includes gingival oedema, erythema, suppuration, patient discomfort, and flap dehiscence. It evaluates early soft-tissue wound healing recorded at one week and one month postoperatively.

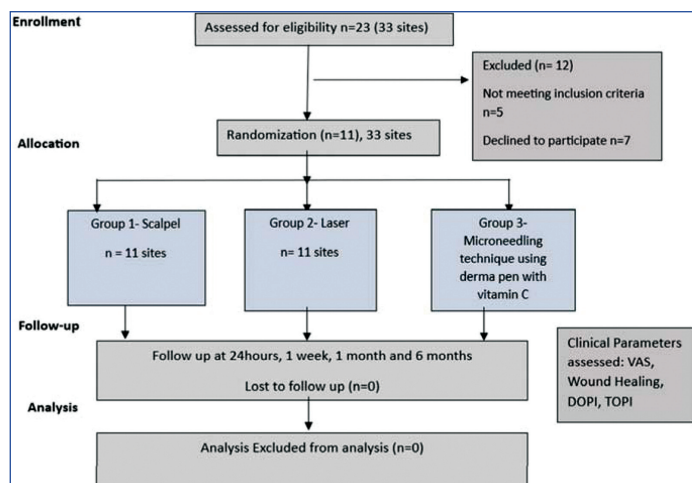
Score 1: uneventful healing with no gingival oedema, erythema, suppuration, or patient discomfort; Score 2: uneventful healing with slight gingival oedema, erythema, patient discomfort, flap dehiscence, or any suppuration;

Score 3: poor wound healing with significant gingival oedema, erythema, patient discomfort, flap dehiscence, or any suppuration. A lower score therefore denotes more favourable healing.

In summary, DOPI and TOPI were recorded at baseline, one month, and six months; VAS pain scores were recorded at 24 hours and one month postoperatively; and the WHI was assessed at one week and one month postoperatively. The Consolidated Standards of Reporting Trials (CONSORT) flow diagram is presented in [Table/Fig-1].

Surgical procedures: The respective surgical (quadrant) site was infiltrated with 2% lignocaine with 1:200,000 adrenaline (Lignox 2%).

- **Group 1 (Conventional scalpel technique) [18]:** The hyperpigmented gingival epithelium was excised using a Bard-Parker blade No. 15, from the free gingival margin to the mucogingival junction, with the blade held almost parallel to the long axis of the tooth, taking care not to expose the underlying bone. Bleeding was arrested with a pressure pack, and the de-epithelialised site was covered with a periodontal dressing (Coe-Pak, GC Corporation) for a period of one week [Table/Fig-2].
- **Group 2 (Laser technique) [19]:** Protective eyewear was worn by staff and patients. An Nd:YAG laser (Fotona) was



[Table/Fig-1]: Flowchart as per CONSORT guidelines.



[Table/Fig-2]: Surgical procedure of scalpel gingival depigmentation; a) Preoperative; b) Depigmentation using scalpel; c) Immediate postoperative; d) Periodontal dressing given.

used in a free-running pulsed mode; the pigmented area was de-epithelialised at a wavelength of 1064 nm, power of 3 W, energy of 60 mJ, and frequency of 50 Hz, using a 320-µm fibre handpiece in contact mode at 1 mm from the tissue. A surgical aspirator evacuated fumes, and sterile saline-soaked gauze removed surface char. No periodontal pack was applied [Table/Fig-3].

- **Group 3 (Microneedling technique) [20]:** The pigmented gingiva was needled for 30-40 seconds circularly using a derma pen (Dr Pen) with 24 microneedles, until pinpoint bleeding was observed. The site was irrigated with 0.9% saline, and a paste of ascorbic acid (NutriJa Lifesciences, 1000 mg/mL) mixed with saline was applied topically and left for 10 minutes before irrigation. No periodontal pack was applied [Table/Fig-4].

Postsurgical period: Patients were instructed to maintain oral hygiene and were prescribed analgesics for five days, and advised to avoid hot and spicy food for seven days. Follow-up assessments were carried out at 24 hours, one week, one month, and six months.

