Lasers Med Sci (2013) 28:1393–1402
DOI 10.1007/s10103-012-1181-5

REVIEW ARTICLE

Effectiveness of diode laser as adjunctive therapy to scaling root planning in the treatment of chronic periodontitis: a meta-analysis

Fabrizio Sgolastra · Marco Severino · Roberto Gatto · Annalisa Monaco

Received: 13 April 2012 / Accepted: 30 July 2012 / Published online: 16 August 2012

Abstract To investigate whether the adjunctive use of diode laser provides additional benefits to scaling root planning alone in patients with chronic periodontitis, a meta-analysis was conducted according to the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-analysis statement and the Cochrane Collaboration. A literature search was performed on seven databases, followed by a manual search. Weighted mean differences and 95 % confidence intervals were calculated for the clinical attachment level, probing depth, and changes in the plaque and gingival indices. The I^2 test was used for inter-study heterogeneity. Visual asymmetry inspection of the funnel plot, Egger's regression test, and the trim-and-fill method were used to investigate publication bias. All outcomes were evaluated at 6 months. No significant differences were observed for any investigated outcome of interest. No evidence of heterogeneity or publication bias was detected. These findings suggested that the use of diode laser as an adjunctive therapy to conventional nonsurgical periodontal therapy did not provide additional clinical benefit. However, given that few studies were included in the analysis, and that three of the five included studies had a high risk of bias, the results should be interpreted with caution. Important issues that remain to be clarified include the influence of smoking on clinical outcomes, the effectiveness of adjunctive diode laser on microbiological outcomes, and the occurrence of adverse events. Future long-term well-designed parallel randomized clinical trials are required to assess the effectiveness of the adjunctive use of diode laser, as well as the appropriate dosimetry and laser settings.

F. Sgolastra (✉) · M. Severino · R. Gatto · A. Monaco
Department of Health Sciences, University of L'Aquila,
San Salvatore 1, Building Delta 6,
67100 L'Aquila, Italy
e-mail: fabrizio.sgolastra@gmail.com

Keywords Chronic periodontitis · Lasers semiconductor · Scaling root planing · Nonsurgical periodontal treatment · Meta-analysis

Introduction

Periodontal disease results from inflammation of the supporting structures of the teeth in response to chronic infections caused by various periodontopathic bacteria [1]. The main goals of periodontal therapy are to eliminate bacterial deposits and niches by removing the supragingival and subgingival biofilms [2, 3] and to restore the biological compatibility of periodontally diseased root surfaces for subsequent attachment of periodontal tissues to the treated root surface [4]. Generally, these objectives are achieved by mechanical scaling and root planning (SRP), which consists of hand- or electronic instrumentation of the periodontally affected sites.

Although SRP produces significant clinical improvements in patients with chronic periodontitis (CP), the complete elimination of bacterial deposits can be difficult to accomplish [5]. Indeed, mechanical therapy alone may fail to eliminate pathogenic bacterial niches in the soft tissue and in areas that are inaccessible to periodontal instruments, such as deep pockets, furcation areas, and root depressions [6, 7]. Moreover, the use of SRP in the treatment of CP may result in a moderate and temporary shift in the composition of the microbial flora [8, 9], particularly in deep pockets where periodontopathic bacteria can persist after SRP. This situation can lead to the recolonization of treated sites [10, 11].

To overcome these limitations of conventional mechanical therapy, several adjunctive protocols have been developed. Among these, the use of lasers has been proposed for its bactericidal and detoxification effects and for its capacity to reach sites that conventional mechanical instrumentation cannot [1]. In particular, studies [12, 13] have shown that the

Table 1 Categories used to assess the quality of selected studies

Category	Description	Grading
A	Sample size calculation, estimating the minimum number of participants required to detect a significant difference among compared groups	0=did not exist/not mentioned/not clear 1=was reported, but not confirmed 2=reported and confirmed
B	Randomization and allocation concealment methods	0=clearly inadequate 1=possibly adequate 2=clearly adequate
C	Clear definition of inclusion and/or exclusion criteria	0=no 1=yes
D	Completeness of follow-up (specified reasons for withdrawals and dropouts in each study group)	0=no/not mentioned/not clear 1=yes/no withdrawals or dropouts occurred
E	Experimental and control groups comparable at study baseline for important prognostic factors	0=no 1=unclear/possibly not comparable for one or more important prognostic factors 2=clearly adequate
F	Presence of masking	0=no 1=unclear/not complete 2=yes
G	Appropriate statistical analysis	0=no 1=unclear/possibly not the best method applied 2=yes

Table 2 Studies excluded and reason for exclusion

Study	Publication year	Exclusion criterion	Study type
Giannelli et al. [29]	2012	A.1	Clinical trial
Obradovic et al. [30]	2012	A.1	Controlled clinical trial
Giannopoulou et al. [32]	2011	B.3	Randomized clinical trial
Lui et al. [35]	2011	A.2	Randomized clinical trial
Mayahara et al. [36]	2010	A.1	In vitro study
de Paula Eduardo et al. [16]	2010	A.1	Review
de Micheli et al. [37]	2011	B.2	Randomized clinical trial
Cobb et al. [38]	2010	A.1	Review
Pejcic et al. [39]	2010	A.1	Controlled clinical trial
Angelov et al. [40]	2009	B.4	Randomized clinical trial
Lin et al. [41]	2009	A.2	Randomized clinical trial
Karlsson et al. [42]	2008	A.1	Systematic review
Lai et al. [43]	2009	A.2	Randomized clinical trial
Schwarz et al. [17]	2008	A.1	Systematic review
Ribeiro et al. [44]	2008	B.2	Randomized clinical trial
Assaf et al. [45]	2007	A.3	Randomized clinical trial
Nonhoff et al. [46]	2006	A.2	Randomized clinical trial
Castro et al. [47]	2006	A.1	In vitro study
Kreisler et al. [48]	2005	B.2	Randomized clinical trial
Chanthaboury and Irinakis [49]	2005	A.1	Review
Kiernicka et al. [50]	2004	A.1	Controlled clinical trial
Qadri et al. [51]	2005	B.2	Randomized clinical trial
Borrajo et al. [52]	2004	B.2	Randomized clinical trial
Rafetto [53]	2004	A.1	Review
Aoki et al. [4]	2004	A.1	Review
Schwarz et al. [54]	2003	B.4	Randomized clinical trial
Sjöström and Friskopp [55]	2002	A.1	Controlled clinical trial
Yilmaz et al. [56]	2002	B.2	Randomized clinical trial
Moritz et al. [57]	1998	B.1	Randomized clinical trial
Walsh [58]	1997	A.1	Review
Rossmann and Cobb [59]	1995	A.1	Review
Rydén et al. [60]	1994	A.3	Randomized clinical trial

application of the diode laser (DL), with a wavelength between 655 and 980 nm, can accelerate wound healing through the facilitation of collagen synthesis, promotion of angiogenesis, and augmentation of growth factor release. Furthermore, DL displays in vitro bactericidal and detoxification effects [14] and can prevent ablation of the root surface [15], which theoretically reduces the risk of normal root tissue removal.

