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COMPARISON OF ERBIUM YAG AND DIODE LASERS IN CONTACT MODE FOR GINGIVAL DEPIGMENTATION IN ADULTS: EFFICACY AND CLINICAL OUTCOMES

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ABSTRACT

Background: Gingival hyperpigmentation, though physiologic, can create esthetic concerns, particularly in patients with a high smile line. Lasers are widely accepted as an effective and minimally invasive alternative to conventional depigmentation methods. Among these, Erbium-YAG (2940 nm) and Diode (980 nm) lasers have shown promising results, each with distinct clinical characteristics. This study aimed to assess patient centered outcomes and compare their effectiveness in gingival depigmentation using a split-mouth approach.

Materials and Methods: A total of 14 healthy adults with bilateral gingival pigmentation were enrolled. Each patient underwent treatment with Erbium-YAG laser on the right side (2940 nm, pulsed mode, 120 m J, 1.8 W, 15 Hz) using water-air cooling and Diode laser on the left side (980 nm, continuous mode, 1 W) without cooling. Clinical parameters evaluated included pain perception, intraoperative bleeding, healing, pigmentation recurrence, and patient preference at 1 and 3 months postoperatively.

Results. Pain scores were statistically lower with Erbium-YAG compared to diode ($p = 0.0002$), whereas bleeding was significantly reduced with diode laser ($p = 0.0001$). Both lasers showed a statistically significant improvement in DOPI over time ($p < 0.001$), with no significant difference between groups. Healing was generally uneventful in both groups, with complete recovery within 7–10 days. Mild recurrence (first degree) was noted in three smokers during follow-up.

Conclusion: Both Erbium- YAG and Diode lasers are effective for gingival depigmentation. Erbium-YAG offers better patient comfort, whereas the Diode laser provides easier handling and favorable esthetics.

KEYWORDS: Gingival depigmentation; Erbium-YAG laser; Diode laser; Split-mouth technique

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INTRODUCTION

A confident smile greatly influences a person's self-image and combines both psychological well-being and facial esthetics. [1] While straight, well-aligned teeth are important, the shade of the gingiva plays an equally vital role in the harmony of a smile. [2] Gingival color is determined by multiple factors, including the size and distribution of blood vessels, epithelial thickness, keratinization, and the presence of pigments such as melanin, carotene, and hemoglobin derivatives. Melanin—derived from the Greek word *melas* meaning "black" is the most significant pigment, produced by melanocytes in the basal and supra-basal layers of the epithelium. [3]

When melanin is deposited excessively, gingival hyperpigmentation occurs. This condition can affect individuals of any age, gender, or ethnicity. [4] The most frequent cause is physiologic or ethnic pigmentation, a genetic trait presenting as diffuse or patchy melanin deposits across the gums. [5] Though medically harmless, many patients feel self-conscious about "black gums," especially when smiling, and often seek treatment to restore a healthier pink appearance. [6,7]

Several techniques have been developed for gingival depigmentation, including scalpel surgery, abrasion, grafting procedures, and laser therapy. [8] Lasers have become increasingly popular due to their precision, reduced bleeding, faster recovery, and minimal discomfort, although the technology remains relatively expensive. [9,10]

Laser-based depigmentation is founded on selective photo-thermolysis, described by Anderson and Parrish in 1983, which enables targeted destruction of melanin-rich cells using specific light wavelengths. [11] Among various laser systems, diode and Er:YAG lasers have gained prominence for their predictable outcomes, patient comfort, and esthetic results. [12] Both modalities offer distinct benefits, such as reduced trauma and faster healing, though operator expertise is crucial to prevent damage to thin gingiva or underlying bone. [13–16]

This Split mouth Clinical study aims to evaluate the efficacy and patient-centered outcomes of diode and Er:YAG lasers in gingival depigmentation through 3 months study period, providing for clinicians seeking optimal esthetic solutions for their patients.

MATERIALS AND METHODS

Study Design

This clinical split-mouth study was conducted to compare the efficacy of Er:YAG laser (2940nm) and Diode laser (980 nm) in the removal of gingival hyperpigmentation. The study was carried out at the Department of Periodontology, Faculty of Dental Medicine, Ain Shams University. The split-mouth design was chosen to minimize inter-patient variability and enhance the reliability of results by allowing direct comparison within the same individual.

The research protocol received approval from the Local Ethical Committee of Ain Shams University, Faculty of Dentistry Approval No: FDASU-Rec IR 112322. All participants were informed about the nature of the study, the procedures involved, potential risks, and benefits. Written informed consent was obtained from each subject prior to their enrollment in accordance with the Declaration of Helsinki. Confidentiality of patient data was strictly maintained.

