Original Article

# The clinical efficacy of Er:YAG lasers in the treatment of peri-implantitis: a systematic review and meta-analysis

**Lu Li, Jie Deng, Shipeng Ren**

Department of Stomatology, Affiliated Hospital of North Sichuan Medical College, Nanchong, China

*Contributions:* (I) Conception and design: L Li; (II) Administrative support: S Ren; (III) Provision of study materials or patients: J Deng; (IV) Collection and assembly of data: L Li; (V) Data analysis and interpretation: L Li; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

*Correspondence to:* Shipeng Ren. Department of Stomatology, Affiliated Hospital of North Sichuan Medical College, Nanchong, China.
Email: 474094435@qq.com.

**Background:** Erbium-doped yttrium aluminum garnet (ER:YAG) lasers have been used to treat peri-implant, but there are some disputes. To dispel these negative views, our study aims to compare the efficacy and safety of Er:YAG lasers versus conventional mechanical debridement in the treatment of peri-implantitis.

**Methods:** Seven databases were used to search for relevant studies and full-text articles which evaluate the comparisons of Er:YAG lasers and mechanical debridement for patients with peri-implantitis. Review Manager 5.4 was employed to assess the effects of the results among the selected studies. Forest plots, subgroup analyses, and on the included articles were also completed. Cochrane risk of bias assessment tool was used to assess the risk of bias.

**Results:** Our study focused on 10 previously conducted studies which included 294 patients with peri-implantitis and a total of 461 implants. No significant differences in clinical attachment level (CAL) (MD =0.17, P=0.25, at 6 months; MD =0.23, P=0.15, at 12 months), reduction in bleeding on probing (BOP) (MD =9.54%, P=0.18, at 6 months; MD =11.28%, P=0.24, at 12 months), or plaque index (PI) (MD =–0.02, P=0.75, at 6 months; MD =–0.07, P=0.66, at 12 months) were observed between the Er:YAG laser group and the mechanical debridement group. However, in reducing probing depth (PD) (MD =0.28, P=0.03, at 6 months; MD =0.35, P=0.002, at 12 months) and gingival recession (GR) changes (MD =–0.12, P=0.04, at 6 months; MD =–0.16, P=0.03, at 12 months), the Er:YAG laser group showed some advantages at 6-month and 12-month intervals following treatment. No significant publication bias existed in our meta-analysis by using funnel plot and Egger's test (PD: P=0.65; CAL: P=0.73).

**Discussion:** Our research supported the premise that Er:YAG lasers offer health benefits to patients with peri-implantitis and can effectively reduce PD and GR. Due to the limitations of the included studies, further studies should be carried out to validate our findings.

**Keywords:** Er:YAG laser; peri-implantitis; surgical; meta-analysis

Submitted Jun 15, 2021. Accepted for publication Aug 05, 2021.
doi: 10.21037/apm-21-1853
**View this article at:** https://dx.doi.org/10.21037/apm-21-1853

## Introduction

Peri-implantitis is the inflammation of the soft and hard tissues around an osseointegrated implant, and it is accompanied by abscesses, bleeding, bone loss, and other symptoms which form peri-implantitis bags and leads to osseointegration failure (1,2). It has been reported that about 7% of implant patients have peri-implantitis (3), with a number of studies showing that its pathogenesis is related to microbial reproduction (4-6). Therefore, the primary treatment for peri-implantitis is the removal of bacterial biofilms and stones from an implant's surface (7).

At present, the treatment principles of peri-implantitis mainly mirror the treatment guidelines for periodontitis

(8,9). However, recent studies have shown the difficulties of using conventional mechanical treatments for removing implants with screw threads or rough surfaces (10,11). In addition, the rough surface of an implant may also shelter bacteria from being removed by conventional mechanical methods (12). More studies have shown that after subgingival mechanical scaling, the clinical indicators of patients with peri-implantitis are not significantly improved and changes to the microbial flora on the surface of implant structures are relatively limited (13,14). Therefore, this study aims to find more effective treatment methods for peri-implantitis, a condition which has become an important issue for treating clinicians (15).

The main treatment for peri-implantitis include both surgical and non-surgical methods (16,17). Non-surgical methods include laser treatment, local medicine administration, sandblasting, plastic curettage, carbon fiber implant scaling, and so on (18-21). The purpose of this treatment is to remove stones and bacteria from an implant's surface. Some studies have shown that an erbium-doped yttrium aluminum garnet (Er:YAG) laser has strong bactericidal abilities at low energy densities, can clean and disinfect an implant's surface safely and effectively, and will not cause morphological changes to an implant's surface structure or cause heat damage to surrounding bone (22,23).

Although there are strong advantages to using ERL in the treatment of peri-implantitis, many scholars still dispute the efficacy of ERL (5,8,10). Our study conducted a systematic review and meta-analysis of relevant studies to determine the efficacy and safety of Er:YAG lasers versus conventional mechanical debridement in the treatment of peri-implantitis.

We present the following article in accordance with the PRISMA reporting checklist (available at https://dx.doi.org/10.21037/apm-21-1853).

## Methods

### *Literature search strategy*

Electronic databases including PubMed, Cochrane Library, Medline, Web of Science (WOS), Excerpta Medica Database (Embase), and China National Knowledge Infrastructure (CNKI) were systematically searched for eligible studies between January 2000 and May 2021. The following keywords were used for the search: (I) Er:YAG laser; (II) peri-implantitis; (III) surgical therapy. These keywords were used in combination with the Boolean operators 'AND' or 'OR' to search the literature. We conducted a comprehensive search across several databases, and no restrictions were placed on either the language or publication status of the investigated studies. In order to maximize the specificity and sensitivity of the search, the author of this study checked the reference list of each research article to determine other relevant studies which had not been found using the initial search strategy. Disagreements between reviewers were resolved with consensus.

### *Study selection*

The inclusion criteria were as follows: (I) patients with peri-implantitis; (II) comparisons of patients receiving Er:YAG laser treatment and conventional mechanical treatment; (III) containing indicators evaluating the differences in effectiveness between Er:YAG laser treatment and conventional mechanical treatment; (IV) available in full text.

The exclusion criteria were as follows: (I) research does not meet the inclusion criteria; (II) study lacks available data; (III) review or abstract only (not full text), or duplicate publication.

### *Data extraction and quality assessment*

The search and data extraction were both done by two reviewers, with disagreements being resolved by consulting a third reviewer. Reviewers extracted the following data from each eligible study: the author listed first, country of origin, year of publication, sample size, study duration, intervention, treatment approach, and primary outcome.

Study quality was evaluated by the Cochrane risk of bias assessment. The methodological quality of each trial was evaluated according to the following items: (I) random sequence generation; (II) allocation concealment; (III) blinding of participants and personnel; (IV) blinding of result evaluation; (V) incomplete result data; (VI) selective reporting; (VII) other biases. Each item was assessed as low risk, high risk or unclear. Any discrepant judgments were resolved by joint discussion that arrived at consensus.