Despite these potential beneficial effects, controversial clinical results for DL have been reported by studies conducted on humans comparing the adjunctive use of DL (SRP+DL) to SRP alone [16, 17]. Furthermore, important issues with paramount clinical implications remain to be defined, such as the effectiveness of adjunctive DL on microbiological outcomes and its clinical safety [17, 18]. Given the contrasting results of the studies and the absence of any previous meta-analyses, there is a great need to assess the literature systematically.

The aim of the present meta-analysis is to evaluate scientific evidence concerning the effectiveness of SRP+DL compared with SRP alone in the treatment of patients affected by CP.

Materials and methods

The present meta-analysis was conducted according to guidelines of the Cochrane Collaboration [19] and Preferred Reporting Items for Systematic Reviews and Meta-analysis [20].

Search

The following databases were searched from their earliest records through 18 March 2012: MEDLINE, Cochrane Controlled Clinical Trial Register, Cochrane Database of Systematic Reviews, CINAHL, Science Direct, ISI Web of Knowledge, and SCOPUS. The following search algorithm was used to explore databases, using Boolean operators and the asterisk symbol (*) as truncation: (“Periodontitis” [Mesh] OR “Chronic Periodontitis” [Mesh] OR “Periodontal Diseases” [Mesh] OR “Periodontal Pocket” [Mesh] OR “Periodontal Attachment Loss” [Mesh] OR “Tooth Mobility” [Mesh] OR periodontitis OR periodontal disease* OR periodontal pocket* OR attachment loss OR alveolar bone loss OR pocket depth OR clinical attachment level OR periodontal non surgical treatment OR periodontal non

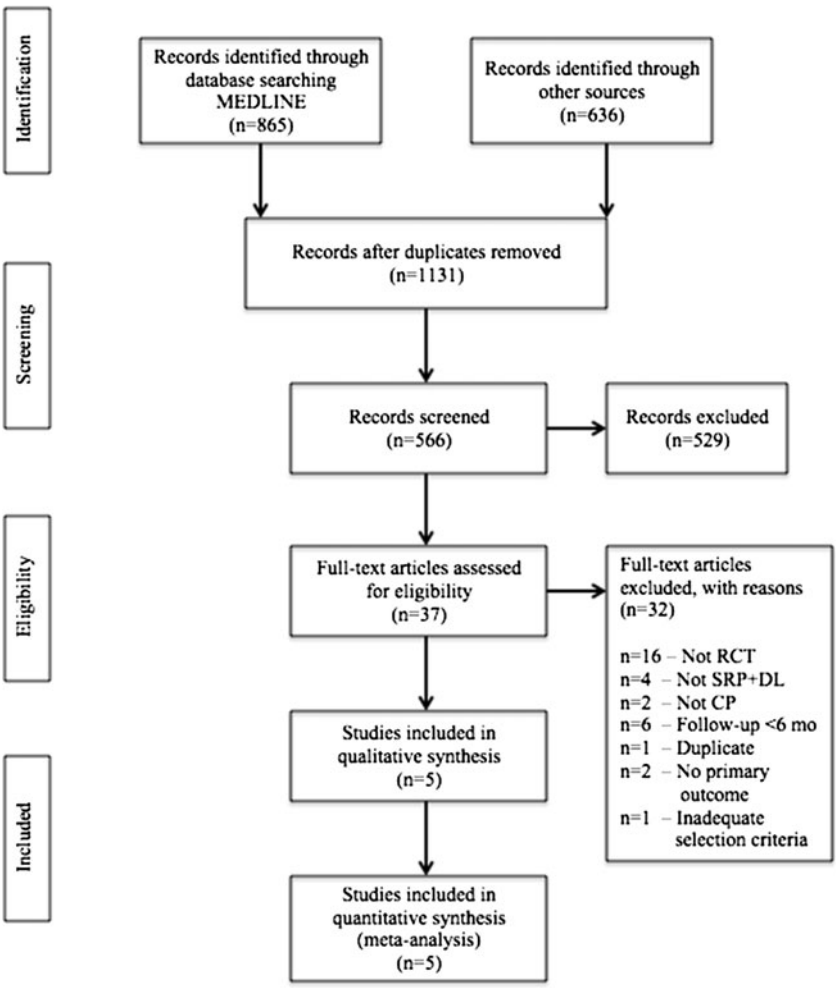

Fig. 1 PRISMA flowchart of study selection process

surgical therapy OR scaling root planing OR dental scaling OR periodontal treatment OR periodontal therapy OR calculus remov* OR calculus debridement OR dental debridement OR periodontal debridement OR "Dental Scaling" [Mesh] OR "Root Planing" [Mesh] OR "Dental Prophylaxis" [Mesh]) AND ("Lasers" [Mesh] OR "Laser Therapy" [Mesh] OR "Laser Therapy, Low-Level" [Mesh] OR "Lasers, Semiconductor" [Mesh] OR diode laser OR semiconductor laser OR low power laser OR gallium aluminum arsenide OR gallium arsenide). In the CINAHL, SCOPUS, ISI Web of Knowledge, and Science Direct databases, the MeSH terms were not used.