A total of 14 patients (4 males and 10 females) aged between 21 and 49 years were included in the study. The sample size was determined based on previous studies and clinical feasibility. The participants presented with a primary complaint of dark brown or black gingival pigmentation in the anterior aesthetic zone. They were systemically healthy and demonstrated good oral hygiene compliance. The study protocol initially included close monitoring of the participants through periodic visits over 6 months to evaluate any pigmentation recurrence; however, due to restrictions and limitations imposed by the COVID-19 pandemic, the follow-up period was shortened, and evaluations were conducted only at 1 month and 3 months postoperatively.

Eligibility Criteria

The inclusion criteria were as follows: presence of bilateral gingival pigmentation involving the anterior maxillary and/or mandibular vestibular gingiva (canine-to-canine region), clinically healthy periodontium with no signs of active periodontal disease, and patient willingness to adhere to postoperative instructions and follow-up visits. **The exclusion criteria** included: systemic or hormonal disorders contributing to pigmentation, conditions that impair healing such as uncontrolled diabetes mellitus or immunological disorders, history of leukemia, smoking habits, medications known to cause pigmentation such as antimalarials or minocycline, pregnancy, lactation, and patients with previous gingival depigmentation procedures.

Prior to the intervention, all patients underwent thorough preoperative care. This included a complete oral prophylaxis involving supra- and subgingival scaling using ultrasonic and hand instruments to ensure a clean surgical field and reduce bacterial load. Patients were educated on optimal oral hygiene practices, including proper toothbrushing techniques and the use of interdental cleaning aids. Chlorhexidine gluconate mouthwash (0.12%) was prescribed twice daily for one week before the procedure to minimize the risk of postoperative infection. Patients were also advised to discontinue any habits that could affect healing, such as smoking, at least two weeks before the procedure.

The depigmentation procedure was performed using two different laser systems in a split-mouth fashion: Er:YAG laser for the right side and Diode laser for the left side of the maxillary and mandibular arches .parameters and specifications of Er:YAG and Diode laser systems used in the gingival depigmentation procedure under a split-mouth study design are summarized in **Table 2**

Local infiltration anesthesia was achieved with 2% lidocaine containing 1:80,000 epinephrine. Laser safety protocols were strictly followed, including the use of protective eyewear for both operator and patient. The diode laser was applied at an angle of 45 degrees in gentle sweeping motions from the mucogingival junction toward the free gingival margin and interdental papillae. Carbonized tissue and debris adhering to the fiber tip were regularly removed using saline-moistened gauze to prevent excessive heat accumulation, which could delay healing. No periodontal dressing was applied after completion of the procedure.

Postoperative care included detailed verbal and written instructions. Patients were advised to maintain meticulous oral hygiene, avoid mechanical trauma to the surgical sites, and refrain from smoking, alcohol consumption, acidic beverages, and spicy foods for at least one week. A soft-bristled toothbrush was recommended for gentle cleaning starting 48 hours after surgery. Analgesics (Ibuprofen 400 mg) were prescribed on an as-needed basis for pain control.

The clinical evaluation included assessment of pain using a Visual Analog Scale (VAS), bleeding during the procedure, wound healing, and pigmentation changes. Pigmentation intensity was recorded using the Dummett-Gupta Oral Pigmentation Index (DOPI) [17]. Clinical Indices and Assessment Parameters is shown in **Table 1** . Follow-up visits were scheduled at a month, 3 months. Standardized intraoral photographs were taken at baseline and each follow-up visit using a digital camera under consistent lighting and distance settings to ensure reproducibility. Photographs were analyzed using Adobe Photoshop software for objective evaluation of color changes.

TABLE (1) Clinical Indices and Assessment Parameters

Parameter	Description	Scoring System
Pigmentation Index (DOPI)	Dummett Oral Pigmentation Index (Dummett & Gupta, 1964)	Score 1: No pigmentation, coral pink gingiva Score 2: Mild pigmentation, light brown Score 3: Moderate pigmentation, mixed pink and brown Score 4: Severe pigmentation, dark brown or bluish black
Hedin Melanin Index (HMI)	Measures spread of pigmentation (Hedin, 1977) [18]	Grade 0: No pigmentation Grade 1: 1–2 isolated units in papillae Grade 2: >3 units without continuous ribbon Grade 3: Short continuous ribbon Grade 4: Continuous ribbon across canines
Bleeding During Treatment	Assessed during laser session	0: No bleeding 1: Minor (<5 mm) 2: Moderate (>5 mm) 3: Profuse bleeding
Wound Healing	Assessed 1week post-surgery (blind evaluation)	With healing: No redness/ulceration Without healing: Presence of redness/ulceration
Pain & Discomfort (VAS)	Recorded within 24 hrs. post-treatment using Visual Analogue Scale	Grade 0: 0 mm (No pain) Grade 1: 1–30 mm (Mild) Grade 2: 31–60 mm (Moderate) Grade 3: 61–100 mm (Severe)

TABLE (2) Summaries the parameters and specifications of Er:YAG and Diode laser systems used in gingival depigmentation procedure.

