

Efficacy of different lasers of various wavelengths in treatment of peri-implantitis and peri-implant mucositis: A systematic review and meta-analysis

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Abstract

Aim: Peri implant diseases lead to pathological changes in the peri implant tissues and loss of osseointegration. The purpose of this analysis is to evaluate the effect of various lasers and photodynamic therapy (PDT) on peri implant diseases compared to conventional procedures.

Setting and Design: This meta analysis was conducted as per the Preferred Reporting Items for Systematic Reviews and Meta Analyses guidelines.

Materials and Methods: A systematic search of the electronic databases such as PubMed, ICTRP, CT.gov, Embase, and Cochrane Library was done additional to manual search of peer review article on peri-implant diseases. Eleven randomized control clinical trials were included in which laser therapy and PDT were used as an interventional procedure.

Results and Statistical Analysis Used: Review Manager 5.03 (RevMan, Nordic Cochrane Center, Copenhagen, Denmark), and random effects model were used to assess mean difference (MD). Bivariate differential mean statistic was used in intergroup estimate with 95% confidence interval (CI). I² test statistics was applied for heterogeneity and $P < 0.05$ was considered significant statistically. The literature search yielded a total of 113 articles among which 11 articles were included for quantitative analysis. The selected outcome PD reported MD -0.01 with 95% CI $(-0.13, 0.16)$, $P = 0.84$, and CAL reported MD -0.09 with 95% CI $(-0.32, 0.14)$, $P = 0.45$, respectively.

Conclusion: Laser treatment as an adjunctive therapy or monotherapy in peri implantitis does not show any superior effects than conventional measures as per evidence. However, cases with peri implant mucositis have shown far more promising results with laser therapy compared to peri implantitis.

Keywords: Laser therapy, meta-analysis, peri-implant mucositis, peri-implantitis, photodynamic therapy

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INTRODUCTION

Implants have become the treatment of choice in many, if not most, situations when missing teeth require replacement.^[1] However, implants are not without potential problems. A tangible number of implants do not integrate or do not survive for long-term function.^[2] Complications and loss of implants can be costly, both in terms of time and financial resources. Loss of integration can be troublesome, resulting in an edentulous space more difficult to restore.^[3] Stability of bone support for the implants is an important criterion for determining success.^[4,5]

Among the various failures that endosseous implants experience, 10% of the failures have been attributed to peri-implantitis. Bacterial invasion of the peri-implant tissues results in soft-tissue inflammatory changes and rapid bone loss.^[6]

Among peri-implant diseases, peri-implant mucositis is a reversible condition with no loss of attachment or bone loss in the coronal/apical portion of the implant, but the process of peri-implantitis begins at the coronal aspect of the implant, whereas the more apical portion remains clinically stable (osseointegrated).^[7-10]

The major clinical parameters used to diagnose peri-implant inflammation include the assessment of the presence of dental plaque, bleeding on gentle probing, suppuration, peri-implant probing depth (PD), and evidence of radiographic bone loss.^[10-12] Depending on the clinical features and eventually the radiographic diagnosis, a protocol of therapeutic measures has been designed to head off the development of peri-implant lesions.^[13-16] This system is cumulative in nature and includes four steps as a sequence of therapeutic procedures. Supportive therapy which is part of cumulative protocol includes mechanical debridement, debridement using chemotherapeutic agents, and laser therapy.^[17-19]

Results from various *in vitro* and *in vivo* studies have shown that CO₂, diode, and erbium-doped yttrium aluminum garnet (Er:YAG) lasers can be effective in reducing microbial load around implant surfaces. These lasers showed no adverse effects on titanium surfaces and any major increase in temperature on surrounding implant surfaces if proper settings are applied.^[20-22]

Lots of literature has been published regarding the efficacy of laser therapy on peri-implant diseases. Therefore, qualitative and quantitative assessments of the scientific data are important to generate a scientific

evidence on the use of laser in peri-implant diseases.^[21-23] Previously, Kotsakis *et al.* assessed data from January 1990 to June 2013 regarding the use of laser therapy on peri-implantitis and formulated a systemic review and meta-analysis to assess the efficacy.^[24] From 2013 onward, laser has evolved continuously as an emerging treatment modality in different fields of dentistry. Despite this, published data in between 2013 and 2020 had not been assessed to evaluate the success of different lasers of different wavelengths in the treatment outcome of peri-implant diseases (peri-implantitis and peri-implant mucositis). Therefore, the aim of this systemic review is to assess the efficacy of laser therapy as an adjunctive or primary therapy in the treatment of peri-implantitis and peri-implant mucositis. Thus, the Population, Intervention, Comparison, Outcomes, and Study (PICOS) question was formulated as follows “what is the role of laser as a primary or as an adjunctive treatment modality in comparison with the one treated with only conventional surgical or nonsurgical treatment protocols in reducing PD and increasing clinical attachment level (CAL) in patients having peri-implant diseases?”