In addition, a manual search was performed of issues from the last 15 years of the following journals: *Lasers in Medical Science*, *Lasers in Surgery and Medicine*, *Photomedicine and Laser Surgery*, *Journal of Periodontology*, *International Journal of Periodontics and Restorative Dentistry*, *Journal of Clinical Periodontology*, *Journal of Dental Research*, *Journal of Periodontal Research*, *Periodontology 2000*, *Journal of Dentistry*, *Journal of the American Dental Association*, *Journal of Clinical Dentistry*, and *Clinical Oral Investigations*. To be as inclusive as possible, no restrictions were applied with regard to the publication year or language of the studies. The references of all selected full-text articles and related reviews were scanned.

Study selection

Screening was performed independently by two blinded reviewers (F.S. and M.S.). Interreviewer reliability in the study selection process was determined by the Cohen *k* test, assuming an acceptable threshold value of 0.61 [21, 22]. In cases of disagreement regarding the inclusion or exclusion of studies, the issue was discussed until consensus was reached.

Eligibility criteria

The study selection process was performed by two blinded reviewers (R.G. and A.M.) in two phases. In the first phase, the studies were analyzed according to the following inclusion criteria (A): (1) randomized clinical trials (RCTs), (2) studies comparing SRP+DL with SRP±Placebo DL, and (3) patients with diagnosed CP.

Only studies that met all inclusion criteria in (A) were admitted to the second phase, which consisted of analysis of the preselected studies according to the following exclusion criteria (B): (1) studies not reporting data as mean and standard deviation (SD), (2) inclusion of patients with systemic disease or who were assumed to be taking medications that are known to affect periodontal tissue and/or treatment or who had undergone periodontal therapy within the last month, (3) follow-up of <6 months, (4) duplicate or

Table 3 Design and demographic characteristics of the included studies

Study	Design	Country	Population	Mean age	Age range	Female/male ratio	Smokers/nonsmokers ratio	Laser type	Laser parameters	Follow-up	Adverse events
[14]	RCT and SM	Second University of Naples, Naples, Italy	13 patients			N.A.	N.A.	Diode laser (Valure S9 Lasering Medical Laser Modena; Italy); fiber tip Ø, 400 μm; and tip angulation, 20°	Wavelength, 980 nm; power output, 2.5 W; frequency, 30 Hz; pulse duration, 10 ms; and application time, 30 twice with 60-s interval/pocket	1, 2, 3, and 6 months	–
[28]	RCT and SM	São Paulo University, São Paulo, Brazil	36 patients	46.8±8.11 years	37–64 years	23/13	Not included in study	Diode laser (ZAP Softlase, Pleasant Hill, CA), fiber tip Ø 400 μm	Wavelength, 808±5 nm; power, 1.5 W; power density, 1,193.7 W/cm^2; and application time, 20 s/pocket	1 day, 1 and 6 weeks, 6 months	–
[31]	RCT, SM	Cairo University, Cairo, Egypt	16 patients		22–50 years	12/4	None	Diode laser and tip angulation, 90°	Wavelength, 830 nm; power density, 3 W/cm^2; dose, 3 J/cm^2; and application time, 30 s/site	5 weeks, 3 months, and 6 months	–
[33]	RCT, SM	University of Geneva, Geneva, Switzerland	29 patients	42 years	36–74 years	8/21	12/29	Diode laser (Elexxion CLAROS supplied by Elexxion Dental Academy)	Wavelength, 810 nm; power output, 1 W; and application time, 60 s	2 weeks, 2 months, and 6 months	–
[34]	RCT, P	Istanbul University, Istanbul, Turkey	36 patients	SRP group, 42.22 ±7.53 years SRP+DL group, 43.56±6.7 years	31–53 years 31–58 years	14/22	≥10 cig./day (18/36)	Diode laser (Fotona XD-2, Fotona, Ljubljana, Slovenia) and spot size, 0.28 cm^2	Wavelength, 808 nm; average output, 0.25 W; energy density, 4 J/cm^2; and application time, 10 s in incisors and 20 s in premolars and molars	1, 3, and 6 months	None related to laser use

RCT randomized clinical trial, *P* parallel, *SM* split mouth, *N.A.* not analyzed

Table 4 Quality assessment of selected studies prior to and after contact (parentheses) with corresponding authors

Study	A (0–2)	B (0–2)	C (0–1)	D (0–1)	E (0–2)	F (0–2)	G (0–2)	Estimated risk of bias
[34]	0	2	1	1	2	2	2	High
[33]	2	2	1	1	2	2	2	Low
[14]	0	2	1	1	2	0	0	High
[28]	2	2	1	1	2	2	2	Low
[31]	0	0	1	1	2	2	2	High

A–G refer to categories of quality assessment illustrated in Table 1

ancillary studies, and (5) primary outcome of interest not analyzed.

Outcome variables

The primary outcomes were changes in clinical attachment level (CAL) gain (in millimeters) and probing depth (PD) reduction (in millimeters). Secondary outcomes were changes in plaque index (PI), gingival index (GI), bleeding on probing (BOP), microbiological changes, adverse events, and cost/effectiveness ratio. All outcome variables were analyzed at 6 months of follow-up.

Data extraction

Data were collected by two independent reviewers (F.S. and R.G.). The following data were extracted from the included studies: year of publication, country, study design, demographic characteristics of participants, number of smokers per intervention arm, laser parameters, frequency and type of adverse events, and follow-up length. If data were presented both numerically (in tables or text) and graphically (in figures), only numeric data were extracted. The reviewers cross-checked all extracted data. Disagreements were resolved by discussion until consensus was reached.

Assessment of risk of bias

The quality of the methodologies of the included studies (Table 1) was analyzed independently by two blinded reviewers (F.S. and A.M.) according to the revised recommendations of the CONSORT statement [23]. The level of agreement between reviewers was calculated as described above. After determining the score of each study, the overall plausible risk of bias (low, moderate, or high) was estimated for each selected study. A low risk of bias was estimated when all of the criteria were met, a moderate risk was estimated when one or more criteria were partly met, and a high risk of bias was estimated when one or more criteria were not met [19].

