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*Research Article*

# A comparative evaluation of the efficacy of diode laser as an adjunct to conventional flap surgery versus conventional flap surgery alone in the treatment of chronic periodontitis – a systematic review and meta-analysis

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**INTRODUCTION**

Chronic periodontitis is one of the most prevalent oral conditions in the world (1), characterized by the destruction of the periodontium and resulting in alveolar bone resorption (2). Periodontitis is the result of complex interrelationships between infectious agents such as bacteria, host, and environmental factors (3,4,5), which play a major etiological role and cause both direct as well as host-mediated tissue injury (6). The disease is caused by mixed bacterial infections, primarily involving a limited number of anaerobic microbiota in the subgingival region which leads to the breakdown of supporting structures of the teeth (7, 8).

The treatment of periodontitis focuses on eliminating or modifying these factors to arrest or control the disease process. The main goal of periodontal therapy is to remove biofilm and regenerate both hard and soft tissue components of the attachment apparatus. This process aims to restore function and achieve long-term benefits by using predictable methods for tissue regeneration (9). Conventional methods for treating periodontitis typically involve disrupting the biofilm through mechanical removal of subgingival plaque, sometimes supplemented with antimicrobial agents and surgical debridement of damaged pocket and root surfaces. An alternative approach, proposed by Marsh (ecological plaque hypothesis), suggests altering the pocket environment to prevent the growth of pathogens (10).

While Complete mechanical debridement being the "gold standard" of periodontal treatment (11) can significantly reduce subgingival microbial prevalence and levels, certain periodontopathogens like A. actinomycetemcomitans and P. gingivalis can penetrate deep into periodontal tissues, crossing the epithelial barrier which may be challenging to remove with nonsurgical periodontal therapy (NSPT) alone (12). Additional procedures like soft tissue curettage using ultrasonics and adjunctive locally delivered agents (e.g., antimicrobials, antiseptics, anti-inflammatories, host-modulating agents) have been explored to enhance treatment outcomes with varying success (13). However, their predictability is uncertain, and antimicrobial use may contribute to developing resistant strains. Also, according to Schenk et al. (14), sonic and ultrasonic instrumentation does not lead to the killing of periopathogens but helps to reduce the bacterial load by the mechanical removal of plaque and calculus. Moreover, the complete removal of bacterial deposits and toxins from the root surface is challenging with conventional nonsurgical methods due to limited access to areas like furcations, concavities, and developmental grooves. This limitation necessitates surgical intervention for thorough treatment (15, 16).

Surgical therapy is often recommended for cases with persistent inflammation, deeper pockets, class II and III furcation defects, and intrabony defects. This approach provides better accessibility to root surfaces and osseous defects, making it effective in addressing these challenging conditions. Flap surgery, indicated for deeper pockets, typically results in greater immediate pocket reduction and attachment gain compared to nonsurgical methods (17). One of the most commonly used flaps is the modified Widman flap (MWF), given by Ramfjord and Nissle in 1974, which is also recognized as an open flap curettage technique, and it involves removing the lining of the periodontal pocket (1) and has shown promising results.

Laser-assisted periodontal therapy has gained attention as a potential alternative or adjunct to conventional mechanical debridement in the treatment of periodontal disease. It is based on the concept of subgingival curettage, reattachment, and regeneration of the attachment apparatus, often referred to as "non-surgical" therapy (18, 19). Lasers offer the potential to simultaneously remove diseased soft tissues, target microorganisms, and stimulate wound healing, presenting a comprehensive approach to periodontal treatment (20). A part of the laser energy scatters and penetrates during irradiation into periodontal pockets. The attenuated laser at a low energy level might then stimulate the cells of surrounding tissue resulting in the reduction of the inflammatory conditions (Shimizu et al.) (21), in cell proliferation (Quadri et al.) (22), and in increased flow of lymph (Shimotoyodome et al.) (23) improving the periodontal tissue attachment and possibly reducing postoperative pain. Hence, it offers higher patient comfort and acceptance compared to conventional methods (24) and eliminates pockets with minimal recession or repositioning of the gingival margin (25), providing several advantages such as better accessibility into periodontal pockets due to thin and flexible fibers, hemostasis, reduced postoperative discomfort including pain and swelling, significant reduction in bacterial counts at the surgical site, lack of need for suturing, and faster healing (20, 26). Carbon dioxide (CO2) laser, neodymium-doped yttrium-aluminum-garnet (Nd: YAG) laser, and diode and erbium-doped yttrium-aluminum-garnet (Er: YAG) laser have been utilized in periodontal therapy for both hard tissue and soft tissue management. Studies have shown that Er: YAG laser efficiently removes subgingival calculus (27), CO2 laser is effective for root conditioning (28), while Nd: YAG and diode laser (DL) are beneficial for controlling bacteremia and removing pocket epithelium (29, 30).

The diode laser is the most popular choice of laser technology for general dental practitioners since it is economical, portable, and convenient to use. In addition, since it has good tissue penetration (31), and is well absorbed in pigmented tissues, it can specifically target the pigmented bacteria and granulation tissue (32). The radiation of the diode laser shows greater absorption and less penetration than does the Nd: YAG laser, especially in blood-rich tissues. Therefore, collateral damage with diode lasers is less than with Nd: YAG or CO2 lasers (33). The diode laser is a solid-state semiconductor laser that typically uses a combination of gallium (Ga), arsenide (Ar), and other elements such as aluminum (Al) and indium (In) to change electrical energy into light energy (34). Laser energy at 800–980 nm is poorly absorbed in water but highly absorbed in hemoglobin and other pigments (35) Since the diode laser does not interact with dental hard tissues, this type of laser is an excellent soft-tissue surgical laser, indicated for cutting and coagulating gingival and oral mucosal tissues and for carrying out soft-tissue curettage or sulcular debridement. It also has a bactericidal effect (32, 36). The use of diode lasers in various periodontal procedures generates a zone of thermal necrosis of < 1mm, providing sufficient surgical precision and hemostasis for many soft-tissue procedures (37). Diseased periodontal tissues contain melanin, hemoglobin, and chromophores that are the main target of DL energy (36, 38).

The use of low-level laser therapy (LLLT) as a therapeutic agent was first investigated by Mester et al. in 1971 (39, who found that it improved wound healing in rats. However, its role in periodontal treatment is still being investigated in humans and animals. Low-level lasers emit visible red and near-infrared wavelengths (600-1100 nm) absorbed by photoreceptors in cells, targeting mitochondrial membranes (40). This absorption increases ATP formation, stimulating cell function and possibly enhancing wound healing (41,42). Cytochrome c oxidase (Cox), a primary photo-acceptor in mitochondria plays a key role in this process, leading to increased ATP production, modulation of reactive oxygen species, and activation of transcription factors like NF-κB, resulting in beneficial effects of LLLT (43). The low-level lasers chiefly work on the principle of biostimulation or photo biomodulation (44). (LLLT) provides an instant analgesic effect; hence, extensively used for reducing pain as it accelerates the regenerative process (45 - 48).

However, the evidence available so far is insufficient to prove the adjunctive effect of dental lasers in surgical periodontal therapy (68) . Thus, the primary purpose of conducting this study was to evaluate and compare clinically and microbiologically the effectiveness of diode laser to facilitate the removal of remnant epithelium, reduction of perio-pathogens, and biostimulation after MWF for the treatment of chronic periodontitis.

## MATERIALS AND METHODS

### Protocol and Registration

A systematic review of literature and meta-analysis was performed. This study followed the (PRISMA 2020) Preferred Reporting Items for Systematic Review 2020, the Cochrane Handbook for systematic reviews of interventions, version 5.1.0. and 4th Edition of the JBI Reviewer's Manual and was registered at INPLASY under registration code _____INPLASY2023110046_____

**Focused review question**

Is there a difference in the effectiveness of Diode lasers as an adjunct to Conventional Flap Surgery versus Conventional flap surgery alone in patients with Chronic Periodontitis as measured by clinical parameters?

**Aims:**

To evaluate clinically the effectiveness of Diode lasers as an adjunct to Conventional Flap Surgery versus Conventional flap surgery alone in patients with Chronic Periodontitis.

**Objectives:**

- To evaluate the reduction in pocket depth and gain in clinical attachment level
- To evaluate plaque index, gingival index, bleeding on probing, gingival recession, post-operative pain

**Eligibility criteria:**

**[A]Inclusion criteria:**

a.Population –

Studies with systemically healthy patients aged between 20 - 50 years that are diagnosed with chronic periodontitis requiring periodontal flap surgery irrespective of gender, ethnicity, and nationality.

b. Intervention –

Studies assessing the efficacy of surgical periodontal treatment using a laser (diode) as an adjunct to Conventional Flap Surgery

c.Comparison –

Studies using conventional flap surgery for treatment of chronic periodontitis.

d. Outcome –

Primary outcome: Studies assessing either or all of the following outcomes at minimum of one month follow-up interval and measured in millimetres using a standardized periodontal probe or a calliper:

i. Probing depth: Defined as the distance from the FGM to the bottom of the sulcus mid-facially
ii. Clinical attachment level: Measured from the CEJ and the bottom of the periodontal pocket
iii. Gingival recession depth (GRD): Defined as the distance from the Cemento-enamel junction (CEJ) to the free gingival margin (FGM) mid-facially

Secondary outcome: Studies assessing plaque index, gingival index, bleeding on probing, post-operative pain, along with either or all of the primary outcomes post operatively and at subsequent follow-up interval.

**[B] Exclusion criteria:**

i. Studies not fully available in the database.
ii. Single intervention studies without the comparative group were excluded
iii. Observational studies, Review reports, case series, in-vitro and animal studies were excluded.
iv. Studies providing only abstract and not full text.
v. Trials involving participants who had a history of significant medical conditions, or took any medication that could have influenced the results of the study.

