ORIGINAL ARTICLE

EFFECT OF LASERS ON DENTINE HYPERSENSITIVITY: EVIDENCE FROM A META-ANALYSIS

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ABSTRACT

Objectives

The aim of the study was to evaluate the immediate and long-term desensitizing effect of lasers in reducing dentine hypersensitivity (DH) compared with negative controls.

Material and methods

Six databases were searched to identify relevant articles published up to June 8, 2018. Randomized controlled trials comparing lasers with placebo or no treatment control in adult patients who suffer from DH were included. The risk of bias was assessed according to the Cochrane guidelines, and the quality of the evidence was evaluated using the Grading of Recommendations Assessment, Development and Evaluation tool. Inverse-variance random effects meta-analyses of standardized mean differences and 95% confidence intervals were performed using the RevMan 5.3 software.

Results

Twenty-two randomized controlled trials were finally included in the meta-analysis, and 21 studies of these were conducted to analyze the immediate and long-term effects. All types of lasers had better immediate and long-term desensitizing effects on DH than negative controls. The quality of evidence of the included studies showed that lasers compared with negative controls had moderate-quality immediate and long-term effects on DH. The statistical heterogeneity of these comparisons was high, for which the result of I^2 ranged from 90% to 98%.

Conclusions

Our results indicate that all types of lasers had a better desensitizing effect on DH than negative controls, both in immediate and long term. Furthermore, more high-quality studies with a large sample size are needed to confirm our results (PROSPERO CRD42018102260).

INTRODUCTION

Dentine hypersensitivity (DH) refers to the short and sharp pain in the exposed dentine in response to external stimuli, which cannot be ascribed to any other kinds of dental defects or pathology.[1] DH is an important and complicated oral health problem, and its prevention, diagnosis, and treatment have attracted great attention from researchers.[2] It is not an independent disease but a common

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symptom of many dental diseases.[3] DH has a negative effect on the quality of life associated with oral health, which causes discomfort in patients while eating, drinking, and even breathing.[4]

At present, the pathogenesis of DH is not clear. There are four theories about its etiology, but the most widely accepted one is the hydrodynamic theory that was proposed by Brannstrom and Astrom.[5] Based on this theory, the ideal DH treatment should be able to reduce fluid flow in the dentine tubules or block pulpy nerve impulses or both.[6] Laser was one of the methods to treat DH, which was first introduced in the mid 1980s.[7] Compared with other treatments, lasers are advantageous as they are simple to operate, are safe and reliable, and have a quick analgesic effect.[8,9] There are two main mechanisms for laser treatment of DH. The mechanism of high-energy laser, such as neodymium-doped yttrium aluminium garnet (Nd:YAG), erbium-doped yttrium aluminium garnet (Er:YAG), erbium, chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG), and CO_2, involves irradiation that causes the dentine tubules to melt and recrystallize to reduce or close dentine tubules, which reduces the effect of external stimulation in the dental pulp.[7] The mechanism of low-energy laser, such as diode laser, involves irradiation that causes the neurophysiological changes in the dentine tubules of the exposed area and reduces neurofibrillary response to stimulation.[10]

Some *in vivo* and *in vitro* studies have demonstrated the effectiveness of lasers in the treatment of DH.[8,11] However, some research studies have shown that there was no significant difference in the effect of desensitization between the laser treatment and placebo.[12–14] Some researchers think that the results of these studies are not enough to make a convincing conclusion.[15–17] Some previous systematic reviews using meta-analysis or network meta-analysis have questioned the efficacy of lasers for treatment of DH,[18,19] but there are some shortcomings in the included studies. The number of studies included in the aforementioned reviews is relatively small, and the check-time points selected for the study are the final follow-up time, without considering the comparison of immediate desensitization efficacy. In addition, in the systematic review of Lin et al.,[18] subgroup analysis for different kinds of lasers was not performed. A recently published systematic review only analyzed the efficacy of low-power lasers for the treatment of DH.[20] Therefore, a more comprehensive and updated systematic analysis needs to be conducted to study the effect of lasers on DH.

Based on these, the purpose of this study was to analyze all the up-to-date literature on the desensitization effect of lasers to determine whether there is sufficient evidence to support their immediate and long-term effects on DH relative to negative controls.

MATERIALS AND METHODS

This meta-analysis was carried out according to the recommendations of the Cochrane Collaboration[21] and the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement[22] and is registered in PROSPERO (CRD42018102260).

Search Strategy

The first author searched for relevant studies in the six databases PubMed, EMBASE, the Web of Science, CENTRAL (Cochrane Library), China National Knowledge Infrastructure, and the Chinese Biomedical Literature Database without any limitations, from their inception up to June 8, 2018. The search strategy was to identify all the English- and Chinese-language articles on the clinical efficacy of lasers in the treatment of DH.