MATERIALS AND METHODS

This systematic review and meta-analysis were conducted as per Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Objectives

The purpose of this present systemic review is to check the effect of application of laser or photodynamic therapy (PDT) on peri-implant diseases in comparison with conventional debridement procedures. The study follows the PRISMA format guidelines and meta-analyses statement.^[25]

Inclusion and exclusion criteria

Eligibility criteria were determined before the literature search was performed. PD and CAL were included as outcome parameters for peri-implant diseases.

The inclusion criteria were as follows:

- Randomized controlled clinical trials
- Outcome parameters for peri-implant diseases must include PD and CAL
- Studies using laser or PDT as an interventional procedure
- Published articles from the year 2000 to 2020.

The exclusion criteria were as follows:

- Prospective and retrospective studies
- Animal studies, *in vitro* studies, and literature reviews

- Studies including smokers as sample
- Studies with incomplete data.

The focus question was formulated following the PICOS format

- Population: Patients having peri-implantitis and peri-implant mucositis surrounding dental implants
- Intervention: Lasers used as a primary or adjunctive therapy
- Comparison: Conventional surgical or nonsurgical therapies for peri-implant diseases
- Outcome: PD and clinical attachment level around dental implants
- Study design: Randomized controlled clinical trials.

The question according to PICOS can be explained as “what is the role of laser as a primary or as an adjunctive treatment modality in comparison with the one treated with only conventional surgical or nonsurgical treatment protocols in reducing PD and increasing CAL in patients having peri-implant diseases?”

Information sources

Published literatures between 2000 and 2020 were searched in the following databases MEDLINE, PubMed, ICTRP, CT.gov, Embase, and Cochrane Library. The search was conducted between January and February 2020 by two independent reviewers (RS and BB). Electronic search was also done in Rajiv Gandhi Health University Library for additional articles. In addition, a manual search was made of the literature by reviewing the references in the articles found in the electronic search. Additional hand search was done from gray literature or unpublished studies.

Search strategy

The following keywords were used: “laser,” “laser therapy,” “photodynamic therapy,” “peri-implant diseases,” “peri-implantitis,” “peri-implant mucositis,” “randomized controlled clinical trial,” and “therapeutic aids.” The keywords were combined with Boolean operators OR and AND. Literature search was limited to human studies and English languages only.

Data analysis

The data were extracted by two independent reviewers from all the included studies, and in case of any disagreement, consultation of the third reviewer was taken and filled into predetermined forms. The form consisted of two parts: basic information and main outcome. The first part was about basic information such as author name, year of study, sample size and characteristics, interventions, follow-up period, dropout, and confounding factor (if

present). The second part was about clinical outcomes including PD and CAL of intervention group treated with laser or PDT as a primary or adjunctive therapy and control group.

Quality assessment of studies included

Recommendations of the Consolidated Standards of Reporting Trials statement were used for assessing the risk of bias across the studies.^[26] Assessment of risk of bias for individual study was done using the Cochrane’s tool for Systematic Reviews of Interventions.^[27] The scoring systems including “yes,” “no,” or “unclear” were recorded for individual studies that had “low risk of bias,” “high risk of bias,” or “unclear risk of bias,” respectively. Overall, the studies were considered “high quality” if all conditions met, “low quality” if ≥ 1 condition did not meet, or “moderate quality” if ≥ 1 condition was partly met.

Statistical analysis

For meta-analysis, after inclusion of articles and identification of outcome variables, the software Review Manager 5.03 (RevMan, Nordic Cochrane Center, Copenhagen, Denmark) was used. Bivariant differential mean statistic was applied for intergroup estimate (laser therapy versus conventional therapy) with 95% confidence interval (CI) to measure outcome mean. Random-effects model with inverse-variance statistics was used. To identify study heterogeneity, I^2 test statistics were applied ($I^2 < 25\%$ – no heterogeneity, I^2 value 50%–75% – serious heterogeneity), and $P < 0.05$ was considered significant statistically. Forest plots were produced for the outcome variables with 95% CI and overall treatment effects and subgroup effects at a significance level of 0.05. Funnel plot asymmetry was checked to report any publication bias.

The extracted data were stratified and tabulated according to chronological order.

Information related to various characteristics of the included studies was described as a summary-like format to enumerate the information.

