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REVIEW ARTICLE

Erbium lasers in non-surgical periodontal therapy: an umbrella review and evidence gap map analysis

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Abstract

The literature on the efficacy of erbium lasers for nonsurgical periodontal therapy is inconsistent. The objective of the umbrella review was to collate the information available in the systematic reviews to provide a comprehensive synthesis of clinical and patient reported outcomes following the use of erbium lasers for non-surgical periodontal therapy. An electronic database search was carried out, and systematic reviews/meta-analyses which assessed the efficacy of erbium lasers as monotherapy or as an adjunct to scaling and root planing were included. The methodological quality and reporting quality of the included studies were assessed. 15 Systematic reviews/meta-analyses were obtained after title, abstract, and full text search. The meta-analyses data revealed a clinical attachment level gain, reduction in probing pocket depth at 1 and 3-month follow-up, and no additional benefit at ≥ 6-month follow-up in the erbium laser group. The evidence gap map revealed lack of clinical outcome data at > 6-month follow-up and dearth in studies assessing patient reported outcome measures and adverse events. Erbium lasers may provide short-term clinical benefits, and further studies with standardized laser parameters evaluating long-term follow-up, patient-reported outcome measures, and adverse events are needed.

Keywords Lasers · Solid-state · Nonsurgical periodontal therapy · Evidence gap map · Clinical attachment level · Patient-reported outcome measures; Periodontitis

Introduction

Periodontal disease is a chronic condition of bacterial origin that is characterized by inflammation of the supporting structures of the tooth [1]. The prevalence of periodontitis ranges between 20 and 50% [2], and it is reported to be the 11th most prevalent condition in the world [3]. The recent evidence-based 2017 classification of periodontal diseases had proposed a multi-dimensional staging and grading system of periodontitis that includes both chronic and aggressive forms of the disease [4]. Non-surgical periodontal therapy (NSPT) is recommended for the debridement

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of plaque and calculus as the initial step in the management of periodontitis [5]. Advances in technology such as the erbium lasers have revolutionized the approach to non-surgical periodontal therapy. According to the consensus statement of the 6th European Workshop in Periodontology, erbium lasers, among all other available lasers, may be considered as the most suitable for NSPT [5]. The erbium family of lasers includes the erbium:YAG (2,940 nm) and erbium, chromium:YSGG lasers (2,780 nm), both of which have shown high absorption in water and hydroxyapatite, which facilitates the effective removal of calculus from the root surface without deleterious effects [6].

The American Dental Association published clinical practice guidelines on the non-surgical treatment of chronic periodontitis by SRP with or without adjunctive therapy [7]. Sub-antimicrobial-dose doxycycline (SDD), systemic antimicrobials, chlorhexidine chips, and photodynamic therapy with diode lasers all had beneficial effects with moderate levels of certainty when used as adjuncts [8]. Erbium lasers have been used as monotherapy/adjunct to SRP, with various outcomes being reported in the literature [9, 10]. Patient-reported outcomes have also been found to favor the use of erbium lasers in NSPT [11].

The amalgamation of scientific evidence with personal clinical expertise and patient needs/preferences forms the core of evidence-based dentistry. Systematic reviews (SR) and meta-analysis (MA) represent the highest level of evidence in research and pave the way for the formulation of clinical practice guidelines. Numerous systematic reviews have been published on the effectiveness of erbium lasers for NSPT [12–15]. Variations in the laser parameters used, time points of assessment, methods of usage, and use as monotherapy/adjunct to SRP have contributed to heterogeneity in the outcomes reported in the systematic reviews [16, 17]. The need of the hour is to obtain a critical insight into whether the use of erbium lasers in NSPT is clinically effective and predictable. Hence, this umbrella review aimed to collate the information available in systematic reviews to provide a comprehensive synthesis of clinical and patient-reported outcomes following the use of erbium lasers in NSPT.

Methods

Systematic collection and evaluation of multiple SR/MA were performed to create a standardized, accessible, and applicable document. The study protocol for the umbrella review was registered at the International Prospective Register of Systematic Reviews — PROSPERO (Ref No: CRD42020156118) [Registered on 28 April 2020]. A revision to this protocol was uploaded on 13 February 2021. This umbrella review addresses the specific research question on the use of erbium lasers in non-surgical periodontal therapy.

Search strategy

The search was performed by two independent reviewers in databases such as Medline via PubMed, EMBASE, Cochrane Database of Systematic Reviews, Science Direct, Google Scholar, LILACS, and Open Grey to include high-impact journals as well as grey literature.

The following keywords and the Boolean operators "AND" and "OR" were used to filter the information: (Laser solid state OR erbium laser) AND (non-surgical periodontal therapy OR scaling and root planing OR dental scaling) AND (periodontitis) AND (systematic review OR meta-analysis) NOT (letter OR newspaper article) (Supplementary Fig. 1).

In addition to the above search strategy, the following search combinations were used in PubMed to narrow the list of included studies:

#1 "Lasers, Solid-State" [MeSH] OR "Erbium" [MeSH] OR "Lasers" [MeSH].
#2 "scaling root planing" OR "Dental Scaling" [MeSH] OR "Root Planing" [MeSH] OR non-surgical periodontal therapy".
#3 "Periodontitis" [MeSH] OR "Chronic Periodontitis" [MeSH].
#4 systematic reviews [MeSH] OR meta analysis [MeSH].
#5 #1AND#2AND#3AND#4.

Initially, two investigators (VL, DK) independently evaluated titles and abstracts to select probable articles. After all duplicate references were excluded, the remaining articles were reviewed in full text. References from the full-text articles were screened to identify eligible papers. Any disagreements were resolved by a consensus involving a third investigator [MM].

Inclusion and exclusion criteria

The time frame of the included studies was between January 2000 and January 2021, and only articles in English were selected. Systematic reviews with or without meta-analysis involving human subjects and comparing erbium lasers alone or as an adjunct to SRP vs conventional approaches to non-surgical periodontal therapy were included. Gain in clinical attachment level (CAL) was considered as the primary outcome, while secondary outcomes included probing pocket depth (PPD) reduction, reduction in overall or specific microbial counts in the sub-gingival pocket area, and patient-related outcome measures (PROM). Systematic reviews that documented changes in the primary outcomes

recorded at baseline and at least 3 months after interventions were included in this umbrella review. Systematic reviews involving animal studies, in vitro studies, other types of lasers (Nd:YAG/diode/photodynamic therapy/photobiomodulation), narrative reviews, consensus reports, and position papers were excluded.

Data extraction

All authors had access to the data throughout the study, and the following parameters were extracted prior to review: author name(s), year of publication, period during which the included original studies were published, sources searched, objectives, number of studies, number of participants, types of study design included, instrument of quality assessment used, interventions, control(s), laser settings, method of statistical analysis, heterogeneity, outcomes assessed, and study observations. Data extraction was performed by VL and DD.

Quality assessment and assessment of risk of bias

An assessment of the validity of the results presented in systematic reviews was critical for the recommendations and was performed by the Risk Of Bias In Systematic Reviews (ROBIS) tool. Each systematic review was assessed independently by two investigators (VL, AM) using the three phases of the ROBIS tool: (A) assessment of relevance, (B) identification of concerns with the review process, and (C) judgment of the risk of bias in the review. The second phase involves four domains: assessment of study eligibility (Domain 1), identification and selection of studies (Domain 2), data selection and study appraisal (Domain 3 — risk of bias), and synthesis and findings (Domain 4) critical to the minimization of bias. Risk of bias was determined as low/high/unclear based on the interpretation of the four domains.

Statistical analysis

Pooled data from the outcomes were analyzed to generate a forest plot. Corrected covered areas (CCA) analysis was done to assess primary study overlap in the included systematic reviews. An evidence gap map (EGM) was developed by means of EPPI Reviewer Version 4.12.1.1.0.

Results

Search results and description of the included systematic reviews and meta-analyses

A comprehensive literature search was performed, and 583 publications were identified based on the selection criteria. Eight duplicate articles were removed, and the search was narrowed to 575 articles. The title and abstract search resulted in the exclusion of 515 articles (which were either systematic reviews on peri-implantitis or lasers other than those in the erbium family or study designs other than systematic reviews). Of the remaining 60 articles screened for full text, 43 were excluded as narrative reviews, and two systematic reviews were excluded since they did not assess outcomes chosen for this umbrella review. Of the 15 systematic reviews included in the qualitative synthesis, 10 had meta-analysis data (Figure 1). The excluded studies and the reasons for exclusion are listed in Supplementary Table 1.