Parameter	Er: YAG Laser (Fotona)	Diode Laser (DIODENT MICRO 980)
Wavelength	2940 nm	980 nm
Mode	Pulsed	Continuous
Energy	120 mJ	—
Power	1.8 W	1 W
Frequency	15 Hz	—
Pulse Duration	1000 μs	—
Application Mode	Contact	Contact
Fiber Tip Diameter	0.8 mm (Sapphire tip)	320 μm
Cooling	Water-air cooling (ratio 1:4)	No cooling

Er: YAG laser parameters were selected for efficient ablation of pigmented gingival epithelium with minimal thermal damage, while the Diode laser settings aimed to ensure controlled coagulation and pigment removal with minimal patient discomfort. The differences in wavelength and mode reflect the distinct tissue interaction properties of each laser type [19].

Fig. (1) Components and parameters of the laser systems used in this study. (A) Fiber tip of the Er: YAG laser with specifications: sapphire, conical 8/0.8, Fotona® part number 72560, fiber tip efficiency 100%, maximum laser energy 350 mJ. (B) Operational settings and laser parameters of the Er: YAG laser system. (C) Operational settings and laser parameters of the Diode laser system.

Fig. (2) Sequential stages of gingival depigmentation treatment and healing. (A,E) Pre-treatment view showing severe gingival pigmentation. (B,F) Immediate postoperative appearance following laser depigmentation with Er: YAG laser for the right side and Diode laser for the left side of the maxillary and mandibular arches . (C, D,G,H) One-month & 3 months postoperative stage demonstrating complete epithelialization and stable gingival color.

Statistical Analysis

Data was analyzed using both descriptive and inferential statistical methods. Categorical variables such as bleeding scores and pain grades were expressed as frequencies and percentages. The split-mouth design and ordinal nature of the data required non-parametric tests. Pain and bleeding scores between Er: YAG and diode-treated sites were compared using the Wilcoxon Signed Rank Test. Changes in the Pigmentation Index (DOPI) at baseline, 1 month, and 3 months were assessed using the Friedman Test, with post-hoc pairwise comparisons performed using Wilcoxon tests when significant differences were observed. Healing and recurrence were summarized descriptively due to limited variation across groups. All statistical analyses were performed using SPSS software (version 16.0, SPSS Inc., Chicago, IL, USA), and a p-value < 0.05 was considered statistically significant.

RESULTS

Comparative Clinical Outcomes of Er: YAG and Diode Lasers are shown in **Table 3.** Concerning Preference**,** Patient esthetic preference was evenly distributed, with 50% favoring the Er: YAG side and 50% favoring the diode side as shown in **Figure 3**.

Pain perception was noticeably lower with the Er: YAG laser, where 42.9% of cases reported no pain, 42.9% reported mild pain, and only 14.2% experienced moderate pain. In contrast, all diode-treated sites exhibited higher discomfort, with 85.7% reporting moderate pain and 14.3% reporting severe pain as shown in **Figure 4**.

TABLE (3) Comparative Clinical Outcomes of Er: YAG and Diode Lasers in Gingival Depigmentation

Parameter	Er: YAG Laser (n, %)	Diode Laser (n, %)
Pain Grade		
Grade 0 (No pain)	6 (42.9%)	0 (0%)
Grade 1 (Mild)	6 (42.9%)	0 (0%)
Grade 2 (Moderate)	2 (14.2%)	12 (85.7%)
Grade 3 (Severe)	0 (0%)	2 (14.3%)
Bleeding Score		
No bleeding	0 (0%)	12 (85.7%)
Minor (<5 mm)	0 (0%)	2 (14.3%)
Moderate (>5 mm)	0 (0%)	0 (0%)
Profuse (Obstructed vision)	14 (100%)	0 (0%)
Healing Status		
Complete Healing	12 (85.7%)	14 (100%)
Incomplete Healing	2 (14.3%)	0 (0%)
Pigmentation Index (DOPI)		
Baseline	4	4
1 Month	0–1	0–1
3 Months	0–1	0–1
Patient Preference	50% (7 patients)	50% (7 patients)
Recurrence	3 smokers (21.4%) at 3 months; stable at 4 months	3 smokers (21.4%) at 3 months; stable at 4 months

Note: Gingiva returned to pink within 1 week for all cases. White layer appeared within 2 days in 50% of patients on both sides. All patients were completely satisfied and willing to repeat the procedure.

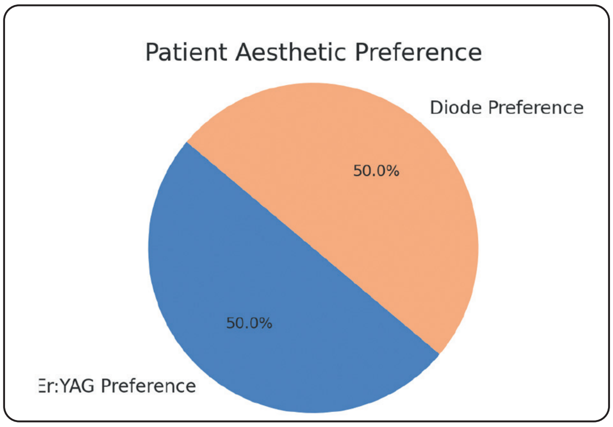

Fig. (3) This chart displays patient preference between the two laser types, showing an equal distribution of 50% for Er: YAG and 50% for Diode.

