Efficacy of Er:YAG and diode laser on gingival depigmentation. A systematic review

Premkumar Prabhakaran, Yakkishni Bharati. M, Siddique Sha Muhammed Hussain, Rajthilak Boomiraj, Dinesh Nandakumar, Dhivya S.R

Department of Public Health Dentistry,Best Dental Science College, Madurai

Department of Public Health Dentistry,Best Dental Science College, Madurai

Department of Dentistry, College of Medicine,Komar University of Science and Technology, Sulaymaniyah, Kurdistan Region, Iraq.

Department of Prosthodontics,Best Dental Science College, Madurai.

Department of Orthodontics and Dentofacial Orthopaedics ,Best dental science college, Madurai

Department of Public Health Dentistry,CSI College of dental sciences and Research, Madurai

Abstract:

Objectives: This systematic review and meta-analysis aims to evaluate the efficacy of Er:YAG and diode lasers in gingival depigmentation by synthesizing existing literature on their clinical effectiveness, and patient satisfaction (patients' discomfort during treatment in terms of pain, and bleeding during the procedure). **Materials and Methods:** The literature review was carried out utilizing the Medline (through PubMed), Embase, Web of Science, Scopus, and Google Scholar databases. Following the aggregation of articles from these diverse sources, duplicates were recognized and removed based on similarities in title, author, and publication year. This was succeeded by a screening process involving the title and abstract, followed by a thorough examination of the full text of the articles. Data extraction was conducted using the articles that passed the final screening. **Results:** A total of 4 studies were included in this systematic review following a comprehensive screening process and gingival depigmentation was consistently evaluated across all four studies using the Degree of Oral Pigmentation Index (DOPI). Results indicated significant improvements in gingival pigmentation following treatment with both Er:YAG and diode lasers **Conclusion:** However, there was no statistically significant differences were observed between the two modalities. **Clinical Significance:** Excess melanin in gingival tissues can create cosmetic concerns, affecting a patient's smile and self-confidence. Gingival hyperpigmentation may be associated with underlying systemic conditions or syndromes. In such cases, treating the pigmentation may be part of a broader diagnostic or treatment plan. Understanding the cause of hyper pigmentation is crucial appropriate management of gingival hyperpigmentation. Effective treatment of gingival hyperpigmentation can also improve the patient's psychological well-being. By addressing the cosmetic concerns associated with the condition, treatment can boost self-esteem and confidence, leading to a positive impact on overall quality of life.

Key words: Er YAG laser, Diode laser, Depigmentation, gingival pigmentations

Introduction:

An aesthetic smile reflects self-esteem that consists of psychological and aesthetic aspects.(1) Apart from the well aligned dentition, the color of the gingiva also plays an important role for dental aesthetics. A beautiful smile involves interaction of various components of periodontium along with dentition.(2) Color of the gingiva depends on the number and size of blood vessels, epithelial thickness, quantity of keratinization, and pigments within epithelium like melanin, carotene, reduced haemoglobin, and oxyhemoglobin. Melanin is derived from the Greek word "melas," which means black. It is produced in the basal and suprabasal layers of the epithelium by the melanocytes and is an endogenous pigment. Melanin is the most common natural pigment contributing to the color of the gums.(3)

Melanin hyperpigmentation of the gingiva occurs as the result of abnormal melanin deposition and affects all races, ages, and sexes.(4) Several physiologic and/or pathologic factors can cause hyperpigmentation. However, the most common cause is physiologic or ethnic hyperpigmentation. Physiologic hyperpigmentation is genetically determined and is clinically manifested as variable amounts of diffuse or multifocal melanin pigmentation in different ethnic Groups.(5)

Although physiologic hyperpigmentation is entirely harmless, some individuals encounter aesthetic concerns consequently, with black gums being the prevailing manifestation. These individuals typically aspire to eliminate gingival coloration to enhance the aesthetic appeal of their smile. Gingival hyperpigmentation (GHP), or "black gum," constitutes one of the contributing elements that significantly impact how someone looks when they smile.(6)

