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Diode laser targeting red-complex bacteria in periodontitis: a systematic review

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Abstract. – OBJECTIVE: This systematic review examines the effectiveness of diode laser irradiation in reducing the levels of red complex bacteria as well as periodontal parameters of pocket depth and clinical attachment level.

MATERIALS AND METHODS: We conducted electronic searches across databases such as Scopus, Embase, Medline, and Web of Science databases in July 2022. Randomized controlled trials that evaluated the reduction of red-complex bacteria in patients with periodontitis using diode lasers were included. The primary focus was the reduction in the microbial count of red complex bacteria, whereas probing depth and attachment level were considered secondary outcomes. Articles in languages other than English were excluded. Study quality was assessed based on the Cochrane Handbook for Systematic Reviews of Interventions and the ROB2 tool.

RESULTS: After searching the databases, eight independent studies were included, with a sample size of 210 subjects. The average age group of the study population was 30-60 years, and there was a lack of consensus on the antimicrobial effect of diode lasers. Out of the eight studies, four studies reported no significant difference in the levels of red complex bacteria before and after laser application. Three studies reported significantly lower levels of red complex bacteria in the intergroup comparison. One study reported that laser had no significant effect on intergroup bacterial levels. The combination of diode laser irradiation with scaling reduced the count of red complex bacteria and improved the clinical parameters, although not significantly.

CONCLUSIONS: Based on the limited evidence available, the adjunctive use of diode laser for scaling and root planning may provide some additional benefit in terms of reduction of red complex bacterial count and clinical parameters. Further well-designed trials and the use of objective measures are necessary before outlining universal guidelines for best practice. The adjunctive use of diode laser in non-surgical periodontal therapy may provide a reduction in the red complex microbial count and improvement in clinical parameters, decreasing the need for periodontal surgery.

Key Words:
Bacteria, Laser, Periodontitis, Red complex pathogens.

Introduction

Periodontitis, an inflammatory condition of the supportive tissues of the teeth, is caused by specific microbes and leads to progressive destruction of the periodontal ligament and bone, pocket formation, and gingival recession[1]. This condition is the primary cause of tooth mobility and poses a significant threat to oral health[2]. Periodontal disease is the most prevalent oral condition affecting humans, with a reported prevalence of 15-30% among the global adult population. According to the Global Burden of Disease Study 2019[3,4], epidemiological research indicates that around 1.1 billion individuals globally are afflicted by periodontitis, and there has been a consistent rise in its prevalence over the last thirty years. Due to the increased prevalence of periodontitis, extensive research studies[5] have been carried out to identify the disease's risk factors and its underlying pathogenic mechanisms. Although the pivotal role of specific bacteria in initiating and progression of the disease is well known, the multifactorial nature of the disease remains an area of active investigation.

Periodontitis is initiated by complex microbial biofilms that colonize the sulcular region and cause clinical attachment loss and pocket formation. The bacterial flora linked to periodontitis is characterized by its extensive diversity, encompassing approximately 700 distinct phylotypes estimated to exist within plaque biofilms.

Numerous investigations[6] have observed variations in microbial composition between individuals with good health and those experiencing illness. Martellacci et al[7] characterized the peri-implant and sub-gingival microbiota involved in periodontitis. A systematic review by Patini et

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al[8] also reported substantial evidence supporting the link between three new species/genera and the development of periodontitis. The red complex bacteria, comprising *Porphyromonas gingivalis, Treponema denticola,* and *Tannerella forsythia*, are considered secondary colonizers and are present in areas exhibiting advanced periodontitis[9]. In chronic periodontitis, pockets, or advanced lesions, a significant number of these periopathogens are reported to be present in large numbers[10,11].

The management of periodontitis includes non-surgical and surgical approaches, which are determined based on the advancement of the disease. Scaling and root planning (SRP) is the standard non-surgical treatment for periodontitis that eliminates local risk factors and promotes the resolution of inflammation[12]. However, SRP has limitations in terms of access to furcations, grooves, concavities, and complex pockets, leading to incomplete removal of plaque and calculus and persistence or recurrence of periodontitis[13]. Additionally, the success of SRP is affected by several risk factors, such as smoking and diabetes[14]. Therefore, the use of adjunct or alternative therapies such as laser therapy has gained popularity[15].