**SCREENING PROCESS**

i. Studies published in any language where English translation is possible.
ii. Studies published between 1-1-2000 to 30-9-2023
iii. Clinical trials, in-vivo studies, randomized clinical trials, controlled clinical trial, non-randomized clinical trials, Quasi experimental studies, non-experimental studies, cohort studies, cross-sectional studies.
iv. Studies with full-text articles were included

**SEARCH STRATEGY**

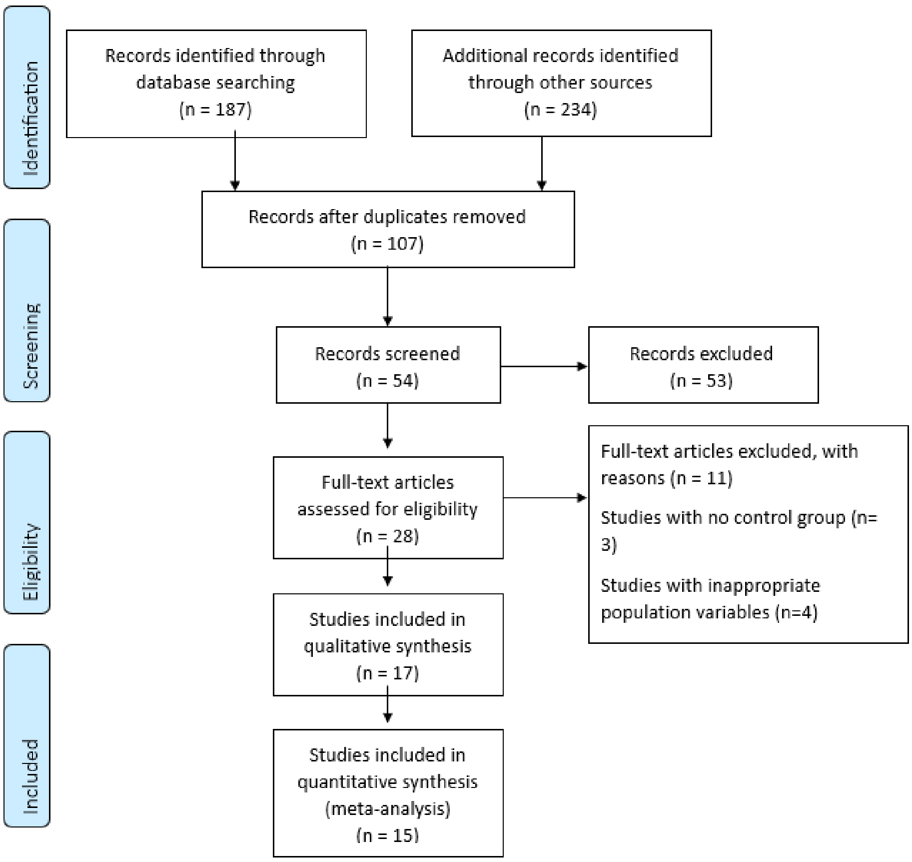
Studies were selected based on the PICOS inclusion criteria in the review protocol. Two reviewers assessed titles and abstracts to identify potentially eligible studies. Any queries were discussed with a third reviewer.

- The preferred reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for conducting a meta-analysis were followed.
- The electronic data resources consulted for elaborate search were Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, CINAHL, EMBASE, PsycINFO, Scopus, ERIC, ScienceDirect with controlled vocabulary and free text terms. (Table 1)
- Articles published from 01/01/2010 until 30/09/2023 were searched, without any restriction concerning the publication's language.
- Following keywords and MeSH terms were used in combination with Boolean operators in the advanced search option.

**Table 1: The search strategy and PICOS tool**

| **Search strategy** | |
|---|---|
| **Focused Question** | Is there a difference in the effectiveness of Diode lasers as an adjunct to Conventional Flap Surgery versus Conventional flap surgery alone in patients with Chronic Periodontitis as measured by clinical parameters? |
| **Search strategy** | |
| Population | ("periodontal"[All Fields] OR "periodontally"[All Fields] OR "periodontically"[All Fields] OR "periodontics"[MeSH Terms] OR "periodontics"[All Fields] OR "periodontic"[All Fields] OR "periodontitis"[MeSH Terms] OR "periodontitis"[All Fields] OR "periodontitides"[All Fields]) |
| Intervention (#1) | "lasers"[All Fields] OR " Diode Lasers"[All Fields] OR " Diode Laser"[All Fields] OR " Gallium Aluminum Arsenide Lasers"[All Fields] OR " GaAlAs Lasers"[Supplementary Concept] OR " GaAlAs Laser"[All Fields] OR " Gallium Arsenide Lasers"[MeSH Terms] OR " Diode Laser-Assisted"[All Fields])) |
| Comparisons (#2) | (((Conventional flap" [Text Word] "Laterally positioned flap" [Text Word] OR "Laterally closed tunnel technique"[Text Word] OR "Modified coronally advanced flap" [Text Word] OR "Modified Widman flap" [Text Word] OR "Periosteal pedicle Flap" [Text Word] OR ("Semilunar coronally advanced flap" [Text Word]))) |
| Outcomes (#3) | (Bleeding on Probing [Text Word] OR - Clinical Attachment Loss [Text Word] OR Probing Depth [Text Word] OR Plaque Index [Text Word] OR Gingival Bleeding Index [Text Word] OR Full Mouth Bleeding Index [Text Word])) |
| Study design (#4) | ((Randomized controlled studies [Text Word] OR randomized control trials [MeSH] OR randomized control clinical trial [MeSH])) |
| Search Combination | #1 AND #2 AND #3 AND #4 |
| **Database search** | |
| Language | Articles in English language |
| Electronic Databases | PubMed/MEDLINE, Cochrane Central Register of Controlled Trials, Scopus, DOAJ |
| Period of Publication | Studies published between 1-1-2010 to 30-09-2023 |

**Figure 1: PRISMA flow diagram**



**STUDY SELECTION**

The title and the abstract of each study were reviewed and critically assessed by two independent reviewers. The methods used to apply the selection criteria were the following:

i. integration of the searched outcomes to delete duplicate entries
ii. examination of titles and abstracts to delete clearly irrelevant articles
iii. recovery of the full text of potentially relevant articles
iv. binding and gathering of multiple articles of the very same study
v. examination of the articles' full text to verify the degree of compliance that the studies had with the eligibility criteria
vi. establishing connection with researchers, if necessary, to clarify the study's eligibility
vii. deciding about the study's inclusion and proceeding with data gathering.

**DATA COLLECTION**

Two reviewers independently extracted data from the included studies. Disagreements were again resolved through discussion. Data gathered was carried out using a verification list of items that were considered for data extraction. The main items of this list were as follows:

1. Authors, Year and Title of study
2. Country
3. Study design
4. Sample size
5. Age group of participants
6. Gender
7. Intervention
8. Comparison
9. Outcomes
10. Methods of outcome assessment
11. Conclusion and other items

Details regarding the publication and the study, the participants, settings, the interventions, the comparators, the outcome measures, study design, statistical analysis and results, and all other relevant data (funding; conflict of interest etc.) were carefully and accurately extracted from all included studies. Data extraction was done and accurately recorded in the excel sheets for all the primary outcomes separately.

**Table 2: Characteristics of included studies**

| Study ID | Place of study | Study design | Sample size | Age | Gender | Type of flap | Intervention | Control | laser type | wavelength | Power | Mode | time of application | Energy | Author conclusions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gokhale 2012** | India | RCT split mouth | 30 30/30 | 30-50 | N/A | conventional access flap | diode laser with mechanical debridement | mechanical debridement | Diode | 980nm | 2.5W | continuous | N/A | 50J/cm2 | The bactericidal effect of the diode laser was clearly evident by greater reduction of CFU of obligate anaerobes in the test group than in the control group. |
| **Sanz-Moliner 2013** | USA | RCT split mouth | 13 13/13 | 48+-8.5 | 8/5 | modified Widman flap | MWF with the application of an active diode laser inside the flap | MWF and sham ap plication of a diode laser. | Ga-Al-As | 810+-20nm | 1W | continuous | 10s | 4J/cm2 | The use of an 810-nm diode laser provided additional benefits to MWF surgery in terms of less edema and postoperative pain. |
| **Lobo 2015** | India | RCT split mouth | 30 30/30 | 25-60 | 10/20 | modified Widman flap | flap + laser application | only flap surgery | diode | 940nm | 1.5W | continuous | 10s | N/A | The diode laser can be safely and effectively used as an adjunct to the treatment of chronic periodontitis with the advantage of decreased gingival inflammation. |