### *Statistical analysis*

A review manager (Version 5.4, Cochrane Collaboration, 2020) was used to estimate the impact of the results from the selected report. Statistical heterogeneity between studies was assessed by either a chi-squared test or Cochran's

 

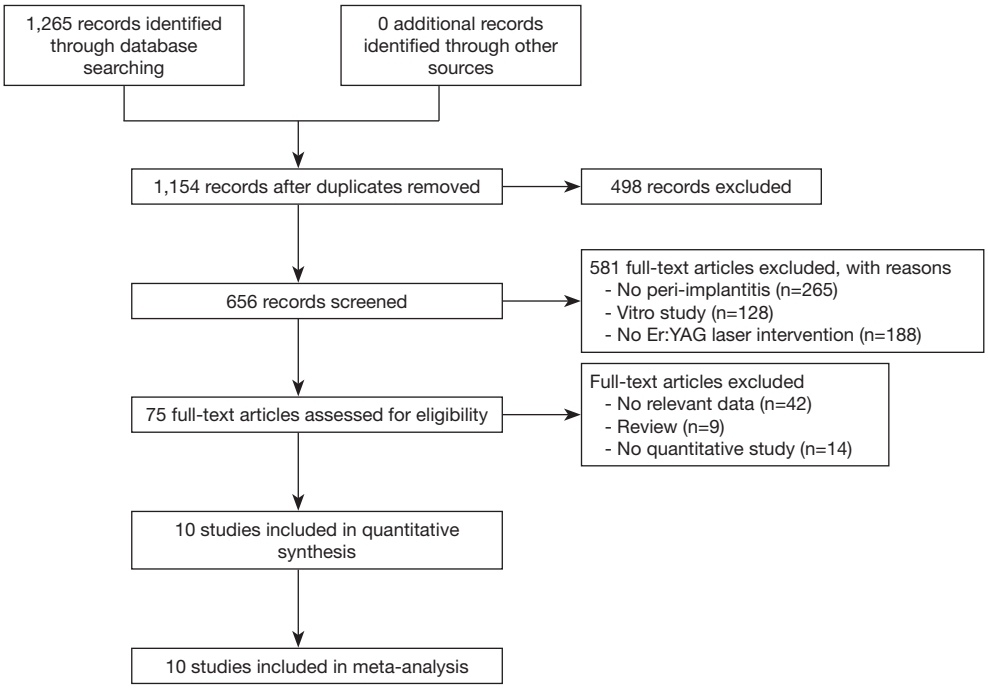


**Figure 1** Flowchart of study selection.

Q test and an $I^2$ statistic, which is a tool that measures inconsistency across study results and describes the proportion of total variation in study estimates that is due to heterogeneity rather than sampling error. We considered $I^2$ values ≥50% to indicate substantial heterogeneity, when heterogeneity was present ($I^2$≥50%), a random effects model was used to calculate the pooled odds ratio (OR) or mean difference (MD), while a fixed effects model was used in its absence. In addition, any potential publication bias was assessed using a funnel plot.

## Results

### *Search process*

A total of 1,265 study titles and abstracts were identified by our electronic search strategy. Of this total, 111 study titles and abstracts were removed due to being duplication, which left 1,154 unique articles. Following application of the inclusion and exclusion criteria during the screening of study titles, 498 further citations were excluded. In consideration of the study's design and lack of data presented, 646 articles were rejected. Thus, 10 studies met the criteria for inclusion in our study's meta-analysis (24-33). The results of the search process are illustrated in the flowchart shown in *Figure 1*.

### *Characteristics of included studies*

*Table 1* shows the main characteristics of the included studies, which amounted to 294 patients with peri-implantitis and a total of 461 implants. Of the 10 studies, 7 were randomized controlled trials, 2 were controlled, parallel design studies, and 1 was a prospective case series study. Patients received both surgical and non-surgical treatments, and the length of follow-up ranged from between 6 and 12 months. The primary outcomes of these studies focused on probing depth (PD), clinical attachment level (CAL), plaque index (PI), bleeding on probing (BOP) and gingival recession (GR).

### *Results of quality assessment*

The methodological quality of the included studies was evaluated for bias risk as according to the Cochrane risk of bias assessment. Among the 10 articles, a high risk of selection bias was found in 2 studies, and a high risk of attrition bias was found in 1 study (*Figure 2A*). A summary of the risk of bias assessment for each study is shown in *Figure 2B*.

**Table 1** Characteristics of included trials

| Study | Country | Study design | Treatment approach | Intervention | | No. of patients | | No. of implants | | Follow-up (months) | Primary outcome |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Test | Control | Test | Control | Test | Control | | |
| Schwarz 2005 | Germany | Controlled, parallel design | Non-surgical | Er:YAG laser | Mechanical debridement (plastic curets + chlorhexidine) | 10 | 10 | 16 | 16 | 6 | PD/CAL/PI/BOP/GR |
| Schwarz 2006 | Germany | Controlled, parallel design | Non-surgical | Er:YAG laser | Mechanical debridement (plastic curets + chlorhexidine) | 10 | 8 | 20 | 16 | 6,12 | PD/CAL/PI/BOP/GR |
| Lopes 2010 | Brazil | RCT | Non-surgical | Er:YAG laser | Conventional scaling and root planning | 19 | 19 | 19 | 19 | 6,12 | PD/CAL/PI/BOP/GR |
| Persson 2011 | Sweden | RCT | Non-surgical | Er:YAG laser | Air-abrasive | 21 | 21 | 55 | 45 | 6 | PD |
| Renvert 2011 | Sweden | RCT | Non-surgical | Er:YAG laser | Air-abrasive | 21 | 21 | 55 | 45 | 6 | PD |
| Schwarz 2011 | Germany | RCT | Surgical | Er:YAG laser | Plastic curets + cotton pellets + sterile saline | 15 | 15 | 19 | 16 | 6 | PD/CAL/PI/BOP/GR |
| Schwarz 2012 | Germany | RCT | Surgical | Er:YAG laser | Plastic curets + cotton pellets + sterile saline | 10 | 14 | 10 | 14 | 12 | PD/CAL/PI/BOP/GR |
| Schwarz 2015 | Germany | Prospective case series | Non-surgical | Er:YAG laser | Mechanical debridement (carbon curets + chlorhexidine) | 17 | 17 | 21 | 24 | 6 | PD/PI/BOP |
| Li 2016 | China | RCT | Non-surgical | Er:YAG laser | Plastic curets + chlorhexidine | 11 | 11 | 12 | 15 | 6 | PD/CAL/PI |
| Wang 2020 | USA | RCT | Surgical | Er:YAG laser | Mechanical debridement + guided bone regeneration | 12 | 12 | 12 | 12 | 6 | PD/CAL/PI/BOP/GR |

RCT, randomized controlled trial; PD, probing depth; CAL, clinical attachment level; PI, plaque index; BOP, bleeding on probing; GR, gingival recession.

