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Review

Low-Level Laser Therapy for Tooth Sensitivity after Tooth Bleaching: A Systematic Review

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Abstract: Tooth bleaching is a popular cosmetic procedure known for its effective whitening results. However, it may cause tooth sensitivity. Various desensitizing therapies, including laser treatments, are used to alleviate pain and improve patient comfort. This study aims to conduct a systematic review to evaluate the effectiveness of low-level laser therapy for treating tooth sensitivity following bleaching therapy. A comprehensive search was conducted across 13 electronic databases (PubMed, Scopus, ScienceDirect, Google Scholar, Web of Science, Ovid, BMJ evidence-based medicine, proQuest, Greylit.org, Ethos, Livivo, Clinical trials gov, and Meta register of controlled trials) to identify relevant studies according to specific eligibility criteria, following the PRISMA guidelines. Two independent reviewers screened and selected the studies, performed data extraction, and assessed the risk of bias using the revised Cochrane risk-of-bias tool for randomized clinical trials (RCTs). The initial search yielded 2875 articles, which were subsequently screened to remove duplicates. After evaluating 1532 articles based on title and 136 by abstract, 21 studies remained for full-text assessment. Ultimately, only six RCTs met all of the eligibility criteria. The application of low-level laser therapy appears to reduce tooth sensitivity following tooth bleaching. Despite the positive reported effects, further research is necessary to determine the optimal use of low-level laser therapy for effective pain relief.

Keywords: low level laser therapy; tooth bleaching; tooth sensitivity

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Citation: Giannakopoulou, P.; Neophytou, C.; Karakostas, P.; Papadimitriou, K.; Dionysopoulos, D.; Tolidis, K.; Davidopoulou, S. Low-Level Laser Therapy for Tooth Sensitivity after Tooth Bleaching: A Systematic Review. *Appl. Sci.* **2024**, *14*, 8068. https://doi.org/10.3390/app14178068

Academic Editor: Emira D'Amico

Received: 6 June 2024
Revised: 4 September 2024
Accepted: 5 September 2024
Published: 9 September 2024

1. Introduction

Tooth bleaching (TB) is a popular cosmetic procedure known for its effective whitening results, minimal patient harm, and non-invasive nature. It can be performed either in-office by a dentist or at home using custom trays, with both methods yielding significant results when used properly. In-office TB is often preferred for its ability to deliver rapid, substantial, and longer-lasting whitening, effectively addressing severe tooth discoloration under professional supervision. Discolored teeth are usually treated with high concentrations of hydrogen peroxide (HP, H_2O_2), typically ranging from 35% to 38%, due to its potent oxidative properties [1]. The outcome depends on the concentration of the bleaching agent, the duration of application, the temperature, and the pH of the bleaching solution [2,3]. While hydrogen peroxide is the most common bleaching agent, carbamide peroxide is also used; it breaks down into hydrogen peroxide and urea, with hydrogen peroxide performing the bleaching action. Hydrogen peroxide decomposes to form reactive oxygen species (ROS), such as hydroxyl radicals OH^-, singlet oxygen O_2^-, and superoxide anion O_2^-, which interact with chromophore molecules within dentin and enamel [4]. This oxidative reaction breaks the double bonds of the chromophores, which absorb light and give teeth their stained appearance. The resulting smaller, less pigmented compounds lead to the whitening of the tooth.

There are some side effects associated with TB, the most significant being tooth sensitivity (TS), which affects 49 to 100% of patients undergoing in-office TB [5–7]. Hydrogen peroxide and its byproducts, due to their low molecular weight (34.01 g/mol), can penetrate the porous enamel and dentin, reaching the pulp tissue and triggering an inflammatory response. Tooth sensitivity is defined as acute pain triggered by thermal, chemical, mechanical, or osmotic stimuli on exposed dentin, varying in intensity and duration, and not attributable to any other dental pathology [8,9]. The intensity of this sensitivity is related to the concentration of peroxide in the bleaching system used, its components, and the duration of its application. Discomfort is usually noticed immediately after the bleaching therapy or within the next few days. Generally, the sensitivity is quite tolerable and can disappear completely with proper treatment [10].