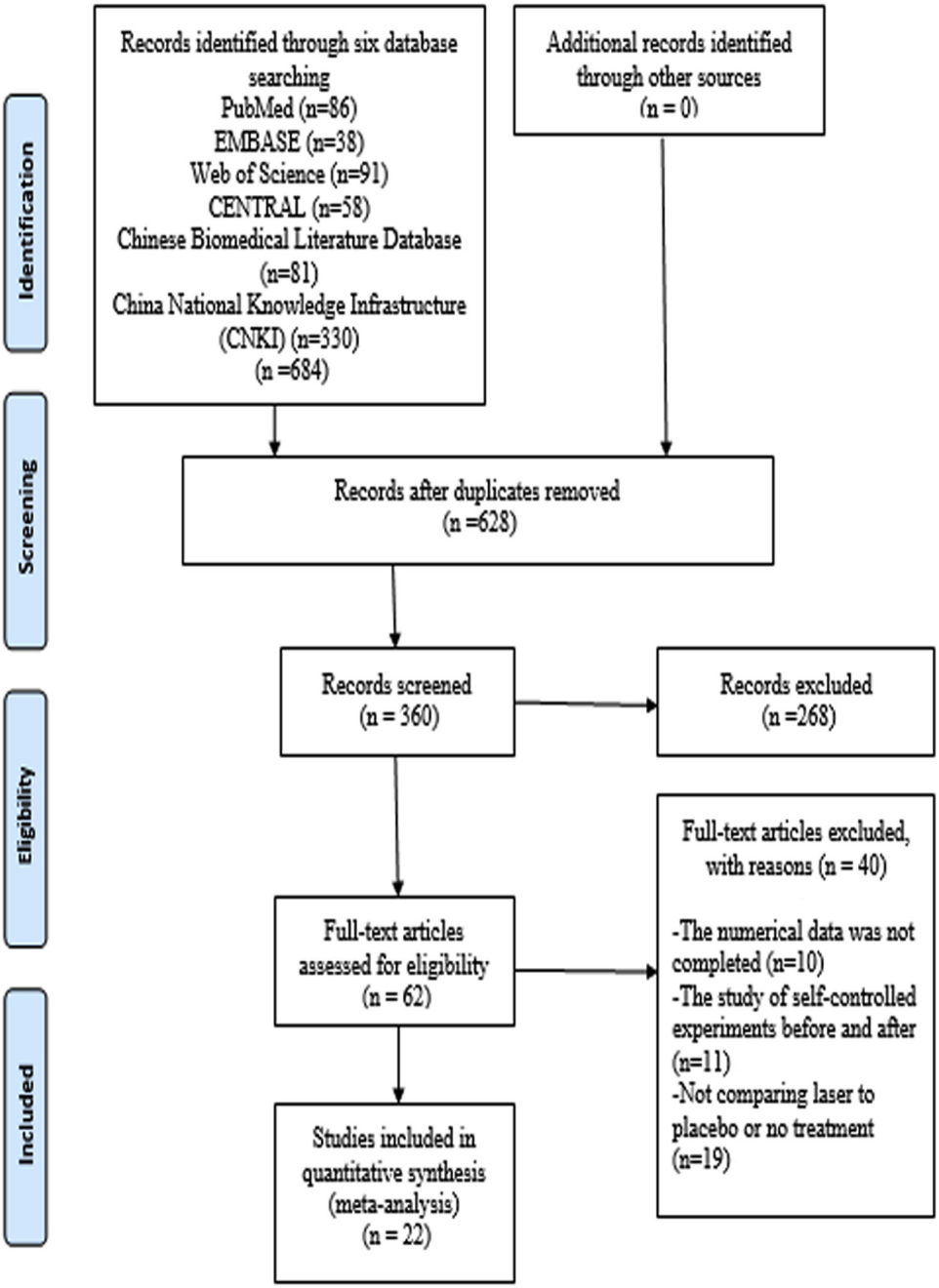
We used the following combined text and MeSH terms to search for relevant articles in databases: "lasers" and "dentine hypersensitivity". For better readability, the complete search strategy of these databases is presented in the appendix. The first author complements the manual search by looking up the reference list of relevant papers and review articles.

Study Selection and Data Extraction

We regarded studies as eligible for inclusion if they were randomized, controlled clinical trials that had intervention and control groups comprising adult participants and evaluated the effect of lasers on DH. The articles were selected according to the selection criteria of PICOS: (1) Patient: adult DH sufferers; (2) Intervention: laser treatment, there were no limits on power, frequency, intervention period, or management method; (3) Comparator: placebo or no treatment controls; (4) Outcomes: air-blast test score (visual analog scale [VAS], Verbal Rating Scale [VRS], or other scales); (5) Studies: randomized controlled trials. Animal experiments, *in vitro* studies, unpublished materials, and review papers were excluded. To reduce the deviation in personal filtering of articles and in data extraction, two authors independently filtered the study titles and abstracts and searched for studies that met inclusion criteria for full-text evaluation. Any disagreements between the two authors can be resolved by consulting a third colleague. The study selected for detailed analysis and data extraction was tested by two investigators as per protocol, and the differences were resolved by a third investigator.

From the studies included in the final analysis, we extracted the following data: the name of first author of the study, publication year, country, number of participants, details of

Figure 1. Flow diagram of identification of relevant trials. CNKI, China National Knowledge Infrastructure.



intervention and control groups, the first and final check-time points of the follow-up period, assessment methods, and the values of test scores in both the intervention and control groups. We extracted data from the first and final evaluations, which indicate the immediate and long-term desensitization effects on DH after the laser treatment.

Risk of Bias and Assessment of the Quality of Evidence

Two independent reviewers assessed the quality of the individual studies using the Cochrane collaboration tool to evaluate the risk of bias in the following areas: random sequence generation, allocation concealment, blinding of

Table 1. Characteristics of randomized controlled clinical trials included in the final analysis (n = 22).