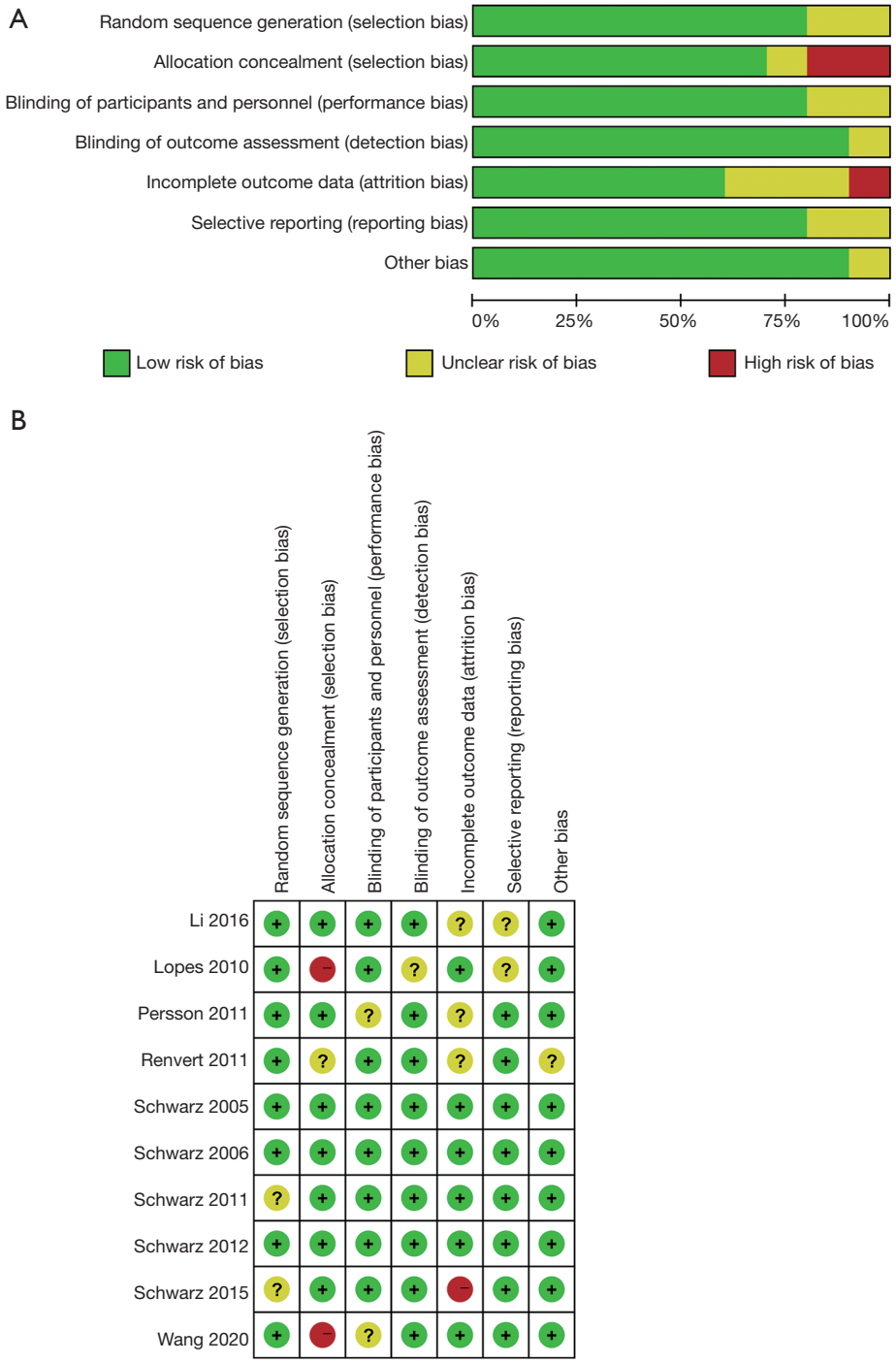


**Figure 2** Quality assessment of included studies. (A) Overall risk of bias of included studies; (B) risk of bias summary of each included study; green: low risk of bias; yellow: unclear risk of bias; red: high risk of bias.