Various desensitizing therapies are employed to alleviate pain and improve patient comfort after TB [11–13]. These treatments include applying chemical desensitizing agents to the sensitive area, which help occlude dentinal tubules and reduce nerve excitability by depositing ions on the dentin surface and promoting remineralization. Common desensitizing agents include sodium fluoride (NaF), potassium nitrate, and strontium chloride. These agents can be incorporated into dentifrices or mouthwashes for at-home use or into gels or varnishes for professional application. Resin sealers, dentin adhesives, and glass ionomers are also used as more permanent solutions to mechanically seal dentinal tubules. While anti-inflammatory and analgesic drugs have also been recommended as desensitizing agents, a recent systematic review and meta-analysis did not support their use for this purpose [14]. Given the mechanism of hydrogen peroxide, treatments using antioxidant substances have emerged as alternatives to mitigate significant oxidative stress and pulp tissue damage. Several in vitro studies have shown that antioxidant compounds such as alpha-tocopherol (vitamin E) and ascorbic acid (vitamin C) could effectively protect against hydrogen peroxide-induced damage to pulp cells [15]. However, randomized clinical trials (RCTs) are needed to confirm their effectiveness. Additionally, advanced technologies such as laser therapy have been proposed as effective modalities for treating TS [16].

The action of lasers for treating tooth sensitivity can be explained through several mechanisms. One mechanism involves the stimulation of the Na^+/K^+ pump, which maintains the electrical balance across the cell membrane, inducing hyperpolarization, increasing the nerve pain threshold, and reducing sensitivity to stimuli [17]. Another theory suggests that laser application can completely inhibit the depolarization of A delta and C fibers [18], thereby suppressing the generation and transmission of nerve impulses and promoting direct nerve analgesia [19]. Additionally, lasers can inhibit the release of agents such as bradykinin, which sensitize pain receptors, while also increasing the production of endorphins, the body's natural pain-relieving substances. Lasers also promote tissue repair and reduce inflammation by enhancing local microcirculation and lymphatic drainage. Finally, they can stimulate pulp mesenchymal cells to differentiate into odontoblasts, producing reparative dentin [20,21].

Low-level laser therapy (LLLT), also known as photobiomodulation (PBM), is a therapeutic technique that uses low-intensity lasers (1–500 mW) at specific wavelengths within the visible to near-infrared spectrum (600–1064 nm) to stimulate cellular function. Diode lasers are preferred for LLLT because they can penetrate to varying depths and deliver targeted light with minimal heating of the surrounding tissues. When the laser interacts with the target tissue, a photobiological reaction occurs involving the absorption of the specific wavelength by a photoreceptor molecule [22]. This initiates a cascade of biochemical reactions in the cells, primarily targeting the mitochondria and specifically cytochrome-c-oxidase, leading to increased production of adenosine triphosphate (ATP). Various other cellular processes are stimulated, including modulation of signaling pathways, reduction of pro-inflammatory mediators, increase in anti-inflammatory mediators, proliferation of fibroblasts, endothelial and mesenchymal stem cells, reduction of oxidative stress, and modulation of reactive oxygen species (ROS) levels [23]. It has also been noted that LLLT can alter gene expression patterns within cells [24]. Consequently, LLLT, with its analgesic, vascular, biomodulatory, and anti-inflammatory effects, can promote tissue repair and wound healing [25].

The quest to determine whether LLLT can effectively alleviate tooth sensitivity following tooth bleaching has gathered significant attention in recent years. Despite some investigations that have been conducted in the past few years, the lack of standardized treatment protocols has led to varied findings across studies and thus to a lack of the robust evidence needed for conclusive recommendations. In the present systematic review, we appraise data provided by all available primary RCTs in order to evaluate whether LLLT is suitable for treating tooth sensitivity when administrated after in-office bleaching therapy.

2. Materials and Methods

The current systematic review adhered to the recommendations and principles of the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) statement guidelines [26], an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses. Prior to conducting the review, a comprehensive protocol was developed and approved accordingly by all authors. This protocol incorporated several sections and research techniques, such as the search strategy, definition of inclusion/exclusion criteria, data extraction, quality assessment, and data synthesis/analysis.

2.1. Eligibility Criteria

To satisfy the primary aim of the study, the focus question was defined as follows:

"Is low-level laser therapy effective in the management of tooth sensitivity following in-office tooth bleaching?"

Clinical variables indicating a decrease in patients' discomfort and tooth sensitivity were set as primary outcomes.

Inclusion criteria were defined as follows in keeping with the focus question above:

i. RCTs investigating the effect of LLLT on TS after in-office TB
ii. a minimum number of 10 patients in each treatment group
iii. test group: LLLT (as a monotherapy) after TB; control group: none; placebo, another desensitizing agent or combination of LLLT with another desensitizing agent; more than two groups are permitted
iv. data related to the reported pain assessment method used
v. studies published in any language

Consequently, according to the exclusion criteria, experimental in vitro studies, animal studies, case reports/case series, case-control studies, cohort studies, non-controlled clinical trials, narrative reviews, systematic reviews, meta-analyses, editor's choices, letters to the author/editor, interviews, commentaries, and book or conference abstracts and summaries were excluded. Figure 1 summarizes the PICOS framework for inclusion and exclusion criteria.