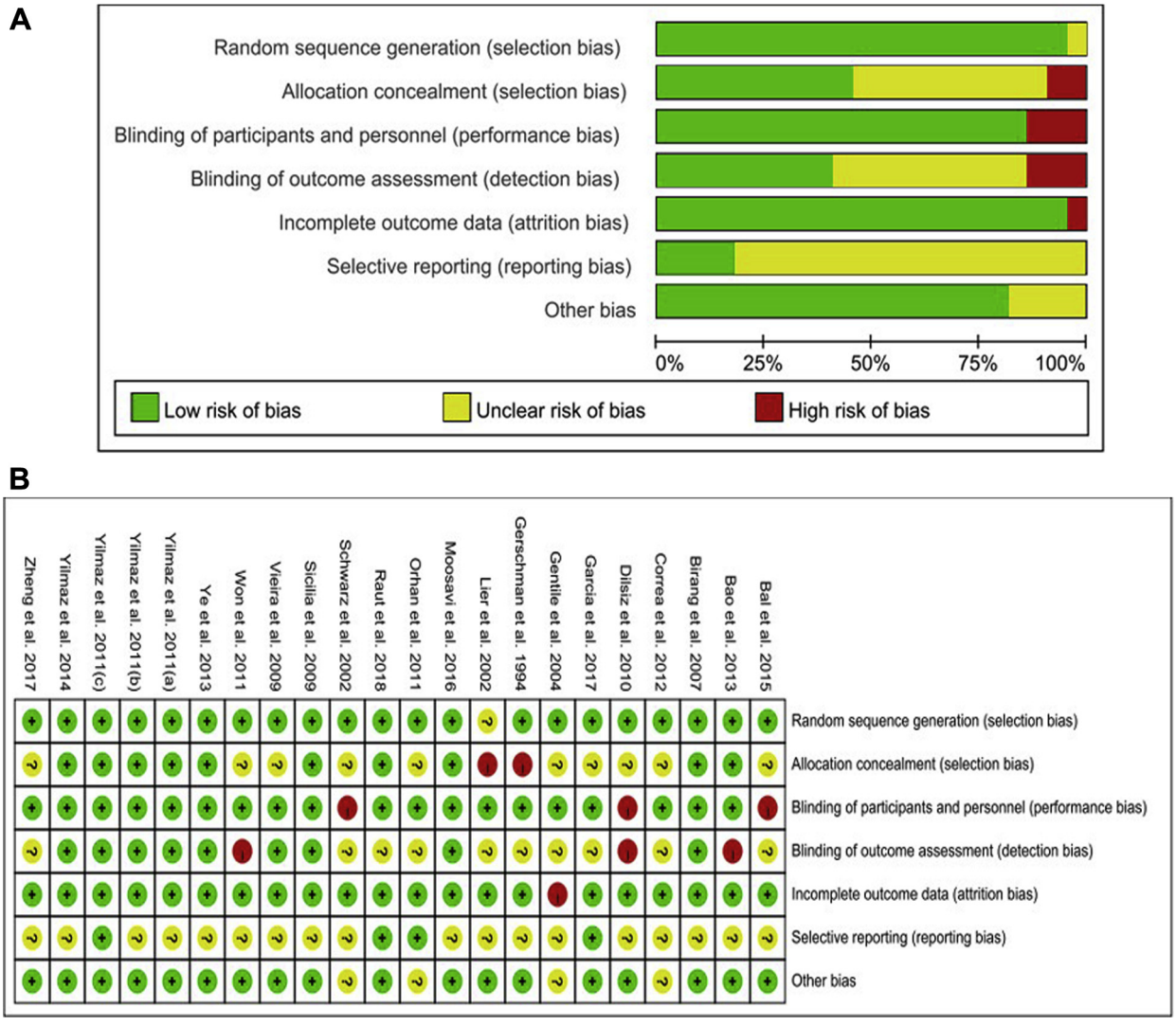
First author of study	Year	Country	Intervention	Control	Unit of randomization	First follow-up time	Final follow-up time	Pain score type
GaAlAs vs placebo or no treatment								
Gerschman et al.	1994	Australia	830 nm, 30 mW, 1.8 J, 60 sec	Placebo	Patient	Immediate	3 months	VAS (0-10)
Gentile et al.	2004	Brazil	670 nm, 15 mW, 120 sec	Placebo	Tooth	–	6 weeks	VAS (0-10)
Vieira et al.	2009	Brazil	660 nm, 30 mW, 120 sec	Placebo	Tooth	Immediate	3 months	VAS (0-10)
Sicilia et al.	2009	Spain	810 nm, 1.5-2.5 mW, 60 sec	Placebo	Patient	15 minutes	2 months	VRS (0-3)
Dilsiz et al.	2010	Turkey	808 nm, 100 mW, 20 sec	No treatment	Tooth	30 minutes	2 months	VAS (0-10)
Yilmaz et al.	2011(a)	Turkey	810 nm, 8.5 J/cm^2, 60 sec	No treatment	Tooth	Immediate	3 months	VAS (0-10)
Yilmaz et al.	2011(b)	Turkey	810 nm, 500 mW, 60 sec	Placebo	Tooth	Immediate	6 months	VAS (0-10)
Won et al.	2011	Korea	904 nm, 0.4 J, 1000 Hz, 3 min	Placebo	Tooth	1 week	4 weeks	VAS (0-100)
Orhan et al.	2011	Turkey	655 nm, 25 mW, 160 sec	Placebo	Tooth	1 day	1 week	VAS (0-100)
Moosavi et al.	2016	Iran	810 nm, 200 mW, 3 J	Placebo	Patient	Immediate	2 days	VAS (0-100)
Nd:YAG vs placebo or no treatment								
Lier et al.	2002	Norway	4W, 120 sec	Placebo	Tooth	Immediate	16 weeks	VAS (0-10)
Birang et al.	2007	Iran	1W, 15 Hz, 60 sec	Placebo	Tooth	Immediate	6 months	VAS (0-5)
Dilsiz et al.	2010	Turkey	1064 nm, 100 mJ/pulse, 15 Hz, 100 sec	No treatment	Tooth	30 minutes	2 months	VAS (0-10)
Bao et al.	2013	China	1064 nm, 180 mJ/pulse, 10 Hz, 5 sec	Placebo	Patient	30 minutes	6 months	VAS (0-10)
Zheng et al.	2017	China	1064 nm, 135 J/cm^2, 5 Hz, 60 sec	Placebo	Patient	10 minutes	3 months	VAS (0-100)
Er:YAG vs placebo or no treatment								

(continued)