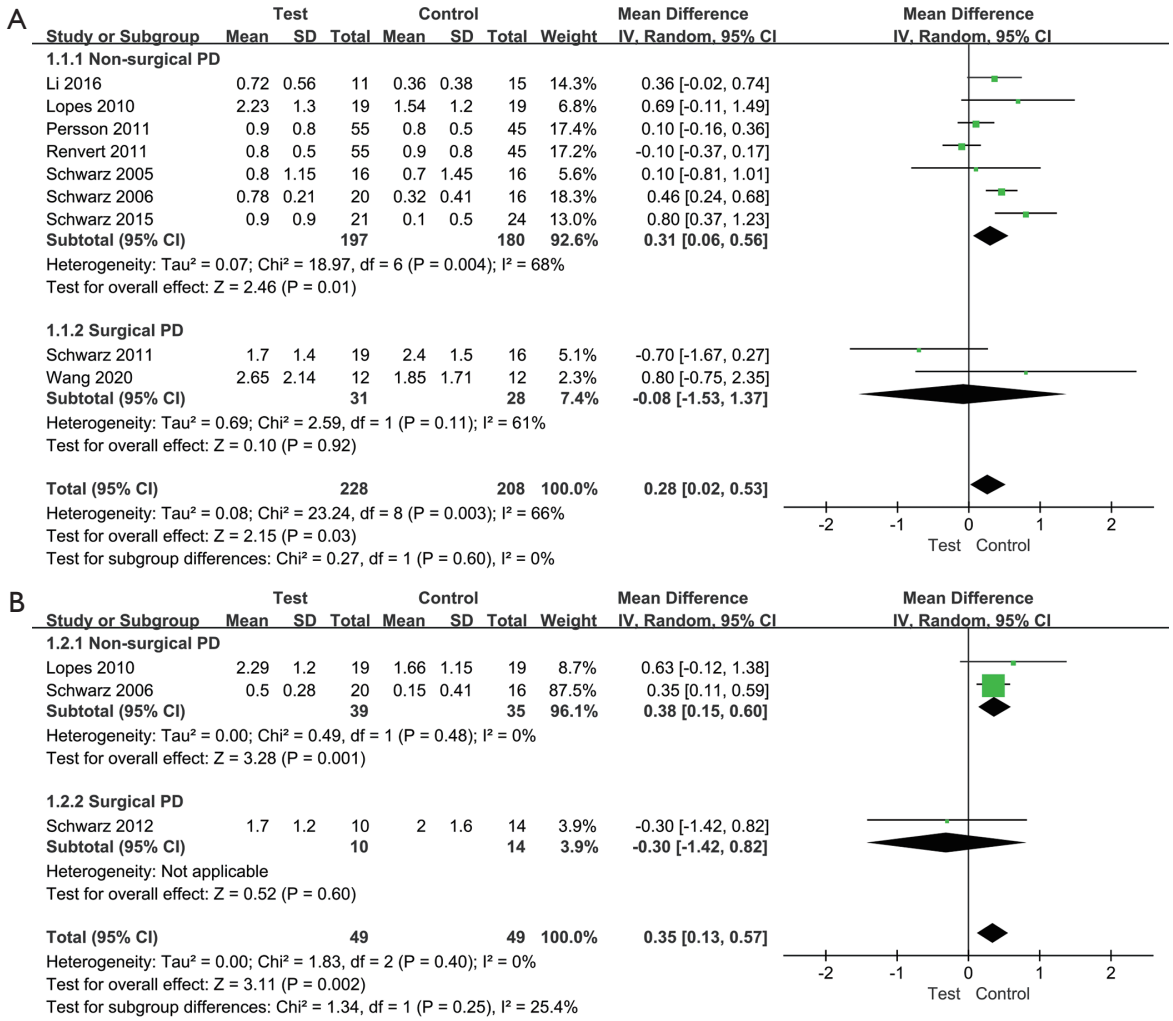


**Figure 3** Forest plot: Er:YAG laser versus conventional mechanical debridement for PD reduction. (A) At 6 months; (B) at 12 months. PD, probing depth.

### *Results of heterogeneity test*

Among the 10 trials, all studies had a follow-up period of 6 months, while 3 studies reported further outcomes at 12 months. Therefore, clinical outcomes in our study analyzed data relating to 6 and 12 months following treatment. In addition, 7 articles adopted non-surgical treatment approaches and surgery was used in the other 3 articles, so a subgroup analysis was conducted to compare the surgical and non-surgical groups.

### *PD*

At 6 months, the ERL group had a statistically greater PD reduction than the control group (MD 0.28, 95% CI: 0.02 to 0.53, P=0.03, random effect model, *Figure 3A*), and the included studies were all heterogeneous ($I^2$=66%, P=0.003). The pooled PD reduction between the two groups at 12 months showed similar results, with an MD of 0.35 (95% CI: 0.13 to 0.57, P=0.002, *Figure 3B*) and no significant heterogeneity ($I^2$=0%, P=0.40).

### *Clinical attachment level*

Six studies reported CAL changes at 6 months, while 3 studies report changes at 12 months. Meta-analysis showed that no significant differences were found at the 6-month evaluation of CAL (MD 0.17, 95% CI: –0.12 to

 

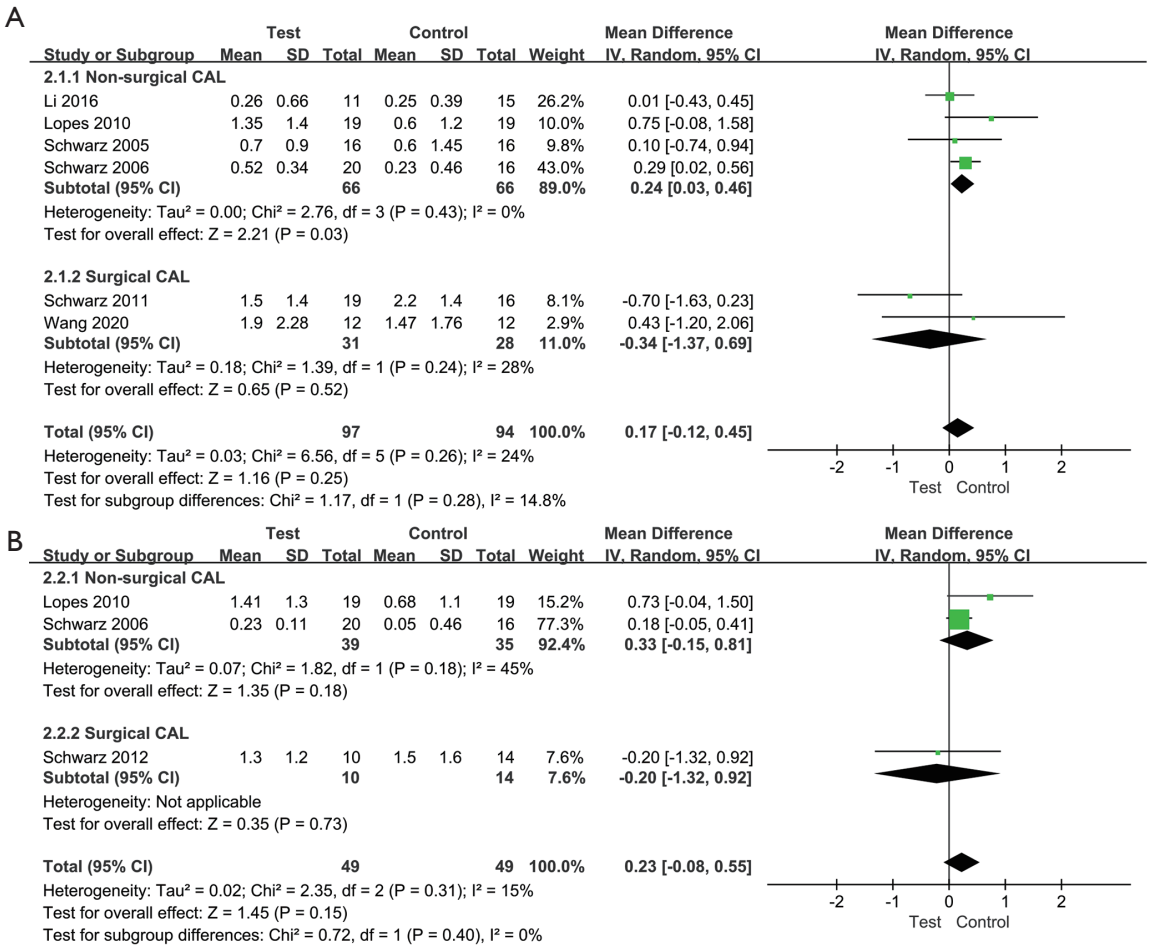


**Figure 4** Forest plot: Er:YAG laser versus conventional mechanical debridement for CAL improvement. (A) At 6 months; (B) at 12 months. CAL, clinical attachment level.

0.45, P=0.25, *Figure 4A*), and similar results was observed after 12 months (MD 0.23, 95% CI: −0.08 to 0.55, P=0.15, *Figure 4B*). There was no significant heterogeneity of the CAL assessments at 6 months (P=0.26, $I^2$=24%) or 12 months (P=0.31, $I^2$=15%).