These persons frequently make a request for removing gingival color to enhance oral esthetics while smiling or speaking.(7) The management of gingival depigmentation involves different therapeutic approaches, among which the conventional scalpel technique, free gingival autograft or cellular dermal matrix allograft to conceal pigmented gingival, abrasion with a large round diamond bur, and lasers.(8) In recent years, lasers have been widely used as an effective, suitable, and reliable treatment option.(9) Since they have many advantages such as easy handling, short treatment time, optimal hemostasis, decontamination and they do not need periodontal dressing. However, they are costly since they require expensive equipment.(10)

Researchers in selective photothermolysis and treatment of cutaneous pigmented lesions have been performed with various lasers. Selective photothermolysis to treat melanotic lesions was first proposed by Anderson and Parrish in 1983. This phenomenon is based on the fact that some structures absorb light of certain wavelength better than others. The absorption of light leads to heat production and consequently to damage of structures when a high enough temperature is reached. As absorption by each structure is wavelength dependent, it is possible to selectively damage certain regions in a tissue by choosing a wavelength with high absorption by the target and low absorption by others.[11]

With evolving trends, lasers have been used to ablate gingival tissues containing melanin. Different dental lasers have been reported for successful treatment of gingival hyperpigmentation such as carbon dioxide (CO2) laser, neodymium-doped yttrium aluminum garnet (Nd:YAG) laser, semiconductor diode laser, and argon laser. Non-heat producing lasers which are erbirum-doped yttrium aluminium garnet (Er:YAG), and Erbium, Chromiumy: yttrium, scandium, gallium, garnet (Er, Cr: YSGG) have also been reported as effective, pleasant, and reliable means with negligible postoperative discomfort and quicker wound healing for depigmentation procedures.[12]

Depigmentation of gingival tissue by diode laser and erbium lasers has been proposed to have some advantages such as less trauma, less pain, less bleeding, and rapid wound healing. But laser beam can damage to the thin biotype of gingiva and underlying periosteum and bone.[13–16] Nevertheless, the process of gingival depigmentation should be performed carefully with adjacent teeth protection, since an improper laser application may postpone wound healing and cause gingival collapse, as well as underlying tissue damage of the periosteum and bone.[8]

Hence, the objectives of this systematic review and meta-analysis aim to evaluate the efficacy of Er:YAG and diode lasers in gingival depigmentation by synthesizing existing literature on their clinical effectiveness, and patient satisfaction (patients' discomfort during treatment in terms of pain, bleeding during the procedure). By analyzing data from multiple studies, we seek to provide a comprehensive understanding of how these technologies compare in treating gingival hyperpigmentation, thereby guiding clinicians in selecting the most appropriate treatment modality for their patients.

The findings from this review will contribute to the growing body of evidence supporting laser applications in dental aesthetics and may influence clinical practice by highlighting the advantages of each laser type in achieving optimal cosmetic results with minimal discomfort.

Materials and Methods:

Review question: This systematic review was carried out following the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) [17] guidelines to respond the following research question, what is the efficacy of Er:YAG and diode laser on gingival depigmentation?. The study protocol can be accessed through the International Prospective

Register of Systematic Reviews, the PROSPERO database, with the following register number: CRD42024602666.

PICO criteria:

The eligibility criteria were marked using PICO definition:

(P) Population: subjects with gingival hyperpigmentation

(I) Intervention: subjects treated with Er: YAG

(C) Comparator: subjects treated with diode laser

(O) Outcome: gingival depigmentation based on DOPI

Eligibility Criteria

Inclusion Criteria

In vivo, randomized controlled trial published which reported on depigmentation of gingiva, pain during and after the procedure and bleeding on procedure between Er: YAG and diode laser were considered eligible.

Exclusion Criteria

Studies were excluded, if 1) Patients treated for gingival inflammation and gingival enlargement other than gingival depigmentation 2) The treatment done apart from Er:YAG and diode laser in gingival depigmentation.