2.2. Literature Search

The research was carried out on 15 February 2024 (with an additional check on 15 May 2024, prior to submission), in accordance with PRISMA guidelines [26]. The literature search was conducted in a systematic manner, and measures were taken to minimize bias; the search strategy was performed in 13 electronic databases (Pubmed, Scopus, Science direct, Google scholar, Web of science, Ovid, BMJ evidence-based medicine, ProQuest, Greylit.org, Ethos, Livivo, Clinical trials gov, and Meta register of controlled trials), including grey literature to avoid publication bias and with no language restrictions in order to limit information bias. Translation upon request would be provided by professionals.

The principal search strategy was as follows: ("dentin sensitivity" [MeSH Terms] OR ("dentin" [All Fields] AND "sensitivity" [All Fields]) OR "dentin sensitivity" [All Fields] OR ("tooth" [All Fields] AND "hypersensitivity" [All Fields]) OR "tooth hypersensitivity" [All Fields]) AND ("lasers" [All Fields] OR "lasers" [MeSH Terms] OR "lasers" [All Fields]

OR "laser" [All Fields] OR "lasered" [All Fields] OR "lasering" [All Fields]). Information on the search strategy used in the other databases is available in Appendix A.

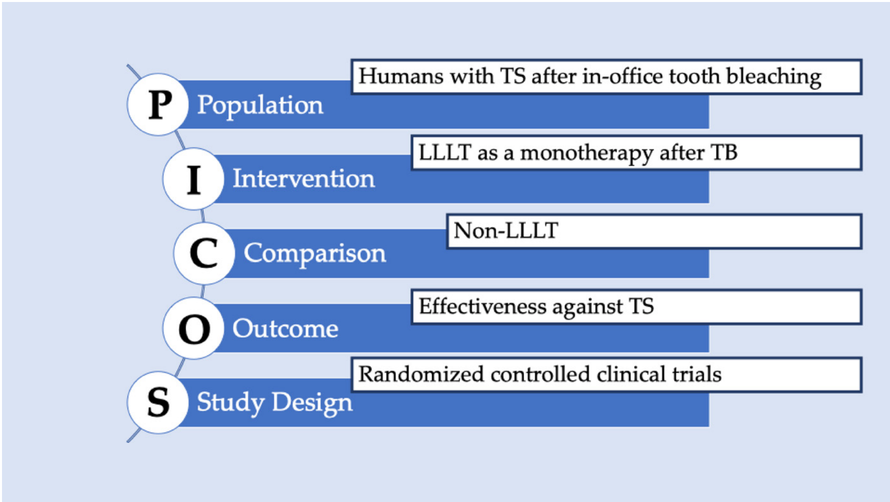

Figure 1. The PICOS framework for inclusion and exclusion criteria.

The screening process was carried out separately, with two of the authors (C.N., E.G.) managing the selection based on title and abstract after duplicates were removed. Clinical trials that met the inclusion criteria at each screening stage, or those with missing information, were kept for final full-text evaluation. Disputes between the two reviewers were addressed via discussion, and if no consensus could be reached, a third review author (P.K.) was authorized to make the final decision. Following the completion of full-text screening, the reasons for studies not meeting eligibility requirements were documented.

In addition, references to relevant articles and all included publications were screened for further relevant studies. Contact with the corresponding authors took place if the whole article for a study was not available. Subsequently, all studies that met the eligibility criteria underwent data extraction and quality assessment.

2.3. Data Extraction

Independent data extraction was performed with standardized forms (Cochrane checklist), and conflicts were resolved via discussion. The corresponding authors were contacted to request any missing data. Data extraction involved general information (title, authors' names), study characteristics (study design, setting, funding sources), participants (eligibility criteria, number of participants, withdrawals), interventions (details, comparison group, co-interventions), outcomes, results, risk of bias, and other information (publication year, country).

2.4. Quality Assessment

The quality assessment of the included RCTs was conducted by two of the authors (K.P., D.S.) using the revised Cochrane risk of bias assessment tool for randomized controlled trials (RoB 2). This tool permits the evaluation of five distinct domains: the randomization process (random sequence generation and allocation concealment), deviations from intended interventions (blinding of participants and personnel and adherence to the intervention), missing outcome data, the measurement of the outcome (blinding of outcome assessment), and the selection of reported results (selective reporting of outcomes). Each domain was assessed as representing a low risk of bias, some concerns, or a high risk of bias.