### *PI*

Six studies reported the PI at 6 months following treatment and in 3 studies at 12 months post-treatment. A random effect model was used to evaluate the heterogeneity of the PI. The results showed no significant differences between the 2 groups at 6 months (MD =−0.02 with 95% CI: −0.17 to 0.13, P=0.75, *Figure 5A*) or 12 months (MD =−0.07 with 95% CI: −0.36 to 0.23, P=0.66, *Figure 5B*). No evidence of heterogeneity was found for the PI estimate, and the $I^2$ statistics were 14% at 6 months (P=0.32) and 0% at 12 months (P=0.73).

### *Bleeding on probing*

In the evaluation of BOP between the ERL and control groups, 6 articles involving 210 implants at 6 months and 3 articles involving 98 implants at 12 months were included. Each BOP was analyzed by a random effect model. The MD of BOP was 9.54% at 6 months, with 95% CI: −4.37% to 23.45% (P=0.18, *Figure 6A*), and 11.28% at 12 months, with 95% CI: −7.70% to 30.27% (P=0.24, *Figure 6B*). The pooled studies were heterogeneous (P=0.0005, $I^2$=77%, at 6 months; P=0.03, $I^2$=72%, at 12 months).

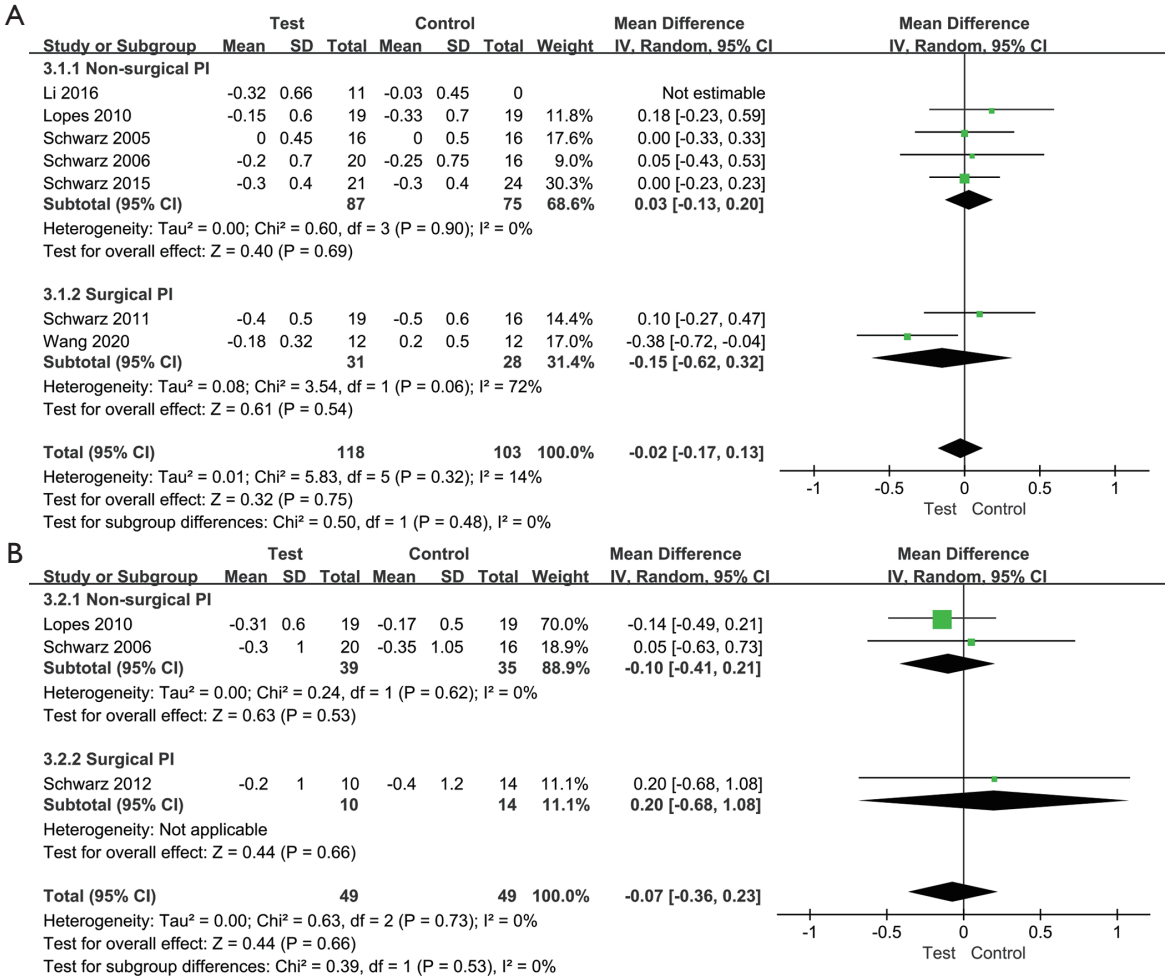


**Figure 5** Forest plot: Er:YAG laser versus conventional mechanical debridement for PI. (A) At 6 months; (B) at 12 months. PI, plaque index.

### *GR*

To analyze the differences in GR changes between the ERL and control groups, we performed a meta-analysis to calculate the overall MD using a random effect model based on heterogeneity analysis. The MD was −0.12 at 6 months with 95% CI (−0.23, −0.00), while the P value of the overall effect was 0.04, with no significant heterogeneity among the included studies (P=0.25, $I^2$=25%, *Figure 7A*). Similar results were obtained in the comparison of GR changes at 12 months, as the MD was −0.16 (95% CI: −0.31 to −0.02, P=0.03, *Figure 7B*) and without significant heterogeneity among the studies (P=0.84, $I^2$=0%).

### *Publication bias*

A funnel plot was drawn to qualitatively evaluate the publication bias for PD and CAL, with the shape of the funnel plots showing evidence of symmetry (*Figure 8*), while an Egger's test was nonsignificant (PD: P=0.65; CAL: P=0.73) and indicated no significant publication bias existed in our meta-analysis.