Diode lasers are widely utilized for their low running costs, compact assembly, low primary investment, and ease of operation compared to other lasers, such as Er: YAG, Nd: YAG, and carbon dioxide lasers[16]. Laser therapy differs from photodynamic therapy, which is an oxygen-dependent reaction occurring by light (laser or LED) mediated activation of a photosensitizing compound (tricyclic dyes, tetrapyrroles, or furocoumarins), generating singlet oxygen, which is cytotoxic to bacteria. This study aims to investigate the efficacy of diode laser therapy as an adjunct or alternative to conventional therapy in the management of periodontitis[17]. The diode laser can be used to eradicate the inflamed pocket epithelium and decrease bacterial levels to promote healing[18]. The wavelength of the diode laser allows stronger penetration depth and affinity for pigments seen in some periopathogens, which act as absorbing chromophores. This property permits penetration into black-pigmented bacteria like *Porphyromonas gingivalis*[19]. However, concerns regarding the cost-effectiveness ratio, optimal application, and discernible clinical benefits of diode laser therapy persist[20]. The efficacy of using the diode laser as an adjunct to scaling and root planning (SRP) in non-surgical periodontal therapy, both clinically and microbiologically, remains uncertain.

Research[21] indicates that there are differences in the clinical and microbiological post-operative parameters at three and six months when comparing combined carbon dioxide laser therapy in continuous mode with SRP and SRP alone. However, no significant differences were observed between the two groups[21]. In the literature was shown that the diode laser as an adjunct to SRP does not significantly reduce the post-operative count of periopathogens, such as *Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis*, *Fusobacterium*, and *Prevotella intermedia*. However, contradictory results were reported indicating significant improvement in bacterial count following diode laser therapy as compared to scaling alone. In addition, some studies[22,23] have also reported improvement in periodontal clinical parameters with the use of the diode laser in combination with SRP. The data regarding the clinical benefits of using the diode laser as an adjunct to SRP, however, is limited and warrants further investigation[14,24]. The debate over the incorporation of diode lasers along with conventional treatment modalities remains ongoing[24,25]. However, the long-term benefits and effects of the lasers as an adjunct to non-surgical periodontal therapy remain unclear[26]. Thus, this review aimed to systematically assess the presently available literature for the effectiveness of diode laser application on red-complex bacteria in non-surgical periodontal therapy.

Materials and Methods

Search Strategy

We performed electronic searches across databases, including Scopus, Embase, Medline, and the Web of Science (July 2022). This systematic review was performed using the Preferred Reporting for Systematic Reviews and Meta-analysis (PRISMA) guidelines[27]. This review was submitted for registration in the International Prospective Register of Systematic Reviews (PROSPERO) with registration number CRD42023463121.

The research question was "Can laser diode treatment reduce the levels of red-complex bacteria in patients with periodontitis?"

Inclusion Criteria

(P) Population: Subjects with periodontitis.
(I) Intervention: Diode laser application.
(C) Control: Scaling and root planning.
(O) Outcome: Primary outcome – count of the

red complex bacteria; secondary outcome – clinical periodontal parameters.

(S) Study type: Randomised control studies, controlled clinical trials, cohort studies.

Exclusion Criteria

Case reports, systematic reviews, opinion articles, letters to the editor, case reports, and articles in languages other than English were excluded. The electronic databases of PubMed, Scopus, Embase, and Web of Science were searched for eligible studies with no restrictions placed on the start date of July 2022. Forward citation tracking was conducted using Google Scholar. Three authors (SP, KA, and CF) independently reviewed the search results for study selection. Duplicates and non-relevant articles were discarded. The researchers independently screened titles and abstracts of studies for eligibility, and any disagreements were resolved through consensus with a fourth author (SGP). Manual supplementary searches of the references of the selected articles were conducted for additional eligible studies. The search strategy is depicted in **Supplementary Table I**.

Data Extraction

Data extraction was independently conducted by two authors (SP and CF) and verified by a third author (FL) for accuracy. Characteristics of the study, along with the author's names, year of publication, country of origin, methodological aspects, sample size, treatment regimen, and duration, were extracted manually into a customized template.