Schwarz et al.	2002	Germany	80 mJ/pulse, 3 Hz, 2 min	No treatment	Tooth	Immediate	6 months	1—4
Birang et al.	2007	Iran	100 mJ, 3 Hz, 60 s	Placebo	Tooth	Immediate	6 months	VAS (0-5)
Dilsiz et al.	2010	Turkey	2940 nm, 60 mJ/pulse, 2 Hz, 20 sec	No treatment	Tooth	30 minutes	2 months	VAS (0-10)
Correa et al.	2012	Brazil	32.4 mJ, 64.8 mW, 2 Hz, 80 sec	Placebo	Patient	Immediate	1 month	VAS (0-100)
Ye et al.	2013	China	10W, 20 Hz, 5 sec	Placebo	Tooth	Immediate	3 months	VAS (0-10)
Er,Cr:YSSG vs placebo or no treatment								
Yilmaz et al.	2011(a)	Turkey	2780 nm, 0.25 W, 30 sec	No treatment	Tooth	Immediate	3 months	VAS (0-10)
Yilmaz et al.	2011(c)	Turkey	0.25 W, 20 kHz, 30 sec	Placebo	Patient	Immediate	3 months	VAS (0-10)
Correa et al.	2012(1)	Brazil	0.278 µm, 0.25 W, 20 Hz, 30 sec	Placebo	Patient	Immediate	1 month	VAS (0-100)
Correa et al.	2012(2)	Brazil	0.278 µm, 0.5 W, 20 Hz, 30 sec	Placebo	Patient	Immediate	1 month	VAS (0-100)
Yilmaz et al.	2014(1)	Turkey	2780 nm, 0.25 W, 30 sec	Placebo	Tooth	Immediate	–	VAS (0-10)
Yilmaz et al.	2014(2)	Turkey	2780 nm, 0.5 W, 30 sec	Placebo	Tooth	Immediate	–	VAS (0-10)
Diode vs placebo or no treatment								
Bal et al.	2015	Turkey	685 nm, 25 mW, 9 Hz, 100 sec	No treatment	Tooth	Immediate	3 months	VAS (0-100)
Moosavi et al.	2016	Iran	660 nm, 200 mW, 15 sec	Placebo	Patient	Immediate	2 days	VAS (0-100)
Garcia et al.	2017	Spain	660 nm, 200 mW, 60 sec	Placebo	Tooth	Immediate	2 months	VAS (0-100)
Raut et al.	2018	India	940 nm. 0.8 W, 80 sec	Placebo	Tooth	15 minutes	1 month	VAS (0-10)

Er,Cr:YSGG, erbium, chromium: yttrium-scandium-gallium-garnet; Er:YAG, erbium-doped yttrium aluminium garnet; GaAlAs, gallium-aluminum-arsenide; Nd:YAG, neodymium-doped yttrium aluminium garnet; VAS, visual analog scale; VRS, Verbal Rating Scale.

Figure 2. The risk for bias graph (A) and summary (B) of the final included trials.



participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias. The disagreements were resolved through discussion and consultation with a third auditor when necessary. We estimated that a study had a low risk of bias when all areas were at low risk, a moderate risk of bias when one or more areas were at risk of uncertain bias or nonbias, and a high risk of bias when one or more areas were at high risk.[23] We assessed the quality of evidence for the prime outcomes of selected studies by using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) tool. This technique is used to determine the overall strength of each meta-analysis.

Statistical Analysis

We assessed the effect of laser treatment on DH using the air or tactile test score at the first and final follow-up periods. The meta-analysis was performed only when adequate similarity was found between the studies. We chose the standardized mean difference (SMD) with 95% confidence interval to evaluate differences in the effects of lasers on DH.[24] To combine data of different scales, the mean difference method is proposed.[25] The standard deviation of each study was used to calculate SMDs that could be compared across studies. The I^2 test was used to evaluate the heterogeneity of the size of the study, and a value >50% was considered to indicate moderate to high

Figure 3. Funnel plots of the long-term (A) and immediate (B) effects of lasers on DH compared with negative controls. CI, confidence interval; DH, dentine hypersensitivity; Er,Cr:YSGG, erbium, chromium: yttrium-scandium-gallium-garnet; Er:YAG, erbium-doped yttrium aluminium garnet; GaAlAs, gallium-aluminum-arsenide; Nd:YAG, neodymium-doped yttrium aluminium garnet; SE, standard error; SMD, standard mean difference.