Databases and Search Strategy

The literature search was conducted on the Medline (via PubMed), Embase, Web of science, Scopus and Google scholar databases. The following search criteria were employed as the keywords to search for relevant articles in the mentioned databases:

Table 1: Search strategy for databases

Database	Search strategy
Web of Science	((ALL=(laser)) OR ALL=("diode laser")) OR ALL=("erbium laser") AND (ALL=("gingival depigmentation")) OR ALL=("oral depigmentation")

Embase	((('laser'/exp OR 'beam, laser' OR 'laser' OR 'laser adapter' OR 'laser adaptor' OR 'laser associate' OR 'laser beam' OR 'laser device' OR 'laser holder' OR 'laser irradiation' OR 'laser radiation' OR 'laser ray' OR 'lasers' OR 'radiation, laser') OR ('erbium YAG laser'/exp OR 'DermaSCULPT' OR 'Er YAG laser' OR 'Er laser' OR 'Erwin Adverl' OR 'Fidelis Plus III' OR 'Fraxel Restore' OR 'KEY Laser II' OR 'P.L.E.A.S.E (erbium YAG laser)' OR 'erbium YAG laser' OR 'erbium laser' OR 'erbium yttrium aluminium garnet laser' OR 'erbium yttrium aluminum garnet laser' OR 'laser, erbium yag') OR ('diode laser'/exp OR 'DIOMED 630' OR 'ELVeS Radial' OR 'Echolaser X4' OR 'Haemato LS PDT 660' OR 'Mediostar' OR 'QuadroStar PRO' OR 'Quanta B' OR 'Quanta C Star' OR 'QuardoStar PRO' OR 'Vari-lase' OR 'WISER (diode laser)' OR 'diode laser' OR 'diode laser cable' OR 'diode laser cable extractor' OR 'diode laser device' OR 'diode laser systems' OR 'diode lasers' OR 'general use diode laser' OR 'general/multiple surgical diode laser system' OR 'laser, diode' OR 'laser, semiconductor' OR 'lasers, semiconductor' OR 'multiple surgical diode laser system' OR 'semiconductor laser' OR 'semiconductor laser device' OR 'semiconductor laser device (physical object)' OR 'semiconductor lasers' OR 'surgical diode laser cable extractor')) AND 'gingival depigmentation'/exp
Scopus	((ALL (laser) OR ALL (lasers) OR ALL ("diode laser") OR ALL (erbium))) AND ((ALL ("gingival depigmentation") OR ALL ("oral depigmentation")))
Medline (via PubMed)	(("lasers, solid state"[MeSH Terms] OR ("lasers"[All Fields] AND "solid state"[All Fields]) OR "solid-state lasers"[All Fields] OR ("er"[All Fields] AND "yag"[All Fields] AND "laser"[All Fields]) OR "er yag laser"[All Fields]) AND ("lasers, semiconductor"[MeSH Terms] OR ("lasers"[All Fields] AND "semiconductor"[All Fields]) OR "semiconductor lasers"[All Fields] OR ("diode"[All Fields] AND "laser"[All Fields]) OR "diode laser"[All Fields]) AND (("gingiva"[MeSH Terms] OR "gingiva"[All Fields] OR "gingival"[All Fields] OR "gingivally"[All Fields] OR "gingivals"[All Fields] OR "gingivitis"[MeSH Terms] OR "gingivitis"[All Fields] OR "gingivitides"[All Fields]) AND ("depigmentations"[All Fields] OR "hypopigmentation"[MeSH Terms] OR "hypopigmentation"[All Fields] OR "depigmentation"[All Fields]))) OR (("gingiva"[MeSH Terms] OR "gingiva"[All Fields] OR "gingival"[All Fields] OR "gingivally"[All Fields] OR "gingivals"[All Fields] OR "gingivitis"[MeSH Terms] OR "gingivitis"[All Fields] OR "gingivitides"[All Fields]) AND ("hyperpigmentated"[All Fields] OR "hyperpigmentation"[MeSH Terms] OR "hyperpigmentation"[All Fields] OR "hyperpigmentations"[All Fields] OR "hyperpigmention"[All Fields]))