Risk of Bias Assessment

The quality of the selected studies was assessed using relevant guidelines from the Cochrane Handbook for Systematic Reviews[28]. Five specific domains were used to assess the external and internal validities of the studies, including randomizations, allocation concealment, blinding, missing outcome data, selective reporting, and other sources of bias. The response for each domain was either high, low, or unclear, with a risk of bias. The absence of pertinent information regarding methodology in the selected study would result in a high risk of biased judgment for the particular domain. An unclear judgment was reserved for use in case of insufficient information. The overall risk of bias was determined using the highest level of risk observed under the domains.

Methods to Assess Quality of Evidence Presented in Summary of Findings

The primary outcome of "reduction in bacterial count" and the secondary outcome of "probing depth and clinical attachment level" were examined in the included studies. We assessed the outcomes in the summary of findings table using the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) tool[29]. The GRADE system was initially applied by one author (SGP). The evidence was reviewed independently by two authors (FL and SB). The final rating was determined after the three reviewers reached a consensus. The certainty of the evidence was graded as high, moderate, low, and very low. Evidence for each outcome was graded as "high quality" at the start in the case of randomized clinical trials (RCTs). The evidence rating was downgraded by one level for serious or two levels for very serious concerns regarding the study limitations, inconsistencies in the outcomes, indirectness of evidence, imprecision of effect estimates, or publication bias.

Results

The initial search resulted in the identification of 490 records. After the removal of duplicates and screening of titles and abstracts for eligibility, the potentially relevant articles were identified. The full text of the articles was selected for complete review. A total of eight articles[30-37] were selected for inclusion in this systematic review. The PRISMA flow diagram for the workflow is shown in Figure 1. From the collective analysis of the eight studies, a comprehensive assessment was carried out on 210 cases. Of the 210 cases, 114 subjects were with chronic periodontitis, 30 subjects were with aggressive periodontitis, and 46 subjects were inconclusive. We also took into consideration the number of teeth screened for each study. A total of 1,048 teeth were screened across five studies[30-32,35,36]. The other three studies[33,35,37] were inconclusive about the number of teeth analyzed. The average age group of the study population was 30-60 years, and all studies were randomized controlled trials. Among these, seven studies[30-36] utilized a split-mouth study design, and the other one[37] used a parallel arm study approach. The studies were conducted in diverse geographical locations such as Italy, the USA, Germany, India, Transylvania, South Africa, and Poland. A summary of the characteristics of the selected trials is shown in **Supplementary Table II**.