Quantitative analysis

Measure of effect size

Data were combined for meta-analysis with the RevMan statistical software package, version 5.0 (The Nordic Cochrane Center, Cochrane Collaboration, Copenhagen, Denmark). The effect size was estimated and reported as the mean difference (MD), and the 95 % confidence interval (CI) was calculated. Due to the expected interstudy heterogeneity, a random effect model [24] was used. The pooled effect was considered significant if p was <0.05. Forest plots for each meta-analysis present the raw data (i.e., means, SDs, and sample sizes), point estimates (displayed as blocks), and CIs (displayed as lines) for the chosen effect, heterogeneity statistic (I^2), total number of participants per group, overall average effect (MD and Z-statistics) in the random effect model, and percent weight given to each study.

Heterogeneity

Heterogeneity was assessed by the χ^2-based Q-statistic method and I^2 measurement, with significance indicated by $p<0.1$.

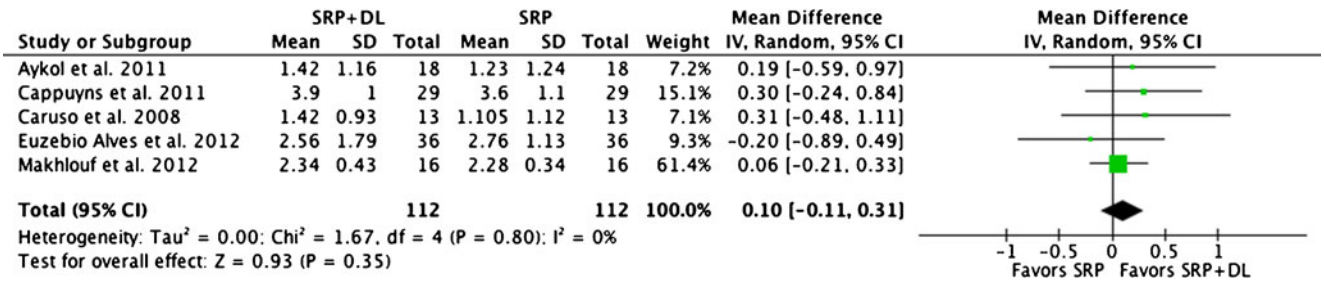

Fig. 2 Forest plot for PD reduction at 6 months for SRP+DL vs. SRP

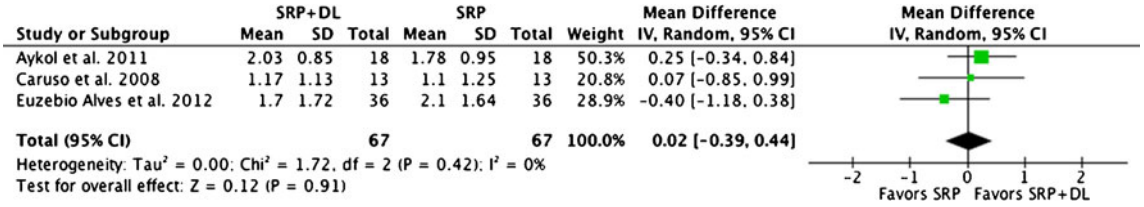

Fig. 3 Forest plot for CAL gain at 6 months for SRP+DL vs. SRP

Publication bias

Publication bias was investigated for each outcome of interest by two methods. Visual detection was used to analyze the funnel plot [25]. Quantitative analysis was performed by the regression asymmetry test [26] and the trim-and-fill method [27]. Publication bias was assessed with the Stata 10 Intercooled statistical software package (StataCorp LP, College Station, TX).

Results

Search results

A total of 1,501 articles were found through the electronic and manual searches: 865 in MEDLINE, 77 in Cochrane Database of Systematic Reviews, 155 in Cochrane Controlled Clinical Trial Register, 25 in CINHAL, 1 each in Science Direct and SCOPUS, and 377 in ISI Web of Knowledge. After removing duplicates, 1,131 articles qualified for screening, which resulted in the elimination of 1,094 studies via the Abstract and Title. Therefore, 37 articles [4, 14, 16, 17, 28–60] were evaluated for eligibility. A total of 22 studies [4, 16, 17, 29, 30, 35, 36, 38, 39, 41–43, 45–47, 49, 50, 53, 55, 58–60] were excluded for not satisfying one or more inclusion criteria, and 10 studies [32, 37, 40, 44, 48, 51, 52, 54, 56, 57] were excluded for meeting one or more exclusion criteria (Table 2). Finally, five studies [14, 28, 31, 33, 34] were included in the systematic review and meta-analysis (Fig. 1).

Description of included studies

Four [14, 28, 31, 33] of the five included studies adopted a split-mouth design, whereas one study [34] used a parallel design. The included studies used different definitions of CP. The PD threshold value for inclusion of CP patients was PD of ≥5 mm in two studies [14, 28], PD of >4 mm in one study [33], and 4 mm< PD<6 mm in one study [31]. One study [34] included patients with moderate to advanced CP. Two studies [33, 34] reported the inclusion of smokers but only one [34] included a clear definition of smoking status.

All studies used DL, but the applied wavelength varied among included RCTs (range, 808 to 980 nm), as did the fiber tip diameter, tip angulation, and power settings (Table 3). The protocol of laser application also differed among the studies: one study [34] performed three sessions of DL in 1 week; one study [31] performed ten sessions of DL in 5 weeks; and one study [28] performed two sessions of DL in 1 week. In two studies [14, 33], the number of laser application sessions was not clearly stated.

Microbiological outcomes were analyzed in three studies [14, 28, 33]. None of these studies reported significant differences between SRP and SRP+DL in terms of the number of subjects positive for the investigated pathogens at 6 months. One study [33] did not find significant differences in the reduction of the total bacterial count. Another study [28] failed to observe any significant differences between the SRP and SRP+DL groups for the CFU of the investigated periodontal pathogens. Only one study [34] analyzed adverse events, reporting that no adverse events related to the application of DL occurred during the study period.