Bleeding control varied significantly between the two lasers. All Er: YAG- treated sites experienced profuse bleeding that obstructed visibility, whereas diode-treated sites showed superior control, with no bleeding in 85.7% of cases and only two cases (14.3%) exhibiting minor bleeding as shown in **Figure 5**.

Complete healing was achieved in all diode-treated sites within one week, while two Er: YAG-treated sites showed incomplete healing characterized by slight redness. A white layer was observed within two days in 50% of patients on both sides. Pigmentation index (DOPI) improved

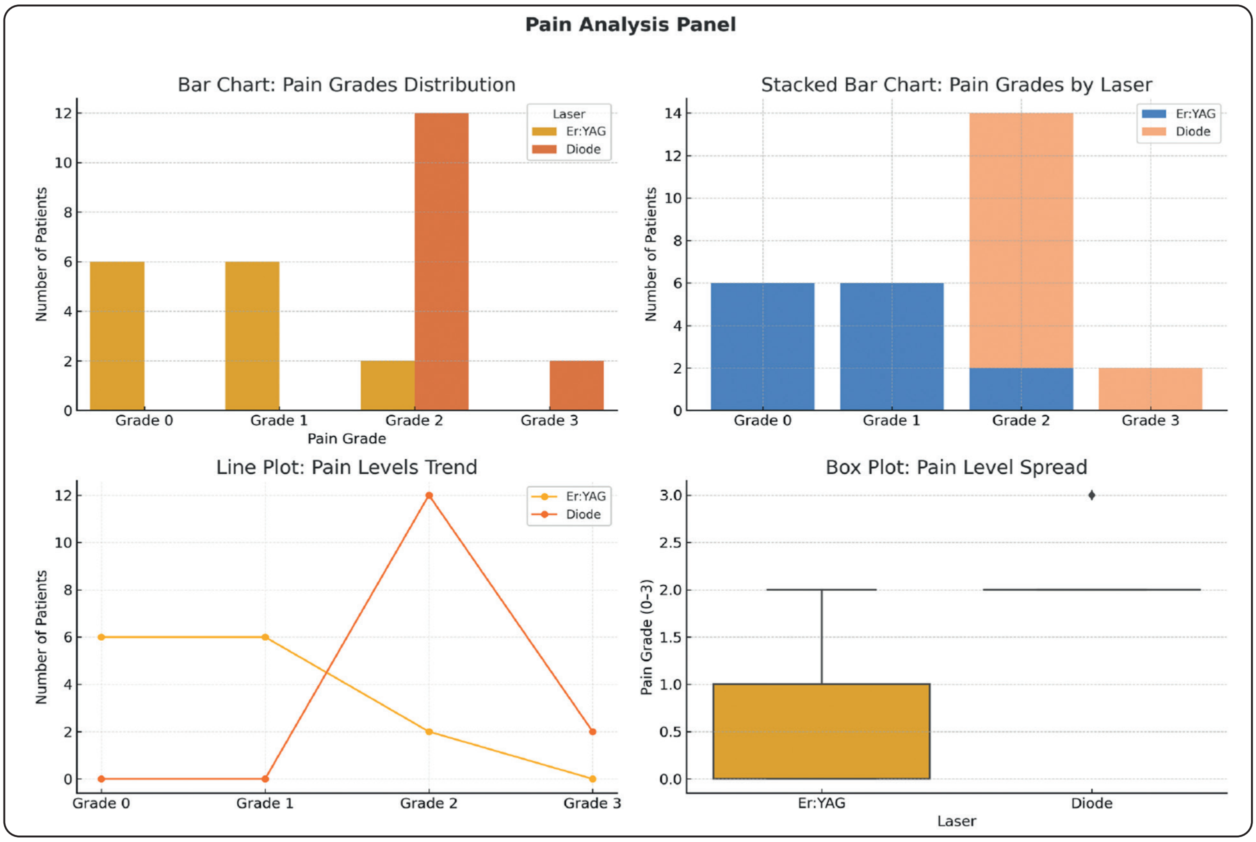

Fig. (4) This panel illustrates the distribution and variation of pain scores between Er:YAG and Diode lasers using multiple visualization methods (Bar Chart, Stacked Bar, Line Plot, Box Plot).

markedly in both groups, dropping from a baseline score of 4 to 0–1 after one month, and remained stable throughout the three months follow-up periods as shown in **Figure 6** .