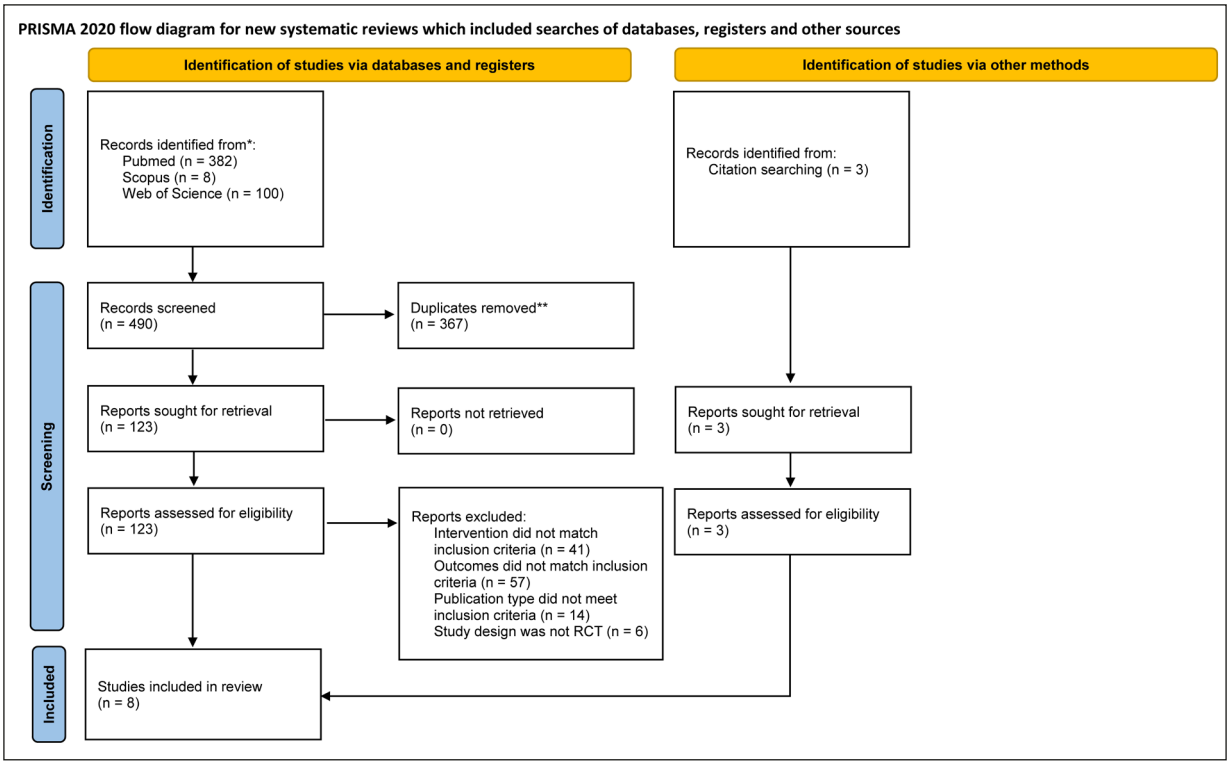

Figure 1. PRISMA flow chart.

Quality Assessment

The majority of studies[31,32,35] showed significant concerns about the risk of bias. Four studies[31-33,35] exhibited high overall risk bias. The remaining three[30,34,36] reported certain risk biases. Only one study[37] reported a low risk of bias. The studies by Kamma et al[31] and Ciurecsu et al[34] were single-blinded, whereas the studies by Staden et al[36] and Samulak et al[37] showed double-blinding. The study by Mahalakshmi et al[35], Fenol et al[33] and Romanos and Brink[32] lacked information regarding the blinding of the subjects, while the data presented by Caruso et al[30] was inconclusive regarding the same. A summary of the risk of bias assessment is presented in Figure 2[38].

Certainty of Evidence

Our review examined eight studies with 210 samples. Based on GRADE, the overall quality of evidence for both the outcomes in this study was low. This suggests limited confidence in estimating the effect of diode laser on bacterial count reduction of red complex bacteria and on clinical parameters of probing depth and attachment level. The serious risk of bias and inconsistency in the studies raises doubts regarding the magnitude of the effect of the interventions examined. The reasons for downgrading the study were due to methodological insufficiencies i.e. the inconsistency and the risk of bias. The majority of the involved studies were at either some concerns or a high risk of bias. **Supplementary Table II** shows the summary of the findings.

Characteristics of the Selected Studies

Study design

All studies included for this review were split-mouth randomized controlled trials, of which five studies included subjects with chronic periodontitis[30,33-36], whereas one study[31] included subjects with aggressive periodontitis. The study by Romanos and Brink[32] mentions the inclusion of active periodontal sites; however, is inconclusive about the type of periodontitis. Similarly, the study by Samulak[37] was inconclusive about the type of periodontitis. Methodological insufficiencies were seen in the studies. Only three studies mentioned subject dropouts[34,35,37]. Kamma et al[31], Fenol et al[33] and Romanos and Brink[32] provided no information about the dropouts, whereas the information provided by the others was not conclusive. Three studies[30,32,35] did not reveal gender distribution. Four studies[31,36,35,37]