3. Results

The search strategy initially identified 2875 articles for screening. After eliminating duplicates, the total was reduced to 1532. Upon screening based on title and abstract, only

21 articles remained for the subsequent stage of the process. Screening at the full-text level resulted in just six articles [5,27–31] fulfilling all eligibility criteria. The flow diagram of the screening and selection process, according to the PRISMA guidelines, is presented in Figure 2.

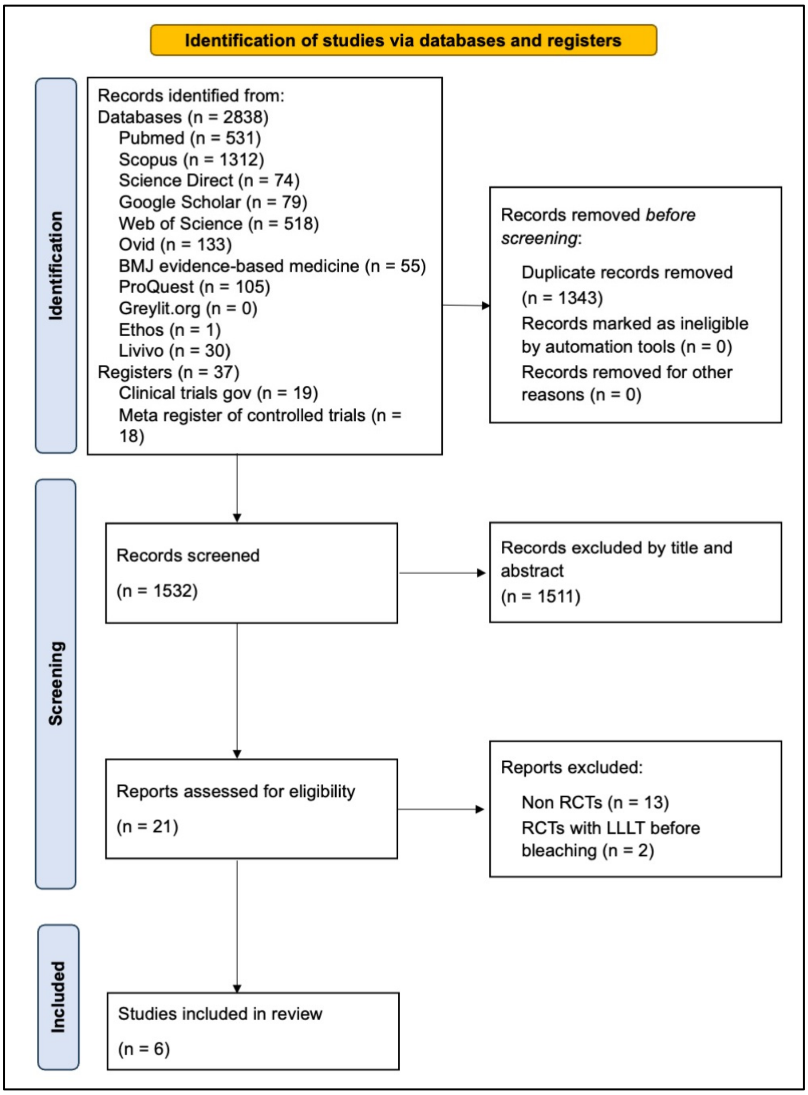

Figure 2. PRISMA flow diagram of the literature search and selection process.

Six studies met the inclusion criteria and were included in the systematic review. All studies were written in English and were published in the last 9 years. They were all RCTs, with a total of 308 patients treated with either LLLT as a monotherapy (n = 160) or non-LLLT (n = 148) after in-office tooth bleaching. All patients had good oral health and were free from medical conditions. Cracked teeth or teeth with caries were eliminated from the test samples.

The characteristics of the included studies are summarized in Table 1. Significant variability in terms of study design, population, timeline, parameters of bleaching system, LLLT, and control therapy is observed among the studies. Heterogeneity is also observed in the methodology of evaluating TS regarding the scale used (VAS, modified VAS, or VRS), the assessment periods (varying from 48 h to 21 consecutive days), and the use of any stimulation (evaporative, mechanical) to assess patients' pain (Table 2).

Table 1. Characteristics of the included studies.