Recurrence, there was a slight recurrence in three cases of all of whom were smokers (21.4% of the total sample), but it was mild and of the first degree, according to Dummett and Gupta index, while two them showed improvement in the shape of the gingiva after 3 months without a recurrence. Changes in the Dummett Oral Pigmentation Index (DOPI) over the study period, which extended up to 3 months. Both Er: YAG and Diode lasers showed a significant reduction from a baseline score of 4 to 0–1 after 1 month, with no further changes observed at the 3-month follow-up. The box plot confirms the consistency of these results across all patients as shown in **Figure 7**.

All parameters as shown in **Table 4** showed statistically significant differences between the two laser systems ($p < 0.05$). Pain scores were significantly lower for Er: YAG (Median = 1) compared to diode (Median = 2), confirming superior patient comfort with Er: YAG. Conversely, bleeding scores were markedly higher for Er: YAG (Median = 3) than diode (Median = 0), reflecting the diode laser's strong advantage in achieving hemostasis. Both lasers demonstrated significant reductions in the pigmentation index (DOPI) over time ($p < 0.05$), indicating that, despite differences in comfort and bleeding control, both systems are equally effective for pigment removal

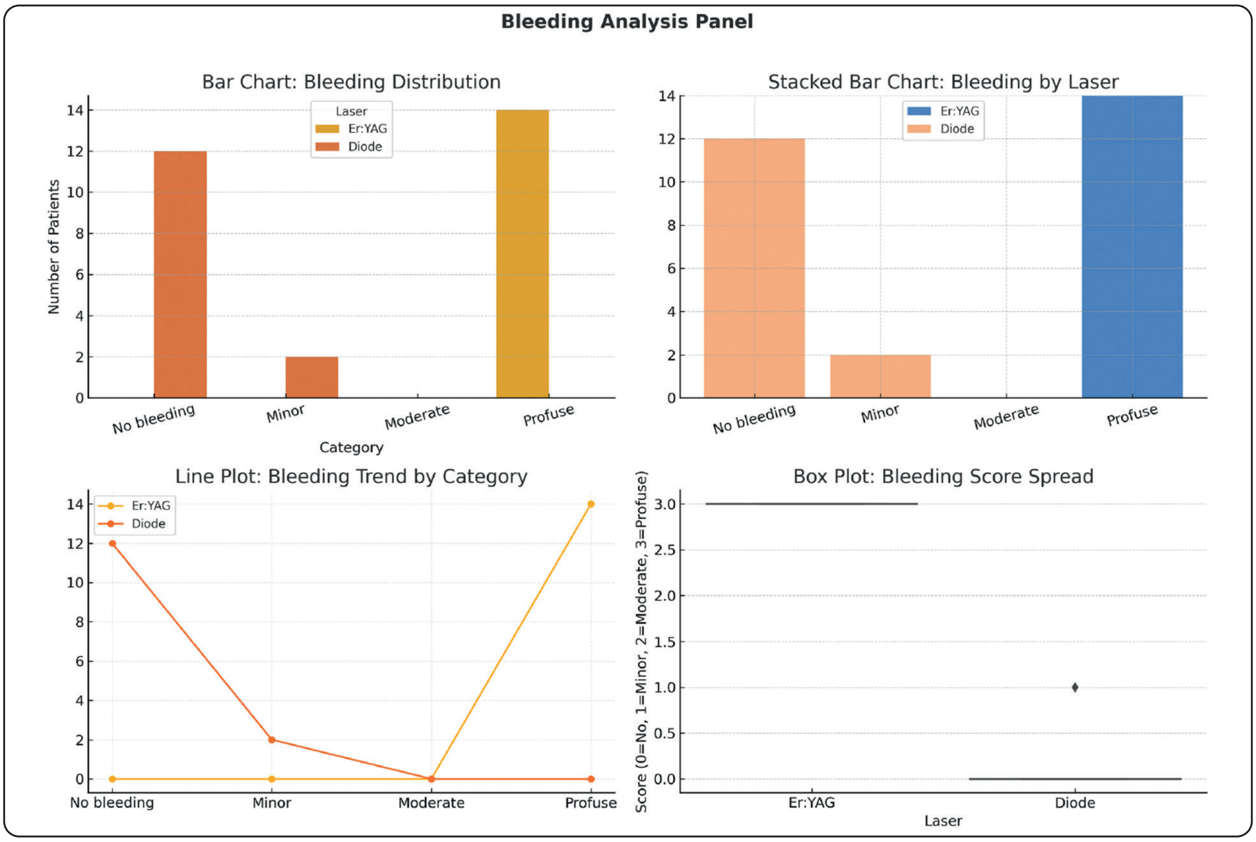

Fig. (5) This panel provides a comprehensive visualization of bleeding severity across categories for both laser types. It features bar and stacked bar charts, a line plot, and a box plot to depict variations and distribution patterns.