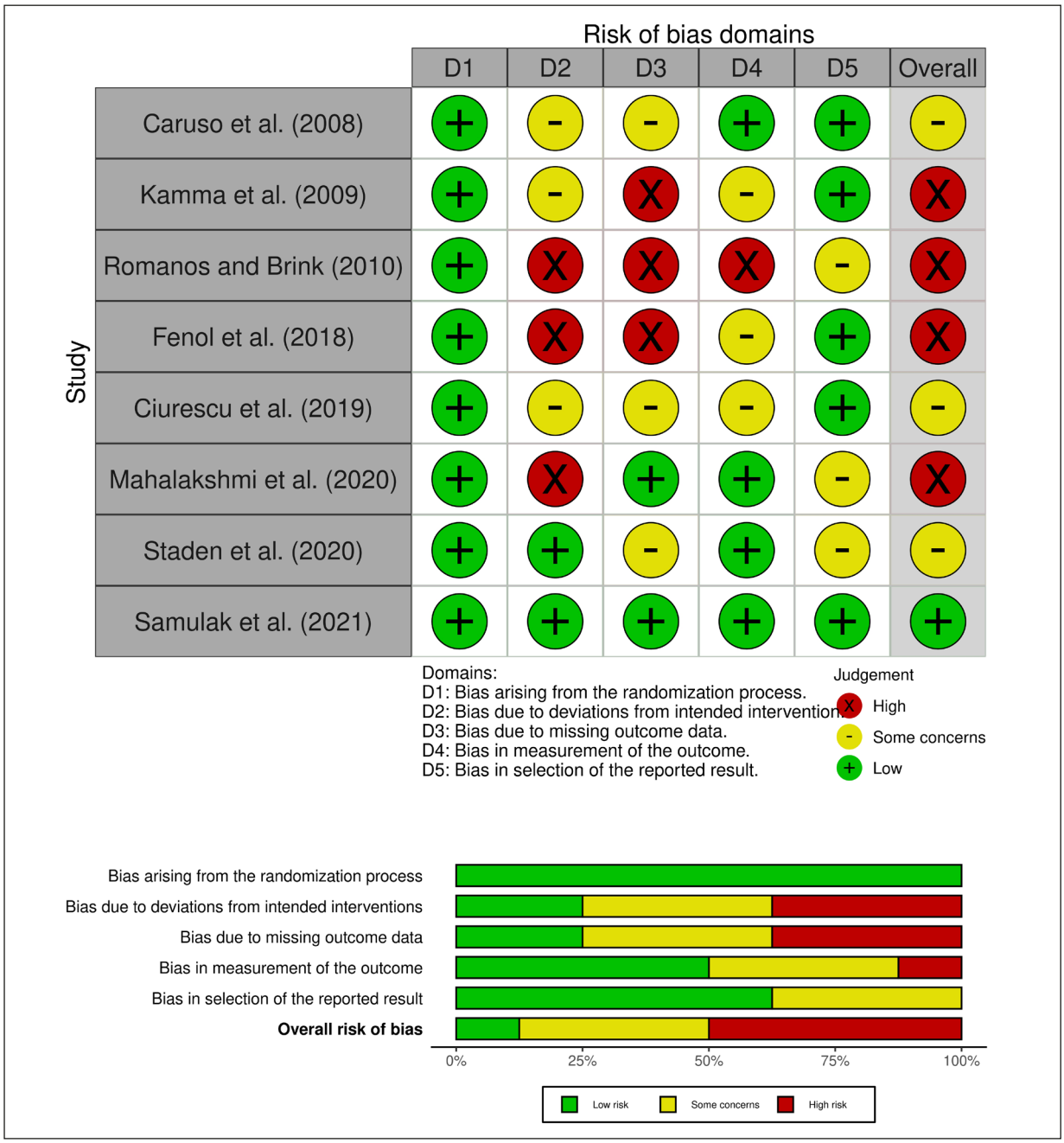

Figure 2. Summary of risk of bias assessment.

included smokers in their sample. Two studies[32,33] excluded smokers, and there was no mention of smokers in the other two studies[30,35]. One study[37] recruited only subjects having periodontitis with a history of myocardial infarction.

Laser wavelength and mode

Six studies[30-33,35,37] used the diode laser at a wavelength of 980 nm. One study[34] used the Er,Cr: YSGG laser of 2,780 nm along with the diode laser of 980 nm, while Staden et al[36] used the wavelength of 810 nm.

Two studies[30,35] used diode the laser in the pulse mode. While the other five[31,33,34,36,37] utilized the continuous mode. The mode of use of the diode laser was not mentioned in one study[32].

Duration of studies

The follow-up period varied between the studies, with the shortest being 6 weeks. Three trials

(Caruso et al[30], Ciurescu et al[34], and Kamma et al[31]) had the longest follow-up periods of 6 months, whereas the trial by Mahalakshmi et al[33], Romanos[30], and Samulak et al[37] had a follow-up period of 3 months. Fenol et al[33] maintained a recall period of two months. However, the trial by Staden et al[36] had a duration of only 6 weeks.

Evaluation of primary outcome

Four studies[30,35-37] evaluated the number of red complex bacteria using the polymerase chain reaction (PCR) technique. One study utilized the ssRNA probes and one used a DNA test kit, respectively[31,34]. Another study[32] utilized the Benzoyl-DL Arginine-2-Naphthylamide (BANA) test. However, the technique of bacterial evaluation was not stated in one study.