Selection of Studies

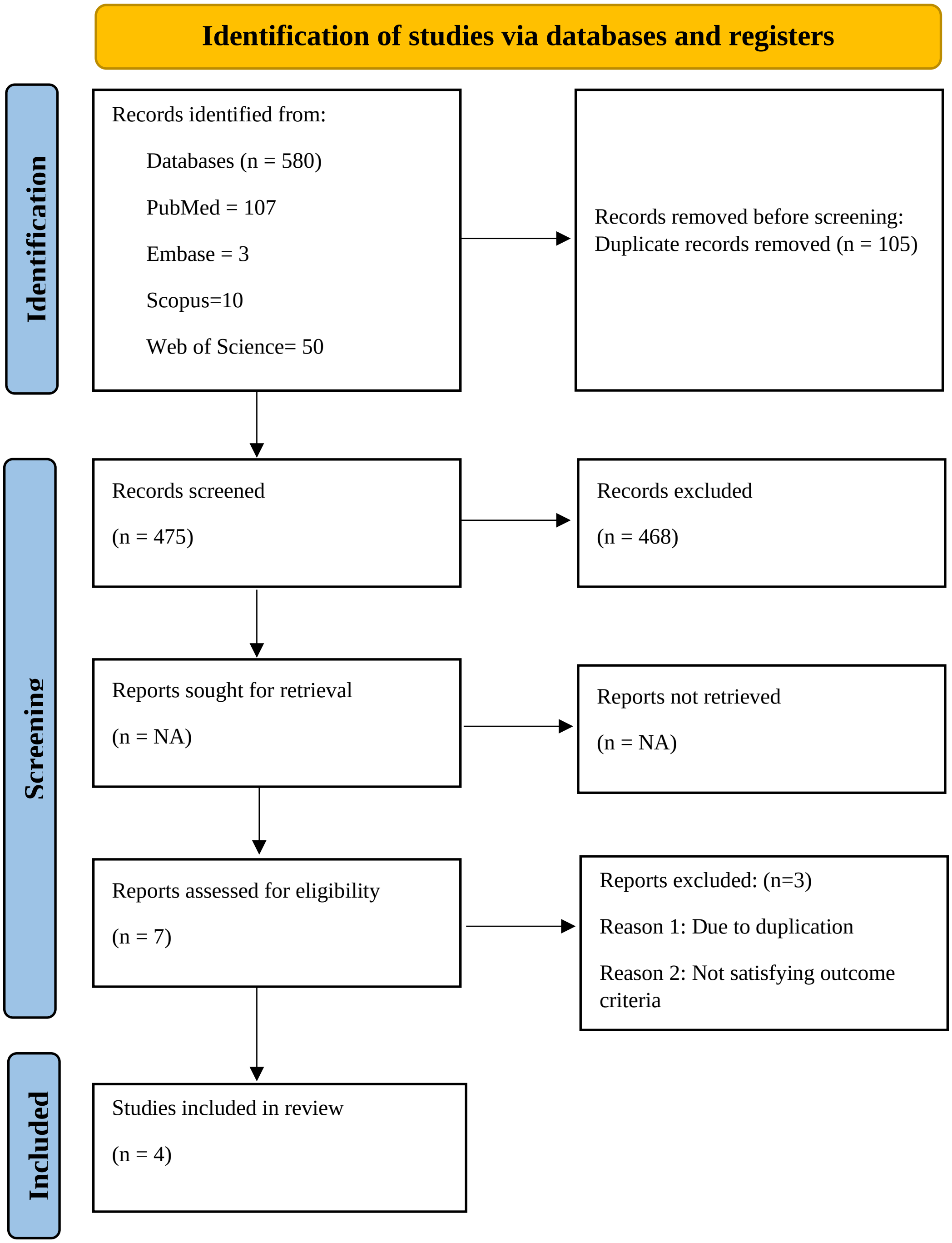
The investigators looked over the titles and abstracts of the studies that were found using the search strategy to find the ones that would be fully read. Then, the studies were looked at to see if they met the inclusion and exclusion criteria. In the event of disagreement among the investigators, a consensus was reached through external consultation and discussion.