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| **Deshmukh 2018** | India | RCT split mouth | 20 20/20 | 20-54 | N/A | periodontal open flap | closed pocket debridement with diode laser group | open flap debridement | Ga-Al-As | 810nm | 1.5W | continuous | 60s | N/A | The laser-treated group (Group I) was found to be better in terms of decrease in clinical PD as compared to Group II. The bactericidal effect of the diode laser was, also, clearly evident by a greater reduction of CFUs of periodontal pathogens in Group I as compared to Group II. |
| **Jonnalagadda 2018** | India | RCT split mouth | 17/17 | 25-60 | 8/9 | full thickness muco-periosteal flap | diode laser-assisted access flap surgery | flap surgery alone | semiconductor diode laser | 810nm | 1.5W | continuous | 30s | N/A | Tthe use of diodelaser as an adjunct to periodontal flap surgery did not significantly enhance the treatment outcome on the whole. Thus, the high investment cost for the laser equipment has to be weighed along with the proven clinical benefits. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kartgikeyan 2018** | India | RCT split mouth | 20 20/20 | 35-60 | | kirkland flap | flap surgery + laser assisted open flap debridement | flap surgery | diode | 970nm | 2.5W | continuous | 60s | 50J/cm2 | Diode Laser as an adjunct to Kirkland flap surgery has resulted in a greater reduction in clinical and microbiological parameters compared with Kirkland flap surgery alone, thereby offering additional benefit in treating generalized chronic periodontitis patients. |
| **Nagaraj 2020** | India | RCT | 10 | 30-60 | 5/5 | open flap | laser therapy following conventional periodontal flap surgery | flap surgery only | diode | 810nm | 0.8W | continuous | 30s | N/A | Lasers currently have a variety of uses in dentistry, although low-level lasers have been found beneficial in reducing the pain response after periodontal surgery in present study, but studies with larger sample are required to see significant association. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agarwal 2021** | India | RCT split mouth | 36 36/36 | 49.2+-9.04 | 21/15 | modified widman flap | flap + sham application of laser | flap+active laser | Diode | 940nm | 1W | continuous | | 796W/cm2 | The present study confirmed the useful role of DL with MWF to manage chronic periodontitis. |
| **Khan 2021** | India | RCT split mouth | 20 20/20 | 25-45 | N/A | modified widman flap | MWF surgery + active laser application | MWF surgery + sham laser application | Diode | 980nm | 1.5W | continuous | 10s | N/A | Diode laser as an adjunct to MWF in chronic periodontitis can provide enhanced clinical attachment gain with little postoperative discomfort. |
| **Dogan 2022** | Turkey | RCT split mouth | 18 18/18 | N/A | N/A | modified widman flap | flap + sham application of laser | flap+active laser | diode | 810nm | 1W | N/A | 30s | 4J/cm2 | The present study findings suggest that the use of DL together with MWF may have positive effects in the therapy of CP patients by reducing the microbial load. |
| **Kolamala 2022** | India | RCT split mouth | 15 15/15 | 38.9+-7.56 | 10/5 | open flap | laser assisted open flap debridement | open flap debridement | Diode | 980nm | 2W | N/A | N/A | N/A | The use of 980 nm diode laser provided additional benefits over conventional flap therapy. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mistry 2022** | India | RCT split mouth | 20 20/20 | 30-50 | N/A | full thickness muco-periosteal flap | laser assisted open flap debridement | open flap debridement | diode | 940nm | 2.5W | continuous wave mode | 10s | N/A | Lasers can be used as an adjunctive treatment with open flap debridement as a part of periodontal therapy in the future. |
| **Roy 2022** | India | RCT split mouth | 10 patients, 40 sites 10/10/10/10 | 25-55 | 7/3 | 1. kirkland flap, 2. modified widman flap | laser assisted open flap debridement | open flap debridement | arsenide, indium, gallium diode laser | 940+-10nm | 1.5W | continuous | 30s | 4J/cm2 | Diode laser as an adjunct to the surgical procedure can demonstrate appreciable benefits by increasing the CAL and minimizing the postoperative pain and the probing pocket, but such additional effects were not observed with gingival inflammation. |
| **Shetty 2020** | India | RCT split mouth | 15 15/15 | N/A | N/A | full-thickness mucoperiosteal flap | laser assisted open flap debridement | open flap debridement | diode | 980nm | 2.5W | continuous | 3 min | N/A | Laser assisted flap procedures showed better therapeutic outcomes when compared to the conventional open flap debridement with respect to microbial parameters. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Silviya 2022** | India | RCT parallel | 40 20/20 | N/A | N/A | N/A | SFA + LLLT | SFA | diode | 790-810 nm | 0.4-0.7W | N/A | N/A | N/A | The results suggested the positive effect of LLLT over CAL gain; thus, LLLT may be combined with SFA to potentially enhance the early wound healing and higher clinical outcomes in terms of increase in CAL and decrease in PPD. |
| **Saha 2023** | India | RCT split mouth | 12 12/12 | N/A | 2/10 | mucoperiosteal flap | laser assisted open flap debridement | open flap debridement | Diode | 980nm | 2W | N/A | 10s | N/A | Using lasers in addition to flap surgery can produce outcomes that are more promising than those of conventional treatments. The long-term effects of using a DL during flap surgery must therefore be evaluated through additional longitudinal studies with a larger sample size. |
| **Shakoush 2023** | Syria | RCT split mouth | 10 patients, 70 sites 35/35 | mean 45 years | 5/5 | open flap | LLLT | open flap debridement placebo | near infrared laser | 808nm | 250mW | N/A | 12s | 3J/cm2 | Both groups were clinically effective in |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | laser therapy | | | | | | | treating stage III periodontitis, with a significant preference in reduction of GI and PD and gain of RAL, and decreased postoperative pain (after 24 hours and 3 days) and dentinal hypersensitivity (after 1 week and 1 month) for open flap debridement + LLLT. |

**Critical appraisal of retrieved studies**

For randomized controlled trials, Cochrane RoB-2 tool[50] was used for quality assessment.

According to this tool, risk of bias is assessed at study level under seven domains:

1. Random sequence generation
2. Allocation concealment
3. Blinding of participants and personnel
4. Blinding of outcome assessment
5. Incomplete outcome data
6. Selective reporting
7. Other bias

**RISK OF BIAS**

The overall risk for individual studies was assessed as low, moderate or high risk based on domains and criteria. The study was assessed to have a low overall risk only if all domains were found to have low risk. High overall risk was assessed if one or more of the six domains were found to be at high risk. A moderate risk assessment was provided to studies when one or more domains were found to be uncertain, with none at high risk.

Risk of bias was evaluated using RevMan (Review Manager Version 5.3) software.

**Quality assessment of RCTs**

Among the included RCTs, ten studies[52,53,56-61,63,67] showed low risk of bias, five[55] showed moderate risk and two studies[3,6] showed high risk of bias.

In studies Gokhale 2012 and Deshmukh 2018 details of randomization, allocation concealment and blinding were not mentioned which led to high risk of bias in these studies.