Characteristics of included systematic reviews

The selected 15 systematic reviews included 50 randomized controlled trials (RCTs) with 1,681 participants. A qualitative synthesis was performed for all 15 included systematic reviews (Table 1), and a quantitative synthesis was performed using meta-analysis data from eight of the 15 systematic reviews. Only four of the 15 systematic reviews compared the efficacy of erbium lasers vs conventional therapy in NSPT [13, 15, 16, 18]. The remaining 11 systematic reviews compared the efficacy of lasers (including erbium lasers/diode laser/Nd:YAG laser/photodynamic therapy) vs conventional therapy in NSPT [8, 12, 14, 17, 19–25] The outcomes assessed in the included systematic reviews were probing pocket depth, clinical attachment level, reduction in microbial count, plaque index (PI), gingival index (GI), gingival recession (REC), bleeding on probing (BOP), visual analog scale (VAS) score, and patient comfort and adverse events following the use of erbium lasers/conventional therapy.

Most of the systematic reviews (12/15) evaluated PPD/CAL as the primary outcome, except the SR by Mikami et al. (2020) [24], wherein the authors evaluated VAS as the primary outcome variable and the studies by Akram et al. (2016) [20] and Kellesarian et al. (2017) [21], who evaluated the GCF levels of pro-inflammatory cytokines as the primary outcome variable. The secondary outcome measures evaluated in the included systematic reviews were bleeding on probing, plaque index, gingival index, gingival recession, and reduction of microbial levels.

Nine of the systematic reviews chose a minimum follow-up period of 3 months for inclusion of the RCTs [12–15, 18, 19, 22, 23, 25], whereas three of the systematic reviews included RCTs with a follow-up of at least 6 months [8, 16, 17]. The systematic review by Akram et al. (2016) [20] reported 8 weeks as the minimum follow-up time point for inclusion, and Kellesarian et al. (2017) [21] reported no specific time points for inclusion criteria; however, those authors included two RCTs evaluating erbium lasers with follow-up time points of 4 and 8 weeks. The systematic review by Mikami et al. (2020) [24] evaluated VAS as the

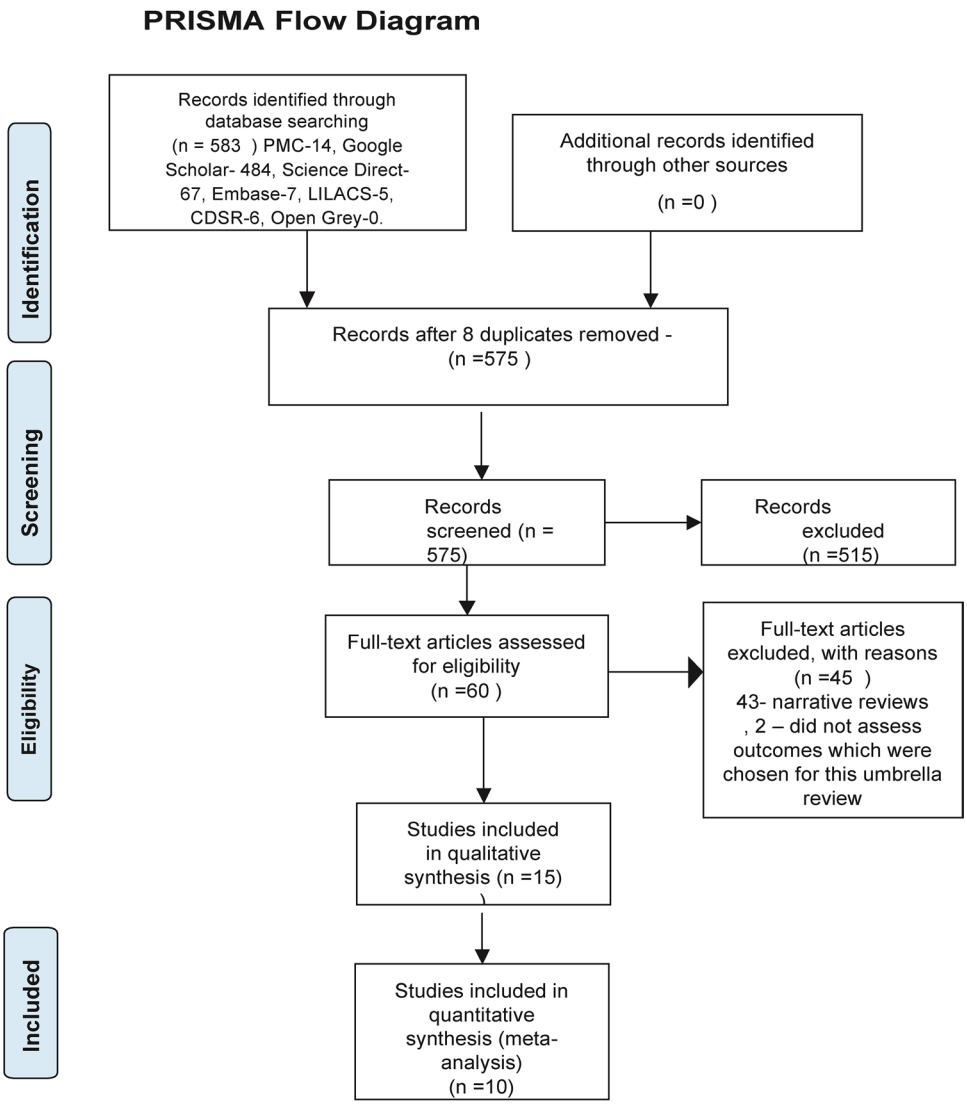

Fig. 1 PRISMA flow diagram — search results for the Umbrella review.

primary outcome variable, and hence the follow-up time points ranged from immediately post-operative to 30 days.

VAS was assessed in the systematic review by Mikami et al. (2020) [24], who concluded that the use of erbium lasers (HLLT) could suppress post-operative pain. In a recent systematic review [18], the authors observed significantly lower VAS scores following the use of Er:Cr:YSGG laser as an adjunct or monotherapy for non-surgical treatment of periodontitis.

Systematic reviews by Akram et al. (2016) [20] and Kellesarian et al. (2017) [21] assessed the evidence on the influence of the use of lasers as an adjunct to SRP on the expression of inflammatory cytokines in GCF and concluded that the existing evidence was insufficient.

Subgroup analysis was done in three of the 15 selected systematic reviews [13, 14, 22]. The criteria used for subgroup analysis included (a) laser energy, (b) fluorescence feedback laser use, (c) quality of trial [13], (d) different modes of lasers [14], and (e) types of treatment and phases of therapy (non-surgical, maintenance, and surgical phase of treatment) [22] (Table 1).