RESULTS

Study selection

The literature search yielded a total of 113 articles from various electronic databases and journals. After removal of the duplicates ($n = 87$), initial screening of titles and abstracts was performed by two independent reviewers (RS and BB). In this stage, 12 articles were excluded by screening titles and abstracts. A total of 14 articles were selected for full-text reading;^[28-43] of these 14 articles, 11 studies^[28-38] were included for quantitative analysis and

data extraction and 3 studies were excluded due to various reasons.^[41-43] We excluded three randomized control trials for the following reasons [Table 1]: one of the studies used prospective study design,^[41] Zeza *et al.* used experimental study design,^[43] and Renvert *et al.* had the same study sample and study design as Renvert *et al.*^[42] Any disagreement between the reviewers was solved by discussion. Figure 1 illustrates the study identification flowchart according to the PRISMA guidelines.

Study characteristics

All the included studies in this systematic review and meta-analyses were randomized controlled clinical trials and are, therefore, defined by the National Health and Medical Research Council guidelines as level of evidence II.^[44] Risk of bias assessment for individual studies was done using the Cochrane’s tool for Systematic Reviews of Interventions.^[27] Table 2 represents the result of risk of bias assessment for each of the trials. Although all studies described randomization, five studies did not adequately describe how sequence generation for randomization was done. Two studies did not mention about the blinding procedure.^[30,31] Four studies were classified as having low risk of bias due to adequate reporting of randomization technique, sequence generation, blinding, and patients’ withdrawal.^[29,33,34,38] Four trials were classified as moderate depending on Cochrane tool of analysis of risk of bias^[28,30,32,35] and three studies had a high risk of bias.^[30,36,37]

Characteristics of the outcome data

The included 11 clinical trials were conducted in 6 different countries and included 629 participants (312 in the control group and 317 in the test group). Table 3 shows the details

of study population, intervention, follow-up time, and any confounding factor if present in the studies. Table 4 represents the outcome and data assessment of the studies. The test group can be divided into various subgroups depending on the type of laser therapy applied, and outcomes measured in this analysis were PD and CAL.

Diode laser

Three clinical trials used diode laser as treatment modality.^[36-38] Aimetti *et al.* compared the diode laser therapy in the treatment of peri-implant mucositis with mechanical debridement (ultrasonic and manual instrumentation).^[38] The wavelength of 980 nm diode laser was applied in apicocoronal and mesiodistal direction of the implants for 30 s with 300 μ optical fiber placed parallel to the long axis of the implant. Both therapeutic modalities showed similar clinical improvement with reduction in PD value at 3 months, but there was no

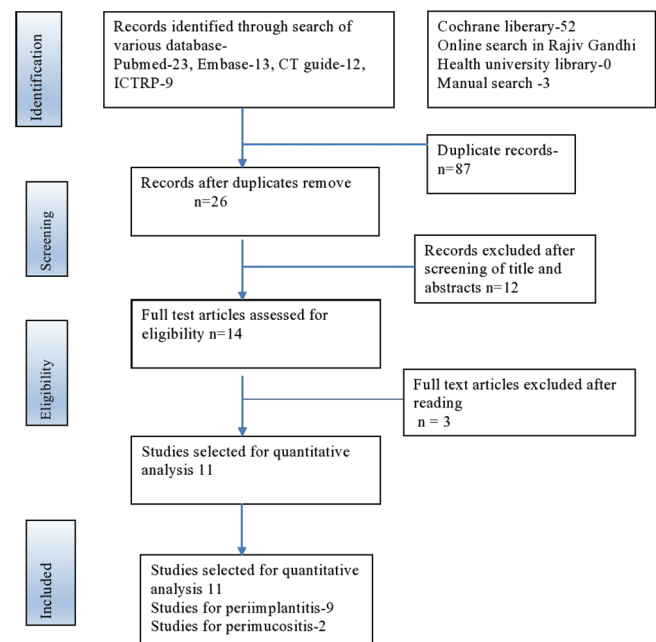


Figure 1: Study selection procedure

Table 1: Excluded studies

Excluded study	Reason for exclusion
Renvert <i>et al.</i> (2011)	Used same study sample and study design as Persson <i>et al.</i>
Bombecari <i>et al.</i> (2013)	Used prospective study design
Zeza <i>et al.</i> (2017)	Used experimental study design

Table 2: Assessment of quality of studies included

Investigators	Sequence generation	Allocation concealment	Selective outcome reporting	Incomplete outcome data	Blinding of study participants and personnel	Risk of bias
Schwarz <i>et al.</i> 2004	Yes	Yes	No	No	Not clear	High
Schwarz <i>et al.</i> 2006	Yes	Yes	Yes	No	Not clear	Moderate
Schar <i>et al.</i> 2010	Yes	Yes	Yes	No	Yes	Low
Persson <i>et al.</i> 2011	Yes	Yes	Yes	No	Yes	Low
Schwarz <i>et al.</i> 2011	Yes	Yes	Yes	No	Yes	Low
Schwarz <i>et al.</i> 2012	Yes	Yes	No	No	Yes	Moderate
Bassetti <i>et al.</i> 2013	Yes	Yes	No	No	Yes	Moderate
Schwarz <i>et al.</i> 2013	Yes	Yes	No	No	Yes	Moderate
Papadopoulos <i>et al.</i> 2015	Yes	Yes	No	Yes	No	High
Aimetti <i>et al.</i> 2019	Yes	Yes	Yes	No	Yes	Low
Sanchez-Martos <i>et al.</i> 2020	Yes	No	No	No	Yes	High