## Discussion

In recent years, different laser types have been used to treat peri-implantitis, either directly or assisted by conventional debridement (34,35). There are three varieties of laser which are used for this treatment, the solid-state laser, gas laser, and semiconductor laser (36-38). The application of laser therapy has many advantages, such as ease of operation, good hemostatic effects, and significant bactericidal effects on periodontal pathogens. It has been

 

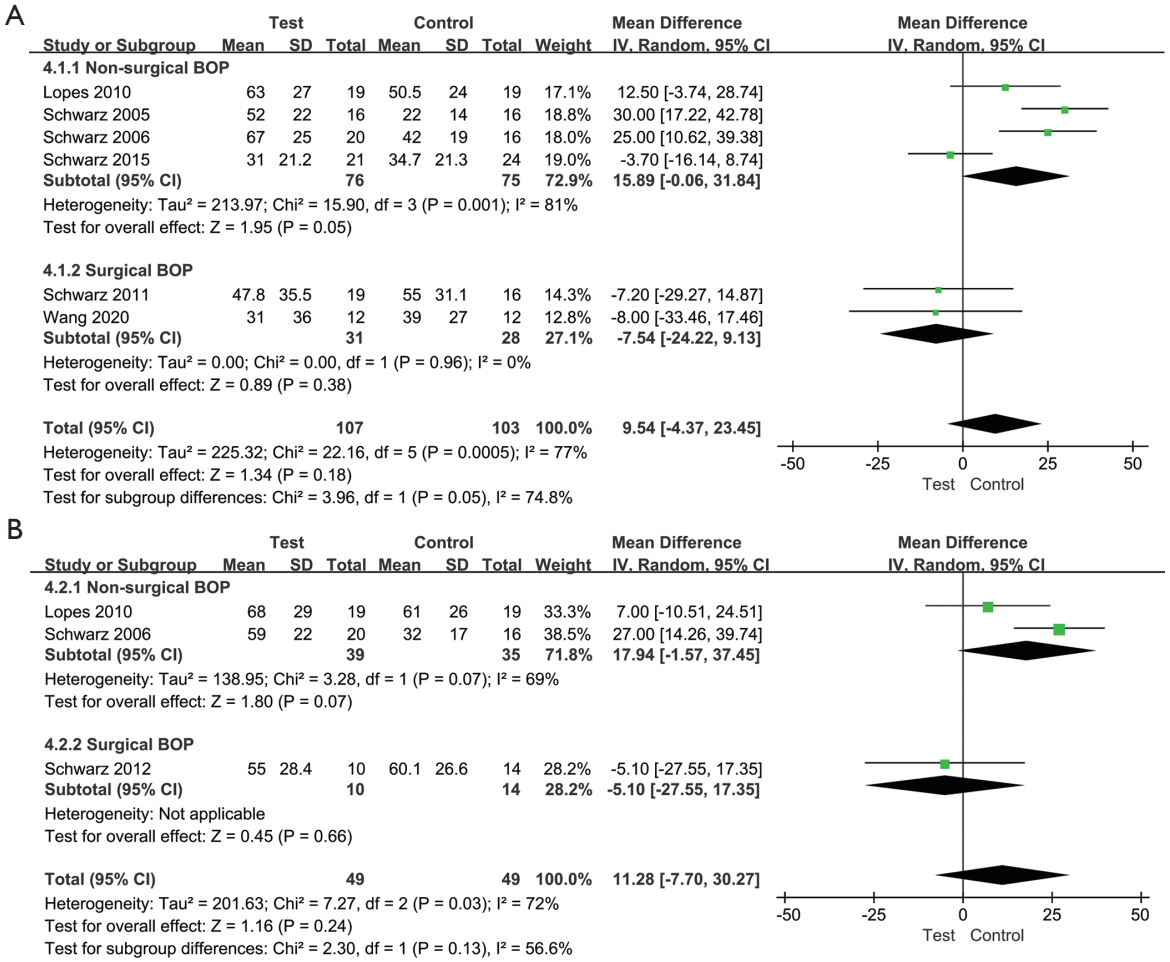


**Figure 6** Forest plot: Er:YAG laser versus conventional mechanical debridement for BOP reduction. (A) At 6 months; (B) at 12 months. BOP, bleeding on probing.

reported that use of lasers is conducive to the improvement of targeted therapeutic effects (39).

It has been reported that an Er:YAG laser had been used to irradiate the surface of a titanium implant (40,41), and it has been observed that if the power parameter was 30–200 mJ/pulse, the temperature of the implant surface could increase to 60 ℃ (42). It was also emphasized in the literature that longer follow-up clinical trials are needed to prove the clinical efficacy of Er:YAG lasers, and that the long-term clinical efficacy of Er:YAG lasers in the treatment of peri-implantitis was still unknown (43,44).

In our study, we compared the clinical efficacy of Er:YAG lasers and subgingival mechanical debridement in the treatment of peri-implantitis. The results of the meta-analysis showed that when compared with traditional mechanical debridement, ERL had no significant improvement in CAL (P=0.25 at 6 months, P=0.15 at 12 months) or reduction of BOP (P=0.18 at 6 months, P=0.24 at 12 months) or PI (P=0.75 at 6 months, P=0.66 at 12 months) when compared with the control group. However, with regards to PD reduction (P=0.03 at 6 months, P=0.002 at 12 months) and GR changes (P=0.04 at 6 months, P=0.03 at 12 months), the ERL group was shown to have greater advantages than the control group after periods of 6 and 12 months. Therefore, the results this study obtained can provide scientific and reliable bases for clinical workers in the selection of treatment options.

There were some limitations in this meta-analysis. For example, the lack of statistical differences may be due to an insufficient sample size. Furthermore, the inclusion criteria for each study were different, and the treatment designs of each trial were not completely identical, with 3 trials

 