Assessment of methodological quality of included systematic reviews

The methodological quality of the systematic reviews was assessed according to the ROBIS checklist. In this umbrella review, six systematic reviews were found to have low risk of bias, four had high risk of bias, and the remaining five had an unclear risk of bias (Table 2). The reporting quality was assessed by means of the PRISMA checklist. A score of 0 or 1 was allotted for each criterion of the PRISMA checklist based on whether the systematic review had fulfilled the criteria or not, respectively. The PRISMA scores are summarized [Supplementary Tables 2,3]. Most SRs with meta-analysis had scores

Table 1 Summary of the descriptive data of the included systematic reviews

Author and year	Aim and objectives	No of included studies and participants **P —** Population **I —** Intervention **C —** Comparator	**O-** Outcomes assessed	Quality assessment of included studies.	Subgroup analysis (I) Sensitivity analysis (II) Publication bias assessed (III) Operating parameters of the laser (IV) Adverse events after laser use (V)	Summary
Schwarz F et al. 2008 [12] [a]	The primary aim was to address the following focused question: What is the clinical effect of laser application compared with mechanical debridement in nonsurgical periodontal therapy in patients with chronic periodontitis? A secondary aim was to survey the relevant literature in relation to safety of laser applications	Total included: 12 studies/294 participants. Studies using erbium laser: 197 participants/7 studies **P —** Patients with chronic periodontitis **I —** 1. Erbium laser (monotherapy) 2. SRP + erbium laser (adjunctive therapy) 3. Other lasers (monotherapy) 4. Other lasers +SRP (adjunctive therapy) **C —** Scaling and root planing, Ultrasonic + Chlorhexidine, Ultrasonic alone	Probing pocket depth and clinical attachment level, plaque index, bleeding on probing, sensitivity, pain/discomfort	Yes Risk of bias Low — 2 studies: Derdilopolou et al. 2007 [32], Tomasi et al. 2006 [30] Unclear (moderate) — 4 studies: Schwarz et al. 2001 [27], 2003a [28] , 2003b [29], Sculean et al. 2004 [9] High — 1 study: Crespi et al. 2007 [31]	(I) Not reported (II) Not reported (III) Not reported. (IV) Similar laser operating parameters used by all the studies (V) Reported	Er:YAG laser application in nonsurgical periodontal therapy compared with mechanical debridement resulted in similar clinical outcomes, both in the short and the long term (up to 24 months), in patients with chronic periodontitis. There is insufficient evidence to support the clinical application of either CO2, Nd:YAG, Nd:YAP, or different diode laser wavelengths
Karlsson MR et al. 2008 [19] [a]	The aim of this systematic review was to evaluate the effect of laser therapy as an adjunct to nonsurgical periodontal treatment in terms of changes in CAL (DCAL), PD (DPD), and BOP (DBOP) in subjects with chronic periodontitis	Four studies /83 subjects included. Only one erbium laser study: Er,Cr:YSGG — 10 patients only **P-** Patients with Chronic Periodontitis **I-** SRP + Erbium laser (adjunctive therapy) 2. Other lasers (Nd:YAG. Nd:YAP) +SRP **C-** Scaling and root planing,	**Primary outcomes:** Probing pocket depth and clinical attachment level, bleeding on probing **Secondary outcomes:** Plaque index, adverse events	Unclear — 1 study Kelbauskeine and Maciulskiene 2007 [33]	(I) Not reported (II) Not reported (III) Not reported (IV) Not reported (V) Reported	No consistent evidence supports the efficacy of laser treatment as an adjunct to non-surgical periodontal treatment in adults with chronic periodontitis. More randomized controlled clinical trials are needed
Sgolastra F et al. 2012 [16] [b]	The primary aim of this systematic review was to address the following focused question: "What is the efficacy of Er:YAG, when used as alternative treatment to SRP in the treatment of patients with chronic periodontitis?" A secondary aim was to survey the literature in relation to the clinical safety of Er:YAG treatment	Five studies/85 participants Only 4 studies in the final analysis as one study (Schwarz F et al. 2003[29] was long-term follow-up of Schwarz F et al. 2001[27]) **P —** Patients with chronic periodontitis **I —** 1. Erbium laser (monotherapy) 2. SRP + erbium laser (adjunctive therapy) **C —** Scaling and root planing	**Primary outcomes:** Probing pocket depth, clinical attachment level **Secondary outcomes:** Plaque index and gingival index, bleeding on probing, adverse events and microbiological changes	Risk of bias was high for Schwarz 2001 [27], 2003 [29] and Sculean 2004 [9] ROB was low for Rotundo et al. 2010 [35] and Lopes et al. 2010 [36]	(I) Not done due to small no of studies included (II) Not reported (III) No publication bias detected (IV) Different laser operating parameters were used in all studies (V) All studies reported no adverse events for Er: YAG laser.	Meta-analysis was carried out, and no statistically significant differences were found in any of the investigated clinical parameters among the five RCTs entered into the study indicating that there was no evidence of effectiveness. However, significant heterogeneity, a high risk of bias in 3 of the 5 included studies and methodological shortcomings indicate that the results should be considered with caution

Table 1 (continued)

Author and year	Aim and objectives	No of included studies and participants **P —** Population **I —** Intervention **C —** Comparator	**O-** Outcomes assessed	Quality assessment of included studies.	Subgroup analysis (I) Sensitivity analysis (II) Publication bias assessed (III) Operating parameters of the laser (IV) Adverse events after laser use (V)	Summary
Zhao Y et al. 2014 [13] [b]	The main aims of this review were (1) to evaluate clinical outcomes of the Er:YAG laser alternative to SRP for chronic periodontitis in 3-, 6- and 12-month observations; (2) to evaluate whether Er:YAG laser adjuvant to SRP has an additional advantage for chronic periodontitis	Twelve studies/245 participants Five studies included smokers, remaining did not include **P —** Adult patients with Chronic Periodontitis **I —** 1. Erbium laser (monotherapy) 2. SRP + erbium laser (adjunctive therapy) **C** — Scaling and root planing	**Primary outcome**: Clinical attachment level **Secondary outcomes:** Probing pocket depth, plaque index, and gingival recession	Yes but the authors have not reported the quality data for individual RCTs included in the SR	(I)Yes. Based on 1. Laser energy 2. Fluorescent feedback or not 3. Quality of trials (II) Sensitivity analysis done as heterogeneity was observed. Crespi et al. 2007 [31] was the source of heterogeneity. After removal of Crespi et al. 2007 [31], consistent results were obtained (III) No publication bias detected (IV) Similar laser operating parameters used by all the studies (V) Not Reported	The authors reported no difference in clinical outcomes between Er:YAG laser and SRP for chronic periodontitis in the 3-month follow-up. Evidence concerning clinical outcome evaluations at 6 and 12 months postoperatively remained insufficient. Furthermore, clinical benefits of Er:YAG laser as adjuvant to SRP were still lacking. Since Er:YAG laser has certain benefits compared with SRP, it could be expected to be a novel short-term alternative choice for chronic periodontitis management.
Smiley CJ et al. 2015 [8] [b]	Question 1: In patients with chronic periodontitis, does SRP (hand or ultrasonic), when compared with no treatment, supragingival scaling and polish (prophylaxis), or debridement, result in greater improvement of CAL? Question 2: In patients with chronic periodontitis, does the use of local antibiotics or antimicrobials, systemic antibiotics, combinations of local and systemic antibiotics, agents for biomodification or host modulation, or nonsurgical lasers as adjuncts to SRP, compared with SRP alone, result in greater improvement of CAL?	Seventy-three studies selected, and out of 72 studies, only 3 studies were erbium family Two studies Er:YAG and 1 study Er,Cr:YSGG laser was used. SRP+Erb Vs SRP alone involved a total of 82 participants **P —** Patients with chronic periodontitis **I — 1.** SRP + erbium laser (adjunctive therapy) 2. Other lasers +SRP (adjunctive therapy) 3. LDD/systemic antimicrobials/ host modulatory agents +SRP (adjunctive therapy) **C —** Scaling and root planing	Only change in clinical attachment level was evaluated	**Low risk of bias:** Rotundo et al. 2010 [35], Kelbauskiene et al. 2011 [40], Lopes et al. 2010 [36]	(I) Not reported (II) Not reported (III) Not reported (IV) Different laser operating parameters were used in all studies (V) Reported. The authors made a statement that since the operator determines the protocol, the potential for adverse events is higher than with other local delivery systems	Compared with SRP alone, SRP + erbium laser resulted in a 0.18 mm mean gain in CAL (95% CI, −0.63 to 0.98). Erbium laser when used as adjunct to SRP was better than SRP alone. However, the levels of evidence were *low* for use of erbium Lasers. The authors concluded protocols need to be defined

Table 1 (continued)