Table 3: Characteristics of included studies on peri-implantitis and peri-implant mucositis

Study and year	Study design	Sample description	Test group	Control group	Follow-up time	Dropout	Confounding factor
Characteristics of included studies on peri-implantitis							
Schwarz <i>et al.</i> ^[30] 2004	Pilot control study	n=20; mean age - 50 years, gender - men - 12, women - 8	Er:YAG laser+0.2% chlorhexidine gluconate	Mechanical debridement	Baseline, 3, 6, months	2	No
Schwarz <i>et al.</i> ^[35] 2006	RCT	n=20; age - 56±14 years in test group, 52±11 years in control group. Gender - men - 9, women - 11	Er:YAG laser+0.2% chlorhexidine gluconate	Mechanical debridement	Baseline, 3, 6, 9, 12 months	1	No
Schar <i>et al.</i> 2010	RCT	n=40; mean age - 58 years (27-78 years) Gender - men - 20, women - 20	Mechanical debridement + diode laser (PDT at 660 nm wavelength)	Mechanical debridement + minocycline (LDD)	6 months	0	No
Persson <i>et al.</i> ^[34] 2011	RCT	n=48; age and gender - not mentioned	Er:YAG laser+oral prophylaxis	Air abrasive + oral prophylaxis	6 months	6	Smoking habit in patients
Schwarz <i>et al.</i> ^[33] 2011	RCT	n=32; age - 60.8±10.9 years; gender - men - 11, women - 21	Mechanical debridement + 0.2% chlorhexidine gluconate + open flap + Er:YAG laser	Mechanical debridement + 0.2% chlorhexidine gluconate + open-flap surgery + plastic curette + saline	Baseline, 6 months	2	No
Schwarz <i>et al.</i> ^[31] 2012	RCT	n=24; age - 62.3±10.0 years; gender - men - 8 and women - 16	Mechanical debridement + 0.2% chlorhexidine gluconate + open flap+Er:YAG laser	Mechanical debridement + 0.2% chlorhexidine gluconate + open flap + plastic curette + saline	Baseline, 6, 12, 24 months	8	No
Bassetti <i>et al.</i> ^[28] 2013	RCT	n=40; mean age - 58 years (27-78 years) Gender - men - 20 women - 20.	Mechanical debridement + diode laser (PDT at 660 nm wavelength)	Mechanical debridement + minocycline (LDD)	1 year (3, 6, 9, 12 months)	1	No
Schwarz <i>et al.</i> ^[32] 2013	RCT	n=21, age=62±0.0 years gender - men - 6, women - 15	Mechanical debridement + 0.2% chlorhexidine gluconate + open flap+Er:YAG laser	Mechanical debridement + 0.2% chlorhexidine gluconate + open flap + plastic curette + saline	Baseline, 6, 12, 24, 48 months	8	No
Papadopoulos <i>et al.</i> ^[36] 2015	RCT	n=19; age=55±8.7 years gender - men - 10, women - 10	Mechanical debridement + saline + open-flap surgery + diode laser	Mechanical debridement + saline + open-flap surgery	6 months	3	No
Characteristics of included studies on peri-implant mucositis							
Aimetti <i>et al.</i> ^[38] 2019	RCT	n=220; age - 58.1±10.1 years in test group, 56.8±10.2 years in control group. Gender: men - 32, women - 78 in test group, men - 39, women - 71 in control group	Mechanical debridement + diode laser	Mechanical debridement	3 months		Smoking, history of periodontal disease
Sanchez-Martos <i>et al.</i> ^[37] 2020	RCT	n=68, age - 57±11.39 years; gender: men - 40, women - 28	Mechanical debridement + diode laser	Mechanical debridement	3 months		

Er:YAG: Erbium-doped yttrium aluminum garnet, RCT: Randomized control trial, PDT: Photodynamic therapy, LDD: Local drug delivery

statistically significant clinical benefit obtained with laser therapy compared to mechanical debridement only. The clinical signs of the inflammation reduced more in the laser group after 1 month, but no long-term benefits were found. A study done by Sánchez-Martos *et al.* used diode laser as an adjunctive therapy in peri-implant mucositis along with mechanical and chemical debridement in the test group.^[37] On re-evaluation at 6 weeks, statistically significant differences were observed between the test and control groups in relation to PD. Papadopoulos

et al. used diode laser in the study along with surgical open-flap debridement and concluded that additional use of diode laser offered limited clinical benefit as results were nonsignificant between the study group and the test group.^[36]