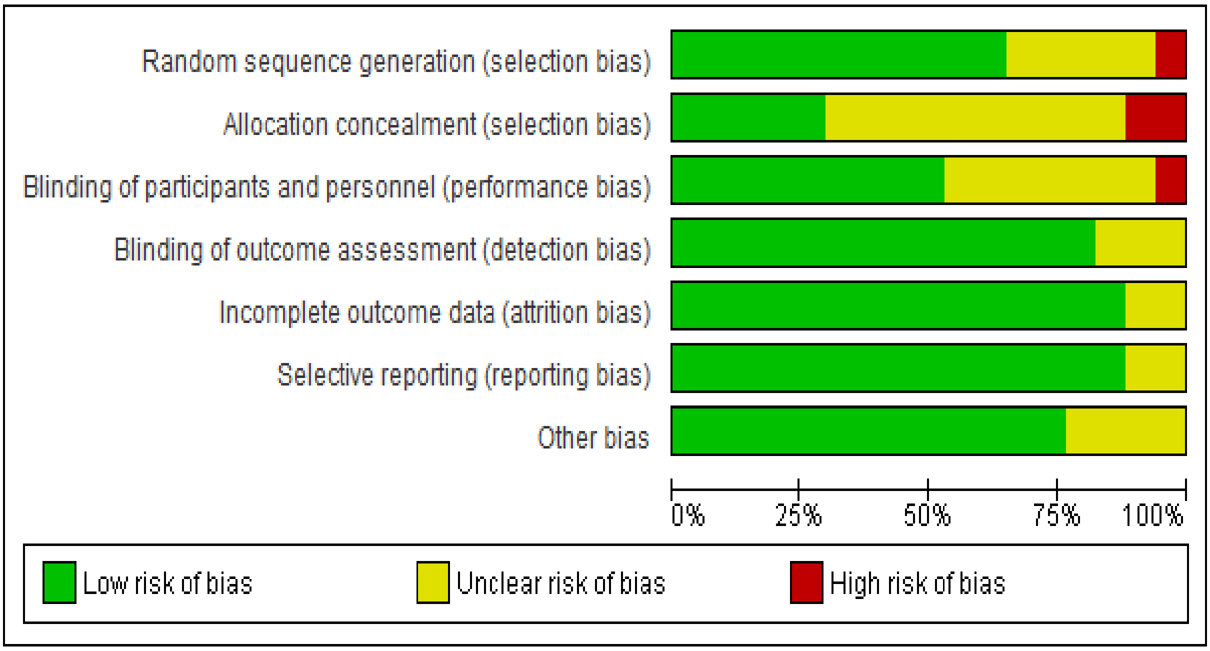


**Figure 2: Risk of bias graph**

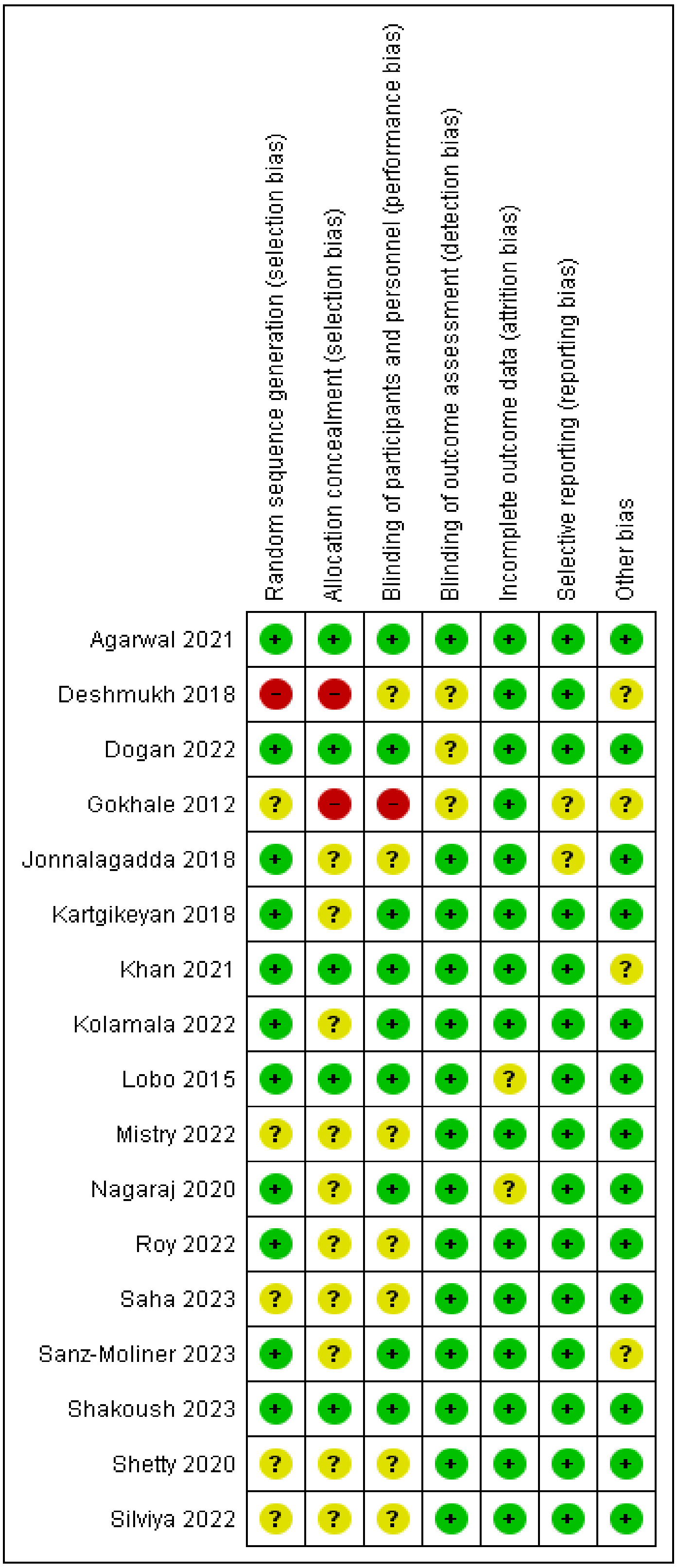


**Figure 3: Risk of bias summary**

## META-ANALYSIS

### Meta-analysis

Review Manager (RevMan) 5.3 was used for statistical analysis. The combined results were expressed as mean and standard deviation for the continuous data at 95% confidence intervals (CIs) and P<0.05 was considered significant. Chi-square and Tau-square were used to assess whether the observed difference was homogeneous or heterogeneous among the studies. Statistical heterogeneity was assessed by the $I^2$ test at $\alpha=0.10$.

**Assessment of Heterogeneity:**

Clinical heterogeneity refers to differences between studies with regards the participants, interventions, comparators, settings, and outcomes. Methodological heterogeneity refers to the study design and the methodological quality of the studies (risk of bias).

The I square statistic ($I^2$) represents the percentage of the variability in effect estimates that is due to heterogeneity. $I^2$ is the proportion of observed dispersion of results from different studies included in a meta-analysis that is real, rather than spurious.

Heterogeneity was considered statistically significant if $P < 0.05$. A rough guide to the interpretation of $I^2$ given in the Cochrane handbook is as follows:

(1) from 0 to 30%, the heterogeneity might not be important.

(2) from 30% to 60%, it may represent moderate heterogeneity.

(3) from 50% to 90%, it may represent substantial heterogeneity.

(4) from 75% to 100%, there is considerable heterogeneity.

For $I^2$>50%, the random-effects model was applied. Subgroup analysis was performed to reduce the sources of clinical heterogeneity among the studies. Also, the statistical significance was set at p-value (two-tailed) <0.05.

## RESULTS

**Literature search**

The PRISMA statement flowchart summarising the selection process is shown in Figure 1. Among 28 full-text articles, 17 were selected after pre-screening, applying the eligibility criteria, and addressing the PICOS question. Eleven studies were excluded as 3 did not have a control group, 4 had inappropriate population variables, and 4 applied inappropriate injection technique, hence only 17 studies were included in the qualitative and 15 studies in quantitative analysis.

**Study characteristics**

Seventeen studies were included in this systematic review whose general characteristics are mentioned in Table 2. All the included studies were randomized controlled trials. Sixteen studies were RCT with split-mouth design while one study[65] was RCT with parallel design. A majority of studies were conducted in India[51,53-59,61-66], one in USA[52], one in Turkey[60], one in Syria[67]. Different types of flaps were used in these studies such as – conventional access flap[3], modified Widman flap[52,53,58-60,63], periodontal open flap[54,57,61,67], full thickness muco-periosteal flap[55,62,64,66], Kirkland flap[56,63].

The conclusions of all studies indicated that adjunctive use of Laser therapy provided additional benefit in treating patients with generalized chronic periodontitis.

**Meta-analysis**

Data synthesis was carried out using a descriptive synthesis, with a summary of the characteristics of each included study. For quantitative synthesis, a summary of the combined estimate related to the intervention effect was calculated as a mean of the differences of the effects of post-intervention in individual studies.

**Effect measures**

Effect measures refer to statistical constructs that compare outcome data between two intervention groups. The standardized mean difference is used as a summary statistic in meta-analysis when the studies all assess the same outcome but measure it in a variety of ways. In this circumstance it is necessary to standardize the results of the studies to a uniform scale before they can be combined. Hence for quantitative assessment in this study, standardized mean difference (SMD) was use as effect measure.

For pocket depth, CAL and gingival recession, mean difference was used as effect measure.

**1. Plaque index (PI)**

Plaque index was evaluated at 3 months and 6 months follow-up.

At 3 months, 199 participants were evaluated in intervention and control group. The pooled value obtained was -0.12[-0.41, 0.18] implying that plaque index was reduced with adjunctive laser therapy as compared to control group. Overall, the results were not statistically significant (p>0.05), with 54% heterogeneity.

At 6 months, 118 participants were evaluated in intervention and control group. The pooled value obtained was -0.84[-1.74, 0.05] implying that plaque index was reduced with adjunctive laser therapy as compared to control group. Overall, the results were not statistically significant (p>0.05), with 90% heterogeneity.

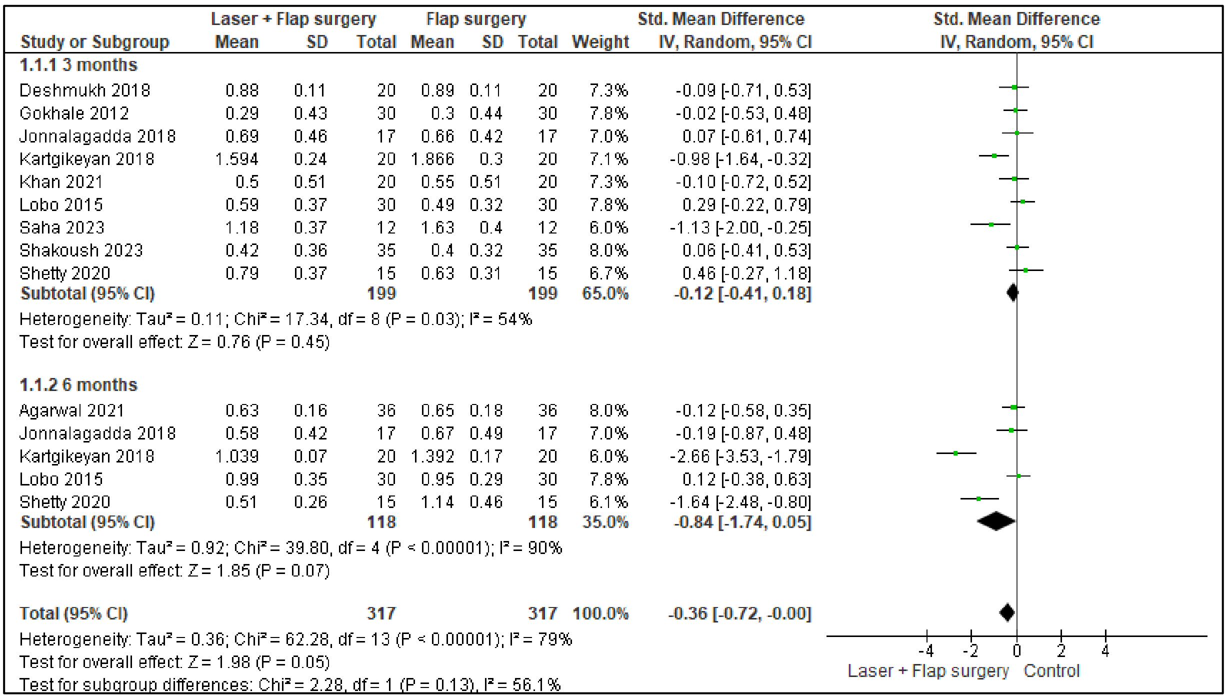


**Figure 4: Forest plot for plaque index**

## 2. Gingival index (GI)

Gingival index was evaluated at 3 months and 6 months follow-up.

At 3 months, 179 participants were evaluated in intervention and control group. The pooled value obtained was -0.71[-1.16, -0.26] implying that gingival index was reduced with adjunctive laser therapy as compared to control group. Overall, the results were statistically significant ($p<0.05$), with 75% heterogeneity.

At 6 months, 98 participants were evaluated in intervention and control group. The pooled value obtained was -0.43[-0.86, 0.00] implying that gingival index was reduced with adjunctive laser therapy as compared to control group. Overall, the results were statistically significant ($p<0.05$), with 54% heterogeneity.