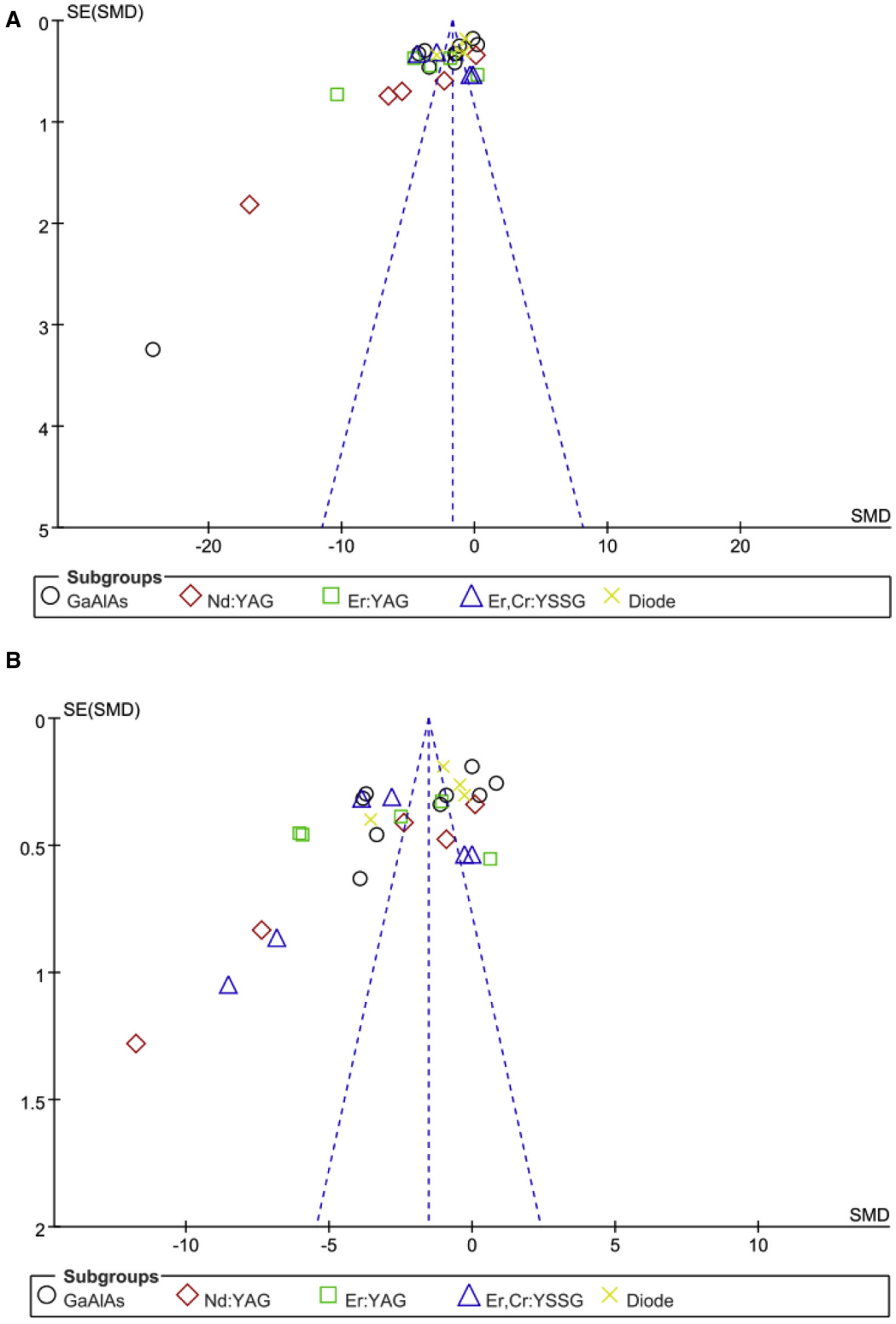


Table 2. GRADE summary of randomized controlled clinical trials included in the analysis of immediate outcomes (n = 21).

Certainty assessment							No. of patients		Effect		
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Lasers	Negative	Absolute (95% CI)	Certainty	Importance
Lasers vs negative											
29	Randomized trials	Serious[a]	Not serious	Not serious	Not serious	None	887	864	SMD 2.6 lower (3.34 lower to 1.85 lower)	⊕⊕⊕◯ Moderate	Critical
GaAlAs lasers vs negative											
9	Randomized trials	Serious[a]	Not serious	Not serious	Not serious	None	322	318	SMD 1.71 lower (2.95 lower to 0.48 lower)	⊕⊕⊕◯ Moderate	Critical
Nd:YAG lasers vs negative											
5	Randomized trials	Serious[a]	Not serious	Not serious	Not serious	None	96	96	SMD 4.21 lower (6.95 lower to 1.47 lower)	⊕⊕⊕◯ Moderate	Critical
Er:YAG lasers vs negative											
5	Randomized trials	Serious[a]	Not serious	Not serious	Not serious	None	159	159	SMD 2.96 lower (5.34 lower to 0.58 lower)	⊕⊕⊕◯ Moderate	Critical
Er,Cr:YSSG lasers vs negative											
6	Randomized trials	Not serious	Not serious	Not serious	Not serious	None	154	154	SMD 3.55 lower (5.39 lower to 1.71 lower)	⊕⊕⊕⊕ High	Critical
Diode lasers vs negative											
4	Randomized trials	Serious[a]	Not serious	Not serious	Serious[b]	None	156	137	SMD 1.26 lower (2.39 lower to 0.14 lower)	⊕⊕◯◯ Low	Important

CI, confidence interval; Er,Cr:YSGG, erbium, chromium: yttrium-scandium-gallium-garnet; Er:YAG, erbium-doped yttrium aluminium garnet; GaAlAs, gallium-aluminum-arsenide; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; Nd:YAG, neodymium-doped yttrium aluminium garnet; SMD, standardized mean difference.
[a] The assessment of risk of bias revealed that over half of the studies had a moderate risk or high risk.
[b] The sample size of the study is small, and the number of participants is small.

Table 3. GRADE summary of randomized controlled clinical trials included in the final analysis of long-term outcomes (n = 21).

Certainty assessment							No. of patients		Effect		
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Lasers	Negative	Absolute (95% CI)	Certainty	Importance
Lasers vs negative											
28	Randomized trials	Serious[a]	Not serious	Not serious	Not serious	None	882	842	SMD 2.92 lower (3.66 lower to 2.17 lower)	⊕⊕⊕◯ Moderate	Critical
GaAlAs lasers vs negative											
10	Randomized trials	Serious[a]	Not serious	Not serious	Not serious	None	357	336	SMD 2.4 lower (3.54 lower to 1.26 lower)	⊕⊕⊕◯ Moderate	Critical
Nd:YAG lasers vs negative											
5	Randomized trials	Serious[a]	Not serious	Not serious	Not serious	None	96	96	SMD 5.87 lower (9.52 lower to 2.22 lower)	⊕⊕⊕◯ Moderate	Critical
Er:YAG lasers vs negative											
5	Randomized trials	Serious[a]	Not serious	Not serious	Not serious	None	159	159	SMD 3.91 lower (6.51 lower to 1.3 lower)	⊕⊕⊕◯ Moderate	Important
Er,Cr:YSSG lasers vs negative											
4	Randomized trials	Not serious	Not serious	Not serious	Serious[b]	None	114	114	SMD 1.95 lower (3.8 lower to 0.1 lower)	⊕⊕⊕◯ Moderate	Important
Diode lasers vs negative											
4	Randomized trials	Serious[a]	Not serious	Not serious	Serious[b]	None	156	137	SMD 1.35 lower (2.21 lower to 0.49 lower)	⊕⊕◯◯ Low	Important

CI, confidence interval; Er,Cr:YSGG, erbium, chromium: yttrium-scandium-gallium-garnet; Er:YAG, erbium-doped yttrium aluminium garnet; GaAlAs, gallium-aluminum-arsenide; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; Nd:YAG, neodymium-doped yttrium aluminium garnet; SMD, standardized mean difference.
[a] The assessment of risk of bias revealed that over half of the studies had a moderate or high risk.
[b] The sample size of the study is small, and the number of participants is small.

Figure 4. Forest plot of the long-term (A) and immediate (B) effects of lasers on DH compared with negative controls. CI, confidence interval; DH, dentine hypersensitivity Er,Cr:YSGG, erbium, chromium: yttrium-scandium-gallium-garnet; Er:YAG, erbium-doped yttrium aluminium garnet; GaAlAs, gallium-aluminum-arsenide; Nd:YAG, neodymium-doped yttrium aluminium garnet; SD, standard deviation.