Four studies[30,35-37] reported no significant differences in the levels of red complex bacteria before and after laser application. Three studies[30,33,34] reported a significant difference in the bacterial levels in the intergroup comparison. The study by Romanos and Brink reported a 71.65% reduction in bacterial levels from baseline to 3 months post-diode laser therapy. However, it did not report any data on the significance of intergroup comparison of bacterial levels[32]. In one study, even though the levels of *Porphyromonas gingivalis* and *Tanarella forsythia* declined post-laser application, the differences in the bacterial levels were not statistically significant before and after laser treatment[36]. Kamma et al[31] reported significantly lower bacterial levels of *Porphyromonas gingivalis* ($p>0.05$) and *Treponema denticola* ($p>0.05$) 6 months post-treatment compared to the other groups. Caruso et al[30] reported an increase in the levels of *Porphyromonas gingivalis* in the test group at the end of six months. Levels of *Treponema denticola* remained unchanged, while that of *Tanarella forcithia* decreased slightly. All these values were statistically insignificant in the intergroup comparison.

Evaluation of secondary outcome

All studies evaluated probing depth, and clinical attachment levels as the secondary outcomes. Three studies[31,33,34] stated that both reductions in probing pocket depth and clinical attachment levels were statistically significant on the intergroup comparison at the end of the studies. Other three studies[30,36,37] stated that the reduction in the inter-group probing pocket depth and clinical attachment levels were not statistically significant ($p>0.05$). Mahalakshmi et al[35] reported a mean reduction in pocket depth from baseline to 3 months with no statistically significant difference between the groups ($p<0.05$). However, the study reported a statistically significant difference in the clinical attachment level at 3 months between the test group and control group ($p>0.05$) (Table I).

Discussion

Despite scaling and root planning being a well-documented treatment modality for chronic periodontitis, it has been critically evaluated in various backgrounds for their limitations[38,39]. These limitations led to the incorporation of other methods, such as laser treatment, along with

Table I. Summary of findings table.

Quality assessment						Summary of findings		
Outcome	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Impact	No. of participants (Studies)	Certainty of evidence (GRADE)
Effect of diode laser on bacterial count reduction of the red complex bacteria	Serious[a]	Serious[c]	Not serious	Not serious	Not serious	Our confidence in the effect estimate is limited	210 (8)	Low
Effect of diode estimate is limited probing depth and clinical attachment levels	Serious[b]	Serious[d]	Not serious	Not serious	Not serious	Our confidence in laser on the effect	200 (7)	Low

[a]Five studies showed a high risk of bias. [b]Five studies showed a high risk of bias. [c]Large differences in effect across studies. [d]Magnitude of effect is unclear.

scaling and root planning to achieve an effective treatment outcome. Diode lasers are commonly used in dental practice due to their compactness as well as cost effectiveness[18]. However, there has been no systematic review to comprehend the overall effectiveness of adding a diode laser with scaling and root planning. Hence, in this review, we evaluated the efficacy of utilizing diode lasers in non-surgical periodontal therapy by assessing the red-complex bacterial population.

We found that the adjunctive use of diode laser along with scaling and root planning has propitious results[31,33,34]. The studies differed in their conclusions. All studies uniformly reported an overall decrease in the levels of red complex bacteria after laser therapy. However, four studies[35-37] found that these decreases were not statistically significant.

The secondary outcomes that we investigated were clinical parameters of probing depth and clinical attachment level. However, the results were not consistent across all the studies. In three studies[31,33,35], it was reported that the use of lasers leads to reductions in probing pocket depth and clinical attachment levels. However, the observations from the other three studies[30,36,37] were contrary to the above results. It was found that the reduction in the inter-group probing pocket depth and clinical attachment levels were present in both treatment modalities but were not statistically significant.

The conflicting results in the studies included in this review are clearly evident from the literature. Three out of eight studies in this review found that diode laser therapy significantly reduced post-treatment bacterial count. This finding is in broad agreement with other studies[40,41] linking diode laser therapy with reduced bacterial count. Moritz et al[40] used a diode laser (805 nm) and reported considerable microbial elimination from pockets at a greater level than the group with scaling alone, especially in terms of *Aggregatibactor actinomycetumcommitans*. A later study[41] by the same authors examined the effects of diode lasers in conjunction with scaling and hydrogen peroxide mouthwash used in one group against scaling with a diode laser (805 nm). After 6 months, the study reported significantly reduced total bacterial count as well as levels of *Aggregatibactor actinomycetumcommitans*, *Prevotella intermedia*, and *Porphyromonas gingivalis* levels.