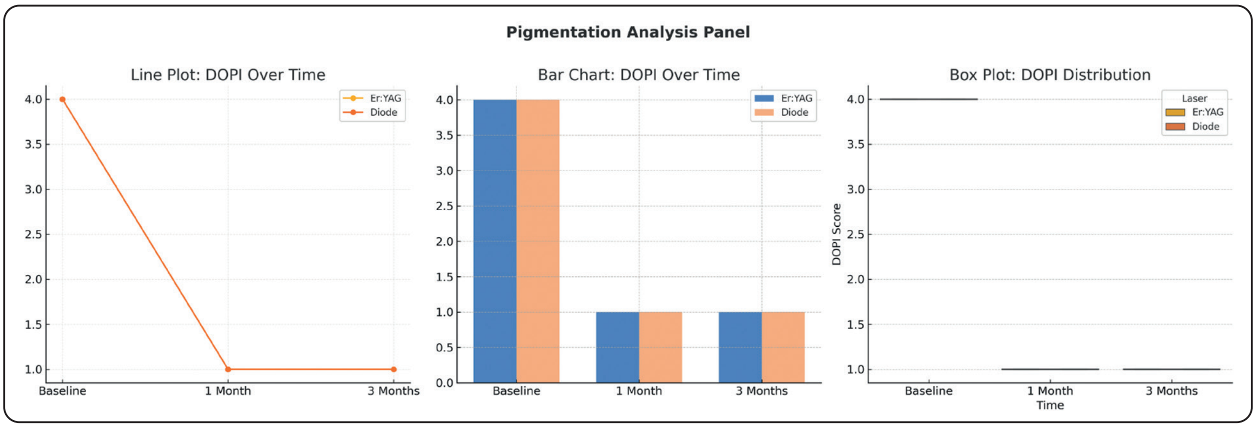

Fig. (6) This panel illustrates the reduction in pigmentation index (DOPI) over time at baseline, 1 month, and 3 months postoperatively. It includes a line plot, bar chart, and box plot to demonstrate the trend and consistency across both lasers.

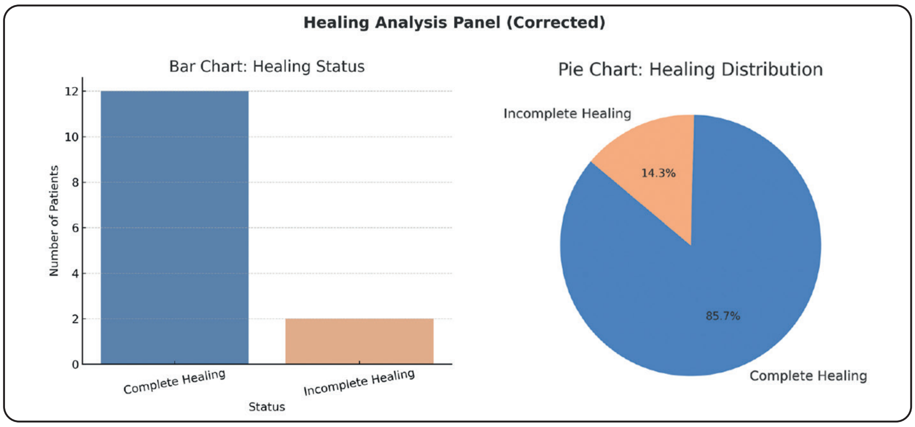

Fig. (7) This panel illustrates the distribution of complete and incomplete healing across both laser types using bar and pie charts. Most cases achieved complete healing, with only two incomplete cases observed in Er: YAG-treated sites

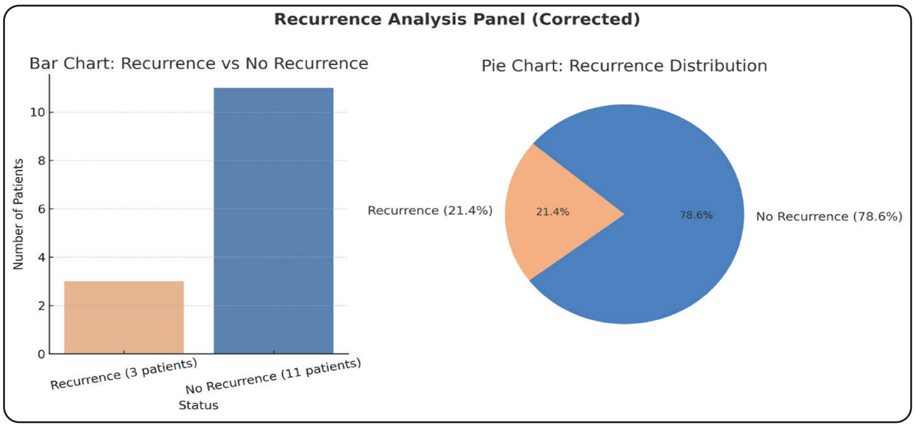

Fig. (8) This panel illustrates the distribution of recurrence among the study population. Mild re-pigmentation (Grade 1) was observed in three patients (21.4%), all of whom were smokers.