Author and year	Aim and objectives	No of included studies and participants **P —** Population **I —** Intervention **C —** Comparator	**O-** Outcomes assessed	Quality assessment of included studies.	Subgroup analysis (I) Sensitivity analysis (II) Publication bias assessed (III) Operating parameters of the laser (IV) Adverse events after laser use (V)	Summary
Cheng Y et al. 2016 [14][b]	The aim of this review was to comprehensively estimate, in an evidence-based way, the efficacy of adjunctive laser therapy on non-surgical periodontal treatment	Twelve studies — 302 participants Of the 12 studies, 11 RCT split-mouth method, and 1 quasi-RCT, allocation method is not mentioned. Total 5 studies used erbium family of laser. 4 studies were Er:YAG and one study evaluated Er,Cr:YSGG laser. No of participants in studies using erbium laser alone: 135 **P** — Patients with chronic periodontitis. **I** — SRP + erbium laser (adjunctive therapy) 2. Others lasers +SRP (adjunctive therapy) **C** — Scaling and root planing	**Primary outcomes:** Probing pocket depth **Secondary outcomes:** Clinical attachment level, bleeding on probing, adverse events, usage modes of laser	Erbium studies — risk of bias: Low — Rotundo et al. 2010 [35] High — Lopes et al. 2010 [36]. Unclear — Yilmaz et al. 2012 [41], 2013 [45]; Kelbauskiene et al. 2011 [40]	(I) Subgroup analysis done for different usage modes of lasers (II) Not done (III) At 6 months for PPD reduction and CAL gain, at 3 and 6 months, publication bias was observed (IV) Different laser operating parameters were used in all studies (V) Reported. Yes. Two studies used diode lasers. Rotundo et al. 2010 [35] used Er; YAG laser. The authors reported periodontal abscess , necrosis, etc. as adverse effects, but stated the above-mentioned events were not associated with laser use	Meta-analysis suggested that adjunctive laser therapy reduced PPD at 3 months mean difference (MD)= −0.26,95% CI range = −0.43 to −0.09, $p = 0.003$} but did not demonstrate significant effect on the CAL at either 3 months (MD = −0.03, 95% CI range = −0.25 to 0.19, $p = 0.79$) or 6 months (MD = −0.11, 95% CI range = −0.38 to 0.16, $p = 0.43$). Subgroup analysis indicated that laser therapy would be more effective when the probes were set up outside the periodontal pockets. The adjunctive laser therapy might be effective in reducing PPD and BOP in a relatively shorter term (3 months) without detecting any adverse effect. In terms of CAL gain, there is insufficient evidence to prove that setting laser probes outside periodontal pockets are more effective
Akram Z et al. 2016 [20] [a]	The aim of the present study was to systematically review the available evidence on the effect of aPDT or LT as adjunct to SRP on GCF inflammatory proteins in periodontal disease	Seven hundred eighteen participants/18 studies Only one study using erbium laser involving 30 participants [15 SRP + LT and 15 SRP alone] **P —** Patients with chronic and aggressive periodontitis. **I —** SRP + erbium laser (adjunctive therapy) 2. aPDT +SRP (adjunctive therapy) **C —** Scaling and root planing	GCF Pro-inflammatory cytokine levels- IL-1 beta, TNF alpha, IL-6, MMP-8, probing pocket depth and clinical attachment level	High risk of bias — Dominguez et al. 2010 [38]	(I) Not reported (II) Not reported (III) Not reported (IV) Different laser operating parameters were used in the studies (V) Not Reported	Only 1 RCT (assessed the efficacy of erbium lasers on pro-inflammatory cytokine levels (Dominguez A 2010) [38]. The authors reported significant reduction of IL-1β and TNF-α levels following adjunctive use of erbium lasers. In addition, total antioxidant levels were assessed and remained unchanged. Since the objective of the systematic review was evaluation of the influence of different lasers (aPDT/HILT) on cytokine levels, the authors concluded that the evidence was unclear
Kellesarian SV et al. 2017 [21][a]	The aim of the present systematic review was to assess the efficacy of laser-assisted (LLLT, HILT, or aPDT) SRP compared with SRP alone on the expression of inflammatory cytokines in the GCF of patients with CP	Only 2 studies used Er: YAG laser- Lopes et al. 2008 (34) and Dominguez et al. 2010 (38) - 51 participants in total **P** —Patients with chronic periodontitis **I —** 1. SRP + erbium laser (adjunctive therapy) 2. aPDT + SRP (adjunctive therapy 3. Other lasers +SRP (adjunctive therapy) **C —** Scaling and root planing	GCF Pro-inflammatory cytokine level, bleeding on probing, probing pocket depth, clinical attachment level, plaque index, and gingival index	Low risk of bias — Lopes et al. 2008 [34] High risk of bias —Dominguez et al. 2010 [38]	(I) Not reported (II) Not reported (III) Not reported (IV) Different laser operating parameters were used in the studies (V) Not Reported	Only 2 RCTs (Lopes BM et al. 2008 [34] and Dominguez A et al. 2010 [38]) evaluated the influence of erbium lasers on pro-inflammatory cytokine levels in GCF. Lopes BM et al. 2008 [34] reported no significant differences in IL-1β levels between groups, and in contrast Dominguez A et al. 2010 [38] reported significant reduction in IL-1β and TNFα levels in the erbium laser as an adjunct to SRP group. The role of laser-assisted SRP on the expression of pro-inflammatory cytokines in the GCF of patients with CP remains unclear

Table 1 (continued)

Author and year	Aim and objectives	No of included studies and participants **P —** Population **I —** Intervention **C —** Comparator	**O-** Outcomes assessed	Quality assessment of included studies.	Subgroup analysis (I) Sensitivity analysis (II) Publication bias assessed (III) Operating parameters of the laser (IV) Adverse events after laser use (V)	Summary
Ma L et al. 2018 [15][b]	To systematically appraise the available evidence concerning the effectiveness of ERLs as an adjunct to scaling and root planing (SRP) for non-surgical periodontal treatment	Three hundred seven participants from 10 studies **P** — Patients with chronic periodontitis **I —** SRP + erbium laser (adjunctive therapy) **C** — SRP/U/S / Erb+SRP	Probing pocket depth, clinical attachment level and visual analogue scale score	Six studies —low risk of bias: Lopes et al. 2008 [34], 2010 [36], Sanz Sanchez et al. 2015 [50], 2016 [51], Rotundo et al. 2010 [35], Yilmaz et al. 2012 [41], Yilmaz et al. 2013 [45], Kaiyue W et al. 2017 [61] Four high risk of bias — Ming et al. 2015 [47], Zhou LF et al. 2016 [54], Weiyan L et al. 2017 [64], Shuxia S et al. 2017 [65]	(I) Not reported (II) Sensitivity Analysis done for PPD reduction and VAS score (III) No publication bias identified. (IV) Not Reported (V) Reported- Rotundo et al. 2010 [35] reported no adverse events with erbium laser	There were statistically significant differences in the assessed clinical parameters at the 3 month follow-up. PPD reduction (WMD = 0.32, 95% CI range from 0.14 to 0.51, $p < 0.001$; $p = 0.003$, $I^2 = 69.7\%$) ; CAL gain (WMD = 0.31, 95% CI range from 0.22 to 0.40, $p < 0.001$; $p = 0.209$, $I^2 = 28.8\%$); and VAS scores (WMD = −1.38, 95% CI range from −2.45 to –0.31, $p < 0.001$; $p = 0.182$, $I^2 = 44\ \%$). There were no significant differences at the 6- and 12-month follow-up. ERLs + SRP provides additional short-term effectiveness and that patients experience less pain compared to SRP. There were no significant differences at the medium-term and long-term follow-ups
Chambrone L et al. 2018 [22][b]	This systematic review assesses the efficacy of infrared laser therapy used alone or as an adjunct to nonsurgical or surgical periodontal therapy, on clinical and patient-centered outcomes in patients with periodontitis. The following specific focused question was addressed in the systematic review: "Do infrared lasers (i.e., CO2, Nd:YAG, Er:YAG, or diodes), when used alone or as an adjunctive treatment, provide superior clinical and patient- preferred outcomes compared with conventional periodontal therapy in patients with moderate to severe periodontitis?"	Infrared lasers were evaluated. Total number of studies — 28 with 794 participants. Only 13 studies evaluated the use of erbium laser as adjunct to SRP/ monotherapy. Two studies were excluded in this review as the studies evaluated erbium use in surgical periodontal therapy Hence, a total of 11 studies evaluated erbium use in NSPT Number of participants in the 11 selected studies — 336 **P—** Patients with chronic and aggressive periodontitis. **I—** 1. Erbium laser (monotherapy) 2. SRP + erbium laser (adjunctive therapy) 3. Other lasers +SRP (adjunctive therapy) **C —** Scaling and root planing	Probing pocket depth, clinical attachment level, gingival recession, bleeding on probing, microbial colonization, bone defect fill, discomfort, esthetics, function, treatment costs	Ten studies — high risk of bias: Crespi et al. 2007 [31], Lopes et al. 2010 [36], Malali et al. 2012 [42], Rotundo et al. 2010 [35], Schwarz et al. 2003 [29], Sculean et al. 2004 [9], Soo et al. 2012 [11], Krohn-dale et al. 2012 [43], Ratka-krueger et al. 2012 [44], Tomasi et al. 2006 [30] One unclear risk of bias: Derdilopolou et al. 2007 [32]	(I) Yes. Subgroup analysis done as per the type of periodontal treatment and phase of therapy a. Non-surgical phase b. Maintenance phase c. Surgical phase (II) Not reported (III) Not reported (IV) Similar laser operating parameters have been reported in all studies (V) Not reported for erbium laser. Reported for Nd:YAG and diode lasers, wherein, the authors concluded that some degree of pain may occur within the first few days following SRP + laser group (diode and Nd:YAG)	The use of infra-red lasers (Er:YAG or Nd:YAG) alone did not add value to PPD or CAL outcomes than those achieved by SRP alone. In patients with moderate to severe periodontitis, the nonsurgical treatment of AgP and CP by SRP plus infrared diode laser and the surgical treatment of CP by Er:YAG laser therapy alone may promote statistically significant improvements in PPD and CAL. However, these gains are relatively small (< 1 mm) and provide modest clinical relevance compared with SRP alone