However, four studies[30,35-37] reported that while diode lasers may have reduced the bacterial count, it did not have a statistically significant effect on the reduction in bacterial count. This finding mirrors previous studies by Euzebio Alves et al[42], Yadwad et al[43], and De Micheli et al[44]. Euzebio Alves et al[42], in their split-mouth randomized controlled trial, treated all 36 chronic periodontitis subjects with scaling and root planning with the addition of diode laser therapy in the test group. Results revealed no association between the groups and the prevalence of *Porphyromonas gingivalis*, *Prevotella intermedia*, and *Aggrebactor Actinomycetum commitans* at 6 months recall[42]. Similarly, Yadwad et al[43] treated 40 systemically healthy subjects with chronic periodontitis with scaling along with diode lasers (980 nm) with sham lasers as control. They evaluated the *Porphyromonas gingivalis* levels using real-time polymerase chain reaction (RT-PCR) and found clinically relevant but statistically insignificant intergroup differences in the bacterial levels. De Micheli et al[44] also reported no significant difference in the colony forming units count (CFU count) of *Porphyromonas gingivals*, *Prevotella intermedia*, and *Aggrebactor actinomycetumcommitans* after treatment with SRP and laser without activation (sham procedure) in one group and SRP with high power diode laser in the experimental group. It has been reported the detection frequencies of the red complex bacteria may be significantly lower 2 weeks after photodynamic therapy and by scaling and root planning as compared to diode laser therapy. However, at 2 and 6 months, these differences were not significant[45-49].

Three studies[31,33,34] demonstrated that diode laser therapy can positively improve clinical attachment levels. These results corroborate previous literature that has advocated the use of diode lasers. Studies by Saglam et al[46] and De Micheli et al[44] reported a statistically significant difference in the clinical attachment levels post diode laser therapy. Koçak et al[50] conducted a randomized controlled clinical trial on 60 type-2 diabetics with chronic periodontitis. Similar to the results of Saglam et al[46] and De Micheli et al[44], Koçak et al[50] also demonstrated a significant difference in the clinical attachment levels in the SRP with diode laser group as compared to SRP alone[37].

Contrary to the above observations, three studies[42,43,47] reported no significant reduction in postoperative clinical attachment levels when using the diode laser. This finding is consistent with several other clinical trials. For instance, Euzebio Alves et al[42] and Yadwad et al[43] demonstrated no significant difference in the postoperative clinical attachment levels after the application of the diode laser as an adjunct to SRP. Nguyen et al[47], in their single-blinded trial, reported no significant

reduction in the clinical attachment levels between diode laser therapy in combination with SRP and SRP alone as a part of periodontal maintenance. Assessing the pocket depth, three studies[31,33,34] in the present review found that laser diode therapy positively influenced pocket depth. However, the majority of the studies[30,35-37] in this review showed no significant difference in intergroup comparison of pocket depth. This finding is contrary to previous studies[42,43,47,48] that have suggested that diode laser application may improve pocket depth. Dengizek Eltas et al[49] reported a significant difference in the pocket depth six months after diode laser therapy in poorly controlled type 2 diabetics. Saglam et al[46] also reported a significant difference in the intergroup pocket depths as well as plaque index, gingival index, and bleeding on probing levels. Similarly, Koçak et al[50] and Dukić et al[51] had similar outcomes of pocket depth.

The findings of this review are moderately limited due to the high risk of bias and conflicting experimental results regarding the magnitude of the intervention. Overall, our review suggests there is low-level evidence that diode lasers can reduce bacterial load and improve clinical parameters of probing depth and attachment level. Heterogeneity in the study designs precluded the performing of a meta-analysis.

Overall Completeness and Applicability

The results of this review cannot be generalized due to the limited number of articles evaluating the efficacy of high irradiation diode laser on red-complex bacteria adjunctive to conventional therapy. Even though a literature search found several articles evaluating the effect of photodynamic therapy using a diode laser on red complex bacteria, they do not meet the inclusion criteria for the present review[51-53]. The observations were also limited by the sample size of the reviewed articles. For example, studies by Caruso et al[30] and Romanos and Brink[32] had a low sample size of thirteen and ten subjects, respectively.