Screening of articles:

After pooling articles from various databases, duplicates were identified and excluded based on similarities in title, author, and year of publication. Studies that did not meet the specified PICO criteria were excluded upon mutual agreement. Any disagreements regarding article selection were resolved through discussion. Subsequently, the full texts of eligible articles were reviewed individually.

Data extraction:

For all studies meeting the eligibility criteria, data extraction was conducted. The extracted data included the following parameters: (a) Author and year of publication, (b) Type of study, (c) Study location, (d) Data source, (e) Characteristics of the study group, (f) Characteristics of the control group, (g) Evaluation parameters, (h) Evaluation period, (i) Results in the test group, (j) Results in the control group, (k) Statistical significance between groups, and (l) Overall inference.



Flowchart 1: PRISMA Flowchart showing the inclusion process of the studies that composed in the review

Risk of Bias:

Each article was critically evaluated using the JBI critical appraisal tool of Risk of Bias for randomized controlled trials.[18] This tool encompasses four element of assessment that collectively determine the overall risk of bias. Each element contains a specific set of questions, with responses categorized as "yes," "no," "unclear," and "not applicable." A summary score was generated for each study based on its adherence to quality criteria and fulfilment of requirements.

Results:

Search and included studies

Initially, 580 studies were found, from which 475 were selected after removing 105 duplicates. These 475 studies were then screened by reading the titles and abstracts, and 4 were selected. The full-text of these 7 studies was accessed and 3 study was excluded as 2 studies are duplicates and 1 study had different outcome parameter; 4 studies were included (Flowchart 1 depicts this process).

General Study Characteristics

A total of four studies were included in this systematic review following a comprehensive screening process that involved removing duplicates, screening titles and abstracts, and conducting full-text reviews. Among these, two studies utilized a split-mouth design, while the other two employed a randomized controlled trial (RCT) design. All studies investigated the efficacy of Er:YAG laser as the experimental intervention, with diode laser serving as the control. The studies were conducted across diverse geographical locations, with evaluation periods ranging from three months to sixteen months. A combination of clinical parameters, including gingival pigmentation, post-operative pain, wound healing, post-surgical discomfort, and bleeding during treatment, were assessed, offering insights into both short- and long-term outcomes of the interventions.

Table 2: General characteristics of included studies.

Author & Year	Type of study	Study location	Data location	Study group (n)	Control group (n)	Evaluation parameter	Period of evaluation
Simşek Kaya et al 2012	Randomized Prospective Study	Turkey	Table 1	10	10	• Gingival Pigmentation • Post- operative pain • Post- surgical discomfort	16 months
Giannelli, M et al 2014	A randomized Split Mouth clinical trial	Italy	Figure 2 & Table 3	21	21	• Gingival Pigmentation • Wound healing • Bleeding upon treatment	3 months
Jnaid Harb et al 2021	A split mouth clinical comparative study	UAE	Table 5, Table 6 & Table 8	15	15	• Gingival Pigmentation • Wound healing • Bleeding upon treatment • Post- operative pain	6 months
Arif, R.H et al 2021	A comparative study	Iraq	Table 2 & Table 6	10	10	• Gingival Pigmentation • Post- operative pain • Wound healing • Bleeding upon treatment	6 months

Primary Outcome

The primary outcome, gingival depigmentation, was consistently evaluated across all four studies using the Degree of Oral Pigmentation Index (DOPI). Results indicated significant improvements in gingival pigmentation following treatment with both Er:YAG and diode lasers. However, no statistically significant differences were observed between the two modalities. Giannelli et al. (2014) reported a mean DOPI reduction to 0.1 in the Er:YAG group and 0 in the diode laser group, with comparable outcomes in both. Similarly, Arif et al. (2021) reported mean DOPI scores of 10.75 and 10.25 in the Er:YAG and diode laser groups, respectively ($p = 0.831$), while Jnaid Harb et al. (2021) observed DOPI scores of 0.39 ±

0.20 and 0.36 ± 0.19 for the two groups, with no significant differences (p = 0.93). These findings demonstrate that both lasers effectively reduce gingival pigmentation, with equivalent efficacy.

Table 3: Primary Outcome characteristics of included studies.