Erbium-doped yttrium aluminum garnet laser

Six clinical trials reported the results of Er:YAG laser therapy as an adjunctive therapy or monotherapy. Persson *et al.* used Er:YAG laser as monotherapy treatment modality

Table 4: Outcome variables of included studies on peri-implantitis and peri-implant mucositis

Study	Intervention	Mean±SD				Adverse event
		PD (mm)		CAL (mm)		
		Baseline	Outcome	Baseline	Outcome	
Studies on peri-implantitis						
Schwarz <i>et al.</i> 2004	Test group - peri-implantitis treated with Er:YAG laser	5.4±1.2	4.6±1.1	5.8±0.9	5.1±0.9	
	Control group - peri-implantitis treated with mechanical debridement and antiseptic mouthwash	5.5±1.5	4.8±1.4	6.2±1.5	5.6±1.4	
Schwarz <i>et al.</i> 2006	Test group - Peri-implantitis treated with Er:YAG laser, divided into "A" and "B" groups depending on initial PD and radiographic bone loss	4.6±0.9	4.1±0.4	5.3±1.0	5.0±0.7	
	Control group - peri-implantitis treated with mechanical debridement and antiseptic mouthwash, divided into "A" and "B" groups depending on initial PD and radiographic bone loss	5.9±0.9	5.5±0.6	6.5±1.2	6.3±1.1	
	Control group - peri-implantitis treated with mechanical debridement and antiseptic mouthwash, divided into "A" and "B" groups depending on initial PD and radiographic bone loss	4.5±0.8	4.3±0.5	5.1±1.0	5.0±0.9	
Schar <i>et al.</i> 2010	Test group - adjuvant photodynamic therapy after mechanical debridement using titanium curette and glycine-based powder air polishing	4.19±0.55	3.83±0.58	2.66±0.73	2.50±0.77	
	Control group - locally delivered minocycline microspheres after mechanical debridement using titanium curette and glycine based air polishing	4.39±0.77	3.90±0.78	2.72±0.72	2.53±0.65	
Persson <i>et al.</i> 2011	Test group - peri-implantitis treated with Er:YAG laser	5.9±1.7	4.1±0.8			
	Control group - peri-implantitis treated with air-abrasive device	6.2±1.9	4.2±0.5			
Schwarz <i>et al.</i> 2011	Test group - peri-implantitis treated with Er:YAG laser	5.1±1.6	3.4±0.6	6.4±2.0	4.9±1.1	
	Control group - peri-implantitis treated with mechanical debridement and sterile saline-soaked cotton	5.5±1.8	3.1±0.6	0.7±2.2	4.5±1.4	
Schwarz <i>et al.</i> 2012	Test group - peri-implantitis treated with Er:YAG laser	4.9±1.4	3.8±1.3	6.4±2.0	5.4±2.0	
	Control group - peri-implantitis treated with mechanical debridement and sterile saline-soaked cotton	5.2±1.5	3.7±1.1	6.5±2.0	5.3±1.8	
Basetti <i>et al.</i> 2013	Test group - adjuvant photodynamic therapy after mechanical debridement using titanium curette and glycine based powder air polishing	4.19±0.55	4.08±0.81	2.66±0.73	2.58±0.94	
	Control group - locally delivered minocycline microspheres after mechanical debridement using titanium curette and glycine based powder air polishing	4.39±0.77	3.83±0.85	2.72±0.72	2.41±0.70	
Schwarz <i>et al.</i> 2013	Test group- peri-implantitis treated with Er:YAG laser	5.1±1.5	3.8±1.1	7.3±1.9	6.1±1.1	
	Control group - peri-implantitis treated with mechanical debridement and sterile saline-soaked cotton	5.5±1.7	4.3±1.2	6.7±1.8	5.2±1.9	
Papadopoulos 2015	Test group - peri-implantitis treated with open-flap debridement and Diode laser	5.92±0.5	4.44±0.4	5.25±0.1	4.46±0.1	
	Control group - peri-implantitis treated with open-flap debridement	5.52±0.5	4.32±0.35	4.94±0.1	4.77±0.1	
Studies on peri-implant mucositis						
Aimetti <i>et al.</i> 2019	Test group- peri-implant mucositis treated with mechanical debridement with adjuvant diode laser irradiation	3.5±0.7	2.9±0.6			
	Control group - peri-implant mucositis treated with mechanical debridement using curettes and ultrasonic tips	3.4±0.9	3.0±0.7			
Sanchez-Martos <i>et al.</i> 2020	Test group - peri-implant mucositis treated with nonsurgical mechanical debridement procedure with adjuvant diode laser	1.28±0.35	1.07±0.10			
	Control group - peri-implant mucositis treated with nonsurgical mechanical debridement procedure	1.30±0.41	1.17±0.26			