STATISTICAL ANALYSIS

Data were entered in Microsoft Excel 2007 and analysed using Statistical Package for the Social Sciences (SPSS) software (version 23.0). Descriptive statistics (mean±Standard Deviation(SD)) were computed for all parameters. Normality of the data distribution was assessed using the Shapiro-Wilk test, and homogeneity of variances using Levene's test; the data satisfied the assumptions for parametric testing. Intergroup comparisons at each time interval were performed using One-way ANOVA. Intragroup comparisons across time intervals were performed using the paired t-test. A p-value ≤0.05 was considered statistically significant.



[Table/Fig-3]: Surgical procedure of laser gingival depigmentation: a) Preoperative; b) Laser depigmentation; c) Immediate postoperative; d) 1 week postoperative; e) 1 month follow-up; f) 6 months follow-up.



[Table/Fig-4]: Surgical procedure of microneedling using derma pen with vitamin C gingival depigmentation: a) Preoperative; b) Use of derma pen for depigmentation; c) Bleeding points created; d) Topical application of Vitamin C; e) Immediate postoperative; f) 1 week follow-up.

RESULTS

A total of 11 patients (8 females (72.7%), 3 males (27.3%); mean age 27±6.35 years) contributing 33 gingival sites were included and equally allocated to the three treatment groups; as each patient contributed one site to every group, baseline demographic characteristics were identical across groups [Table/Fig-5].

Demographic data	Group 1 (Scalpel)	Group 2 (Laser)	Group 3 (Microneedling)	p-value
Age (years), Mean±SD	27±6.35	27±6.35	27±6.35	1.000
Males, n (%)	3 (27.3%)	3 (27.3%)	3 (27.3%)	1.000
Females, n (%)	8 (72.7%)	8 (72.7%)	8 (72.7%)	1.000

[Table/Fig-5]: Demographic data of the study participants (N=11).

*p≤0.05 statistically significant; NS: not significant. The three treatment groups are drawn from the same 11 patients, so age and sex distribution are, by definition, perfectly matched. This confirms that any differences seen later in pigmentation, pain, or healing scores reflect the treatment applied to each site, not underlying differences between patients.

The scalpel group achieved a rapid, significant drop in pigmentation by one month (DOPI and TOPI both p<0.001), but pigmentation increased again between one and six months (DOPI p=0.010)-indicating partial recurrence. Pain was highest of the three groups at 24 hours but resolved significantly by one month. Wound healing scores improved significantly between one week and one month, consistent with a full-thickness surgical wound that takes longer to settle than the other two techniques. Pigmentation indices (DOPI, TOPI): At baseline, DOPI and TOPI scores were comparable across the three groups (p>0.05), confirming a uniform starting point. Both indices fell to near-zero in all groups within one month of treatment (p<0.001 for each group, intragroup). By six months, however, a

significant intergroup difference emerged for DOPI ($p=0.013$) and approached significance for TOPI ($p=0.073$), driven by pigment recurrence in the scalpel (DOPI 0.909 ± 0.944 ; TOPI 0.364 ± 0.505) and laser (DOPI 0.727 ± 0.786 ; TOPI 0.364 ± 0.505) groups, whereas the microneedling group maintained a complete absence of pigmentation at six months (DOPI and TOPI= 0.000 ± 0.000) [Table/Fig-6-8].

Laser therapy also produced a significant, rapid fall in DOPI and TOPI by one month, with a comparable degree of pigment recurrence by six months (DOPI $p=0.012$). Pain was minimal from the outset (24-hour VAS 0.273) and did not change significantly by one month, reflecting the low-trauma nature of the technique. Wound healing improved between one week and one month but the change did not reach statistical significance ($p=0.082$), suggesting healing was already fairly settled by one week.

Parameter	Time interval	Mean $\pm$ SD	Intragroup comparison (Paired t-test)	p-value
DOPI	Baseline	2.818 $\pm$ 0.603	Baseline vs. 1 Month	<0.001*
	1 Month	0.000 $\pm$ 0.000	1 Month vs. 6 Months	0.010*
	6 Months	0.909 $\pm$ 0.944	Baseline vs. 6 Months	<0.001*
TOPI	Baseline	2.000 $\pm$ 0.000	Baseline vs. 1 Month	<0.001*
	1 Month	0.091 $\pm$ 0.302	1 Month vs. 6 Months	0.082
	6 Months	0.364 $\pm$ 0.505	Baseline vs. 6 Months	<0.001*
VAS Pain	24 Hours	3.636 $\pm$ 0.924	24 Hours vs. 1 Month	<0.001*
	1 Month	0.909 $\pm$ 0.701	-	-
WHI	1 Week	1.818 $\pm$ 0.405	1 Week vs. 1 Month	0.025*
	1 Month	1.273 $\pm$ 0.467	-	-

[Table/Fig-6]: Group 1 (Scalpel)- Intragroup comparison of clinical parameters across time intervals.