Table 1 (continued)

Author and year	Aim and objectives	No of included studies and participants **P —** Population **I —** Intervention **C —** Comparator	**O-** Outcomes assessed	Quality assessment of included studies.	Subgroup analysis (I) Sensitivity analysis (II) Publication bias assessed (III) Operating parameters of the laser (IV) Adverse events after laser use (V)	Summary
Coluzzi D et al. 2020 [17][a]	To evaluate the scientific literature to ascertain whether lasers have a beneficial role when used adjunctively in initial non-surgical periodontal therapy. This review will answer the question: can adjunctive use of lasers provide an additional benefit during initial non-surgical therapy for chronic periodontitis when compared to a control group where a laser was not used at a 6-month evaluation?	Total of 20 studies, out of which 9 evaluated erbium laser (Er:YAG, Er,Cr: YSGG) with 304 participants Out of the 9 studies, 6 evaluated erbium laser as adjunct to SRP, 2 used erbium laser as a monotherapy/adjunct to SRP, and 1 evaluated erbium laser as a monotherapy **P —** Patients with chronic periodontitis **I —** 1. SRP + erbium laser (adjunctive therapy) 2. Other lasers +SRP (adjunctive therapy) 3. Diode laser+ Erbium laser +SRP **C** — Scaling and root planing	Biomarkers- cytokines, probing pocket depth and clinical attachment level, bleeding on probing, plaque index, bleeding index, microbial reduction, gingival recession, volatile sulfur compounds	Six studies — low risk of bias: Ciurescu et al. 2019 [10], Zhou X 2019 [71], Celik et al. 2019 [72], Magaz et al. 2016 [56], Kelbauskiene et al. 2011 [40], Lopes et al. 2010 [36] Three studies — moderate risk of bias: Dereci et al. 2016 [57], San Sanchez et al. 2015 [50] , Rotundo et al. 2010 [35]	(I) Not reported (II) Not reported (III) Not reported (IV) Different laser operating parameters were used in the studies (V) Not Reported for Erbium laser, reported for Nd:YAG laser	This systematic review found that 70% of the included studies reported significantly better outcomes in certain clinical parameters, but no improvement in others. The remaining 30% of the manuscripts reported no significant difference in any of the measurements. With consideration of correct parameters, lasers have an adjunctive role in initial non-surgical periodontal therapy
Jia L et al. 2020 [23][b]	The objective of this study was to evaluate the clinical attachment level (CAL) gain of Er:YAG, Er,Cr; YSGG, Nd:YAG; and diode laser (DL) as monotherapy or adjunctive to scaling and root planing (SRP) of chronic periodontitis by network meta-analysis (NMA)	Four hundred thirty-two participants in 16 studies — erbium family, 13 Er:YAG studies and 3 Er,Cr:YSGG studies **P —** Patients with chronic periodontitis **I —** 1. Erbium laser (monotherapy) 2. SRP + erbium laser (adjunctive therapy) 3. Other lasers +SRP (adjunctive therapy) 4. Erbium laser + other lasers +SRP (adjunctive therapy) **C-** Scaling and root planing	Clinical attachment level	Has been assessed. Data not provided for individual studies	(I) Network meta-analysis done (II) Not reported (III) Limited bias detected for CAL gain at 3 and 6 months (IV) Not reported (V) Reported. most studies have reported no adverse events. Malali et al. 2012 [42] has reported adverse event with erbium laser	The results of the NMA revealed CAL gain at 3 months, the ranking result from best to worst was as follows: Er:YAG as monotherapy, DL adjunctive to SRP, Er:YAG adjunctive to SRP, Er:Cr:YSGG as monotherapy, Nd:YAG adjunctive to SRP, and SRP. In terms of CAL gain at 6 months, the ranking result from best to worst was as follows: DL adjunctive to SRP, Nd:YAG adjunctive to SRP, SRP, Er:YAG adjunctive to SRP, and Er:YAG as monotherapy. Laser-assisted periodontal treatment could be superior to SRP alone and could serve as a good adjunctive treatment tool. Laser-assisted periodontal treatment has better clinical effectiveness in CAL gain than mechanical SRP
Zhao P et al. 2020 [25][b]	The objective of this study was to compare adjunctive PDT, different lasers, and scaling and root planing (SRP) in the management of chronic periodontitis.	Forty-four studies with 1465 participants. Total of 10 studies: Er; YAG studies, 7;Er,Cr:YSGG studies, 3 with 319 participants All studies have used Erbium as adjunctive to SRP **P —** Patients with chronic periodontitis **I —** 1. SRP + erbium laser (adjunctive therapy) 2. aPDT +SRP (adjunctive therapy) 3. Other lasers +SRP (adjunctive therapy) **C—** Scaling and root planing	**Primary outcome**: Clinical attachment level. **Secondary outcomes:** Probing pocket depth, plaque index, gingival index, bleeding on probing, sulcus bleeding index	Has been assessed. Data not provided for individual studies	(I) Not reported (II) Has been done. Smokers excluded and analysis done (III) No publication bias detected as assessed by funnel plot. (IV) Not reported (V) Not Reported	Pairwise meta-analysis revealed Er:YAG + SRP was significantly better than SRP alone at 3 and 6 months

Table 1 (continued)