Er:YAG: Erbium-doped yttrium aluminum garnet, SD: Standard deviation, PD: Probing depth, CAL: Clinical attachment level

in the test group and abrasive therapy in the control group.^[34] No statistically significant difference was found between the test and control groups regarding PD and bleeding on probing. However, the air abrasive group showed a greater reduction of pathogenic microflora compared to the laser group. Three studies utilized the same approach for 6 months, 24 months, and 48 months, respectively, using Er:YAG device with mechanical debridement using plastic curette, cotton pellet, and sterile saline in test groups.^[31-33] These approaches were applied after treating all the cases with open-flap surgery. At 6th and 24th months, there was no statistically significant increase of CAL and reduction of PD, but at 48 months, the control group showed an increase in CAL values.

The other two studies utilized the nonsurgical approach, Er:YAG laser therapy was used as monotherapy in the test group, and in the control group, mechanical debridement using plastic curettes followed by antiseptic rinse was done with 0.2% chlorhexidine gluconate.^[30,35] Results from the studies suggested that there was a significant increase in the test group in CAL values at 6 months, but at 12 months, there was no significant difference in relation to reduction of PD and increase of CAL values.

Photodynamic therapy

Two clinical trials used PDT as treatment modality for peri-implantitis management.^[28,29] In PDT, dye phenothiazine chloride combined with laser (wavelength

660 nm) was applied in pocket surrounding implants and left *in situ* for 3 min, subsequently, pocket was irrigated with 3% H₂O₂, and PDT therapy was repeated 1 week later. The control group received minocycline hydrochloride microspheres adjuvant with 3% hydrogen peroxide irrigation. PD and CAL values were relatively the same after treatment in both the groups in 6 months and 12 months.

Results of meta-analysis

Test for funnel plot asymmetry [Figure 2] showing both positive and negative trials is included in this study as studies are present on both the sides of the vertical line. The main outcomes of this study are presented in Table 4. Forest plots [Figures 3-5] show that there is no statistically significant evidence in treatment effects of laser therapy in reduction of PD and in increase of CAL in comparison to conventional debridement procedures (forest plot 1 – mean difference [MD]: 0.01, 95% CI: -0.13–0.1, $P = 0.84$; forest plot 2 – MD: -0.09, 95% CI: -0.32–0.14, $P = 0.45$).

DISCUSSION

The dental implants have shown long term success, but treatment with dental implants is also not without failures. Improper treatment planning, failure to identify the risk factors, and improper maintenance phase can lead to inflammation around the implants.^[45] The pathogenesis of peri implantitis is quite similar to periodontitis of natural teeth. In both types of diseases, there is an occurrence of biofilm formation with high concentration of bacteria. However, implant associated biofilm contains more number of *Staphylococcus aureus* and *Actinomyces* species. Various risk factors for peri implantitis include previous periodontal diseases, poor plaque control, residual cement, smoking, genetic factors, and uncontrolled systemic diseases like diabetes mellitus. The treatment therapy used for peri implantitis can be broadly classified into two types:

1. Nonsurgical
2. Surgical.

Nonsurgical treatment includes various modalities such as local debridement, air abrasion, drug therapy, laser therapy, and newer modality called PDT. However, surgical treatments include resective surgery, regenerative surgery, and implantoplasty.^[46,47]

The new treatment modality PDT generates reactive oxygen with the help of laser and photosensitizer like toluidine blue. This therapy uses a diode laser in the range of 580–1400 nm and toluidine blue with concentration between 10 and 50 µg/ml to produce bactericidal effect against aerobic and anaerobic bacteria. PDT is said to be effective against bacterial species such as *Aggregatibacter actinomycetemcomitans*, *Streptococcus mutans*, *Porphyromonas gingivalis*, *Prevotella intermedia*, and *Enterococcus faecalis*.

In this systematic review, included studies^[28-38] have used various nonsurgical or surgical treatment modalities. Out of nine studies on peri-implantitis, four studies used a surgical approach^[31-33,36] and five studies^[28-30,34,35] used a nonsurgical approach.

Three included studies used the same study design and sample but varying in duration of the study. Initially, the test group which was given laser therapy along with surgical approach showed improved result with reduction in mean bleeding on probing and CAL values than the control group, but this result was not sustained in later follow-up period. After 48 months, the control group showed greater improvement than the test group and reduced inflammation around implants.

One more study,^[36] which used surgical approach, concluded that additional use of laser therapy showed limited clinical benefit. There was no statistically significant difference between the two groups in terms of outcome variables.