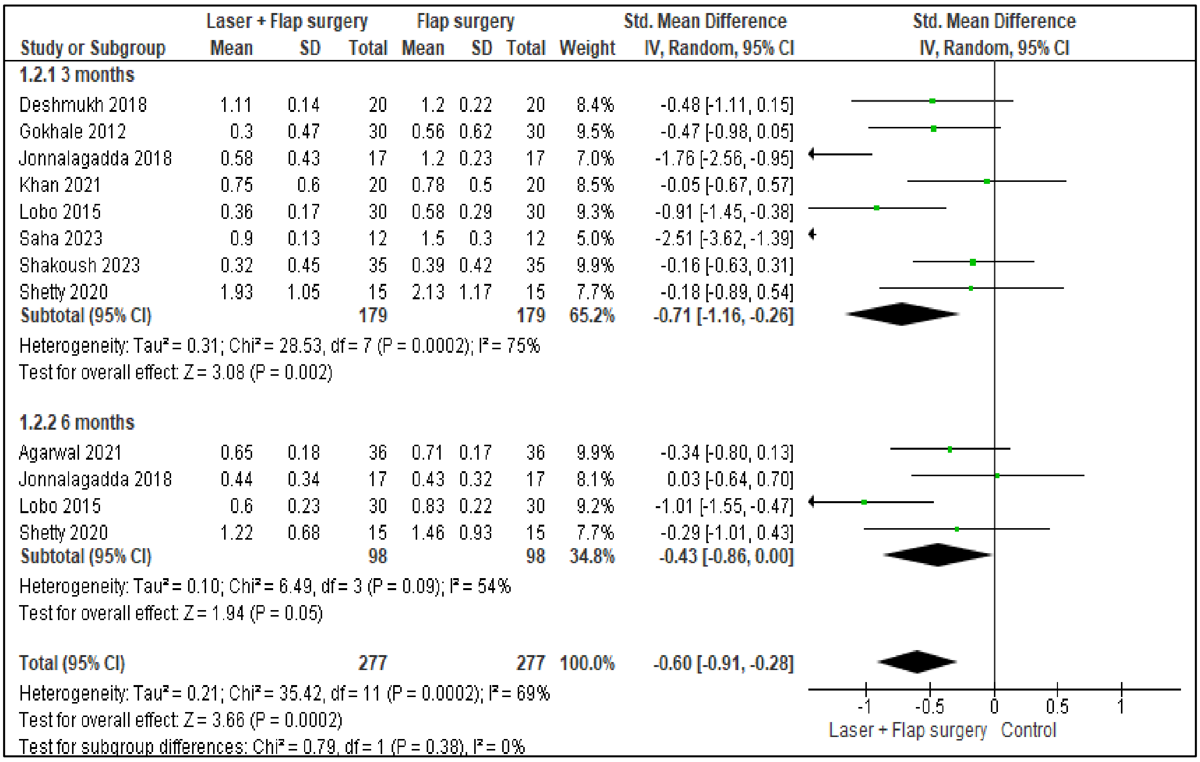


**Figure 5: Forest plot for gingival index**

### 3. Pocket depth (PD)

Pocket depth was evaluated at 3 months and 6 months follow-up.

At 3 months, 254 participants were evaluated in intervention and control group. The pooled value obtained was -0.30[-0.59, -0.01] implying that pocket depth was decreased with adjunctive laser therapy as compared to control group. Overall, the results were statistically significant (p<0.05), with 86% heterogeneity.

At 6 months, 160 participants were evaluated in intervention and 163 participants in control group. The pooled value obtained was -0.33[-0.68, 0.01] implying that pocket depth was reduced with adjunctive laser therapy as compared to control group. Overall, the results were not statistically significant (p>0.05), with 90% heterogeneity.

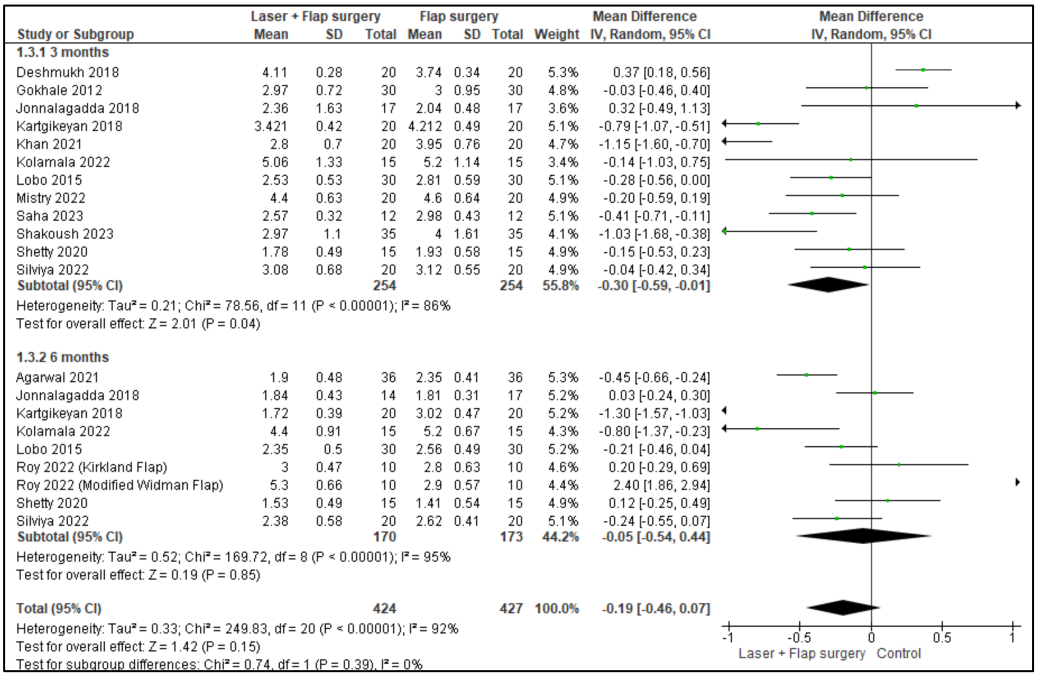


**Figure 6: Forest plot for pocket depth**

### 4. Clinical attachment level (CAL)

CAL was evaluated at 3 months and 6 months follow-up.

At 3 months, 168 participants were evaluated in intervention and control group. The pooled value obtained was -0.95[-.2.42, 0.53] implying that CAL was decreased with adjunctive laser therapy as compared to control group. Overall, the results were not statistically significant (p>0.05), with 99% heterogeneity.

At 6 months, 116 participants were evaluated in intervention and control group. The pooled value obtained was -0.32[-1.03, 0.40] implying that CAL was reduced with adjunctive laser therapy as compared to control group. Overall, the results were not statistically significant (p>0.05), with 94% heterogeneity.

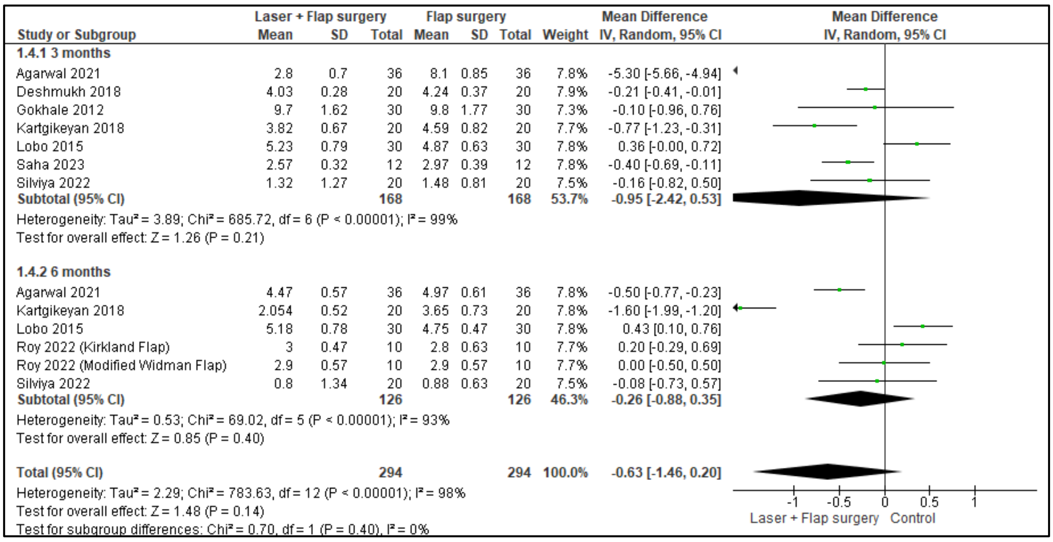


**Figure 7: Forest plot for CAL**

### 5. Gingival recession

Gingival recession was evaluated at 6 months follow-up. Two studies were included in assessment. 66 participants were evaluated in intervention and control group. The pooled value obtained was 0.25[-0.45, 0.94] implying that gingival recession was greater with adjunctive laser therapy as compared to control group. Overall, the results were not statistically significant (p>0.05), with 85% heterogeneity.

| Study or Subgroup | Laser + Flap surgery Mean | SD | Total | Flap surgery Mean | SD | Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Agarwal 2021 | 2.37 | 0.74 | 36 | 2.46 | 0.65 | 36 | 52.3% | -0.09 [-0.41, 0.23] |
| Lobo 2015 | 2.81 | 0.85 | 30 | 2.19 | 0.88 | 30 | 47.7% | 0.62 [0.18, 1.06] |
| **Total (95% CI)** | | | **66** | | | **66** | **100.0%** | **0.25 [-0.45, 0.94]** |

Heterogeneity: Tau² = 0.21; Chi² = 6.56, df = 1 (P = 0.01); I² = 85%
Test for overall effect: Z = 0.70 (P = 0.48)

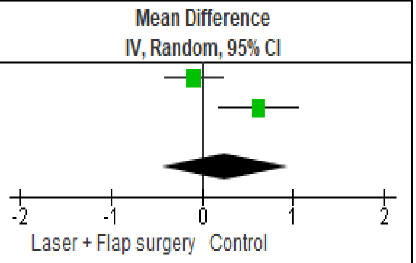


**Figure 8: Forest plot for gingival recession**

### 6. Post-operative pain

Five studies were included in the assessment of post-operative pain irrespective of the time interval. The pooled score obtained was -0.37[-0.72, -0.01] indicating that pain was less with adjunctive laser therapy as compared to flap surgery alone. Overall, the results were statistically significant (p<0.05), with 70% heterogeneity.