Author, year	Variables	Results		Significance	Inference
		Test group (Er:YAG)	Control group Diode		
Giannelli, M et al 2014	Gingival depigmentation (DOPI)	0.1	0		Both Er:YAG and diode laser interventions caused a significant improvement in the gingival hyper pigmentation. Hence, the difference between these two groups were not significant.
Jnaid Harb et al 2021	Gingival depigmentation (DOPI)	0.39±0.20	0.36±0.19	0.93	In both the groups, degree of pigmentation after the treatment was almost the same. Therefore, the difference between Er:YAG and diode laser was insignificant
Arif, R.H et al 2021	Gingival depigmentation (DOPI)	10.75	10.25	.831	There was no significant difference detected between the Er: YAG and diode laser regarding the mean oral pigmentation index ranking 6 months after the surgery.

Table 4: Secondary Outcome characteristics of included studies.

Author, year	Variables	Results		Significance	Inference
		Test group Er:YAG	**Control group Diode**		
Simşek Kaya et al 2012	Pain	1.5	1.0		Mild pain was reported in both groups with no significant differences.
Giannelli, M et al 2014	Pain	1.5±0.1	1.07±0.05	**<0.01****	Subjective perception of Er: YAG and diode Laser evaluated by the patient's responses to a satisfaction questionnaire showed an overall preference for the diode laser and the difference was statistically significant. Whereas in wound healing, the difference between two groups were not statistically significant.
	Bleeding at surgery	2	1		
	Wound healing	1	1		
Jnaid Harb et al 2021	Pain	1.87±0.47	1.33±0.39	0.39	The tendency for bleeding was noticed to be higher at Er:YAG laser treated patients. This difference was statistically significant. Pain and wound healing of the participants in both the groups are similar.
	Bleeding at surgery	1.75±0.13	1.17±0.11	**0.002****	
	Wound healing	3.17±0.16	3.50±0.19	0.21	
Arif, R.H et al 2021	Pain	60%	70%		None of the participants developed bleeding with no statistical difference and no significant differences in pain was observed between the groups.
	Bleeding at surgery	0	0		
	Wound healing	10	10		

Secondary Outcomes

Secondary outcomes, including pain, bleeding during surgery, and wound healing, were assessed across the included studies. Pain levels were generally mild, with no significant differences between the two modalities, except in one study where patients expressed a preference for the diode laser due to lower pain scores (Giannelli et al., 2014; $p < 0.01$). Bleeding during surgery showed mixed results: while one study (Jnaid Harb et al., 2021) reported significantly less bleeding in the diode laser group ($p = 0.002$), others found no significant differences. Wound healing outcomes were comparable between the two groups, with both lasers demonstrating satisfactory and equivalent healing effects. Overall, the secondary outcomes reaffirm the clinical applicability of both lasers, with slight advantages for the diode laser in terms of patient comfort and intraoperative bleeding.

Table 5 - Presentation of results following critical appraisal using the revised JBI critical appraisal tool for randomized controlled trials

			INTERNAL VALIDITY Bias related to:												
		DOMAIN	**Selection and allocation**			**Administration of intervention/exposure**			**Assessment, detection, and measurement of the outcome**			**Participant retention**	**Statistical Conclusion Validity**		
		QUESTION NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
STUDY ID	**OUTCOME**	**RESULT**													
Simşek Kaya et al 2012[19]	Gingival Pigmentation	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
	Post- operative pain	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Post- surgical discomfort	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Giannelli, M. et al 2014[20]	Gingival Pigmentation	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Wound healing	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Bleeding upon treatment	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	N
Arif, R.H et al 2021[21]	Gingival Pigmentation	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Post- operative pain	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Wound healing	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Bleeding upon treatment	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Jnaid Harb et al 2021[22]	Gingival Pigmentation	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Wound healing	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Bleeding upon treatment	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Post- operative pain	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N

*** Y:Yes, N: No, UC: Un Clear, NA: Not Applicable***

Risk of Bias

The methodological quality of the included studies was assessed using the revised JBI critical appraisal tool for RCTs, revealing strong adherence to selection, allocation, and statistical validity criteria across all studies. However, common limitations were identified in blinding (questions 3 and 4) and participant retention (question 12), which could potentially introduce bias. Despite these limitations, most studies demonstrated robust internal validity, particularly in the administration of interventions and outcome assessment. The studies by Giannelli et al. (2014) and Jnaid Harb et al. (2021) showed the highest methodological rigor, achieving "Yes" for 12 out of 13 appraisal domains, while others highlighted minor gaps in reporting and retention strategies. Overall, the methodological strengths of the included studies provide a reliable foundation for interpreting the results of this review.