Author and year	Aim and objectives	No of included studies and participants **P —** Population **I —** Intervention **C —** Comparator	**O-** Outcomes assessed	Quality assessment of included studies.	Subgroup analysis (I) Sensitivity analysis (II) Publication bias assessed (III) Operating parameters of the laser (IV) Adverse events after laser use (V)	Summary
Mikami R et al. 2020 [24][b]	This systematic review and meta-analysis aim to investigate the following clinical question (CQ): does adjunctive use of lasers with conventional therapy suppress the pain associated with periodontal treatment?	Total of 10 studies included [5 HLLT, 4 PBMT, 1-HLLT+PBMT] 291 participants. In the HLLT studies, 2 used Er:YAG and 1 study used Er,Cr: YSGG laser— 98 participants in studies using erbium laser. **P —** Participants with chronic periodontitis **I —** 1. Erbium laser (monotherapy) 2. Erbium laser +SRP (adjunctive therapy) **C —** Non-surgical therapy by manual instrumentation (SRP)	Visual analog scale score, adverse events	High risk of bias — 3 studies: Braun et al. 2010 [37], Rotundo et al. 2010 [35], Ge et al. 2017 [60]	(I) Reported (HILT,PBMT-meta-analysis) (II) Not reported (III) Not reported (IV) Different laser operating parameters were used in the studies (V) Not reported even though mentioned as data collected	Meta-analysis showed that HLLT using Erbium lasers significantly reduced the patient reported pain immediately after (2 RCTs, $p < 0.0001$).
Meng-Meng Li et al. 2021 [18][b]	The meta-analysis aims to systematically evaluate all available pieces of evidence concerning clinical effectiveness of Er,Cr:YSGG laser in non-surgical treatment of patients with chronic periodontitis and provide guidance for clinicians about the application of Er,Cr:YSGG laser during the process of Non-surgical periodontal treatment	Sixteeen studies with 606 participants Er,Cr: YSGG Eleven studies — Er,Cr: YSGG used as adjunct. Five studies — Er,Cr: YSGG used as a monotherapy **P —** Patients with chronic periodontitis **I —** 1. Erbium laser (monotherapy) 2. SRP + erbium laser (adjunctive therapy) **C —** Scaling and root planing alone	Clinical attachment level. Probing pocket depth Visual analogue scale score	Has been assessed. Data not provided for individual studies	(I) Not reported (II) Sensitivity analysis done for different intervention methods and smoking (III) Has been assessed by Begg's test. No inference provided (IV) Not reported (V) Not reported	Statistically significant differences were found between Er:Cr:YSGG lasers adjunct to SRP and SRP alone in the PPD reduction at 1-month follow-up (WMD = −0.35, 95% CI [−0.63, −0.07], $p = 0.013$), 3-month follow-up (WMD = −0.342, 95% CI [−0.552, −0.132], $p = 0.001$, CAL gain at 3-month follow-up (WMD = −0.17, 95% CI [−0.31, 0.03], $p = 0.017$) and VAS (WMD = −2.395, 95% CI [−3.327, −1.464], $p = 0.000$) immediately after treatment. There were no significant differences in PPD reduction and CAL change at 6-month follow-up. The present meta-analysis indicated that Er:Cr:YSGG lasers provided additional effectiveness in PPD reduction and CAL gain at short term follow ups and there was less pain compared with SRP alone

[a]Systematic review without meta-analysis

[b]Systematic review with meta-analysis

SRP Scaling and root planing; *PPD* probing pocket depth; *CAL* clinical attachment level; *BOP* bleeding on probing; *PI* plaque index; *aPDT* antimicrobial photodynamic therapy; *DL* diode laser; *VAS* visual analog score; *ROB* risk of bias; *RCT* randomized controlled trial; *Er:YAG*: erbium yttrium aluminum garnet; *Er,Cr:YSGG laser* erbium, chromium:yttrium selenium scandium garnet laser; *NMA* network meta-analysis

between 22 and 27. The systematic review by Zhao et al. (2020) [25] fulfilled all the PRISMA requirements and received the maximum score of 27. Among the systematic reviews without meta-analysis data, the scores ranged between 15 and 22. The SR by Karlsson et al. (2008) [19] had missing data according to the PRISMA reporting checklist and received the lowest score (15/27) among all the included SRs.

Quantitative synthesis of meta-analysis data

Of the 15 included systematic reviews, five had narrative syntheses [12, 17, 19–21], two had performed network meta-analyses [23, 25], and eight had performed meta-analyses [8, 13–16, 18, 22, 24]. The meta-analysis (MA) data from the included systematic reviews comparing the outcomes of CAL, PPD, REC, PI, and VAS in the experimental group (erbium laser) vs control (mechanical instrumentation for SRP) at various follow-up time points are summarized as forest plots in Figures 2 and 3. Considerable heterogeneity was observed for all the clinical and patient-related outcomes at the time points assessed (1, 3, 6, 12 months). Meta-analysis data for a few outcomes was available only for a few follow-ups time points, due to which a statistical analysis was not performed, and data were represented as available in the forest plot.

Corrected covered areas

A calculation of corrected covered areas (CCA) was performed to assess the influence of the overlapping primary studies in multiple systematic reviews according to a protocol described by Seifo et al. (2019) [26]. CCA = N-r/rc-r, wherein N = number of included publications including those counted twice, r = number of rows (number of indexed publications — RCTs), and c = number of columns (number of included systematic reviews). A CCA value of 0.08 was obtained, indicating moderate overlap of the RCTs in the included systematic reviews (Figure 4).

Evidence gap map development and description

To understand the heterogeneity in the outcome data in quantitative synthesis, we generated an evidence gap map (using EPPI Reviewer Version 4.12.1.1.0) based on interventions and outcomes in the included RCTs and systematic reviews (https://eppi.ioe.ac.uk/cms/Portals/35/Maps/SriRamachandra/EGM_RCT_SR-ErbiumLasers-NSP-RoB.html) (https://eppi.ioe.ac.uk/cms/Portals/35/Maps/SriRamachandra/EGM_RCT_SR-ErbiumLasers-NSP.html).

In total, 65 studies (50 randomized controlled trials and 15 systematic reviews) were included in this EGM. The impact evaluation studies were represented by the 50 randomized controlled trials, whose numbers steadily increased from 2001 to 2019 [9–11, 27–73]. The quality assessment for the

Table 2 Assessment of the methodological quality of the included systematic reviews by Risk of Bias in Systematic Reviews (ROBIS)

Author and year	Phase 1	Phase 2 Domain 1	Phase 2 Domain 2	Phase 2 Domain 3	Phase 2 Domain 4	Overall ROBIS score Phase 3
Schwarz F et al. 2008 [12]	Yes	Low	Low	Low	Unclear [c]	Unclear [c]
Karlsson MR et al. 2008 [19]	Yes	Low	Low	Low	Unclear [c]	Unclear [c]
Sgolastra F et al. 2012 [16]	Yes	Low	Low	Low	Low	Low
Zhao Y et al. 2014 [13]	Yes	Low	Low	Low	Low	Low
Smiley CJ et al. 2015 [8]	Yes	Low	Low	Low	Low	Low
Cheng Y et al. 2016 [14]	Yes	Low	Low	Low	High	High
Akram Z et al. 2016 [20]	Yes	Low	Low	Low	Unclear [c]	Unclear [c]
Kallesarian SV et al. 2017 [21]	Yes	Low	Low	Low	Unclear [c]	Unclear [c]
Ma L et al. 2018 [15]	Yes	Low	Low	High	Low	High
Chambrone L et al. 2018 [22]	Yes	Low	Low	Low	High	High
Coluzzi D et al. 2020 [17]	Yes	Low	Low	Low	Unclear [c]	Unclear [c]
Jia L et al. 2020 [23]	Yes	Low	Low	Low	Low	Low
Zhao P et al. 2020 [25]	Yes	Low	Low	Low	Low	Low
Mikami R et al. 2020 [24]	Yes	Low	Low	Low	High	High
Meng-Meng Li 2021 [18]	Yes	Low	Low	Low	Low	Low

Unclear [c] — As questions 4.4, 4.5, and 4.6 were not addressed in the systematic reviews without meta-analysis (between study variation-heterogeneity, funnel plot/sensitivity analysis, bias — publication bias data not available).