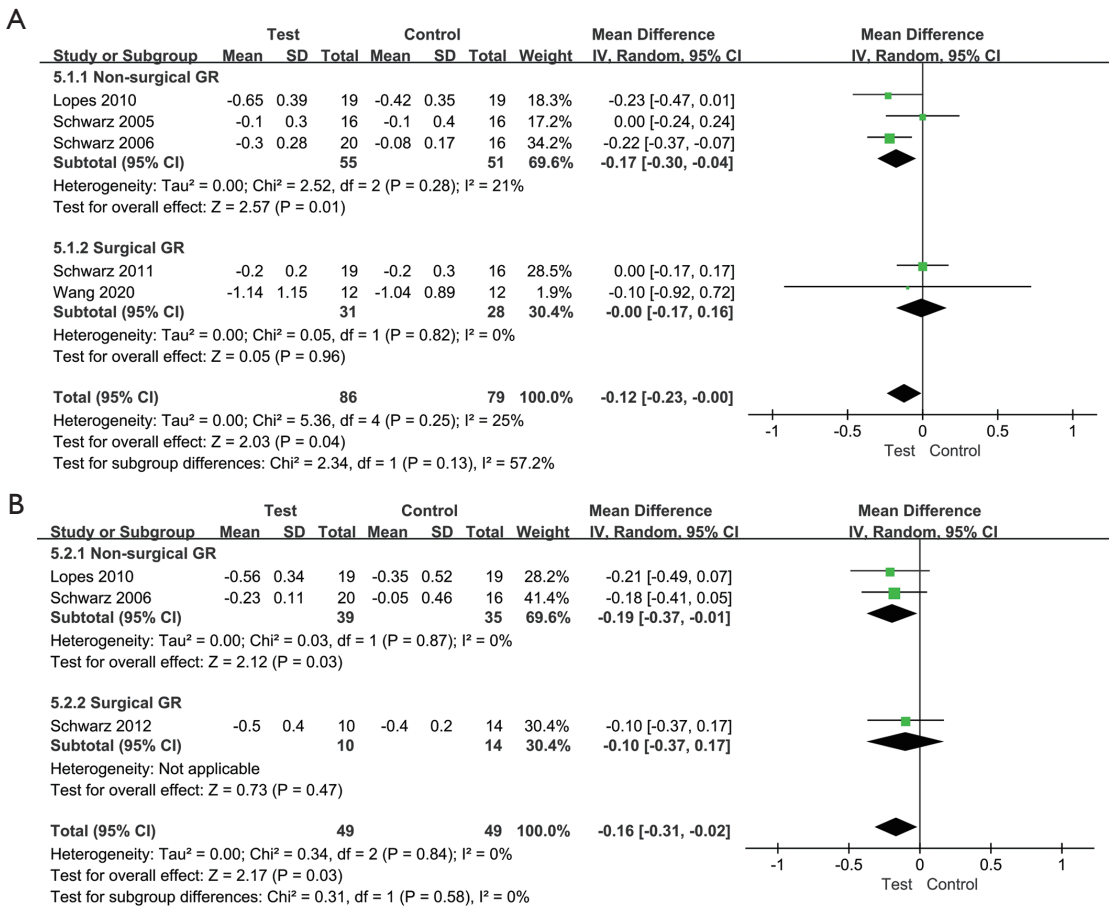


**Figure 7** Forest plot: Er:YAG laser versus conventional mechanical debridement for GR changes. (A) At 6 months; (B) at 12 months. GR, gingival recession.

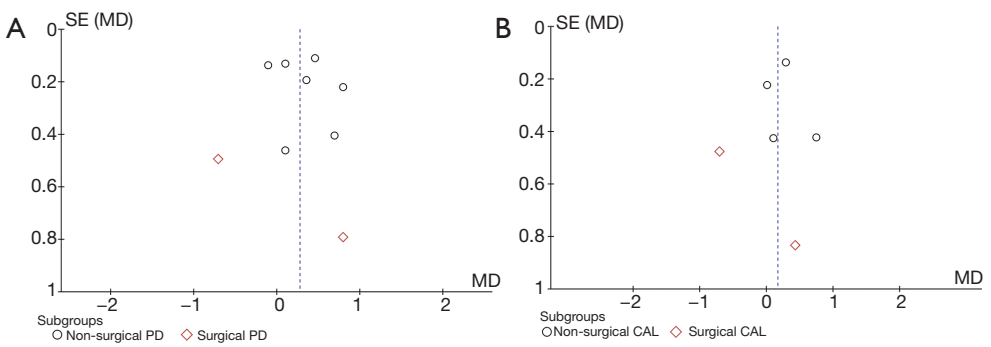


**Figure 8** Funnel plot of publication bias. (A) Er:YAG laser versus conventional mechanical debridement for PD reduction; (B) Er:YAG laser versus conventional mechanical debridement for CAL improvement. PD, probing depth; CAL, clinical attachment level.

combining surgical and non-surgical treatments. The brand and surface structure of the implant would affect bone re-bonding effects, which would affect the final results. In addition, there was no description of an economic benefit-cost ratio in any of the included studies.

In conclusion, Er:YAG laser use was superior to mechanical debridement in the treatment of peri-implantitis. Despite this conclusion and due to the limitations of the included studies, longer-term patient follow-ups, with high-quality, multi-center, large-sample randomized controlled trials are still needed, and studies which discuss economic benefit-cost ratios should be included to confirm the efficacy of Er:YAG lasers in the treatment of peri-implantitis.

## Acknowledgments

*Funding:* None.

## Footnote

*Reporting Checklist:* The authors have completed the PRISMA reporting checklist. Available at https://dx.doi.org/10.21037/apm-21-1853

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/apm-21-1853). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.



## References

1. Peri-implant mucositis and peri-implantitis: a current understanding of their diagnoses and clinical implications. J Periodontol 2013;84:436-43.
2. Renvert S, Polyzois I, Persson GR. Treatment modalities for peri-implant mucositis and peri-implantitis. Am J Dent 2013;26:313-8.
3. Schär D, Ramseier CA, Eick S, et al. Anti-infective therapy of peri-implantitis with adjunctive local drug delivery or photodynamic therapy: six-month outcomes of a prospective randomized clinical trial. Clin Oral Implants Res 2013;24:104-10.
4. Heitz-Mayfield LJ, Lang NP. Comparative biology of chronic and aggressive periodontitis vs. peri-implantitis. Periodontol 2000 2010;53:167-81.
5. Klinge B, Gustafsson A, Berglundh T. A systematic review of the effect of anti-infective therapy in the treatment of peri-implantitis. J Clin Periodontol 2002;29 Suppl 3:213-25; discussion 232-3.
6. Kotsakis GA, Konstantinidis I, Karoussis IK, et al. Systematic review and meta-analysis of the effect of various laser wavelengths in the treatment of peri-implantitis. J Periodontol 2014;85:1203-13.
7. Bassetti M, Schär D, Wicki B, et al. Anti-infective therapy of peri-implantitis with adjunctive local drug delivery or photodynamic therapy: 12-month outcomes of a randomized controlled clinical trial. Clin Oral Implants Res 2014;25:279-87.
8. Ashnagar S, Nowzari H, Nokhbatolfoghahaei H, et al. Laser treatment of peri-implantitis: a literature review. J Lasers Med Sci 2014;5:153-62.
9. Roos-Jansåker AM, Lindahl C, Persson GR, et al. Long-term stability of surgical bone regenerative procedures of peri-implantitis lesions in a prospective case-control study over 3 years. J Clin Periodontol 2011;38:590-7.
10. Mostafa D. Different laser approaches in treatment of peri-implantitis: a review. Lasers in Dental Science 2019;3:71-82.
11. Schwarz F, Sahm N, Becker J. Combined surgical therapy of advanced peri-implantitis lesions with concomitant soft tissue volume augmentation. A case series. Clin Oral Implants Res 2014;25:132-6.
12. Renvert S, Samuelsson E, Lindahl C, et al. Mechanical non-surgical treatment of peri-implantitis: a double-blind randomized longitudinal clinical study. I: clinical results. J Clin Periodontol 2009;36:604-9.
13. Natto ZS, Aladmawy M, Levi PA Jr, et al. Comparison of the efficacy of different types of lasers for the treatment of peri-implantitis: a systematic review. Int J Oral Maxillofac Implants 2015;30:338-45.
14. Schwarz GM, Harris DM. Laser-assisted treatment of