*Statistically significant <0.05, NS (not significant). Group 1 = Scalpel technique. DOPI = Dummert Oral Pigmentation Index; TOPI = Takashi's Oral Pigmentation Index; VAS: Visual Analogue Scale; WHI: Wound Healing Index. For DOPI/TOPI, p-values are listed in the order: Baseline vs 1 Month; 1 Month vs 6 Months; Baseline vs 6 Months (paired t-test). * $p\leq0.05$, NS: Not significant)

Parameter	Time interval	Mean $\pm$ SD	Intragroup comparison (Paired t-test)	p-value
DOPI	Baseline	2.545 $\pm$ 0.688	Baseline vs. 1 Month	<0.001*
	1 Month	0.000 $\pm$ 0.000	1 Month vs. 6 Months	0.012*
	6 Months	0.727 $\pm$ 0.786	Baseline vs. 6 Months	<0.001*
TOPI	Baseline	2.000 $\pm$ 0.000	Baseline vs. 1 Month	<0.001*
	1 Month	0.364 $\pm$ 0.505	1 Month vs. 6 Months	NS
	6 Months	0.364 $\pm$ 0.505	Baseline vs. 6 Months	<0.001*
VAS pain	24 Hours	0.273 $\pm$ 0.467	24 Hours vs. 1 Month	0.167
	1 Month	0.091 $\pm$ 0.302	-	-
WHI	1 Week	1.545 $\pm$ 0.522	1 Week vs. 1 Month	0.082
	1 Month	1.273 $\pm$ 0.467	-	-

[Table/Fig-7]: Group 2 (Laser) – intragroup comparison of clinical parameters across time intervals.

Group 2 = Soft-tissue laser technique. DOPI: Dummert Oral Pigmentation Index; TOPI: Takashi's Oral Pigmentation Index; VAS: Visual Analogue Scale; WHI: Wound Healing Index. For DOPI/TOPI, p-values are listed in the order: Baseline vs 1 Month; 1 Month vs 6 Months; Baseline vs 6 Months (paired t-test). * $p\leq0.05$, NS: Not significant.

Parameter	Time interval	Mean $\pm$ SD	Intragroup comparison (Paired t-test)	p-value
DOPI	Baseline	2.545 $\pm$ 0.820	Baseline vs. 1 Month	<0.001*
	1 Month	0.000 $\pm$ 0.000	1 Month vs. six months	0.120
	6 Months	0.000 $\pm$ 0.000	Baseline vs. 6 Months	<0.001*
TOPI	Baseline	2.000 $\pm$ 0.000	Baseline vs. 1 Month	<0.001*
	1 Month	0.000 $\pm$ 0.000	1 Month vs. 6 Months	0.135
	6 Months	0.000 $\pm$ 0.000	Baseline vs. 6 Months	<0.001*
VAS Pain	24 Hours	1.364 $\pm$ 0.505	24 Hours vs. 1 Month	<0.001*
	1 Month	0.091 $\pm$ 0.302	-	-

WHI	1 Week	1.000 $\pm$ 0.000	1 Week vs. 1 Month	0.162
	1 Month	1.000 $\pm$ 0.000	-	-

[Table/Fig-8]: Group 3 (Microneedling with Vitamin C)- intragroup comparison of clinical parameters across time intervals.

* $p\leq0.05$ statistically significant; NS = not significant. Group 3 = Microneedling with derma pen and topical vitamin C. DOPI: Dummert oral pigmentation index; TOPI: Takashi's oral pigmentation index; VAS: Visual analogue scale; WHI: Wound healing index. For DOPI/TOPI, p-values are listed in the order: Baseline vs 1 Month; 1 Month vs 6 Months; Baseline vs 6 Months (paired t-test). * $p\leq0.05$, NS: Not significant.

Pain (VAS): Postoperative pain at 24 hours differed significantly among the groups ($p<0.001$), and was highest after scalpel surgery (3.636 ± 0.924), intermediate after microneedling (1.364 ± 0.505), and lowest after laser therapy (0.273 ± 0.467). Pain decreased significantly within the scalpel and microneedling groups by one month ($p<0.001$ for both), while the laser Group which had minimal pain from the outset- showed no significant further change ($p=0.167$) [Table/Fig-6-8].