Author, Year, Country	RCT Study Design (Split-Mouth/Parallel) Number of Patients (N)	Treatment	Laser Characteristics	Bleaching System	Bleaching and Laser Applications	Contribution/Funding	University	Open Access	Outcomes	Conclusions
Moosavi et al., 2016, [27] Iran	Parallel N = 66	G1: LLLT (red laser) G2: LLLT (infrared laser) G3: placebo	G1: 660 nm 200 mW 12 J/cm^2 G2: 810 nm 200 mW 12 J/cm^2 CM	40% HP	2 bleaching sessions with 1 week interval 1 laser application	Financial Support—Grant from Mashhad University of Medical Sciences	University of Medical Sciences, Mashhad, Iran	YES	LLLT: no reduction in TS 1 h after bleaching (p = 0.300), but at 24 and 48 h afterward ($p < 0.001$). 810 nm wavelength more effective than 660 nm at 24 h ($p < 0.05$), although both comparable ($p > 0.05$); significantly lower pain level than the placebo group at 48 h ($p < 0.05$).	LLLT better at reducing TS than placebo—a suitable strategy to reduce the intensity of TS after in-office bleaching. Infrared diode laser better than red at 48 h.
Calheiros et al., 2017, [28] Brazil	Parallel N = 50	G2: placebo G4: LLLT	780 nm 40 mW 10 J/cm^2 CM	35% HP	2 bleaching sessions with 1 week interval laser therapy after each session	FGM -> bleaching kits	Ibirapuera University, University of Sao Paulo, University of Campinas	NO	No statistical difference in TS between groups at any time.	Tested PBM parameters not sufficient for preventing TS after in-office dental bleaching.

Table 1. *Cont.*

Author, Year, Country	RCT Study Design (Split-Mouth/Parallel) Number of Patients (N)	Treatment	Laser Characteristics	Bleaching System	Bleaching and Laser Applications	Contribution/Funding	University	Open Access	Outcomes	Conclusions
De Paula et al., 2018, [29] Brazil	Split-mouth N = 50	G1: placebo G2: PBM-LLLT G3: KN03 G4: KN03 + PBM-LLLT	808 nm 60 J/cm^2 CM	35% HP	3 bleaching sessions with 1 week interval 3 laser applications	-	Federal University of Para, Brazil	YES	TS significantly different between G1 and the other groups ($p \leq 0.05$), but not between G2, G3, G4 ($p \geq 0.05$).	PGM-LLLT, KN03, and combination of two are all effective at reducing TS after bleaching; similar effect, not synergistic, better than placebo.
Pompeu et al., 2021, [30] Brazil	Split-mouth N = 50	G1: placebo G2: PBM G3: strontium chloride 10% G4: strontium chloride 10% + PBM	808 nm 100 mW 1.7 J, 60 J/cm^2 CM	35% HP	3 bleaching sessions with 1 week interval 1 laser application	Scholarship support from National Council for Scientific and Technological Development	Federal University of Para, Brazil	YES	G4 showed the greatest reduction in TS after 2nd week ($p \leq 0.05$); G2, G3 and G4: no significant difference after the 1st and 3rd weeks ($p \geq 0.05$); TS greatest for G1.	Individual and combined use of PBM and STRONTIUM after bleaching reduces TS; no difference assessed after 21 days.

Table 1. *Cont.*

Author, Year, Country	RCT Study Design (Split-Mouth/Parallel) Number of Patients (N)	Treatment	Laser Characteristics	Bleaching System	Bleaching and Laser Applications	Contribution/Funding	University	Open Access	Outcomes	Conclusions
Yahya et al., 2021, [31] Saudi Arabia	Parallel N = 39	G1: 5% NaF varnish G2: LLLT G3: 5% NaF+LLLT	660–900 nm 90 mW CM	40% HP	1 bleaching session 1 laser application		Umm At Qura University, Saudi Arabia	YES	Reduction in tooth sensitivity ($p < 0.05$); no significant difference among groups ($p = 0.544$).	5% NaF, LLLT, and combination of both are similarly effective methods for the treatment of post-bleaching TS, with no significant difference among them.
Vochikovski et al., 2022, [5] Brazil	Parallel N = 83	G1: placebo G2: PBM	808 nm 100 mW 100 J/cm^2 CM	35% HP	2 bleaching sessions with 1 week interval, laser therapy after each session	MMOptics -> loan of laser FGM -> bleaching products, Grant National Council for Scientific and Technological Development (CAPES)	State University of Ponta Grossa, Brazil	YES	No statistical difference between groups Risk: G1: 98% (95% CI 88 to 99%) and G2: 95% (95% CI 83 to 99%) (RR = 1.03; 95% CI 0.94 to 1.12; $p = 1.0$) Intensity: $p > 0.65$.	Application of PBM does not reduce the risk and intensity of TS.