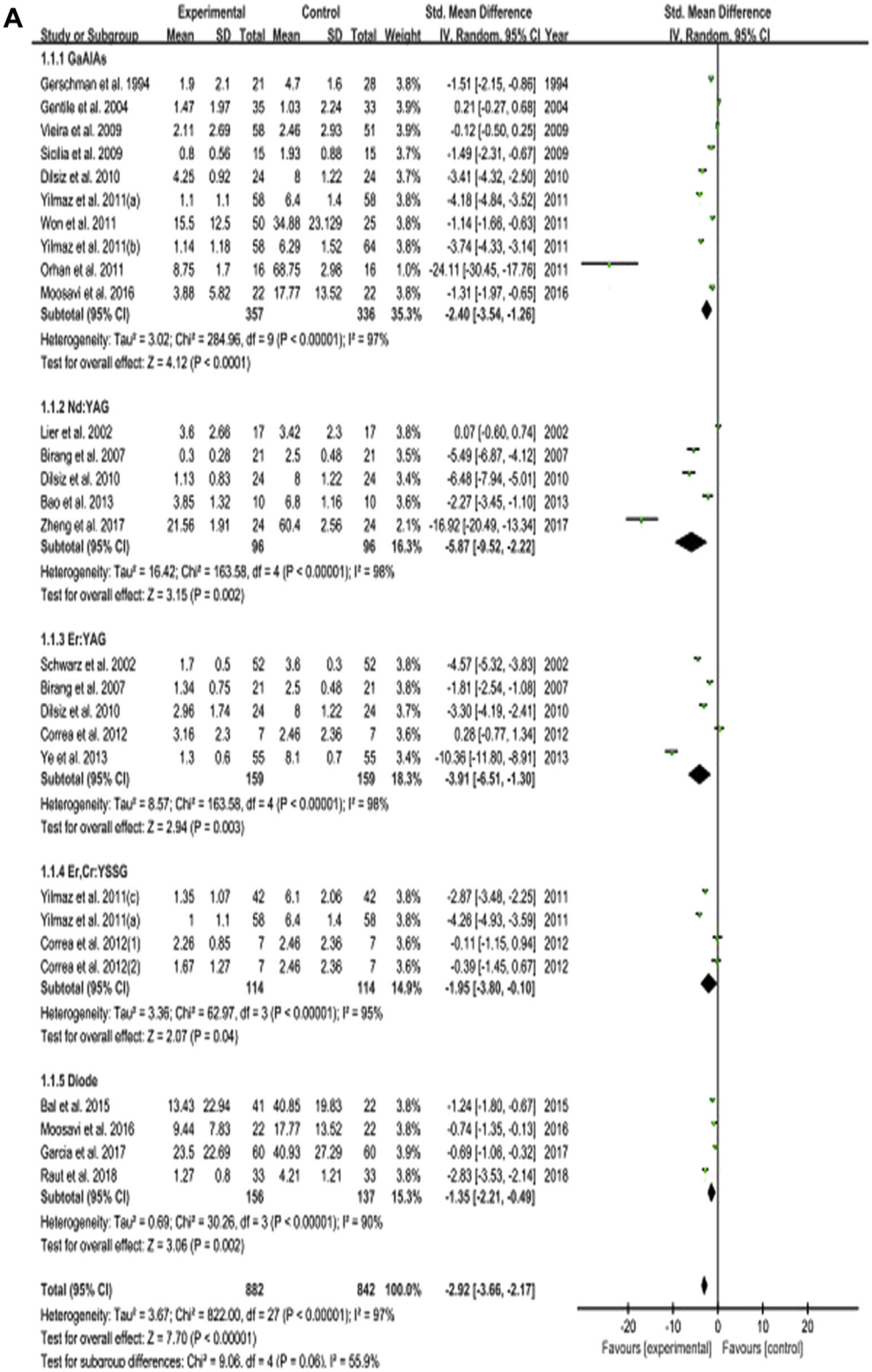
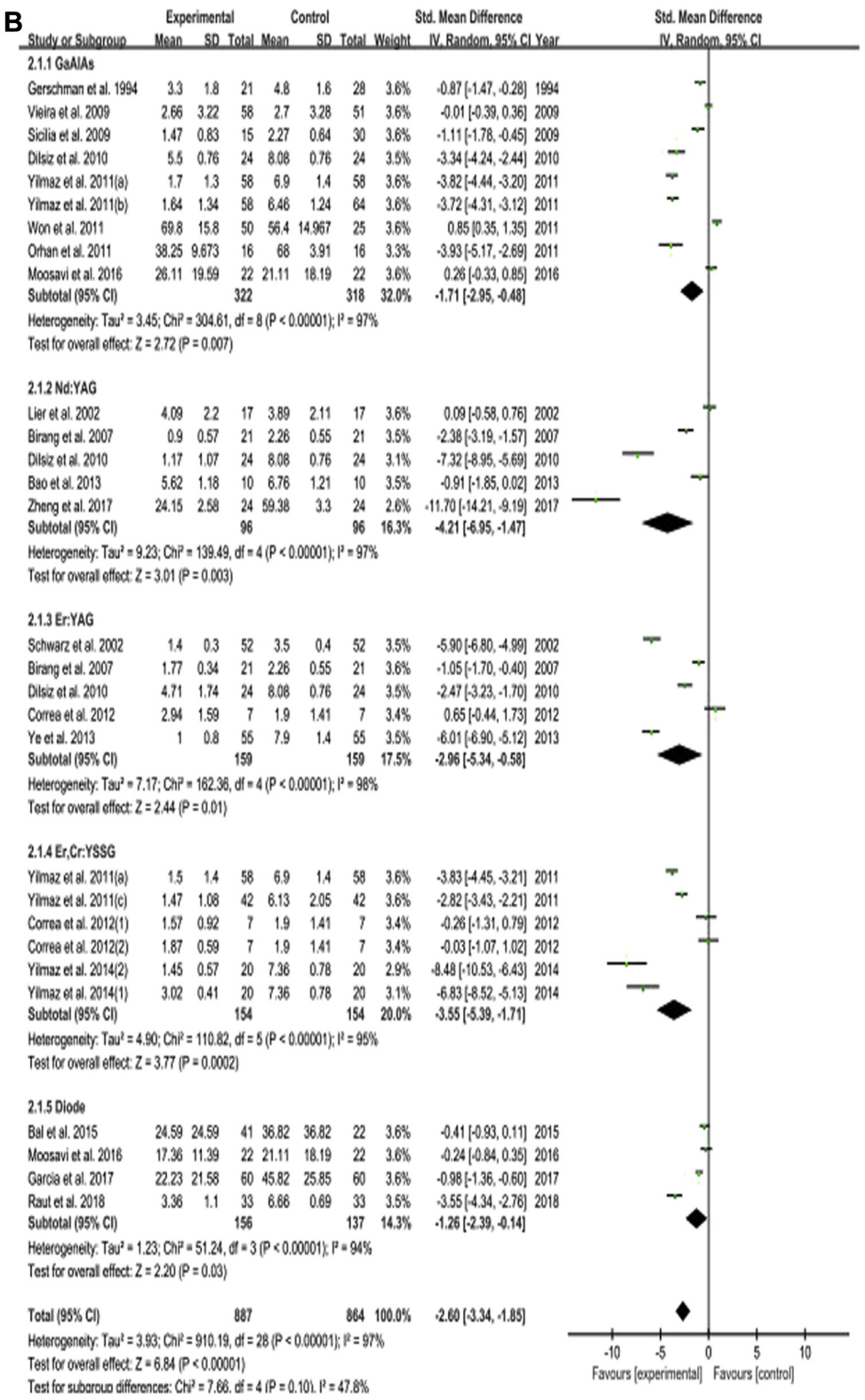