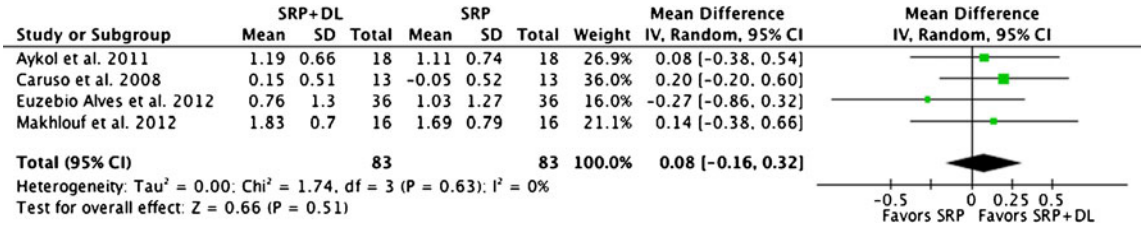

Fig. 4 Forest plot for Pl changes at 6 months for SRP+DL vs. SRP

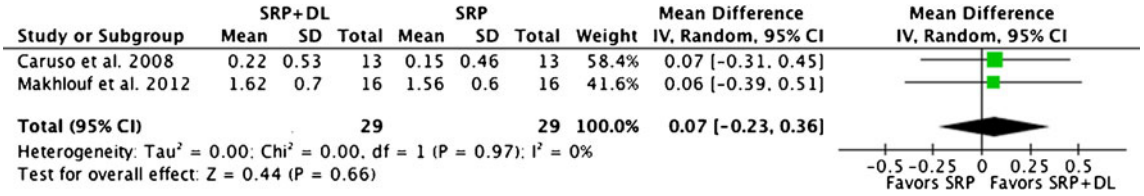

Fig. 5 Forest plot for GI changes at 6 months for SRP+DL vs. SRP

Risk of bias in included studies

The CONSORT-based quality analysis revealed that only two studies [28, 33] were at low risk of bias, whereas three [14, 31, 33] showed a high risk of bias (Table 4). The most frequent methodological shortcoming was related to sample size calculation (criteria A), which was missing in three studies [14, 31, 33]. Methods of randomization (criteria B), the use of masking (criteria F), and adequate statistical analysis (criteria G) were other criteria that were not satisfied by two studies [14, 31]. Two studies [28, 33] satisfied all of the quality analysis criteria.

Effects of intervention

Primary outcomes

No significant differences in PD reduction (MD=0.10, 95 % CI range: –0.11 to 0.31, p=0.35) (Fig. 2) or CAL gain (MD= 0.02, 95 % CI range: –0.39 to 0.44, p=0.91) (Fig. 3) were observed at 6 months between the SRP and SRP+DL groups. No evidence of within- or among-study heterogeneity was observed for PD reduction (χ^2=1.67; p=0.80; and I^2=0 %) or CAL gain (χ^2=1.72; p=0.42; and I^2=0 %).

Secondary outcomes

No significant differences in changes in PI [61] (MD=0.08; 95 % CI range, −0.16 to 0.32; and p=0.51) (Fig. 4) or GI [62] (MD=0.07; 95 % CI range, −0.23 to 0.36; and p=0.66) (Fig. 3) were observed at 6 months between the SRP and SRP+DL groups (Fig. 5). No evidence of within- or among-study heterogeneity was observed for changes in PI (χ^2=1.74; p=0.63; and I^2=0 %) or GI (χ^2=0.00; p=0.97; and I^2=0 %).

Publication bias

Visual inspection of the funnel plots for PD reduction (Fig. 6), CAL gain, PI changes, and GI changes did not suggest the presence of publication bias. Although the trim and fill analysis indicated that one study was missing for PD reduction (Fig. 7) and PI changes, the Egger's regression asymmetry test revealed that the differences between the original estimate and the adjusted effect were nonsignificant for primary outcomes and PI changes. The regression asymmetry test could not be performed for GI changes, because only two studies [14, 31] were pooled (Table 5).

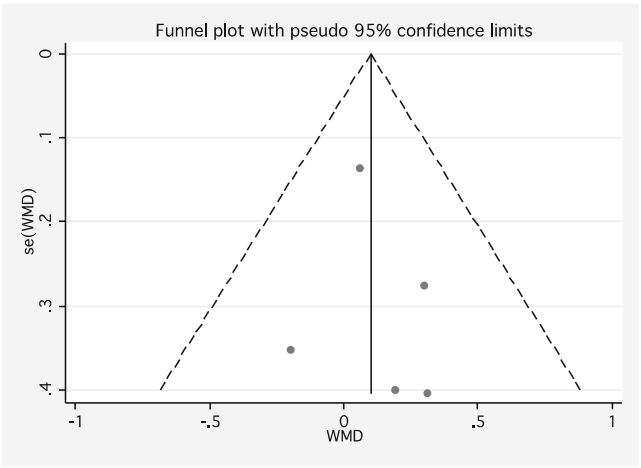

Fig. 6 Funnel plot for PD reduction outcome at 6 months for SRP+DL vs. SRP

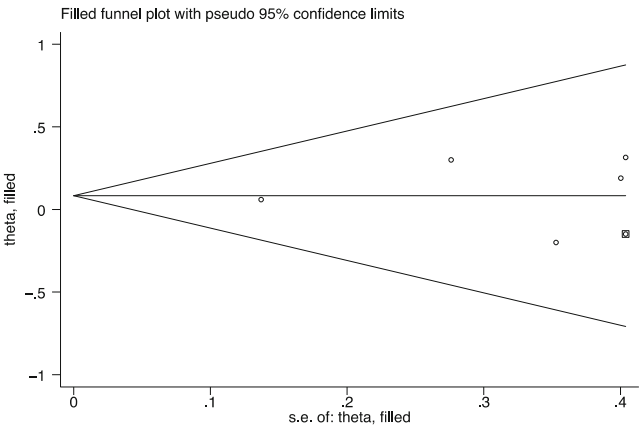

Fig. 7 Funnel plot for PD reduction outcome at 6 months for SRP+DL vs. SRP, adjusted with the trim-and-fill method

Table 5 Quantitative analysis for publication bias assessments

Outcome (SRP+DL vs. SRP)	Original meta-analysis MD (95 % CI)	*p*	Trim-and-fill analysis MD (95 % CI)	Studies trimmed/ total studies	Egger regression *p*
PD reduction at 6 months	0.10 (−0.11 to 0.31)	0.35	0.08 (−0.12 to 0.28)	1/6	0.65
CAL gain at 6 months	0.27 (−0.15 to 0.69)	0.20	0.02 (−0.39 to 0.44)	0/3	0.63
PI changes at 6 months	0.08 (−0.16 to 0.32)	0.51	0.01 (−0.19 to 0.21)	1/5	0.15
GI changes at 6 months	0.07 (−0.23 to 0.36)	0.66	0.06 (−0.22 to 0.35)	0/2	–

Discussion

Summary of main results

The results of the present meta-analysis indicated that the adjunctive use of DL to SRP did not provide additional benefits in terms of the improvement of clinical parameters. These findings are consistent with those provided by a previous systematic review [17], which, however, only included one RCT [48] with a short (3 months) follow-up time. Our findings are also consistent with those achieved by the included studies: four [14, 28, 31, 33] studies failed to observe significant differences at 6 months between SRP and SRP+DL, while only one study observed a significant additional benefit of DL use in the primary outcomes of interest. Furthermore, no study [14, 28, 33] reported an additional positive effect of DL on microbiological outcomes.