CM: continuous mode, HP: hydrogen peroxide, LLLT: low level laser therapy, PBM: photobiomodulation, RR: risk ratio, TS: tooth sensitivity.

Table 2. Tooth sensitivity assessment of each included study.

Author, Year	Assessment Timeline	Scale Used	Assessment Method
Moosavi et al., 2016 [27]	1, 24, and 48 h after therapy	VAS	Pain questionnaire
Calheiros et al., 2017 [28]	Before bleaching, immediately after, and seven consecutive days after each session	VRS	Pain questionnaire
De Paula et al., 2018 [29]	Daily for 21 days after therapy	mVAS	Mechanical and evaporative stimulation, pain questionnaire
Pompeu et al., 2021 [30]	Daily for 21 days after therapy	mVAS	Pain questionnaire
Yahya et al., 2021 [31]	Before bleaching, immediately after, after proposed desensitizing technique	VAS	Evaporative stimulation – endo ice
Vochikovski et al., 2022 [5]	Immediately after bleaching, 1 h, 24 h, and 48 h after the 2 bleaching sessions	NRS and VAS	Pain questionnaire

NRS: numerical rating scale (0 = none, 1 = mild, 2 = moderate, 3 = considerable, and 4 = severe); mVAS: modified visual analogue scale (0–3), VAS: visual analogue scale (0–10); VRS: verbal rating scale (0 = no tooth sensitivity, 1 = gentle sensitivity, 2 = moderate sensitivity, 3 = severe sensitivity).

The Moosavi et al. [27] RCT investigated the effect of LLLT on TS, comparing two different wavelengths (660 and 810 nm, in the red and infrared spectrum, respectively) with each other and with a placebo group (n = 22 patients in each of the three groups), and reported that the two lasers effectively reduced pain level, but only after 24 h, with the LLLT in the infrared spectrum providing better results during the first 24 h but not differing from the red laser at 48 h. Another study [28] with five groups (n = 10 patients in each) aimed to analyze the effect of LLLT when used either before, after, or both (before and after) TB and, unlike the previous study, found no statistical differences between groups at any time point and therefore no difference in the effectiveness of LLLT in preventing TS. The study by de Paula et al. [29] assessed the impact of LLLT in relation to a placebo-control group, a group in which KNO_3 desensitizing gel was applied prior to TB, and a group in which KNO_3 and LLLT were combined (n = 25 in each of the four groups). LLLT was found to be capable of reducing pain sensitivity after TB, with an effect similar to that of KNO_3 and to the combination of these treatments. An additional study [30] correlating LLLT with an alternative desensitizing agent (specifically strontium chloride, n = 25 in each of the four groups) reached similar conclusions, illustrating that LLLT is as effective as strontium (Sr) and as the combination of the two for inhibiting TS after TB. Yahya et al. [31] examined LLLT, 5% NaF, and the combination of the two (n = 13 in each of the three groups) without a control group and identified that all of the desensitizing methods employed reduced post-bleaching TS with no significant differences among them. The lack of a control group in this study makes it impossible to differentiate real treatment efficacy from the natural evolution of the condition and influences the results from the Hawthorne effect [32], hence inserting bias. The most recent study [5] assessing LLLT (n = 43) for reducing TS after TB compared to a control group (n = 40) is in agreement with Calheiros et al. [28], exhibiting no difference in the risk and intensity of TS for two pain scales. This study recruited the largest sample size (N = 83) in two groups, thus yielding the highest statistical power compared to previous studies.

All studies concluded to specific outcomes (Table 1) and based on them, there is evidence on establishing a positive effect of LLLT for reducing TS. Moreover, no adverse events have been reported in any of the included studies.

Quality Assessment and Risk of Bias

We conducted a critical appraisal of all included studies using the Cochrane risk of bias tool [33]. The quality assessment revealed that all RCTs failed to achieve an overall low risk of bias, primarily due to issues with blinding of participants and personnel (Table 3 and Figure 3). While most studies incorporated a placebo treatment and blinded participants, operators were aware of the intervention type in all cases. This was unavoidable due to the nature of these therapeutic techniques. In one study, information was missing regarding the blinding of the outcome assessment, resulting in a high risk of bias for this domain [31]. Consequently, a meta-analysis could not be conducted due to the lack of homogeneity and a low risk of bias among the clinical trials included in the current systematic review.

Table 3. Risk of bias of included studies according to the revised Cochrane assessment tool RoB 2. [(+): low risk of bias; (−): high risk of bias; (?): some concerns)].