Discussion:

The present systematic review aimed to evaluate the comparative efficacy of Er:YAG and diode lasers in the management of gingival depigmentation, encompassing both primary and secondary outcomes. Gingival hyperpigmentation is a common aesthetic concern that can significantly impact patients' self-esteem and quality of life. Recent advancements in laser technology have provided effective alternatives for gingival depigmentation, particularly the Er:YAG (Erbium-doped Yttrium Aluminum Garnet) and diode lasers[26]. Thus, in our review a total of four studies were included, with varying study designs and evaluation periods ranging from three months to sixteen months. Both Er:YAG and diode lasers demonstrated significant efficacy in reducing gingival pigmentation, while the secondary outcomes, including post-operative pain, bleeding during surgery, and wound healing, revealed nuanced differences between the two modalities. The findings from this review contribute to the growing body of literature on laser-assisted therapies in periodontal aesthetics and provide evidence to guide clinical decision-making.

Primary Outcome: Gingival Depigmentation

The primary outcome of this review, gingival depigmentation, was assessed using the Degree of Oral Pigmentation Index (DOPI) across all included studies. Studies have shown that DOPI demonstrates high inter-examiner reliability and strong correlations with other pigmentation indices[27] . Both Er:YAG and diode lasers were shown to significantly reduce gingival pigmentation, as reflected in the DOPI scores. However, consistent with prior research, no statistically significant differences were observed between the two modalities in terms of depigmentation outcomes[28]. For instance, Giannelli et al. (2014) reported comparable DOPI reductions (0.1 for Er:YAG and 0 for diode laser), and Arif et al. (2021) found minimal differences in mean DOPI scores (10.75 for Er:YAG and 10.25 for diode laser, $p = 0.831$). These findings align with previous studies that emphasize the efficacy of both laser types in managing gingival pigmentation with minimal variance in clinical outcomes.[29]

The lack of significant differences between the two laser systems could be attributed to their distinct mechanisms of action. The Er:YAG laser, operating at a wavelength of 2940 nm, achieves selective ablation of pigmented gingival tissue through photomechanical effects.[30] In contrast, the diode laser, with wavelengths typically ranging from 810 nm to 980 nm, utilizes photothermal effects to achieve similar outcomes[31]. Despite these mechanistic differences, the final clinical results appear comparable, underscoring the efficacy of both modalities for gingival depigmentation. Future investigations incorporating histological analyses may provide deeper insights into the tissue-level effects of these lasers and their implications for long-term outcomes.

Secondary Outcomes: Pain, Bleeding, and Wound Healing

The secondary outcomes analyzed in this review revealed subtle but noteworthy differences between the two laser systems. Pain, a critical consideration for patient satisfaction, was reported across all included studies. While pain levels were generally mild for both modalities, the diode laser was favored in one study (Giannelli et al., 2014), where patient satisfaction questionnaires indicated lower pain scores for diode laser treatment (1.07 ± 0.05 vs. 1.5 ± 0.1; $p < 0.01$). This aligns with prior reports suggesting that the diode laser’s photothermal effects may cause less discomfort compared to the Er:YAG laser’s photomechanical ablation.[32] Conversely, other studies included in this review did not report significant differences in pain perception, highlighting the subjective nature of pain and the potential influence of operator technique and patient variability.