Although the I^2 test did not reveal the presence of heterogeneity (i.e., it gave a result of 0 % for all investigated outcomes), important differences in the use of different wavelengths, fiber tip diameters, power settings, laser application times, number of DL sessions, etc., were observed among the included studies. It has been suggested that conflicting results in the literature could be due to the lack of standardization of the reported irradiation parameters and to the inappropriate specification of dosimetry (power, beam area, time, dose, contact, or defocused irradiation mode) [16, 63]. In the present meta-analysis, no sensitivity analysis or meta-regression investigating the effect of different laser parameters on the clinical results could be performed, because only five studies were included. However, given that an optimal dosage has yet to be defined, and that laser parameters are related to the effectiveness of DL [34], future studies should be performed to specify the appropriate laser settings and dosimetry of this method.

The findings of this meta-analysis revealed that relevant differences existed for the presence of an important prognostic factor: namely, smoking. Smoking modifies the results of nonsurgical therapy [64] and wound healing [65]. Indeed, one of the studies in this meta-analysis [28] clearly excluded smokers, whereas another reported that none of the included patients were smokers [31]. In a third study, the inclusion of smokers was unclear [14]. Two studies [33, 34] reported the presence of smokers but only one [34] reported a clear definition of smoking and a stratified analysis. In this latter study, smoking patients receiving SRP+DL showed a greater PD reduction than smokers who received SRP alone. Unfortunately, the study did not indicate whether significant differences were present in the assignment of smokers to the treatment arms.

Interestingly, a wide range of CP definitions, mainly based on PD, were adopted by the included studies. Different levels of CP extension and severity (i.e., moderate, moderate to advanced, severe, etc.) and treatment stages (i.e., untreated patients and maintenance patients) were considered by the included studies. The effectiveness of SRP could depend on PD, because deeper pockets have more potential PD reduction [34]. Accordingly, this issue should be considered when interpreting the findings of the present meta-analysis.

No meta-analysis could be performed with regard to microbiological outcomes. Nevertheless, the studies addressing this issue [14, 28, 33] reported that no significant differences were detected in the number of patients positive for the investigated pathogens, such as *Aggregatibacter actinomycetemcomitans* and *Porphyromonas gingivalis*. Future studies should address the microbiological effects of adjunctive DL.

The present meta-analysis utilized rigorous inclusion/exclusion criteria and a wide search strategy with no language restrictions. In addition, publication bias was analyzed and, through qualitative and quantitative methods, was not found to be present. However, despite the adopted methodology, the current findings should be interpreted with caution. Additional studies are needed to assess the effectiveness of SRP+DL compared with SRP alone.

Quality of the evidence

The quality analysis revealed a high risk of bias for three [14, 31, 33] of the five included RCTs. The most frequently unsatisfied criterion was the lack of a sample size calculation. This methodological shortcoming could theoretically have contributed to the low power for three studies [14, 31, 33]. Four [14, 28, 31, 33] of the five included RCTs assumed a split-mouth design, in which the randomization was performed on the basis of the mouth sides rather than

on the basis of the patients. This design potentially reduces the error variance of the experiment, assumes a higher statistical power [66], and requires fewer patients for the trial [67]. However, comparisons made on a within-patient basis have important disadvantages, because treatments may affect the experimental site in unpredictable ways (i.e., carryover effects) [17]. Furthermore, a recent review [68] highlighted that split-mouth trials showed deficiencies in reporting and in the application of correct statistical procedures. Therefore, unless a priori knowledge indicates that no carryover effects exist, then the reported estimates of the treatment efficacy should be considered to be biased [67].

Limitations of the meta-analysis

The main limitation of the present meta-analysis was the small number of included RCTs, three of which [14, 31, 33] had a high risk of bias. As a result, the findings of this meta-analysis should be interpreted with caution.

Implications for research

Future well-designed parallel RCTs with large sample sizes should be performed to assess whether the adjunctive application of DL to SRP could provide additional clinical benefit to SRP alone. Appropriate dosimetry and complete laser settings should be reported, and additional outcomes, such as microbiological outcomes, occurrence of adverse events, and the cost/effectiveness ratio of the adjunctive use of DL, should be addressed.

Implications for clinical practice

Based on the findings of the present meta-analysis, no clinical recommendation for the adjunctive use of DL with SRP can be given. Until high-quality RCTs become available, DL+SRP should be considered as an experimental and unpredictable treatment.