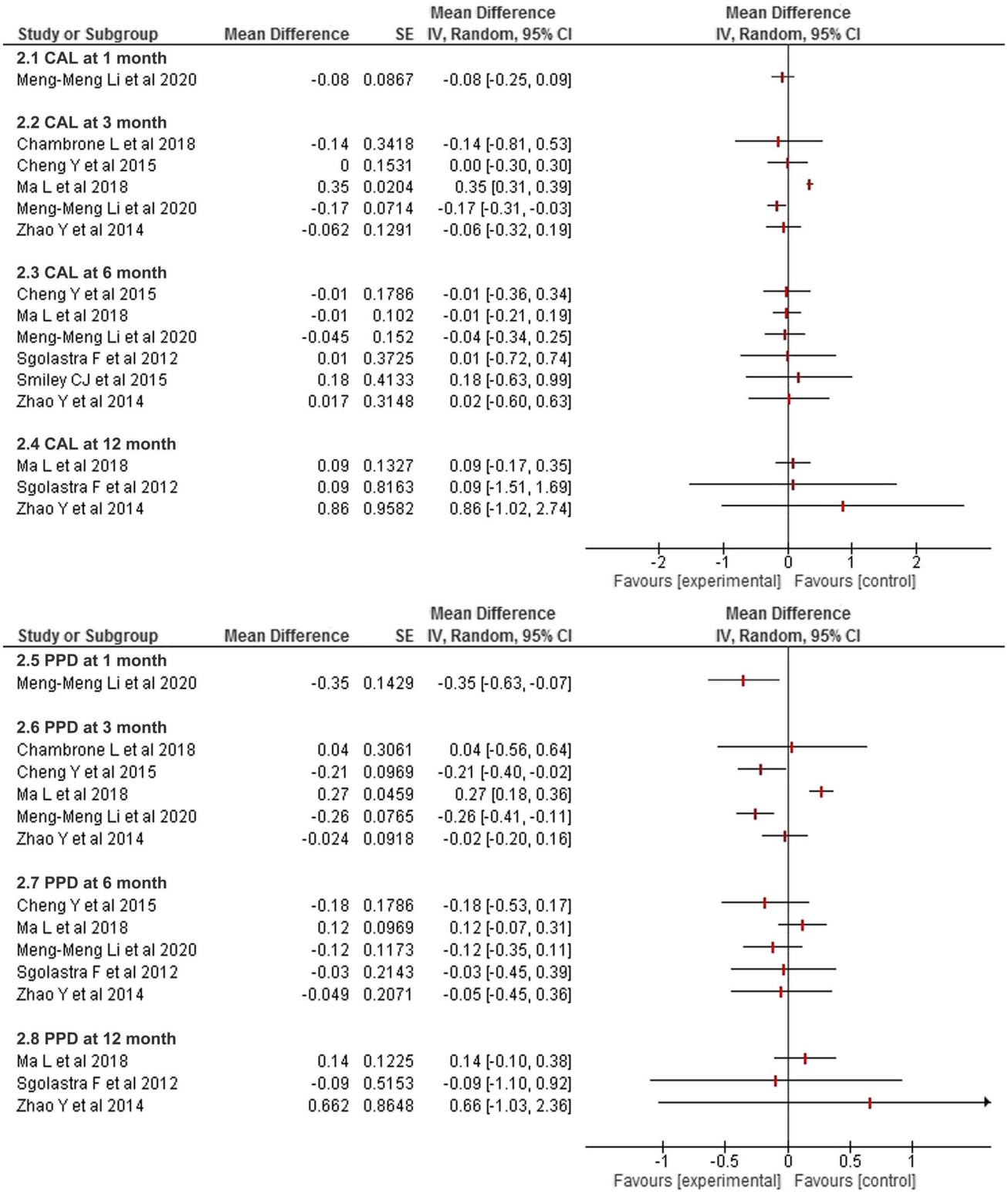

Fig. 2 A forest plot representation of the meta- analysis data of the included systematic reviews comparing the outcome of clinical attachment level (CAL) [2.1 to 2.4] and probing pocket depth (PPD) [2.5 to 2.8] in experimental (erbium laser) versus control (mechanical instrumentation for SRP) at various time points.

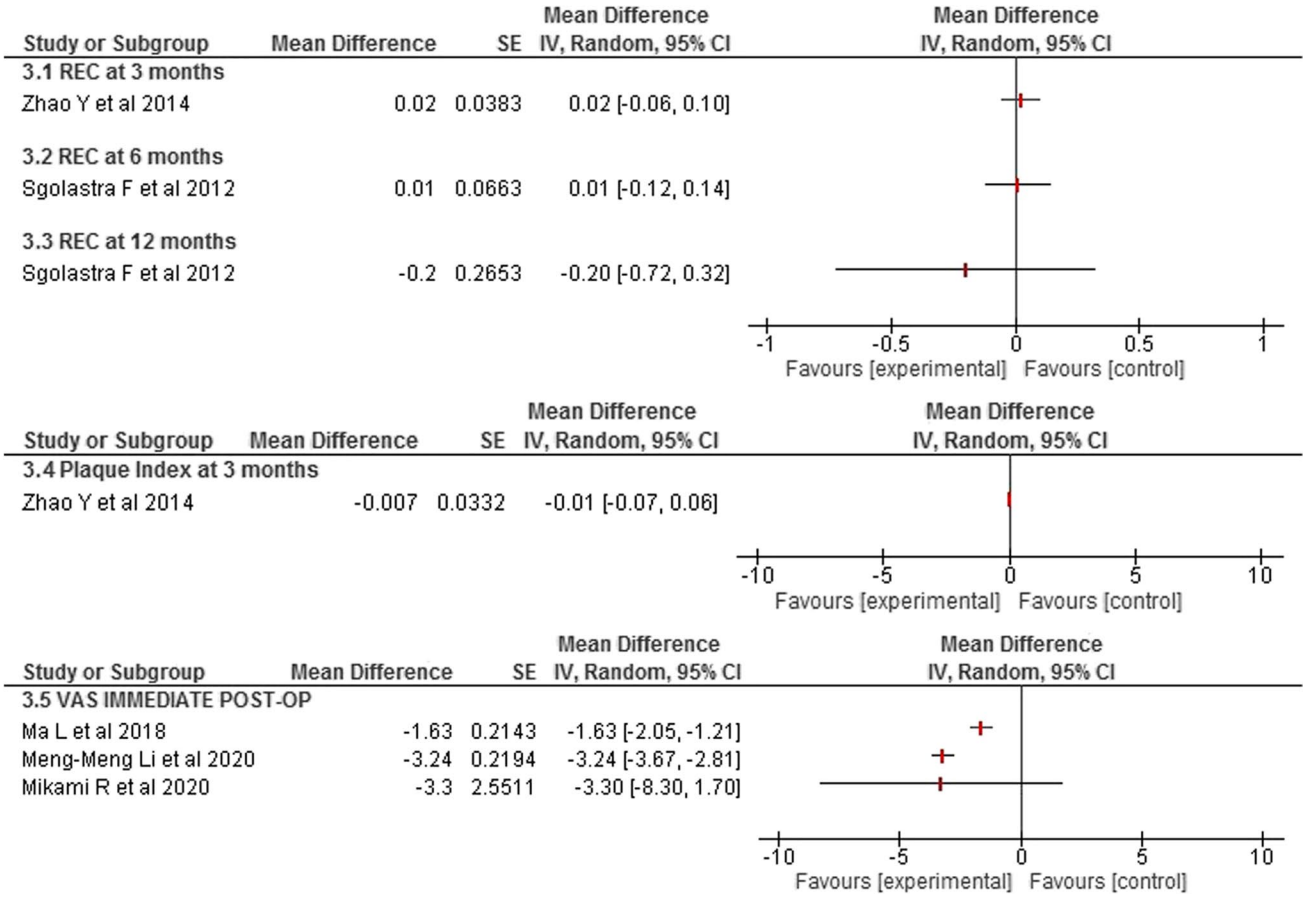

Fig. 3 A forest plot representation of the meta- analysis data of the included systematic reviews comparing the outcome of gingival recession change (REC) [3.1 to 3.3], plaque index (PI) [3.4], and visual analog scale score (VAS) [3.5] in experimental (erbium laser) versus control (mechanical instrumentation for SRP) at various time points.

included RCTs was as reported by the authors of SRs (using the Cochrane risk-of-bias tool). The quality assessment of the included systematic reviews was performed by the authors of this umbrella review using the Risk of Bias in Systematic Reviews (ROBIS) scale. Outcome measures for both the EGMs included clinical outcomes (CAL, PPD, REC. PI, GI, BOP), microbial level reduction, patient-reported outcome measures (VAS), and adverse outcomes reporting.

Among the 50 RCTs included in the EGM, most of the trials had evaluated the efficacy of erbium lasers as a monotherapy (20/50 RCTs — 40%) or as an adjunct to SRP (23/50 RCTs — 46%) in NSPT. Seven studies accounted for the remaining 14%, distributed among the three remaining interventions. The trial quality of the primary studies was also included in the EGM based on the risk of bias as reported by the authors of the systematic reviews. Of the 50 RCTs, the methodological quality of 42 RCTs as reported in the SRs was included in the EGM. The remaining eight RCTs were from the systematic review by Li et al. (2021), wherein the authors discussed the domain-based assessment of the included RCTs and not the individual study quality. The authors of this systematic review were contacted; however, data for the individual study methodological quality could not be obtained. Among the 42 studies with quality assessment data available, 11 had a low risk of bias, 17 studies had high risk of bias, and 14 studies had an unclear risk of bias. Among the primary studies, only 7/50 studies reported the VAS scores, and 2/50 studies reported adverse outcomes following the use of erbium lasers or mechanical instrumentation for SRP. The clinical outcomes commonly reported were CAL, PPD, PI, GI, and REC, and the most frequently reported time points were 3 and 6 months.