In studies using nonsurgical approaches, two of the five studies showed a moderate reduction in BOP (bleeding on probing) values in the laser group than the test group only for 6 months.^[28-33] No statistically significant difference was found in PD and CAL values between both the groups after 6 months. Bassetti *et al.*^[28] used PDT and observed a significant reduction in PD values in sites receiving PDT till 9 months, but the results were not consistent till 12 months. Perhaps, the results were reversed in the opposite direction after 12 months. The other two studies^[29,34] did not show any potentially added advantage of laser therapy comparing to conventional, mechanical, and chemical debridement procedures.

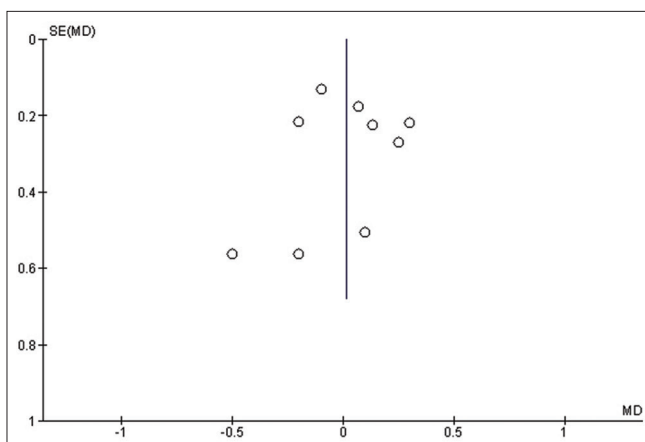


Figure 2: Funnel plot for assessment of publication bias

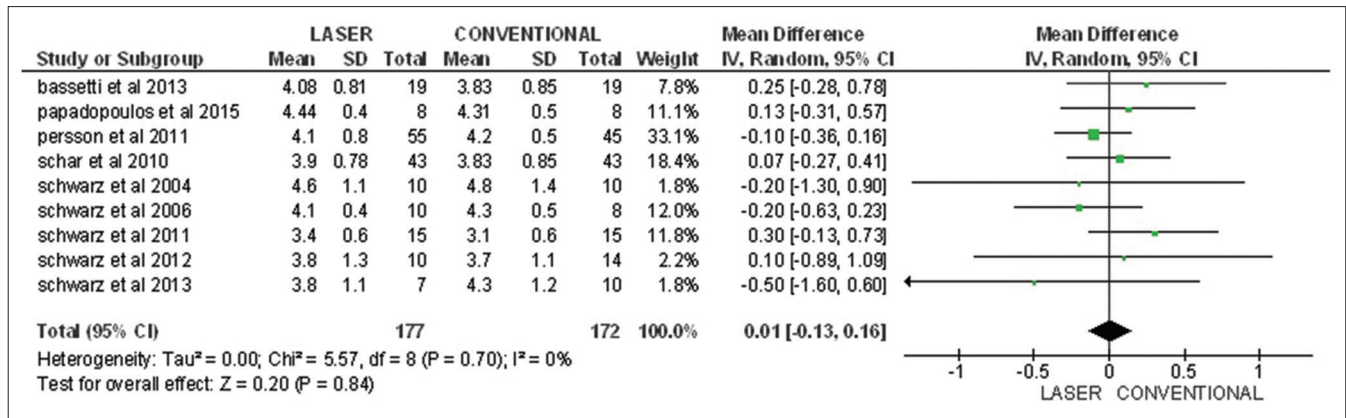


Figure 3: Forest plot showing difference in probing depth (studies on peri-implantitis)

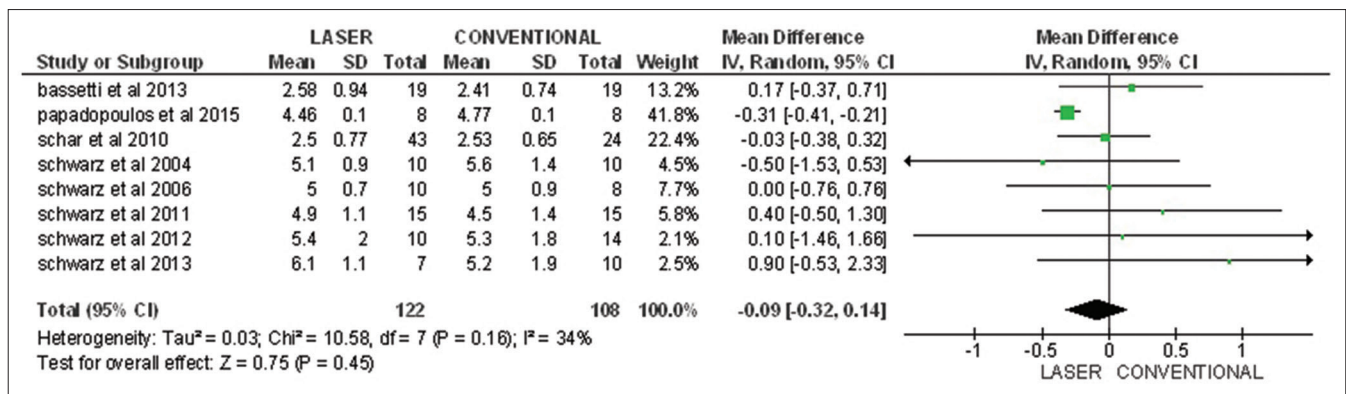


Figure 4: Forest plot showing difference in clinical attachment level (studies on peri-implantitis)