References

1. Darveau RP, Tanner A, Page RC (1997) The microbial challenge in periodontitis. Periodontol 2000 14:12–32
2. Teles RP, Haffajee AD, Socransky SS (2006) Microbiological goals of periodontal therapy. Periodontol 2000 42:180–218
3. Takasaki AA, Aoki A, Mizutani K, Schwarz F, Sculean A, Wang CY, Koshy G, Romanos G, Ishikawa I, Izumi Y (2009) Application of antimicrobial photodynamic therapy in periodontal and peri-implant diseases. Periodontol 2000 51:109–140
4. Aoki A, Sasaki KM, Watanabe H, Ishikawa I (2004) Lasers in nonsurgical periodontal therapy. Periodontol 2000 36:59–97
5. Adriaens PA, Adriaens LM (2004) Effects of nonsurgical periodontal therapy on hard and soft tissues. Periodontol 2000 36:121–145
6. Adriaens PA, Edwards CA, DeBoever JA, Loesche WJ (1988) Ultrastructural observations on bacterial invasion in cementum and radicular dentin of periodontally diseased human teeth. J Periodontol 59:493–503
7. Matia JI, Bissada NF, Maybury JE, Ricchetti P (1986) Efficiency of scaling of the molar furcation area with and without surgical access. Int J Periodontics Restorative Dent 6:24–35
8. Sherman PR, Hutchens LH, Jewson LG, Moriarty JM, Greco GW, McFall WT (1990) The effectiveness of subgingival scaling and root planing. I. Clinical detection of residual calculus. J Periodontol 61:3–8
9. Cobb CM (1996) Non-surgical pocket therapy. Ann Periodontol 1:443–490
10. Renvert S, Wilkstrom M, Dahlen G, Slots J, Egelberg J (1990) Effect of root debridement on the elimination of *Actinobacillus actinomycetemcomitans* and *Bacteroides gingivalis* from periodontal pockets. J Clin Periodontol 17:345–350
11. Sbordone L, Ramaglia L, Gulleta E, Iacono Y (1990) Recolonization of the subgingival microflora after scaling and root planning in human periodontitis. J Periodontol 61:579–584
12. Silveira PC, Streck EL, Pinho RA (2007) Evaluation of mitochondrial respiratory chain activity in wound healing by low-level laser therapy. J Photochem Photobiol B 86:279–282
13. Hawkins D, Abrahamse H (2006) Effect of multiple exposures of low-level laser therapy on the cellular responses of wounded human skin fibroblasts. Photomed Laser Surg 24:705–714
14. Harris DM, Yessik M (2004) Therapeutic ratio quantifies laser antisepsis: ablation of *Porphyromonas gingivalis* with dental lasers. Laser Surg Med 35:206–213
15. Caruso U, Nastri L, Piccolomini R, d'Ercole S, Mazza C, Guida L (2008) Use of diode laser 980 nm as adjunctive therapy in the treatment of chronic periodontitis. A randomized controlled clinical trial. New Microbiol 31:513–518
16. de Paula EC, de Freitas PM, Esteves-Oliveira M, Aranha AC, Ramalho KM, Simões A, Bello-Silva MS, Tunér J (2010) Laser phototherapy in the treatment of periodontal disease. A review. Lasers Med Sci 25:781–792
17. Schwarz F, Aoki A, Becker J, Sculean A (2008) Laser application in non-surgical periodontal therapy: a systematic review. J Clin Periodontol 35(8 Suppl):29–44
18. American Academy of Periodontology (2011) American academy of periodontology statement on the efficacy of lasers in the nonsurgical treatment of inflammatory periodontal disease. J Periodontol 82:513–514
19. Higgins JPT, Green S, (eds) (2009) Cochrane handbook for systematic reviews of interventions, version 5.1. The Cochrane Collaboration. Available at: http://www.cochrane-handbook.org. Accessed 1 March 2012
20. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 151:264–269
21. Landis JR, Koch GG (1997) An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. Biometrics 33:363–374
22. Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. Biometrics 33:159–174
23. Moher D, Schulz KF, Altman DG (2001) The CONSORT statement: revised recommendations for improving the quality of reports of parallel-group randomized trials. Ann Intern Med 134:657–662
24. DerSimonian R, Laird N (1986) Meta-analysis in clinical trials. Control Clin Trials 7:177–188
25. Sterne JA, Egger M (2001) Funnel plots for detecting bias in meta-analysis: guidelines on choice of axis. J Clin Epidemiol 54:1046–1055
26. Egger M, Davey Smith G, Schneider M, Minder C (1997) Bias in meta-analysis detected by a simple, graphical test. BMJ 315:629–634
27. Duval S, Tweedie R (2000) Trim and fill: a simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. Biometrics 56:455–463