Figure 4. (*continued*).



heterogeneity.[26] All the SMDs and 95% confidence intervals were calculated on the basis of the random effects model. Funnel plots were used to evaluate the possibility of publication bias. Data were analyzed using the RevMan 5.3 software (Nordic Cochrane Center, Cochrane Collaboration, Copenhagen, Denmark).

RESULTS

Study Selection

After searching six databases and manually searching the relevant bibliographies, 684 articles were selected, from which 56 were removed due to duplication. After filtering the titles and abstracts, 566 articles did not meet the inclusion criteria and were removed. We reviewed the full text of the remaining 62 articles, after which 40 were excluded according to the predetermined criteria (Fig. 1). We included 22 studies in the final quantitative analysis, and characteristics of these were listed in Table 1.

Description of Included Studies

All the final included studies that compare one type of laser with placebo or no treatment control on immediate and long-term effects on DH, which included gallium-aluminum-arsenide (GaAlAs), Nd:YAG, Er:YAG, Er,Cr:YSSG, and diode laser. The 22 final included articles were full reports published between 1994 and 2018: 17 of them were published in the recent 10 years and 6 of them were published in the recent 5 years.

These studies were conducted in the following countries: Turkey ($n = 7$),[27–33] Brazil ($n = 3$),[12,14,34] China ($n = 3$),[35–37] Iran ($n = 2$),[11,38] Spain ($n = 2$),[39,40] Australia ($n = 1$),[41] Norway ($n = 1$),[13] Germany ($n = 1$),[42] Korea ($n = 1$),[43] and India ($n = 1$).[44]

In the final included 22 studies, the follow-up time ranged from immediately after treatment to 6 months. When evaluating the immediate desensitization effect of lasers, the follow-up time ranged from immediately after treatment to 30 minutes, except in the studies by Won Tae-Hee and Kim Ki-Suk[43] and Orhan et al.[30] in which the follow-up time ranges from immediately after treatment to 1 week and 1 day, respectively. The follow-up time ranged from 4 weeks to 6 months when evaluating the long-term desensitization effect of lasers, except in the studies by Orhan et al.[30] and Moosavi et al.[38] in which the follow-up duration was 1 week and 2 days, respectively. Among these final included studies, the study by Yilmaz and Bayindir[32] just had immediate outcomes and the study by Gentile and Greghi[12] just had long-term outcomes of the desensitization effect of laser treatment.

The methods used to diagnose DH were different among the final included studies, which included cold stimulation, heat stimulation, and tactile stimulation. The cold stimulation, which involves a syringe air blast, was the most widely used method among these studies. DH was quantified using different scales (VAS [0–10], VAS [0–100], VRS [0-3], numeric rating scale [0–10], and other scales), with VAS being the most commonly used.

Risk of Bias Assessment and Evidence Grading

The assessment of risk of bias revealed that only 1 study had a low risk, 13 had a moderate risk, and the remaining 8 had a high risk (Fig. 2). The publication bias is displayed by means of funnel plots (Fig. 3). The quality of evidence of the included studies showed that lasers compared with placebo or no treatment had moderate-quality immediate and long-term effects on DH; the details of the quality of the included studies are showed in Table 2-3.

Result of Individual Studies and Synthesis of Results

The results showed that all types of lasers had better immediate and long-term desensitizing effects on DH than negative controls (Fig. 4). The statistical heterogeneity of these comparisons was high, which is reflected in the results of the I^2 test that ranged from 90% to 98%.

DISCUSSION

Researches indicated that DH has a profound impact on the quality of life of patients.[4,45] At present, various types of lasers are available in clinics to treat this condition. Over the years, however, some researchers have questioned the validity of the evidence of its effectiveness.[7]

This study attempted to analyze all published clinical trials to assess evidence for immediate and long-term effects of laser treatment on DH relative to negative controls. There are a number of problems associated with evaluating the effect of these lasers on DH, such as the pain as a result of DH is an individual and subjective symptom which varies from person to person. An objective evaluation method may not be feasible, and currently, various pain assessment scales, such as the VAS and VRS, are used to evaluate the degree of pain in DH, but there is no "gold standard" scale. The VRS is a scale used to measure pain of the patient, with 0 to 3 representing varying degrees of pain. Some researchers prefer to use the VAS, in which the patients mark their pain on a straight line of 10 or 100 cm in length, from painless to unbearably painful.[46] The VAS method provides more accurate results, but it is more complex to use and has higher error rates, especially in older patients.[47] We used the SMD to combine data of different scales and make comparisons between studies.[48] The parameters or settings of lasers varied greatly from study to study. However, there are no standard parameters of lasers, and only few studies investigated the lasers with the same parameters or settings. Therefore, there is no definite limitation on the parameters of lasers in this review. Of course,

we also should known that different parameters or settings of lasers can affect the treatment effect of DH.[49,50] Besides, it is important to choose the appropriate wavelength, power, and irradiation time of lasers for safe laser treatment.[39] Improper parameters or settings of lasers can lead to potential tissue damage, which included thermal damage on the irradiated surface, gingival tissue, pulp, and adjacent bones.[17]