Wound Healing (WHI): At one week, wound-healing scores were significantly more favourable (lower) in the microneedling group (1.000 ± 0.000 , uneventful healing in all cases) than in the laser (1.545 ± 0.522) and scalpel (1.818 ± 0.405) groups ($p<0.001$). Healing improved significantly within the scalpel group by one month ($p=0.025$) and showed a similar, non-significant trend in the laser group ($p=0.082$), while the microneedling group showed sustained uneventful healing at both time points [Table/Fig-6-8].

Microneedling with vitamin C is the only group in which pigmentation control was fully sustained: DOPI and TOPI dropped to zero by one month and showed no change at all through six months- i.e., no recurrence. Pain was intermediate at 24 hours but fell sharply and significantly by one month. Wound healing was uneventful (WHI=1.000) at both one week and one month, with no change over time, indicating the most predictable and complication-free healing of the three techniques.

All three groups start from a comparable pigmentation baseline and all achieve near-complete resolution by one month, so the techniques are not distinguishable in the short-term. The groups separate out at six months, where microneedling is the only technique with zero recurrence (DOPI $p=0.013$). Pain differs sharply between techniques at 24 hours with scalpel causing the most discomfort and laser the least; by one month this gap narrows. Wound healing at one week clearly favours microneedling (lowest, most favourable WHI), while the 1-month WHI difference is no longer significant, showing the groups converge on healing outcome over time even though they started differently [Table/Fig-9].

Parameter	Time interval	Group 1 (Scalpel) Mean $\pm$ SD	Group 2 (Laser) Mean $\pm$ SD	Group 3 (Microneedling) Mean $\pm$ SD	p-value
DOPI	Baseline	2.818 $\pm$ 0.603	2.545 $\pm$ 0.688	2.545 $\pm$ 0.820	0.587
	1 Month	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	N/A
	6 Months	0.909 $\pm$ 0.944	0.727 $\pm$ 0.786	0.000 $\pm$ 0.000	0.013*
TOPI	Baseline	2.000 $\pm$ 0.000	2.000 $\pm$ 0.000	2.000 $\pm$ 0.000	N/A
	1 Month	0.091 $\pm$ 0.302	0.364 $\pm$ 0.505	0.000 $\pm$ 0.000	0.046*
	6 Months	0.364 $\pm$ 0.505	0.364 $\pm$ 0.505	0.000 $\pm$ 0.000	0.073
VAS	24 Hours	3.636 $\pm$ 0.924	0.273 $\pm$ 0.467	1.364 $\pm$ 0.505	<0.001*
	1 Month	0.909 $\pm$ 0.701	0.091 $\pm$ 0.302	0.091 $\pm$ 0.302	<0.001*
WHI	1 Week	1.818 $\pm$ 0.405	1.545 $\pm$ 0.522	1.000 $\pm$ 0.000	<0.001*
	1 Month	1.273 $\pm$ 0.467	1.273 $\pm$ 0.467	1.000 $\pm$ 0.000	0.171

[Table/Fig-9]: Intergroup comparison of clinical parameters among the three treatment groups at each time interval (One-way ANOVA).

* $p\leq0.05$ statistically significant; NS: not significant. DOPI: Dummert oral pigmentation index; TOPI: Takashi's oral pigmentation index; VAS: Visual analogue scale; WHI: Wound healing index. N/A: ANOVA not computable (zero variance across all groups). * $p\leq0.05$ statistically significant; NS: not significant.

DISCUSSION

Gingival hyperpigmentation is a common aesthetic concern that can negatively affect self-confidence and increase the demand for treatment [21]. Although several depigmentation techniques exist, identifying the most effective method remains challenging, and an ideal technique should be simple, efficient, and yield predictable aesthetic outcomes [22,23]. Surgical depigmentation is considered the gold standard for managing gingival pigmentation [24]; however, it is associated with bleeding, postoperative pain, larger wounds, and a risk of repigmentation [25]. Laser-assisted depigmentation provides better haemostasis but is limited by high cost and the potential for delayed healing and thermal damage. There is therefore increasing interest in minimally invasive, patient-friendly alternatives for gingival depigmentation [26]. Microneedling combined with ascorbic acid was chosen in the present study for its conservative nature, enhanced healing potential, reduced postoperative discomfort, and favourable aesthetic outcomes. A total of 33 sites were equally distributed among the three groups, and clinical parameters (DOPI, TOPI, VAS, and WHI) were assessed at baseline, 24 hours, one week, one month and six months, as applicable.