Among the included systematic reviews, CAL and PPD were the most frequently included and reported clinical parameters in the meta-analysis; however, in a systematic review by Mikami et al. (2020) [24], VAS was reported as the primary outcome measure. Risk-of-bias data can be found in Table 2 and were included in the EGM developed. Some SRs had performed meta-analysis at 3 months [22], some at the 6-month time point [8], and some SRs provided meta-analysis data for 3, 6, and 12 months [13–16, 18].

AUTHOR/YEAR	Schwarz F et al 2008 #	Karlsson MR et al 2008 #	Sgolastra F et al 2012 *	Zhao Y et al 2014*	Smiley CJ et al 2015 *	Cheng Y et al 2016*	Akram Z et al 2016 #	Kellasarian SV et al 2017#	Ma L et al 2018 *	Chambrone L et al 2018 *	Coluzzi D et al 2020 #	Jia L et al 2020*	Zhao P et al 2020 *	Mikami R et al 2020 *	Li et al 2021*
SCHWARZ et al, 2001	*		*	*											
SCHWARZ et al, 2003 a	*		*	*						*					
SCHWARZ et al, 2003 b	*			*											
SCULEAN et al, 2004	*		*	*						*					
TOMASI et al, 2006	*									*					
CRESPI et al, 2007	*			*						*		*			
Derdilopoulou et al, 2007	*									*					
Kelbauskiene & Maciulskiene, 2007		*													*
Lopes BM et al, 2008			*					*	*						
Rotundo R et al, 2010			*	*	*	*			*	*	*		*	*	
Lopes BM et al, 2010				*	*	*			*	*	*	*	*		
Braun A et al, 2010														*	
Dominguez et al, 2010							*	*							
Feng et al, 2011				*											
Kelbauskiene et al, 2011					*	*					*				*
Soo et al, 2012				*						*		*			
Yilmaz S et al, 2012				*		*			*			*	*		
Malali et al, 2012				*						*		*			
Krohn-Dale I et al, 2012										*					
Ratka-Krueger P et al, 2012										*					
Yilmaz S et al, 2013				*		*			*			*	*		
Ge LH et al, 2014												*			*
Ming C et al, 2015									*						
Gutknecht N et al, 2015 *															*
Ji zhangzhang et al, 2015 *															*
Sanz-Sanchez I et al, 2015									*		*	*	*		
Sanz-Sanchez I et al, 2016									*						
Chen MH et al, 2016												*			*
Qu Chunna et al, 2016 *															*
Zhou LF et al, 2016									*						
Cao W et al, 2016 *															*
Magaz VR et al, 2016											*		*		*
Dereci O et al, 2016											*		*		*
Cui JY et al, 2017												*		*	*
Chen M et al, 2017												*			
Ge LH et al, 2017												*			
Kaiyue W et al, 2017									*						
Wang Y et al, 2017												*			
Wang YS et al, 2017 *															*
Weiyan L et al, 2017									*						
Shuxia et al, 2017									*						
Ye Zhifei et al, 2018 *															*
Grzech LK et al, 2018												*			
Ustun K et al, 2018													*		*
Cao Y et al, 2018												*			
Zhao M et al, 2018 *															*
Ciurescu CE et al, 2019											*				
Zhou X et al, 2019											*		*		
Celik TZ et al, 2019											*		*		
Wang Y et al, 2019 *															*

CA=N/rc	113/756	0.14
N=no.of included publications including double counting		
i.e sum of all * boxes		
r= no.of rows (no.of index publications)		
c=no.of columns (no.of reviews)		
CCA=N-r/rc-r		0.08
113-50/765-50 = 63/714 = 0.08		
Systematic Review		
Systematic Review and Meta-Analysis		

Fig. 4 Corrected covered areas analysis of the primary study overlap in the included systematic reviews.

Discussion

This overview of systematic reviews was performed to provide an insight into the efficacy of erbium lasers in NSPT. The published literature includes several systematic reviews that addressed this question, with various results being reported [12, 15, 16]. This overview observed heterogeneity in the outcomes assessed in the included systematic reviews. Hence, an evidence gap map was developed for the identification of any gaps in the study data pertaining to the research question. The following gaps were identified: lack of clinical outcome data at longer follow-up time points (> 6 months), variations in quality assessment for the RCTs included in and assessed by authors of different systematic reviews, need for RCTs with higher methodological quality (since several of the included studies were reported to have a high risk of bias), and very few studies (RCTs/SRs) that assessed patient-reported outcome measures and adverse outcomes.

It can be inferred from the qualitative synthesis of the included systematic reviews that erbium lasers, when used as

an adjunct to SRP, were better than SRP alone. This can be substantiated by the observations of a significant short-term reduction in CAL and PPD and BOP (1–3 months), [14, 15, 18, 23, 25] but results comparable with those of SRP were obtained at ≥ 6-month follow-up time points [8, 12–19, 22].

A quantitative synthesis of the outcome data pooled from the systematic reviews with meta-analysis data available demonstrated considerable variation in outcomes at the time points assessed. The outcomes of CAL and PPD were assessed at 3 and 6 months in most SRs. An improved CAL gain and reduction of PPD were reported at 1 and 3 months, but no additional benefit was observed at longer-term follow-up ≥ 6 months in the erbium laser group as compared with SRP [8, 16]. For outcomes such as VAS score [15, 18, 24], gingival recession, and plaque index [13, 16], only a few systematic reviews had performed a meta-analysis of the data, and hence a clear inference could not be made.

The inclusion of the same primary studies in two or more systematic reviews caused overlap and may have contributed to bias. The degree of overlap can be graphically represented efficiently and pragmatically by the corrected covered areas (CCA) formula. The distribution of the 50 RCTs in the 15 SRs was plotted, and moderate overlap (CCA value — 0.08) was identified.

The EGM provides an abundant source of information on included SRs related to the efficacy of erbium lasers in NSPT. The number of studies, outcomes assessed, interventions performed, and quality of primary studies and systematic reviews are represented visually, allowing for a quick interpretation of the data. The map also has a provision for updating the data as new studies are performed and published, which is convenient for researchers working in the particular field.

This umbrella review has attempted to collate the information from existing SRs on the efficacy of erbium lasers in NSPT. The pooled meta-analyses reveal marginal short-term benefits (3 and 6 months) and no differences in outcomes when compared with SRP at longer-term follow-ups (12 and 24 months). This could be due to a lack of data at long-term follow-up time points (12 and 24 months) in the primary study data, as revealed in the EGM. The umbrella review has also brought to light several inconsistencies in the assessment of trial quality (Supplementary Fig. 2). A confounding variable identified during the qualitative synthesis was the lack of standardization of laser operating parameters by the RCTs, as reported in several of the included systematic reviews [16, 17, 24]. In addition, the EGM has demonstrated that only around 30% of the studies were of high quality (low risk of bias), and the remaining had either high or unclear risk of bias, emphasizing the need for more RCTs with higher quality. It can be inferred from the EGM that there is a lack of information on patient-reported outcome measures and adverse event reporting.

The limitations of this overview were that the trial quality data could not be obtained from the authors of one systematic review [18] and a deviation from the published protocol to include an EGM analysis. However, this overview has reported on the gap in evidence which needs to be corrected for clinical practice guidelines to be developed for erbium laser use in NSPT.

Conclusion

1. The use of erbium lasers as monotherapy or adjunct to scaling and root planing improves clinical and patient reported outcome measures at earlier time points of follow-up.
2. There is a need for multi-center trials with standardized laser parameters, uniformity in outcome assessment and long-term follow-up for demonstration of the efficacy of erbium lasers in nonsurgical periodontal therapy.

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Declarations

Ethics approval Not applicable as it is an umbrella review

Conflict of interest The authors declare no competing interests.

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