The placebo effect also affects the evaluation of the desensitization effect of the laser. Several studies showed that a placebo group can also provide significant improvement in relief of DH, and any meaningful differences between the experimental and placebo groups may be masked.[51] The final follow-up time of DH clinical trials depends on whether the short-term or long-term efficacy of the lasers is assessed. In most studies, the efficacy of lasers have been examined in several check-time points, the first check-time point being used to evaluate immediate efficacy and the last check-time point being used to evaluate long-term efficacy. And, in these studies, different evaluation methods, such as cold air, water, thermal, or tactile stimuli and subjective evaluation, have been adopted.[52,53] The differences in the evaluation methods may lead to differences in the reproducibility of studies, resulting in high heterogeneity.[19] In this study, we chose the air-blast test to reduce the effects of the aforementioned factors because it is the most commonly used method for evaluating DH and it is reliable.[18] Besides, it is closer to the practical situation because patients with DH are exposed to cold stimuli (cold drinks, food, and air) more frequently than to other stimuli. In addition is the question of whether these study populations really represent the individual situation of a general DH patient. Therefore, it is very important to select participants according to the experimental requirements.

Based on the results of this meta-analysis, all types of lasers had a better desensitizing effect on DH than negative controls in immediate and long term, which was consistent with the study by Lin et al.[18]

GaAlAs laser is a type of semiconductor laser, which can change the permeability of the nerve fiber membrane to K^+ and Na^+, increase the action potential of nerve endings, and stimulate the formation of endorphins in axons, which relieves pain. Besides, it can also produce secondary reaction, which stimulates the dentin cells and induces them to produce secondary dentin.[54] Our results concluded that GaAlAs laser had a better desensitizing effect on DH than negative controls in immediate and long term. It is important to note that the GaAlAs laser is a type of diode laser. In some included studies, it is simply mentioned as a diode laser, excluding its main component. In some other studies, the main component of the laser is GaAlAs, which has been explained in detail. Considering the widespread use of the GaAlAs laser and enough literature on it, we performed a separate analysis of the GaAlAs laser.

The thermal effect of the Nd:YAG laser can melt the dentin tubule in an instant, block the fluid flow in the tubule, and lead to loss of the ability of nerve fiber degeneration to conduct pain perception. The maintenance of long-term efficacy is related to the promotion of restorative dentin formation after irradiation.[55,56] From our meta-analysis, we suggest that using the Nd:YAG laser can relieve the symptoms of DH in immediate and long term.

Desensitization with the Er:YAG laser is achieved by absorption of water molecules by hydroxyapatite to produce a microblasting effect and deposition of insoluble salts, which plugs or narrows down dentin tubules. Furthermore, the potential antibacterial characteristic may also contribute to the desensitizing effects.[42] Our results show that Er:YAG laser had better immediate and long-term desensitizing effects on DH than negative controls.

The Er,Cr:YSGG laser, also called the water laser, acts similar to the Er:YAG laser.[14] From our meta-analysis, we suggest that using the Er,Cr:YSGG laser can relieve the symptoms of DH immediately and in long term.

Diode lasers can make dentin cells degenerate, cause calcium salt deposition, and calcify the closure of dentin tubules. Meanwhile, the sensitive area, that is, irradiation by diode laser, also changes the nerve fiber membrane permeability to potassium and sodium, increases peripheral nerve action potentials, and stimulates the formation of neural axon endorphins, which cause an analgesic effect. Our results concluded that diode laser had better immediate and long-term desensitizing effects on DH than negative controls.

DH is a subjective symptom of patients, and the degree of pain is mainly determined from dental patient-reported outcomes. Patient-related factors could influence the effectiveness and response of patients to treatment.[57] Currently, however, VAS and VRS are mainly used to measure DH, which only represent the pain response of patients when they suffer. These scales did not include other conditions of the oral cavity or body that may affect the results.[58,59] At present, some researchers had emphasized the importance of dental patient-reported oral health and suggested that the dental patient-reported outcome measure should be used to obtain the dental patient-reported outcome.[60,61] Therefore, we need to develop a dental patient-reported outcome measure suitable for the evaluation of DH in the future.

We should also know that lasers not only alleviate the pain of teeth that suffer DH but also relieve the pain in other areas of the body. The perceived oral health plays a key role in general health-related quality of life, which are

substantially connected.[62] The oral health-related quality of life and general health-related quality of life instruments are used commonly to make the configuration perceive oral health and general health.[63,64] Oral health-related quality of life is multidimensional, which included orofacial pain, psychosocial impact, oral function, and orofacial appearance.[65]

Finally, our study also has several limitations. First, except the GaALAs laser, the number of other lasers used was small, which may have contributed to the low power of this meta-analysis. Therefore, it was necessary to treat the results for these lasers with caution. Second, because the search was limited to articles published in Chinese and English and to the six major literature databases, there may have been a selection bias. Besides, a high degree of heterogeneity was found, which could also influence the final results of this study. It is also important to note that some included studies used bleaching and periodontal procedures, which may lead to different reasons for the sensitivity of dentine and could bias the results. Therefore, we should hold a conservative view on the results of this article. To overcome these problems, additional high-quality, well-designed clinical trials with larger sample sizes are required.

CONCLUSIONS

Within the limitations of our meta-analysis of 22 final included studies, the results indicate that all types of lasers had a better immediate and long-term desensitizing effect on DH than negative controls. In future research, more high-quality DH clinical trials should be performed to obtain more accurate conclusions on the effects of lasers.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jebdp.2018.12.004.

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