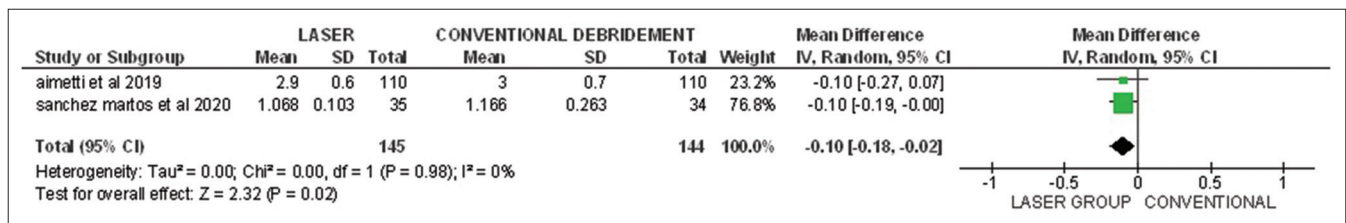


Figure 5: Forest plot showing difference in probing depth (studies on peri-implant mucositis)

Sánchez-Martos *et al.*^[37] used nonsurgical approach and showed a statistically significant improvement using laser therapy in peri-implant mucositis cases; however, another study done by Aimetti *et al.*^[38] on cases with peri-implant mucositis did not show any statistically significant difference after treatment. Hence, further randomized control trials are necessary to formulate any conclusive evidence regarding the effect of laser on peri-implant mucositis.

Based on the findings of various included studies, it is quite evident that laser treatment as an adjunctive therapy or monotherapy does not show any superior effects than other measures taken to treat peri-implantitis.

Based on available trials in literature, this systemic review included all the trials using laser therapy irrespective of the

type of lasers and wavelength used. The adverse effects of irradiation on titanium and peri implant surface are not only depend on the type of specific laser but also on the clinical settings it is applied, such as frequency of application, peak laser power, time of contact, and energy of emitting optic fiber. Sennhenn-Kirchner *et al.* and Tavares *et al.*^[48,49] stated that during laser irradiation of dental implants, an increase in surface temperature beyond critical threshold (10°C) can be reached after only 18 s when using different lasers under different clinical settings. Hence, it is quite evident that the settings and application mode are a major contributing factor in the efficacy of laser treatment.

This review focuses on new treatment approaches used in peri-implant diseases, as implant-supported treatment

approaches are getting more importance in current dental practice; this systematic review and meta-analysis will help in creating stronger evidence related to treatment protocol for inflammation around implant-supported prosthesis. Different studies included in this review used different wavelengths and type of lasers such as Er:YAG and diode lasers (Bassetti *et al.*^[28] and Aimetti *et al.*^[38]). Debridement procedures (mechanical debridement and 0.2% chlorhexidine gluconate, mechanical debridement and minocycline, mechanical debridement and air abrasion, etc.) were also different in different studies in control groups. Hence, further randomized clinical trials are definitely needed with specific clinical settings and characteristics of laser therapy and against a common and accepted debridement procedure to generate further conclusive evidence.

Strength of this systematic review and meta-analysis

This review is based on a well-designed PICOS question and clearly defined inclusion and exclusion criteria. Only randomized controlled clinical trials were included in this review, which are usually considered as studies with high level of evidence.

Limitations of this systematic review and meta-analysis

Only articles published in English languages were selected which may create selection bias during study selection procedures. Another limitation of this study is that many confounding factors were present in the included clinical trials like different types of chemical and mechanical debridement procedures such as 0.2% chlorhexidine gluconate, hydrogen peroxide, and use of titanium and plastic curettes and ultrasonic tips. Hence, further trials should be done to check the efficiency of a specific laser under a predefined clinical setting over a simple and accepted debridement procedure in the control group to minimize the effect of different confounding factors.^[49,50]

CONCLUSION

Based on the studies included for peri-implantitis, laser treatment did not show any specific advantage as a treatment approach over conventional methods. Due to a very limited number of clinical trials that have been conducted to evaluate the effect of laser on peri-implant mucositis, clear evidence cannot be generated regarding the additional benefit of laser therapy for peri-implant mucositis.

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Conflicts of interest

There are no conflicts of interest.

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