28. Euzebio Alves VT, de Andrade AK, Toaliar JM, Conde MC, Zezell DM, Cai S, Pannuti CM, De Micheli G (2012) Clinical and microbiological evaluation of high intensity diode laser adjutant to non-surgical periodontal treatment: a 6-month clinical trial. Clin Oral Invest (in press)
29. Giannelli M, D B, Viti C, Tani A, Lorenzini L, Zecchi-Orlandini S, Formigli L (2012) Comparative evaluation of the effects of different photoablative laser irradiation protocols on the gingiva of periodontopathic patients. Photomed Laser Surg 30:222–230
30. Obradović R, Kesić L, Mihailović D, Antić S, Jovanović G, Petrović A, Peševska S (2012) A histological evaluation of a low-level laser therapy as an adjunct to periodontal therapy in patients with diabetes mellitus. Lasers Med Sci (in press)
31. Makhlouf M, Dahaba MM, Tunér J, Eissa SA, Harhash TA (2012) Effect of adjunctive low level laser therapy (LLLT) on nonsurgical treatment of chronic periodontitis. Photomed Laser Surg 30:160–166
32. Giannopoulou C, Cappuyns I, Cancela J, Cionca N, Mombelli A (2012) Effect of photodynamic therapy, diode laser and deep scaling on cytokine and acute-phase protein levels in gingival crevicular fluid of residual periodontal pockets. J Periodontol (in press)
33. Cappuyns I, Cionca N, Wick P, Giannopoulou C, Mombelli A (2012) Treatment of residual pockets with photodynamic therapy, diode laser, or deep scaling. A randomized, split-mouth controlled clinical trial. Lasers Med Sci (in press)
34. Aykol G, Baser U, Maden I, Kazak Z, Onan U, Tanrikulu-Kucuk S, Ademoglu E, Issever H, Yalcin F (2011) The effect of low-level laser therapy as an adjunct to non-surgical periodontal treatment. J Periodontol 82:481–488
35. Lui J, Corbet EF, Jin L (2011) Combined photodynamic and low-level laser therapies as an adjunct to nonsurgical treatment of chronic periodontitis. J Periodontal Res 46:89–96
36. Mayahara K, Yamaguchi A, Sakaguchi M, Igarashi Y, Shimizu N (2010) Effect of Ga-Al-As laser irradiation on COX-2 and cPLA2-alpha expression in compressed human periodontal ligament cells. Lasers Surg Med 42:489–493
37. de Micheli G, de Andrade AK, Alves VT, Seto M, Pannuti CM, Cai S (2011) Efficacy of high intensity diode laser as an adjunct to non-surgical periodontal treatment: a randomized controlled trial. Lasers Med Sci 26:43–48
38. Cobb CM, Low SB, Coluzzi DJ (2010) Lasers and the treatment of chronic periodontitis. Dent Clin North Am 54:35–53
39. Pejcic A, Kojovic D, Kesic L, Obradovic R (2010) The effects of low level laser irradiation on gingival inflammation. Photomed Laser Surg 28:69–74
40. Angelov N, Pesevska S, Nakova M, Gjorgoski I, Ivanovski K, Angelova D, Hoffmann O, Andreana S (2009) Periodontal treatment with a low-level diode laser: clinical findings. Gen Dent 57:510–513
41. Lin J, Bi L, Wang L, Song Y, Ma W, Jensen S, Cao D (2011) Gingival curettage study comparing a laser treatment to hand instruments. Lasers Med Sci 26:7–11
42. Karlsson MR, Diogo Löfgren CI, Jansson HM (2008) The effect of laser therapy as an adjunct to non-surgical periodontal treatment in subjects with chronic periodontitis: a systematic review. J Periodontol 79:2021–2028
43. Lai SM, Zee KY, Lai MK, Corbet EF (2009) Clinical and radiographic investigation of the adjunctive effects of a low-power He–Ne laser in the treatment of moderate to advanced periodontal disease: a pilot study. Photomed Laser Surg 27:287–293
44. Ribeiro IW, Sbrana MC, Esper LA, Almeida AL (2008) Evaluation of the effect of the GaAlAs laser on subgingival scaling and root planing. Photomed Laser Surg 26:387–391
45. Assaf M, Yilmaz S, Kuru B, Ipci SD, Noyun U, Kadir T (2007) Effect of the diode laser on bacteremia associated with dental ultrasonic scaling: a clinical and microbiological study. Photomed Laser Surg 25:250–256
46. Nonhoff J, Derdilopoulou F, Neumann K, Kielbassa AM (2006) A quadrant-design trial of four therapeutic modalities in chronic moderate periodontitis. Schweiz Monatsschr Zahnmed 116:484–492
47. Castro GL, Gallas M, Núñez IR, Borrajo JL, Varela LG (2006) Histological evaluation of the use of diode laser as an adjunct to traditional periodontal treatment. Photomed Laser Surg 24:64–68
48. Kreisler M, Al Haj H, D'Hoedt B (2005) Clinical efficacy of semiconductor laser application as an adjunct to conventional scaling and root planning. Lasers Surg Med 37:350–355
49. Chanthaboury R, Irinakis T (2005) The use of lasers for periodontal debridement: marketing tool or proven therapy? J Can Dent Assoc 71:653–658
50. Kiernicka M, Owczarek B, Gałkowska E, Wysokińska-Miszczuk J (2004) Comparison of the effectiveness of the conservative treatment of the periodontal pockets with or without the use of laser biostimulation. Ann Univ Mariae Curie Sklodowska Med 59:488–494
51. Qadri T, Miranda L, Tunér J, Gustafsson A (2005) The short-term effects of low-level lasers as adjunct therapy in the treatment of periodontal inflammation. J Clin Periodontol 32:714–719
52. Borrajo JL, Varela LG, Castro GL, Rodríguez-Nuñez I, Torreira MG (2004) Diode laser (980 nm) as adjunct to scaling and root planning. Photomed Laser Surg 22:509–512
53. Rafetto N (2004) Lasers for initial periodontal therapy. Dent Clin North Am 48:923–936
54. Schwarz F, Sculean A, Berakdar M, Szathmari L, Georg T, Becker J (2003) In vivo and in vitro effects of an Er:YAG laser, a GaAlAs diode laser, and scaling and root planning on periodontally diseased root surfaces: a comparative histologic study. Lasers Surg Med 32:359–366
55. Sjöström L, Friskopp J (2002) Laser treatment as an adjunct to debridement of periodontal pockets. Swed Dent J 26:51–57
56. Yilmaz S, Kuru B, Kuru L, Noyan U, Argun D, Kadir T (2002) Effect of gallium arsenide diode laser on human periodontal disease: a microbiological and clinical study. Lasers Surg Med 30:60–66
57. Moritz A, Schoop U, Goharkhay K, Schauer P, Doertbudak O, Wernisch J, Sperr W (1998) Treatment of periodontal pockets with a diode laser. Lasers Surg Med 22:302–311
58. Walsh LJ (1997) The current status of low level laser therapy in dentistry. Part 2. Hard tissue applications. Aust Dent J 42:302–306
59. Rossmann JA, Cobb CM (1995) Lasers in periodontal therapy. Periodontol 2000 9:150–164
60. Rydén H, Persson L, Preber H, Bergström J (1994) Effect of low level energy laser irradiation on gingival inflammation. Swed Dent J 18:35–41
61. Silness J, Löe H (1964) Periodontal disease in pregnancy II. Correlation between oral hygiene and periodontal condition. Acta Odontol Scand 22:112–135
62. Loe H, Silness J (1963) Periodontal disease in pregnancy. I. Prevalence and severity. Acta Odontol Scand 21:533–551
63. Tunér J, Hode L (1998) It's all in the parameters: a critical analysis of some well-known negative studies on low-level laser therapy. J Clin Laser Med Surg 16:245–248
64. McGuire MK, Nunn ME (1996) Prognosis versus actual outcome. III. The effectiveness of clinical parameters in accurately predicting tooth survival. J Periodontol 67:666–674
65. Grossi SG, Zambon J, Machtei EE, Schifferle R, Andreana S, Genco RJ, Cummins D, Harrap G (1997) Effects of smoking and smoking cessation on healing after mechanical periodontal therapy. J Am Dent Assoc 128:599–607
66. Hujoel PP, Loesche WJ (1990) Efficiency of split-mouth designs. J Clin Periodontol 17:722–728
67. Hujoel PP, De Rouen TA (1992) Validity issues in split-mouth trials. J Clin Periodontol 19:625–627
68. Lesaffre E, Garcia Zattera M-J, Redmond C, Huber H, Needleman I (2007) Reported methodological quality of split-mouth studies. J Clin Periodontol 34:756–761