| Study or Subgroup | Laser + Flap surgery Mean | SD | Total | Flap surgery Mean | SD | Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Agarwal 2021 | 2.02 | 0.55 | 36 | 2.86 | 0.83 | 36 | 25.4% | -0.84 [-1.17, -0.51] |
| Gokhale 2012 | 1.9 | 0.96 | 30 | 1.93 | 0.91 | 30 | 20.5% | -0.03 [-0.50, 0.44] |
| Jonnalagadda 2018 | 0.31 | 0.48 | 17 | 0.38 | 0.62 | 17 | 23.8% | -0.07 [-0.44, 0.30] |
| Kolamala 2022 | 4.6 | 0.5 | 15 | 4.93 | 0.25 | 15 | 26.9% | -0.33 [-0.61, -0.05] |
| Sanz-Moliner 2023 | 2.4 | 1.9 | 13 | 3.6 | 2.7 | 13 | 3.4% | -1.20 [-2.99, 0.59] |
| **Total (95% CI)** | | | **111** | | | **111** | **100.0%** | **-0.37 [-0.72, -0.01]** |

Heterogeneity: Tau² = 0.10; Chi² = 13.36, df = 4 (P = 0.010); I² = 70%
Test for overall effect: Z = 2.04 (P = 0.04)

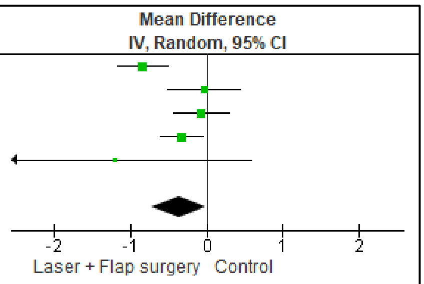


**Figure 9: Forest plot for post-operative pain**

## DISCUSSION

Successful periodontal therapy depends on anti-infective procedures aimed at eliminating or suppressing pathogenic organisms found in dental plaque associated with the tooth surface and within other niches in the oral cavity. Laser-assisted periodontal therapy has attracted attention recently as a potential alternative or adjunct to conventional mechanical debridement (53,69,70). Carbon dioxide ($CO_2$) laser, neodymium-doped: yttrium-aluminum-garnet (Nd:YAG) laser, and diode and erbium-doped: yttrium-aluminum-garnet (Er:YAG) laser have been used in the therapy of periodontal pocket for hard tissue as well as soft tissue management (71,72). Dental lasers have slight advantages but also some inherent drawbacks that must be pointed out, including possible damage to bone owing to overheating and ineffectiveness in removing calculus. Hence, intermittent laser application and correct laser settings are key factors to reduce potential damage (68).

The effective applicability of lasers in the treatment of periodontal disease according to their theoretic advantages (i.e., ablation or vaporization, hemostasis, and sterilization effect) compared to conventional therapy is currently a very controversial topic in clinical periodontics.

Findings from this meta-analysis shows that for PD reduction surgical procedures, adjunctive use of lasers offers no significant clinical advantages in plaque index, CAL gain, PD reduction and gingival recession compared with conventional approaches. Whereas it offers significant clinical advantages in gingival index and post-operative pain compared with conventional approaches. The variability in study designs, laser protocols, and patient demographics underscores the complexity of interpreting pooled effects across heterogeneous datasets.

### PI

The plaque index was recorded to monitor the oral hygiene status of the patients.

The meta-analysis revealed non-significant reductions in plaque index at both 3- and 6-months post-intervention

In contrast to this study,

According to Karthikeyan (2018) on comparison of mean change in PI scores between control and test groups, the test group showed more reduction in PI scores compared with control group from 0 day to third and sixth month and it was statistically significant. A greater decrease in PI scores in DL-assisted periodontal flap surgery group can be attributed to the potential of lasers to breach the protective mechanisms of plaque biofilm (73). In addition, laser beam transmission through flexible optical fibers in the oral cavity provides ease of maneuverability and adaptation to the tooth

anatomy, thereby targeting at disrupting the subgingival biofilm with more accuracy (74).
Similar results seen in study done by Shetty et al (2020)
According to Saha (2023) The PI of the two groups differed significantly from the start of the study to the end of the 90-day follow-up period. Although authors demonstrated a considerable improvement after therapy, they also revealed a minor improving trend over time. Patients were invited back into the trial after 45 and 90 days to receive oral reinforcement, which may have contributed to an even greater decline in PI score

**GI**

"Gingival index" was assessed to evaluate the gingival condition clinically.
The meta-analysis revealed significant reductions in gingival index at both 3- and 6-months post-intervention (which was attributed to the bacterial reduction achieved by the use of laser)
Whereas, in contrast to the present study,
According to Jonnalagadda et al (2018) Gingival index showed no significant difference between the groups at any time point. This is in accordance with few previous studies where diode laser was used as an adjunct to nonsurgical periodontal therapy in which no difference was observed between the case and the control groups with respect to gingival index scores (75).
According to Agarwal (2021) GI exhibited nonsignificant changes after six months, indicating that the patients in both groups showed strict compliance for oral hygiene throughout the study

**PPD**

The PPD measurement is important to evaluate the progression or regression of periodontitis posttreatment.
The meta-analysis revealed significant reductions in pocket depth from baseline to 3 month and it was not statistically significant at the end of 6 months
Significant reductions in pocket depth were observed at 3 months, aligning with clinical improvements in periodontal health. However, at 6 months, the effect diminished, indicating a possible need for ongoing evaluation to understand the sustainability of treatment benefits over time.
Whereas, in contrast to the present study,
According to Karthikeyan (2018) A statistically significant decrease in mean PPD was observed for both control and test groups from baseline to third and sixth month. Test group showed more reduction in PPD compared with control group and it was statistically significant. A greater decrease in PPD in DL-assisted flap surgery group can be attributed to the increased levels of anti-inflammatory cytokine and enhanced microcirculation by laser irradiation (76).
According to Kolamala (2022) LA-OFD showed more reduction in PPD compared with OFD alone group at 6 months, and it was statistically significant ($P = 0.005$), whereas no significance was observed at 3 months. This more significant decrease in PPD in LA-OFD group could be due to increased levels of anti-inflammatory cytokines and enhanced microcirculation by laser irradiation (76).
According to Roy (2022) PPD showed a significant reduction in mean PPD 6 months postoperatively among all study groups with the highest reduction being depicted by Kirkland with laser group, followed by MWF with laser as compared to Kirkland without laser and MWF without laser.
The higher level of anti-inflammatory cytokines and enhanced microcirculation caused by laser irradiation accounts for the increased reduction in the PPD of the laser-treated group.
Acc to Agarwal (2021) . The results showed significant differences in clinical and microbiological parameters in both groups six months postoperatively.

**CAL**

"Clinical attachment level" being the "gold standard" for evaluating the success of periodontal therapy (11)
The meta-analysis revealed non-significant reductions in CAL at both 3- and 6-months post-intervention
Whereas, in contrast to the present study,
According to Agarwal (2021). The results showed significant differences in clinical and microbiological parameters in both groups six months postoperatively.
According to Karthikeyan (2018) On comparison of mean change in CAL between control and test groups, the test group showed more gain in CAL compared with control group from 0 day to third and sixth month and it was statistically significant. In contrast to the effects of mechanical debridement with curettes, promoting apical migration of epithelial cells, Angelov et al. (77) have pointed out more complete epithelial removal with the use of 980 nm DL, thereby indicating the formation of new connective tissue attachment with a gain in CAL in the DL-assisted Kirkland flap surgery. Laser induced thermal necrosis of wound margin retards the stimulus for epithelial migration by sealing the small vasculature and lymphatics and not allowing release of chemical mediators (78).
According to Silviya (2022) The study revealed an increase in CAL gain in both SFA alone and SFA with LLLT from baseline to the 3rd and 6th months, with a high significance of $p < 0.0001$. These results are supported by the results presented in the studies performed by Trombelli, Roberto Farina. The reasons for the increase in CAL gain could be the impact of LLLT on hard and soft tissues, resulting in a decrease in inflammatory conditions and stimulation of bone matrix formation in osteoblasts, enabling periodontal tissue attachment and bone regeneration (79).

**Gingival recession**

The meta-analysis revealed non-significant reductions in gingival recession at 6 months post-intervention

**Post-op pain**

To assess the level of patient's comfort with the treatment, post-procedural pain on a VAS was evaluated and recorded which is highly subjective and dependent on the individual experience.

The meta-analysis revealed significant reductions in Post op pain at both 3- and 6-months post-intervention
This could be due to the prevention of pain signal transmission by laser therapy from the injured site to the brain. This reduces pain perception and increases the production and release of endorphins and enkephalins (natural pain-relieving chemicals) by decreasing nerve sensitivity significantly (80).
According to Gokhale (2012) A VAS was used to determine the pain perception by the patient during the procedure and 1 week postoperatively. There was no statistically significant difference in the readings of VAS in both the groups, indicating that the level of patient comfort was similar in both groups. The use of diode laser as an adjunct to mechanical debridement neither led to postoperative complications nor to delayed healing. This indicates that diode laser did not seem to have any detrimental effect when employed in conjunction with periodontal surgery. According to Chow et al. (81) laser induces inhibitory effects on the peripheral nerves by slowing the conduction velocity (CV) and/or reducing the amplitude of compound action potentials.