Baseline DOPI and TOPI values were comparable among the groups, confirming a uniform starting point. All three techniques produced a marked, statistically significant reduction in pigmentation by one month, with DOPI and TOPI scores falling to near zero in every Group indicating that scalpel, laser and microneedling techniques are all highly effective in the short term. The more clinically informative finding emerged at six months: while the microneedling group sustained a complete absence of pigmentation, both the scalpel and laser groups showed a degree of pigment recurrence (mean DOPI 0.909 and 0.727, respectively), producing a statistically significant intergroup difference ($p=0.013$). This pattern is consistent with reports by Swarna Meenakshi P and Subasree S and Norbu et al., who also described more sustained depigmentation with microneedling-based protocols [27,28], and with Maheshwari A et al., and Chandrasekar D et al., who attributed the more controlled, uniform removal of pigmented tissue with ascorbic acid-assisted microneedling to a lower likelihood of residual melanocytic activity at the treated site [10,29]. The comparable degree of recurrence observed with scalpel and laser techniques in the present study is in keeping with Suragimath G et al., who also reported slight repigmentation in some scalpel-treated cases [30].

Postoperative pain (VAS) was significantly higher after scalpel surgery than after either microneedling or laser therapy at 24 hours, consistent with the more extensive soft-tissue trauma associated with a full-thickness excisional wound. Laser therapy produced the lowest 24-hour pain scores, in agreement with Biswas S et al., who also reported minimal discomfort with laser depigmentation [31]; microneedling produced intermediate pain that resolved substantially by one month. This finding differs from that of Norbu et al., who reported the highest discomfort with microneedling [28]. This discrepancy may reflect differences in needling depth, technique, or patient pain perception across studies.

Wound-healing scores, in which a lower value denotes more favourable (uneventful) healing, were significantly better in the microneedling group than in the laser and scalpel groups at one week, with every microneedling-treated site healing uneventfully. Healing improved significantly in the scalpel group between one week and one month, and showed a similar, though not statistically significant, trend in the laser group, while the microneedling group remained uneventful throughout. This is consistent with the findings of Swarna Meenakshi P and Subasree S et al., and Ghaly AA et al., who attributed faster, more predictable healing after microneedling with ascorbic acid to the avoidance of a full-thickness surgical wound and to vitamin C's role in reducing oxidative stress and promoting collagen synthesis and cellular repair [27,32]. The controlled

microtrauma induced by the derma pen is thought to stimulate growth factors, collagen synthesis, and neovascularisation, further supporting tissue regeneration [20,33]. Taken together, these findings suggest that microneedling with topical vitamin C offers a favourable balance of tolerability, uneventful early healing, and resistance to pigment recurrence, while remaining minimally invasive and comparatively cost-effective.

Limitation(s)

Although the findings are promising, this study has certain limitations, including a modest sample size, a relatively short follow-up period of six months, and the allocation of multiple sites within the same patient across different treatment groups, which may introduce a degree of correlation between outcomes at different sites in the same individual. These factors may limit the generalisability of the findings, and larger, multi-centric trials with longer follow-up are warranted.

CONCLUSION(S)

Gingival pigmentation significantly contributes to an attractive smile, and achieving consistent, long-lasting aesthetics is a key objective in periodontal therapy. The present study found that all three techniques scalpel, laser and microneedling with vitamin C produced marked short-term depigmentation, but microneedling was distinguished by the least postoperative pain relative to scalpel surgery, the most uneventful early wound healing, and the greatest resistance to pigment recurrence at six months. Microneedling with derma pen and topical ascorbic acid therefore represents a promising, minimally invasive alternative to conventional scalpel and laser techniques for gingival depigmentation.

The combination of microneedling with topical vitamin C is a viable, minimally invasive technique for gingival depigmentation, offering durable reduction in pigmentation, favourable early wound healing, and a tolerable pain profile intermediate between laser and scalpel surgery. This method may be considered an effective and realistic alternative to traditional scalpel and laser techniques.

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