 

peri-implantitis: a retrospective cohort study. Gen Dent 2020;68:18-25.
15. Charalampakis G, Leonhardt Å, Rabe P, et al. Clinical and microbiological characteristics of peri-implantitis cases: a retrospective multicentre study. Clin Oral Implants Res 2012;23:1045-54.
16. Claffey N, Clarke E, Polyzois I, et al. Surgical treatment of peri-implantitis. J Clin Periodontol 2008;35:316-32.
17. Roncati M, Lucchese A, Carinci F. Non-surgical treatment of peri-implantitis with the adjunctive use of an 810-nm diode laser. J Indian Soc Periodontol 2013;17:812-5.
18. Arısan V, Karabuda ZC, Arıcı SV, et al. A randomized clinical trial of an adjunct diode laser application for the nonsurgical treatment of peri-implantitis. Photomed Laser Surg 2015;33:547-54.
19. Shibli JA. Is Laser the Best Choice for the Treatment of Peri-Implantitis? Photomed Laser Surg 2018;36:569-70.
20. Geisinger ML, Holmes CM, Vassilopoulos PJ, et al. Is Laser Disinfection an Effective Adjunctive Treatment to Bone Augmentation for Peri-Implantitis? A Review of Current Evidence. Clin Adv Periodontics 2014;4:274-9.
21. Linden E, Vitruk P. Implant-safe settings for SuperPulse 10,600 nm CO2 laser-assisted, closed flap peri-implantitis treatment. Practice 2015;8:1-4.
22. Drago L, Bortolin M, De Vecchi E, et al. Antibiofilm activity of sandblasted and laser-modified titanium against microorganisms isolated from peri-implantitis lesions. J Chemother 2016;28:383-9.
23. Schwarz F, Bieling K, Nuesry E, et al. Clinical and histological healing pattern of peri-implantitis lesions following non-surgical treatment with an Er:YAG laser. Lasers Surg Med 2006;38:663-71.
24. Li FZ, Xue F, Periodontics DO. Clinical effect evaluation of the application of Er:YAG laser to peri-implantitis. Journal of Prevention and Treatment for Stomatological Diseases 2016;6:303-306.
25. Lopes BM, Theodoro LH, Melo RF, et al. Clinical and microbiologic follow-up evaluations after non-surgical periodontal treatment with erbium:YAG laser and scaling and root planing. J Periodontol 2010;81:682-91.
26. Persson GR, Roos-Jansåker AM, Lindahl C, et al. Microbiologic results after non-surgical erbium-doped:yttrium, aluminum, and garnet laser or air-abrasive treatment of peri-implantitis: a randomized clinical trial. J Periodontol 2011;82:1267-78.
27. Renvert S, Lindahl C, Roos Jansåker AM, et al. Treatment of peri-implantitis using an Er:YAG laser or an air-abrasive device: a randomized clinical trial. J Clin Periodontol 2011;38:65-73.
28. Schwarz F, Bieling K, Bonsmann M, et al. Nonsurgical treatment of moderate and advanced periimplantitis lesions: a controlled clinical study. Clin Oral Investig 2006;10:279-88.
29. Schwarz F, John G, Hegewald A, et al. Non-surgical treatment of peri-implant mucositis and peri-implantitis at zirconia implants: a prospective case series. J Clin Periodontol 2015;42:783-8.
30. Schwarz F, John G, Mainusch S, et al. Combined surgical therapy of peri-implantitis evaluating two methods of surface debridement and decontamination. A two-year clinical follow up report. J Clin Periodontol 2012;39:789-97.
31. Schwarz F, Sahm N, Iglhaut G, et al. Impact of the method of surface debridement and decontamination on the clinical outcome following combined surgical therapy of peri-implantitis: a randomized controlled clinical study. J Clin Periodontol 2011;38:276-84.
32. Schwarz F, Sculean A, Rothamel D, et al. Clinical evaluation of an Er:YAG laser for nonsurgical treatment of peri-implantitis: a pilot study. Clin Oral Implants Res 2005;16:44-52.
33. Wang CW, Ashnagar S, Gianfilippo RD, et al. Laser-assisted regenerative surgical therapy for peri-implantitis: A randomized controlled clinical trial. J Periodontol 2021;92:378-88.
34. AlMoharib HS, Steffensen B, Zoukhri D, et al. Efficacy of an Er:YAG laser in the decontamination of dental implant surfaces: An in vitro study. J Periodontol 2021. [Epub ahead of print]. doi: 10.1002/JPER.20-0765.
35. Hultin M, Gustafsson A, Hallström H, et al. Microbiological findings and host response in patients with peri-implantitis. Clin Oral Implants Res 2002;13:349-58.
36. Chambrone L, Wang HL, Romanos GE. Antimicrobial photodynamic therapy for the treatment of periodontitis and peri-implantitis: An American Academy of Periodontology best evidence review. J Periodontol 2018;89:783-803.
37. Mombelli A, Feloutzis A, Brägger U, et al. Treatment of peri-implantitis by local delivery of tetracycline. Clinical, microbiological and radiological results. Clin Oral Implants Res 2001;12:287-94.
38. Persson GR, Samuelsson E, Lindahl C, et al. Mechanical non-surgical treatment of peri-implantitis: a single-blinded randomized longitudinal clinical study. II. Microbiological results. J Clin Periodontol 2010;37:563-73.
39. Badran Z, Bories C, Struillou X, et al. Er:YAG laser in

 

the clinical management of severe peri-implantitis: a case report. J Oral Implantol 2011;37 Spec No:212-7.
40. Heitz-Mayfield LJ, Mombelli A. The therapy of peri-implantitis: a systematic review. Int J Oral Maxillofac Implants 2014;29 Suppl:325-45.
41. Kotsovilis S, Karoussis IK, Trianti M, et al. Therapy of peri-implantitis: a systematic review. J Clin Periodontol 2008;35:621-9.
42. Gosau M, Hahnel S, Schwarz F, et al. Effect of six different peri-implantitis disinfection methods on in vivo human oral biofilm. Clin Oral Implants Res 2010;21:866-72.
43. Lin GH, Suárez López Del Amo F, Wang HL. Laser therapy for treatment of peri-implant mucositis and peri-implantitis: An American Academy of Periodontology best evidence review. J Periodontol 2018;89:766-82.
44. Kyung-Joong, Lee, Jong-Ho, et al. Laser therapy in peri-implantitis treatment: literature review. Journal of Dental Rehabilitation & Applied Science 2015;31:340-8.

(English Language Editors: J. Collie and J. Chapnick)

**Cite this article as:** Li L, Deng J, Ren S. The clinical efficacy of Er:YAG lasers in the treatment of peri-implantitis: a systematic review and meta-analysis. Ann Palliat Med 2021;10(8):9002-9014. doi: 10.21037/apm-21-1853

 