TABLE (4) Median Values and Statistical Significance of Pain, Bleeding, and DOPI

Parameter	Er: YAG (Median)	Diode (Median)	p-value	Significance
Pain	1	2	0.0002	Significant
Bleeding	3	0	0.0001	Significant
Pigmentation Index (DOPI)	-	-	$p < 0.001$.	Significant

DOPI. *p-value* ***< 0.05 indicates statistical significance.***

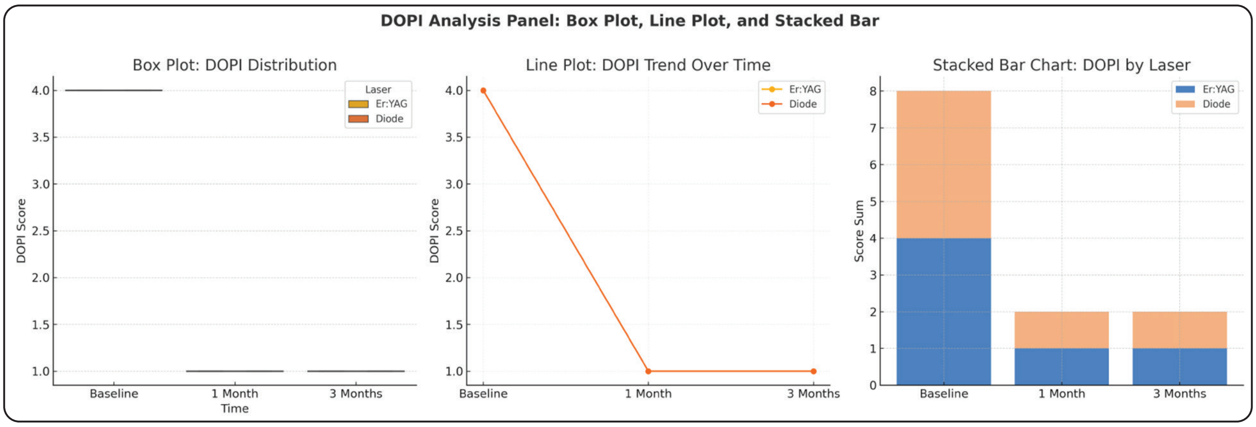

Fig. (9) This analysis illustrates changes in the Dummett Oral Pigmentation Index (DOPI) over the study period, which extended up to 3 months

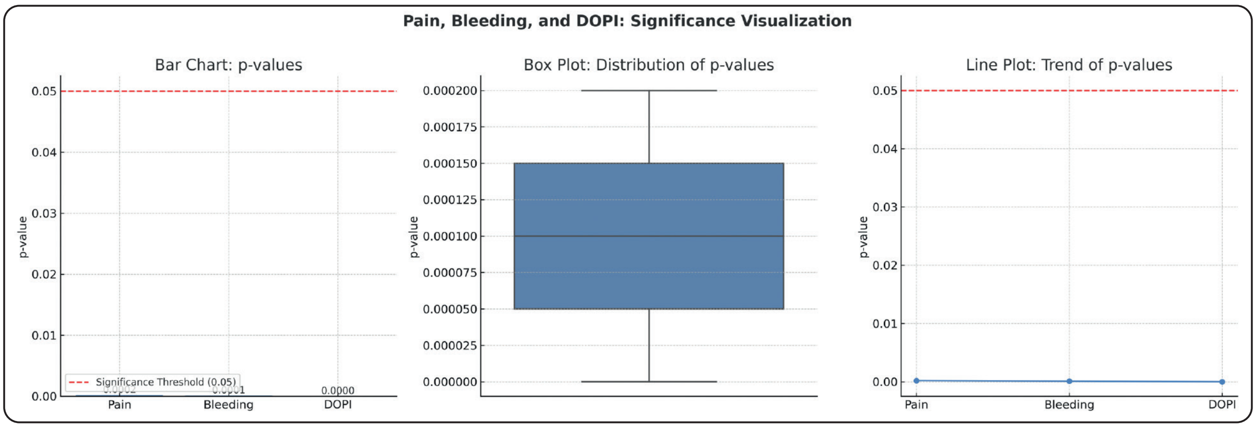

Fig. (10) The bar chart, line plot, and box plot collectively demonstrate that Pain, Bleeding, and Pigmentation Index (DOPI) all exhibited statistically significant differences ($p < 0.05$).

DISCUSSION

Over the years, multiple approaches have been proposed to eliminate gingival pigmentation, ranging from traditional scalpel excision and mechanical abrasion to grafting techniques and, more recently, laser applications [8]. Among these, lasers have gained remarkable popularity as a preferred option because they offer high precision, excellent control of bleeding, quicker healing, and minimal patient discomfort. [10].