According to Jonnalagadda et al (2018) Patients discomfort, or pain perception was recorded on 3rd, 7th, and 14th days postoperative using VAS, which is subjective and highly dependent on individual experience. However, the patient served as both the control and the test. Interestingly, it was found that patients experienced more pain in test sites compared to the control sites at 3 days posttreatment with a similar pattern of consumption of analgesics, i.e., higher after test group surgery. This is in accordance with another study in which similar results were reported (53)

## LIMITATIONS

This review acknowledges several limitations despite systematic efforts in gathering and analysing available evidence. Constraints include the restriction to English-language studies and the potential for publication bias, which may impact the generalizability of findings. Additionally, while meta-analysis offers pooled estimates, significant heterogeneity across studies requires careful interpretation of combined results. Variability in study designs, encompassing differences in laser types, treatment protocols, and follow-up durations, introduces potential biases that should be considered. Moreover, the possibility of underrepresented negative or null findings in published literature may skew overall effect estimates.
These limitations highlight the necessity for further research to validate and refine the conclusions drawn from this meta-analysis, ensuring more robust and reliable evidence in the field of periodontal laser therapy.

## CONCLUSIONS

This systematic review and meta-analysis highlight a lack of significant evidence supporting the effectiveness of dental lasers as an adjunct to resective or regenerative surgical periodontal therapy compared to conventional methods, primarily due to small sample sizes and high heterogeneity among studies. Despite some promising benefits of laser therapy, such as reduced inflammation, improved attachment levels, and increased patient comfort in treating generalized chronic periodontitis, the current evidence is insufficient to firmly endorse its use. Further randomized clinical trials exploring different laser types and wavelengths are necessary to refine treatment protocols, standardize procedures, and address methodological issues.
Clinicians should carefully consider the potential benefits of laser therapy against the costs and resource implications of acquiring and using laser equipment. Addressing these factors will be crucial for advancing the integration of laser therapy into evidence-based periodontal treatment strategies and enhancing patient outcomes and care quality.

## REFERENCES

1. Kinane DF, Lindhe J, Trombelli L. Chronic periodontitis. In: Lindhe J, Lang NP, Karring T, editors. Clinical Periodontology and Implant Dentistry. 5th ed. Oxford: Blackwell Munksgaard; 2008. pp. 420–6
2. Shah A. Periodontitis- A review. Med Clin Rev. 2017; 3:14.
3. Flemming, T. (1999). Periodontitis. Ann. Periodontol. 4, 1–6.
4. Page, R.C., Offenbacher, S., Schroeder, B., Seymour, G., and Kornman, K. (1997). Advances in the pathogenesis of periodontitis: summary of developments, clinical implications, and future directions, Periodontol. 2000. 14, 216–248
5. Kornman KS, Page RC, Tonetti MS. The host response to microbial challenge in periodontitis: assembling the players. Periodontol 2000 1997; 14:33–53. 2. Kornman KS. Mapping the pathogenesis of periodontitis: a new look. J Periodontol 2008;79(suppl 8):1560–1568
6. Tatakis DN, Kumar PS. Etiology and pathogenesis of periodontal diseases. Dent Clin North Am 2005; 49:491–516
7. Haffajee, A.D., and Socransky, S.S. (1994). Microbial etiological agents of destructive periodontal diseases. Periodontol. 2000. 5, 78–111.
8. Darveau, R.P., Tanner, A., and Page, RC. (1997). The microbial challenge in periodontitis. Periodontol. 2000. 14, 12–32
9. Cugini MA, Haffajee AD, Smith C, Kent RL Jr, Socransky SS. The effect of scaling and root planing on the clinical and microbiological parameters of periodontal diseases: 12-month results. J Clin Periodontol. 2000;27(1):30-6. doi: 10.1034/j.1600-051x.2000. 027001030.x
10. Marsh, PD. (1991). Sugar, fluoride, pH and microbial homeostasis in dental plaque. Proc. Finn. Dent. Soc
11. Cobb CM. Non-surgical pocket therapy: Mechanical. Ann Periodontol. 1996; 1:443–90. [PubMed: 9118268]

12. Annaji S, Sarkar I, Rajan P, et al. Efficacy of photodynamic therapy and lasers as an adjunct to scaling and root planing in the treatment of aggressive periodontitis—a clinical and microbiologic short-term study. J Clin Diagn Res 2016;10: ZC08–ZC
13. Hanes PJ, Purvis JP. Local anti-infective therapy: Pharmacological agents. A systematic review. Ann Periodontol. 2003;8:79–98. [PubMed: 14971250]
14. Schenk, G., Fleming, T.F., Lob, S., Ruckdeschel, G., and Hickel, R. (2000). Lack of antimicrobial effect on periodontopathic bacteria by ultrasonic and sonic scalers in vitro. J. Clin. Periodontol. 27, 116–119
15. Adriaens PA, Edwards CA, De Boever JA, Loesche WJ. Ultrastructural observations on bacterial invasion in cementum and radicular dentin of periodontally diseased human teeth. J Periodontol 1988;59:493–503.
16. Ishikawa I, Baehni P. Nonsurgical periodontal therapy— where do we stand now? Periodontol 2000 2004;36:9–13. 6. Aoki A, Sasaki KM, Watanabe H, Ishikawa I. Lasers in non-surgical periodontal therapy. Periodontol 2000 2004; 36:59–97.
17. Heitz-Mayfield LJ, Lang NP. Surgical and nonsurgical periodontal therapy. Learned and unlearned concepts. Periodontol 2000 2013;62:218–231
18. Schwarz F, Sculean A, Berakdar M, Georg T, Reich E, Becker J, et al. Clinical evaluation of an Er: YAG laser combined with scaling and root planing for non-surgical periodontal treatment. A controlled, prospective clinical study. J Clin Periodontol 2003;30:26-34.
19. AokiA, SasakiKM, WatanabeH, IshikawaI. Lasers in nonsurgical periodontal therapy. Periodontol 2000 2004;36:59-97
20. Moritz, A., Schoop, U., Goharkhay, K., and Schauer, P. (1998). Treatment of periodontal pockets with a diode laser. Lasers Surg. Med. 22, 302–311
21. Shimizu, N., Yamaguchi, H., Goseki, T., Shibata, Y., Takiguchi, H., Iwasawa, T., and Abiko, Y. (1995). Inhibition of prostaglandin E2 and interleukin 1b production by low-power laser irradiation in stretched human periodontal ligament cells. J. Dent. Res. 74, 1382–1388.
22. Quadri, T., Miranda, L., Tuner, J., and Gustafsson, A. (2005). The short-term effects of low-level lasers as an adjunct therapy in treatment of periodontal inflammation. J. Clin. Periodontol. 32, 714–719
23. Shimotoyodome, A., Okajima, M., Kobayashi, H., Tokimitsu, I., and Fujimura, A. (2001). Improvement of macromolecular clearance via lymph flow in hamster gingiva by low-power carbon dioxide laser-irradiation. Lasers Surg. Med. 29, 442–447
24. Gold SI, Vilardi MA. Pulsed laser beam effects on gingiva. J Clin Periodontol 1994;21:391-6
25. Crespi R, Barone A, Covani U. Histologic evaluation of three methods of periodontal root surface treatment in humans. J Periodontol 2005;76:476-81.
26. Pick RM, Colvard MD. Current status of lasers in soft tissue dental surgery. J Periodontol 1993;64:589-602.
27. Eberhard J, Ehlers H, Falk W, et al. Efficacy of subgingival calculus removal with Er: YAG laser compared to mechanical debridement: an in situ study. J Clin Periodontol 2003;30:511–518
28. Israel M, Rossmann JA, Froum SJ. Use of the carbon dioxide laser in retarding epithelial migration: a pilot histological human study utilizing case reports. J Periodontol 1995;66:197–204
29. Ben Hatit Y, Blum R, Severin C, et al. The effects of a pulsed Nd: YAG laser on subgingival bacterial flora and on cementum: an in vivo study. J Clin Laser Med Surg 1996; 14:137–143.
30. Slot DE, Jorritsma KH, Cobb CM, et al. The effect of the thermal diode laser (wavelength 808–980 nm) in non-surgical periodontal therapy: a systematic review and meta-analysis. J Clin Periodontol 2014;41:681–692
31. Aoki A, Mizutani K, Takasaki AA, Sasaki KM, Nagai S, Schwarz F, et al. Current status of clinical laser applications in periodontal therapy. Gen Dent. 2008;56:674–87. [PubMed: 19014027
32. . Yilmaz S, Kuru B, Kuru L, Noyan U, Argun D, Kadir T. Effect of gallium arsenide diode laser on human periodontal disease: A microbiological and clinical study. Lasers Surg Med. 2002;30:60–6. [PubMed: 11857606]
33. Dean DB. Concepts in laser periodontal therapy using the Er,Cr: YSGG laser. J Acad Dent Therap Stomatol 2005;10:285-90.
34. Cobb CM, Low SB, Coluzzi DJ. Lasers and the treatment of chronic periodontitis. Dent Clin North Am 2010;54:35-53
35. Kreisler M, Al Haj H, Daubländer M, Götz H, Duschner H, Willershausen B, et al. Effect of diode laser irradiation on root surfaces in vitro. J Clin Laser Med Surg 2002;20:63-9.
36. Cobb CM. Lasers and the treatment of periodontitis: the essence and the noise. Periodontol 2000. 2017;75(1):205-95. doi: 10.1111/prd.12137
37. Rowson JE. The contact diode laser–A useful surgical instrument for excising oral lesions. J Oral Maxillofac Surg. 1995;33:123
38. Goldstep F. Diode Lasers for Periodontal Treatment: The Story Continues. Dentaltown. 2010;11:54-8
39. Mester E, Spiry T, Szende B, Tota JG. Effect of laser rays on wound healing. Am J Surg 1971;122: 532-535
40. Coluzzi DJ. Fundamentals of dental lasers: Science and instruments. Dent Clin North Am 2004;48:751-770, v.