Bleeding during surgery was another key parameter, with mixed findings across studies. While Simşek Kaya et al. (2012) and Giannelli et al. (2014) reported no significant differences between the two lasers, Jnaid Harb et al. (2021) found that bleeding scores were significantly higher in the Er:YAG group (1.75 ± 0.13 vs. 1.17 ± 0.11; $p = 0.002$). This discrepancy may be explained by the higher photocoagulative potential of diode lasers, which can achieve superior hemostasis compared to the ablative mechanism of Er:YAG lasers.[33] Clinicians should consider this when managing patients with a predisposition to bleeding or those requiring extensive depigmentation procedures.

Wound healing outcomes were generally comparable between the two modalities. Simşek Kaya et al. (2012), Giannelli et al. (2014), and Arif et al. (2021) reported equivalent wound healing scores, while Jnaid Harb et al. (2021) observed slightly better healing in the diode laser group, although the difference was not statistically significant (3.50 ± 0.19 vs. 3.17 ± 0.16; $p = 0.21$). These findings align with earlier studies indicating that both lasers promote satisfactory tissue repair, albeit through different mechanisms. The Er:YAG laser's precise ablation minimizes thermal damage, facilitating rapid epithelialization, while the diode lasers photobiomodulatory effects may enhance fibroblast proliferation and collagen synthesis. [34, 35] Further research integrating biomarkers of tissue healing could elucidate the underlying biological pathways and their clinical relevance.

Risk of Bias and limitations

The methodological quality of the included studies was evaluated using the revised JBI critical appraisal tool for randomized controlled trials. While the overall quality was robust, several limitations were identified, particularly concerning blinding and participant retention. Blinding-related issues (questions 3 and 4) were evident in multiple studies, potentially introducing detection and performance biases. Additionally, concerns regarding participant retention (question 12) were noted, which could affect the generalizability of findings. Despite these limitations, the studies demonstrated strong adherence to selection and allocation criteria, ensuring the internal validity of their findings.

Comparative studies of Er:YAG and diode lasers often face challenges related to heterogeneity in study design, evaluation parameters, and follow-up periods. For example, while Giannelli et al. (2014) employed a split-mouth design with short-term follow-up, Arif et al. (2021) utilized a comparative study design with a longer evaluation period. Such variability underscores the need for standardized protocols to ensure consistency and reliability in future research. Additionally, the small sample sizes of the included studies limit the statistical power of the findings, highlighting the need for larger, multicenter trials to validate these results.

Clinical Implications and Future Directions

Both Er:YAG and diode lasers are effective and safe options for gingival depigmentation, offering comparable outcomes in terms of pigmentation reduction, patient comfort, and wound healing. However, the diode laser's superior hemostatic properties and lower pain scores in some studies may make it a preferred choice for certain patient populations. Clinicians should consider factors such as patient preferences, treatment goals, and cost when selecting the appropriate laser modality.

Future research should focus on addressing the methodological limitations identified in this review. Standardized outcome measures, larger sample sizes, and long-term follow-up are essential to establish definitive evidence for the comparative efficacy of these lasers. Additionally, incorporating advanced imaging techniques and histological analyses could provide valuable insights into the biological effects of laser treatments on gingival tissues.

Conclusion

This systematic review on comparative efficacy of Er:YAG and diode lasers for gingival depigmentation demonstrated significant effectiveness in reducing gingival pigmentation, with comparable clinical outcomes across studies, as measured by the Degree of Oral Pigmentation Index (DOPI). Secondary outcomes revealed subtle differences, with the diode laser showing advantages in terms of reduced intraoperative bleeding and lower pain scores in some studies.

The methodological quality of included studies was generally robust, but limitations in blinding and participant retention highlighted the need for cautious interpretation of the findings. Variations in study designs, sample sizes, and follow-up periods further emphasized the importance of standardized protocols in future research. Clinically, both Er:YAG and diode lasers are reliable options for achieving aesthetic gingival depigmentation, with the choice of modality potentially guided by patient preferences, treatment goals, and hemostatic considerations. Future studies should aim to address the identified methodological gaps and incorporate advanced evaluation techniques to better understand the long-term biological effects of laser treatments on gingival tissues. Larger, multicenter trials with standardized measures will be critical to establishing definitive evidence and refining clinical guidelines for laser-assisted periodontal therapies.

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