The current study compared the Both patient centered outcomes and effectiveness of Er: YAG and diode lasers for gingival depigmentation, focusing on pain perception, bleeding control, wound healing, esthetic outcomes, and recurrence. Both laser modalities demonstrated excellent results in terms of pigment removal and patient satisfaction, consistent with previous clinical studies and systematic reviews conducted by Premkumar et al,2025 [20,21].

in accordance to our split-mouth design ,this technique has several advantages including the elimination of the confounding factors such as age, gender, and racial differences [22].

All evaluated parameters in the current study demonstrated statistical significance ($p < 0.05$); however, clinical interpretation highlights distinct strengths for each laser system. Er: YAG exhibited superior patient comfort, reflected by significantly lower pain scores (Grades 0–2) compared to diode-treated sites (Grades 2–3).

Conversely, the diode laser provided markedly statistical significance regarding hemostasis, with 85.7% of cases showing no bleeding versus profuse bleeding in all Er: YAG-treated sites. Both lasers achieved statistically significant reductions in pigmentation index (DOPI) over the 3-month follow-up period, confirming their equal efficacy in pigment removal. These findings suggest that Er: YAG may be preferred for patients with low pain tolerance, whereas the diode laser remains advantageous when optimal bleeding control is a clinical priority.

Pain and discomfort represent key components of patient-centered outcomes. In the current study, most participants reported only mild postoperative discomfort overall; however, Er: YAG was consistently associated with significantly lower pain levels compared to the diode laser.

This observation aligns with previous reports indicating that Er: YAG's photoablation mechanism and minimal thermal effect contribute to enhanced patient comfort [20,23]. In contrast, diode lasers despite their high efficiency in pigment removal, are characterized by deeper tissue penetration and greater thermal effects, which may explain the higher discomfort scores reported in many cases [24].

Interestingly, some authors have documented opposite trends, where diode laser procedures resulted in lower pain ratings than Er: YAG (1.07 ± 0.05 vs. 1.5 ± 0.1; $p<0.01$) [20,24]. Our results, however, clearly demonstrated better comfort with Er: YAG, likely due to its reduced thermal damage combined with an integrated water-air cooling system.

Regarding bleeding, one of the most notable differences between the two systems was intraoperative hemostasis. Er: YAG-treated sites exhibited profuse bleeding that obscured visualization, whereas diode laser sites demonstrated excellent bleeding control. Similar outcomes have been documented in multiple studies, attributing this hemostatic advantage to the diode laser's photo-coagulative properties [22,25]. This observation is further supported by recent systematic reviews comparing soft-tissue lasers, which consistently highlight superior hemostasis as a clinical benefit of diode lasers [20].

Complete epithelialization was achieved within 7–10 days, with most cases showing uneventful healing. This is consistent with previous research stating that both lasers allow rapid healing with minimal postoperative complications[20,26]. In align with our study, Jnaid Harb et al. (2021) (22) reported marginally improved healing outcomes with diode laser treatment; however, this difference did not reach statistical significance (3.50 ± 0.19 vs. 3.17 ± 0.16; $p = 0.21$).

These results are consistent with previous evidence suggesting that both laser systems support favorable tissue recovery, though via distinct biological mechanisms. Er: YAG operates through precise ablation, which limits thermal injury and promotes faster epithelial regeneration, whereas diode lasers may exert photo-biomodulatory effects that stimulate fibroblast activity and collagen formation [27,28]. Future investigations employing molecular biomarkers of wound repair are needed to clarify these healing pathways and their clinical implications.

Concerning Pigmentation Recurrence, our findings confirm what many studies have emphasized: gingival re-pigmentation remains a common challenge after depigmentation procedures. Similar to previous reports, we observed that relapse can occur due to the migration of active melanocytes from untreated areas into treated sites. In our study, mild recurrence was detected in three smokers, with no significant relapse beyond these few cases. Further underscoring the strong influence of smoking on pigmentation stability (22).

Similar patterns were reported by Premkumar et al. [20], attributing recurrence primarily to melanocyte migration and smoking habits. Current evidence continues to identify smoking as a major risk factor for early re-pigmentation [29].

Concerning Patient Satisfaction, High satisfaction rates reported in this study corroborate recent clinical trials and systematic reviews, which highlighted laser depigmentation as a safe, minimally invasive, and esthetically predictable procedure [20,30]. Overall, our findings reinforce the conclusion that both Er: YAG and diode lasers are reliable options for gingival depigmentation, with Er: YAG offering better patient comfort and diode lasers providing superior hemostasis.

CONCLUSION

Both Er: YAG and diode lasers were effective in gingival depigmentation, with significant DOPI reduction over 3 months ($p < 0.001$). Er: YAG showed significantly lower pain scores ($p = 0.0002$), while diode laser provided superior hemostasis ($p = 0.0001$). No significant difference was observed in depigmentation outcomes between groups.

RECOMMENDATIONS

Er: YAG is preferable for patients with low pain tolerance, while diode laser is recommended when bleeding control is essential. Further studies with larger samples and longer follow-up are advised to confirm long-term stability and evaluate healing biomarkers.

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