41. Yu W, Naim JO, Lanzafame RJ. Effects of photostimulation on wound healing in diabetic mice. Lasers Surg Med 1997;20:56-63 (Aykol G, Baser U, Maden I, et al. The effect of low-level laser therapy as an adjunct to non-surgical periodontal treatment. J Periodontol 2011;82:481-488.
42. Lui J, Corbet EF, Jin L. Combined photodynamic and low-level laser therapies as an adjunct to nonsurgical treatment of chronic periodontitis. J Periodontal Res 2011;46:89-96
43. Sanz-Moliner JD, Nart J, Cohen RE, Ciancio SG. The effect of an 810-nm diode laser on postoperative pain and tissue response after modified Widman flap surgery: a pilot study in humans. J Periodontol. 2013;84(2):152-8. doi: 10.1902/ jop.2012.110660
44. Walsh LJ. The current status of low-level laser therapy in dentistry. Part 1. Soft tissue applications. Aust Dent J. 1997;42:247–54. [PubMed: 9316312]
45. Chung H, Dai T, Sharma SK, Huang YY, Carroll JD, Hamblin MR, et al. The nuts and bolts of low-level laser (light) therapy. Ann Biomed Eng. 2012;40:516–33. [PMCID: PMC3288797] [PubMed: 22045511]
46. Sobouti F, Khatami M, Heydari M, Barati M. The role of low-level laser in periodontal surgeries. J Lasers Med Sci. 2015;6:45–50. [PMCID: PMC4431963] [PubMed: 25987968]]
47. Braun A, Jepsen S, Deimling D, Ratka-Kru¨ger P. Subjective intensity of pain during supportive periodontal treatment using a sonic scaler or an Er: YAG laser. J Clin Periodontol 2010;37:340-345.
48. Tomasi C, Schander K, Dahle´n G, Wennstro¨m JL. Short-term clinical and microbiologic effects of pocket debridement with an Er: YAG laser during periodontal maintenance. J Periodontol 2006;77:111-118
49. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. International journal of surgery. 2021 Apr 1;88:105906.
50. Sterne JA, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, Cates CJ, Cheng HY, Corbett MS, Eldridge SM, Emberson JR. RoB 2: a revised tool for assessing risk of bias in randomised trials. bmj. 2019 Aug 28;366.
51. Gokhale SR, Padhye AM, Byakod G, Jain SA, Padbidri V, Shivaswamy S. A Comparative Evaluation of The Efficacy of Diode Laser as an Adjunct to Mechanical Debridement Versus Conventional Mechanical Debridement in Periodontal Flap Surgery: A Clinical and Microbiological Study. Photomed Laser Surg. 2012;30(10):598–603.
52. Sanz-Moliner JD, Nart J, Cohen RE, Ciancio SG. The Effect of an 810-nm Diode Laser on Postoperative Pain and Tissue Response After Modified Widman Flap Surgery: A Pilot Study in Humans. J Periodontol. 2013;84(2):152–8.
53. Lobo TM, Pol DG. Evaluation of the use of a 940 nm diode laser as an adjunct in flap surgery for treatment of chronic periodontitis. J Indian Soc Periodontol. 2015;19(1):43–8.
54. Deshmukh K, Shetty D, Shetty A, Jandrajupalli SB, Chandolu S, Bodduru R, Nayyar AS. Comparative evaluation of the efficacy of closed pocket debridement with diode laser and periodontal open flap debridement: A clinical and microbiologic study. Journal of Clinical Sciences. 2018 Jul 1;15(3):113-22.
55. Jonnalagadda BD, Gottumukkala SN, Dwarakanath CD, Koneru S. Effect of diode laser-assisted flap surgery on postoperative healing and clinical parameters: a randomized controlled clinical trial. Contemporary clinical dentistry. 2018 Apr;9(2):205.
56. Karthikeyan J, Vijayalakshmi R, Mahendra J, Kanakamedala AK, Chellathurai BNK, Selvarajan S, et al. Diode laser as an adjunct to kirkland flap surgery - A randomized split-mouth clinical and microbiological study. Photobiomodulation, Photomedicine, Laser Surg. 2019;37(2):99–109.
57. Nagaraj A, Shetty M, Bhandary S. Effect of 810nm Diode Laser on Post-operative Pain Adjunct to Periodontal Flap Surgery. Indian J Public Heal Res Dev. 2020;11(7):91–6.
58. Agarwal A, Saxena A, Gummaluri SS, Chaudhary B, Sai KSS, Kumar G. Clinical and microbiological evaluation of 940-nm diode laser as an adjunct to modified widman flap for the management of chronic periodontitis: A 6-month randomized split-mouth clinical trial. J Dent Res Dent Clin Dent Prospects. 2021;15(2):133–9.
59. Khan F, Chopra R, Sharma N, Agrawal E, Achom M, Sharma P. Comparative evaluation of the efficacy of diode laser as an adjunct to modified Widman flap surgery for the treatment of chronic periodontitis: a randomized split-mouth clinical trial. Journal of Indian Society of Periodontology. 2021 May;25(3):213.
60. Doğan SB, Akça G. Clinical Evaluation of Diode Laser-Assisted Surgical Periodontal Therapy: A Randomized Split-Mouth Clinical Trial and Bacteriological Study. Photobiomodulation, Photomedicine, Laser Surg. 2022;40(9):646–55.
61. Kolamala N, Nagarakanti S, Chava VK. Effect of diode laser as an adjunct to open flap debridement in treatment of periodontitis–A randomized clinical trial. Journal of Indian Society of Periodontology. 2022 Sep;26(5):451.
62. Mistry D, Dalci O, Papageorgiou SN, Darendeliler MA, Papadopoulou AK. The effects of a clinically feasible application of low-level laser therapy on the rate of orthodontic tooth movement: A triple-blind, split-mouth, randomized controlled trial. Am J Orthod Dentofac Orthop [Internet]. 2020;157(4):444–53. Available from: https://doi.org/10.1016/j.ajodo.2019.12.005
63. Roy S, Singh DK, Manohar B. Comparative

evaluation of postoperative pain and tissue response in patients undergoing conventional flap surgeries with or without 940 nm diode laser exposure-A randomized clinical study. Journal of Education and Health Promotion. 2022;11.

64. Shetty S, Shetty K, Alghamdi S, Almehmadi N, Mukherjee T. A comparative evaluation of laser assisted & conventional open flap surgical debridement procedure in patients with chronic periodontitis–A clinical and microbiological study-A pilot project. Int J Pharm Sci Res. 2020;11:4957-65.
65. Silviya S, C.M A, Prakash PSG, Bahammam SA, Bahammam MA, Almarghlani A, et al. The Efficacy of Low-Level Laser Therapy Combined with Single Flap Periodontal Surgery in the Management of Intrabony Periodontal Defects: A Randomized Controlled Trial. Healthc. 2022;10(7):1–11.
66. Saha A, Kamble P, Mangalekar SB. Comparative Evaluation of Conventional Therapy With and Without Use of Diode Laser (DL) in the Treatment of Chronic Generalized Periodontitis: A Clinico-Microbiological Study. Cureus. 2023;15(Dl).
67. Shakoush G, Albonni H, Almahdi W. Low-level laser therapy has an additional effect with open flap debridement on the treatment of stage III periodontitis: a split-mouth randomized clinical trial. Quintessence Int (Berl). 2023;54(4):274–86.
68. Behdin S, Monje A, Lin GH, Edwards B, Othman A, Wang HL. Effectiveness of laser application for periodontal surgical therapy: Systematic review and meta-analysis. J Periodontol. 2015;86:1352–63. [PubMed: 26269936]
69. Aena PJ, Parul A, Siddharth P, Pravesh G, Vikas D and Vandita A: The clinical efficacy of laser assisted modified widman flap: A randomized split mouth clinical trial. Indian J Dent Res 2015; 26: 384-9
70. Sumra N, Kulshrestha R, Umale V and Chandurkar K: Lasers in non-surgical periodontal treatment – a review, Journal of Cosmetic and Laser Therapy 2019; 21(5): 255- 61.)
71. Rao NR and More CB: “Application of lasers in periodontal therapy: A review of literature with International Journal of Current Research 2016; 8(09): 38985-94.
72. Abdulsamee N: “Soft and Hard Dental Tissues Laser Er: YAG Laser: From Fundamentals to Clinical Applications. Review Article”. EC Dental Science 2017; 11(4): 149-67.)
73. Lewis K. Minireview: riddle of biofilm resistance. Antimicrob Agents Chemother 2001;45:999–100)
74. Cheing-Meei L, Lein-Tuan H, Man-Ying W. Comparison of Nd:YAG Laser versus scaling and root planing in perio)
75. Zare D, Haerian A, Molla R, Vaziri F. Evaluation of the effects of diode (980 nm) laser on gingival inflammation after nonsurgical periodontal therapy. J Lasers Med Sci 2014;5:27-31.)
76. Woodruff LD, Bounkeo JM, Brannon WM, et al. The efficacy of laser therapy in wound repair: a meta-analysis of the literature. Photomed Laser Surg 2004;22:241–247.)
77. Angelov N, Pesevska S, Nakova M, Gjorgoski I, Ivanovski K, Angelova D. Periodontal treatment with a low-level diode laser: clinical findings. Gen Dent 2009;57:510–513.).
78. Moreno RA, Hebda PA, Zitelli JA, Abell E. Epidermal cell outgrowth from CO2 laser- and scalpel-cut explants: implications for wound healing. J Dermatol Surg Oncol 1984; 10:863–868)
79. Trombelli, L.; Simonelli, A.; Schincaglia, G.P.; Cucchi, A.; Farina, R. Single-Flap Approach for Surgical Debridement of Deep Intraosseous Defects: A Randomized Controlled Trial. J. Periodontol. 2012, 83, 27–35. [CrossRef]
80. Cobb CM. Lasers in periodontics: A review of the literature. J Periodontol. 2006;77:545–64. [PubMed: 16584335])
81. Chow, R., Armati, P., Laakso, E.L., Bjordal, J., and Baxter, G.D. (2011). Inhibitory effects of laser irradiation on peripheral mammalian nerves and relevance to analgesic effects: a systematic review. Photomed. Laser Surg. 29, 365–381)