	Bias Arising from the Randomization Process	Bias Due to Deviations from Intended Interventions	Bias Due to Missing Outcome Data	Bias in the Measurement of the Outcome	Bias in the Selection of the Reported Result	Overall Bias
Moosavi et al., 2016 [27]	+	−	+	+	+	−
Calheiros et al., 2017 [28]	+	−	+	−	+	−
de Paula et al., 2018 [29]	+	−	+	+	+	−
Pompeu et al., 2021 [30]	+	−	+	+	+	−
Yahya et al., 2021 [31]	+	−	+	?	+	−
Vochikovski et al., 2022 [5]	+	−	+	+	+	−

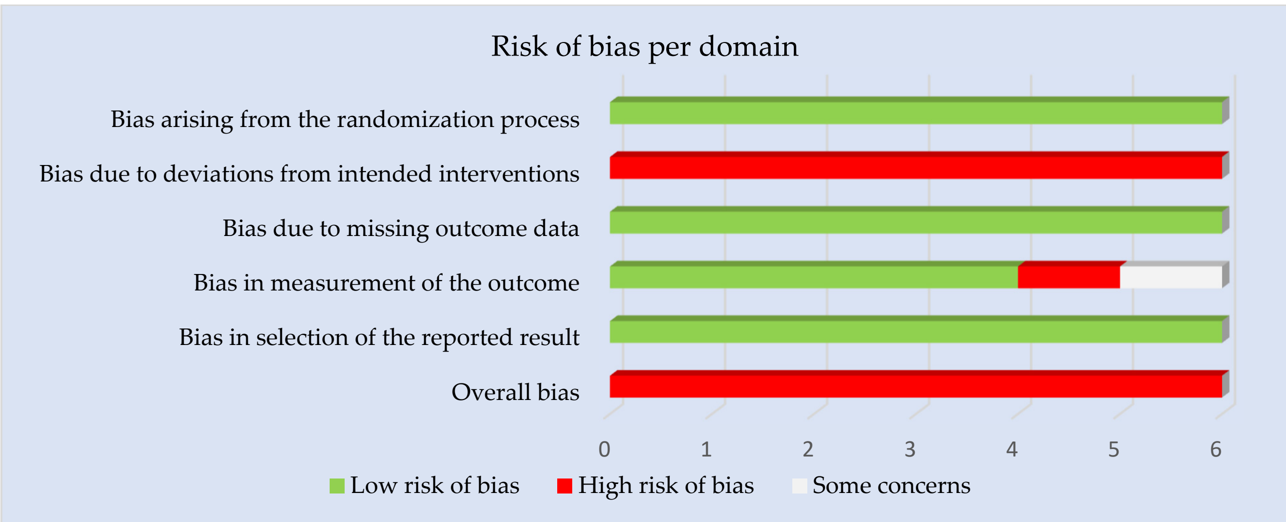

Figure 3. Quality assessment of all studies included per domain according to the revised Cochrane assessment tool RoB 2.

4. Discussion

This systematic review summarizes the best available evidence regarding the effectiveness of low-level laser therapy (LLLT) for managing tooth sensitivity (TS) following tooth bleaching (TB). Although the outcomes do not represent a consensus, it appears that laser application after TB is an effective and safe option for controlling tooth sensitivity. Six RCTs were included in this systematic review, which evaluated the efficacy of LLLT in the prevention of TS after in-office TB compared to a control group [5,27–30] or other desensitizing agents [29–31]. The majority of these studies [27,29–31] demonstrated positive results with LLLT for addressing post-bleaching TS, whereas two studies [5,28] found that the parameters tested were not effective in preventing TS.

Heterogeneity is evident across the studies included. Four out of six of the studies [5,28–30] were conducted in Brazil, one in Iran, and one in Saudi Arabia. Two of the papers received funding (grant or scholarships), while two were supplied with the whitening kit or the laser device. The number of participants ranged from 39 to 83, with differences in the recall period and the follow-ups after TB. In addition, various adjunct products, such as KNO_3, NaF, and strontium chloride ($SrCl_2$), were combined with the main therapy in certain subgroups. The HP used had a concentration of either 35% or 40%, and one, two, or even three bleaching sessions were applied in the different studies. The parameters of LLLT were also non-homogenous across the studies, with wavelengths varying between 660 nm and 900 nm, output power falling between 40 and 200 mW, and energy ranging from 12 to 100 J/cm^2 (refer to Table 2); it does not appear that any specific parameters are more effective for the treatment of tooth sensitivity.