Periodontal therapy is largely influenced by risk factors such as smoking, diabetes, and cardiovascular diseases[13]. Confounders were not accounted for in several trials. For specific example, four studies[31,34,36,37] included smokers, whereas two studies[32,33] excluded smokers. However, there was no mention of smokers in the other two studies[30,35]. Studies[51-57] have reported the effect of smoking on less favourable response to non-surgical periodontal therapy and interfere with the outcome of the study. Similarly, only one study[36] mentioned subjects having systemic diseases such as controlled diabetes and hypertension being recruited in the study. Another study[37] exclusively enrolled periodontitis patients with a history of myocardial infarction. Both periodontitis and cardiovascular diseases, such as myocardial infarction, are inflammatory in origin and share similar risk factors[56].

Another disparity observed among the studies is the diode lasers used in the studies were dissimilar in their wavelength. The diode lasers used were 810 nm in one study, whereas the other studies utilized a wavelength of 980 nm. The wavelength of 980 nm has less pigment absorption and, hence, low heat production as compared to the diode laser of wavelength 810 nm[57]. The studies also differed in the technique used for the detection of red-complex bacteria. Four studies[30,35-37] evaluated the number of red complex bacteria using the polymerase chain reaction (PCR) technique. One study utilized the ssRNA probes[29], and two other studies[33,34] utilized the BANA test and the DNA test kit, respectively. While the PCR is a more sensitive, rapid, and precise technique for detection identification and quantification of periopathogens, literature shows low agreement on the positive bacterial outcome using the RNA probes[58,59]. The BANA test is more accurate and highly sensitive than DNA probes or ELIZA for the detection of red complex bacteria[60]. Although the diode laser is most commonly used in non-surgical periodontics, in a large period of more than a decade (2008 to 2020), only eight studies have examined the effect of the diode laser on red-complex bacteria[16]. Thus, more well-designed randomized controlled trials with larger sample sizes are needed.

Quality of the Evidence

The certainty of the evidence was downgraded at two levels, once for bias and once due to the inconsistency in the studies. We found the quality of evidence for the outcome to be of low quality primarily due to the risk of bias. Overall, there were significant concerns regarding the risk of bias in a majority of studies. The overall risk was high in four studies[31,32,35]. The other three reported certain concerns[30,34,36]. Only one study reported a low risk of bias[37]. Several studies[30,32,33,35], lacked clarity in reporting key information required for quality assessment. Studies by Kamma et al[31] and Ciurescu et al[34] were single-blinded, whereas ones by Mulder-van Staden et al[36] and Samulak et al[37] showed double-blinding. No information about blinding was provided in the study by

Mahalakshmi et al[35], Fenol et al[33] and Romanos and Brink[32], while the information by Caruso et al[30] was inconclusive. The insufficient quality of evidence prevented a reliable conclusion. A sensitive and wide-ranging search strategy was employed to identify studies for inclusion in this review. No restriction was placed on the publication date, and multiple authors independently assessed eligibility using well-defined inclusion criteria to minimize any selection bias. Despite the authors' best efforts, this review has some limitations. The studies lacked definite information that is vital for quality assessment. This led to an unclear response in several domains during the risk of bias assessment. Only English language studies were considered for inclusion. This review may not be exhaustively comprehensive due to the exclusion of articles published in other languages. Further high-quality trials using multiple assessment protocols are necessary before definitive universal guidelines can be issued.

Conclusions

This systematic review evaluated the evidence for the effectiveness of diode laser irradiation on the levels of red complex bacteria. It also assessed its effect on clinical periodontal parameters such as pocket depth and clinical attachment levels. Within the limitations of the systematic review, there is low-level evidence that adjunctive use of diode laser for scaling and root planning may provide some additional benefit in terms of reduction of red complex bacterial count and improvement in clinical periodontal parameters. Further well-designed trials adhering to reporting guidelines and using objective measures are necessary before outlining universal guidelines for best practice.

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Informed Consent
Not applicable.

Data Availability
Not applicable.

Conflicts of Interest
The authors declare no conflict of interest.

Authors' Contributions
S. Patel: Conceptualization, methodology, software.
S. Patil: Data curation, writing- original draft preparation.
S. Bhandi: Visualization, investigation.
C. M.T. Freitas: Supervision.
K. H. Awan: Software, validation.
F.W. Licari: Writing- reviewing and editing.
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