Furthermore, the study design varied, with four of the studies having a parallel design [5,27,28,31], while the other two employed a split-mouth design [29,30]. The latter, although beneficial for reducing the number of patients recruited and minimizing inter-subject variability (as each participant serves as their own test and control), has some limitations that should be taken into consideration. In particular, these include the 'carry-across effect', which refers to the potential leakage of effects from one treatment site to another, and the influence of combining different treatment approaches at separate sites, which may affect the patient's assessment of pain for each treatment independently [34,35].

Five of the studies included had a placebo-control group; only Yahya et al. [31] did not. The inclusion of a placebo group offers the advantage of maintaining patient blinding, especially when the two treatments cannot be made identical. This approach enhances the study's statistical power and internal validity while reducing the risk of ascertainment bias [36].

Two studies [5,27] evaluated color change following bleaching as well. Both showed a significant whitening effect on teeth measured thirty days after TB for all groups, with no difference between them. This suggests that patients undergoing TB can potentially benefit from the adjunctive use of LLLT without compromising the final whitening result.

Of special interest are several studies that, although they did not meet our inclusion criteria, present compelling findings. One such case is a case report study [37] conducted concurrently with that of Moosavi et al. [27] and involving only six participants. The researchers employed a split-mouth design to compare LLLT with a control group after administering two different in-office bleaching agents (35% HP and 6% HP N-doped TiO_2 nanoparticles). Similar to the majority of the RCTs included, this study demonstrated that LLLT effectively reduced pain intensity after mechanical and evaporative stimuli for up to 48 h post-TB, with analgesia persisting after 72 h. Furthermore, a randomized clinical trial by Alencar et al. [38] suggested that teeth subjected to LLLT prior to the bleaching session, followed by the topical application of 5000 ppm sodium fluoride, exhibited less TS than those treated solely with sodium fluoride ($p \leq 0.05$) across various evaluation times. Additionally, De Silva et al. [39], in their split-mouth clinical study, proposed that LLLT, when administered before TB, prevented TS more effectively than a placebo, as indicated by daily pain assessment questionnaires ($p \leq 0.05$), despite showing no significant difference in evaporative stimulus pain evaluation ($p > 0.05$). These studies, despite employing LLLT before bleaching, contribute to the growing body of evidence supporting the efficacy of LLLT for controlling post-bleaching TS.

The primary strength of the present systematic review lies in its rigorous adherence to strict inclusion criteria. Amidst the diverse array of protocols and parameters explored in the literature, this review exclusively incorporates RCTs with a minimum of ten participants in each group and only compares LLLT to non-LLLT interventions following in-office bleaching sessions. This approach aims to enhance the homogeneity and comparability of the studies, thereby bolstering the robustness of the outcomes. Unlike previous reviews, which lacked such stringent criteria, this systematic review includes only studies that meet these specific requirements, making it the first and most comprehensive systematic review encompassing solely RCTs assessing the efficacy of LLLT on tooth sensitivity. The two previous systematic reviews [40,41] encompassed non-RCTs studies where LLLT could be used either before or after tooth bleaching [29,42]. In addition, the current systematic review covers more studies—six in total—including the two most recently published [5,31], which were overlooked in the previous systematic reviews.

The review, however, is marked by certain limitations that necessitate consideration when interpreting its findings. Significant heterogeneity exists among the studies analyzed concerning the type and concentration of bleaching agents, the number and duration of the sessions, and the utilization of light/heat to expedite the process. Similarly, variations in laser parameters—such as type, wavelength, power, energy, pulse duration, total duration, distance from the surface, beam diameter, and point of irradiation—add another layer of complexity to the analysis. Furthermore, the definition of tooth sensitivity varies across studies, which restricts the generalizability of the results obtained. Pain perception is inherently subjective and subject to individual differences influenced by various factors. Moreover, individual variations in tooth anatomy, including enamel and dentin thickness, as well as pulp vitality, can significantly influence sensitivity sensations [19].

From the preceding discussion, it appears that LLLT could offer practical advantages for clinical application and patient care. Initially, its effectiveness has been shown to be comparable to that of other desensitizing therapies for managing post-bleaching tooth sensitivity. Unlike certain desensitizing treatments that require strict adherence to specific application protocols, such as NaF varnish, LLLT demands minimal compliance from patients.

Moreover, despite the initial investment required for acquisition, once obtained, its ease of use and potential long-term benefits may contribute to cost-effectiveness over time. If a dental practice already possesses such a device, the additional cost per treatment session may be negligible compared to the ongoing expense of purchasing desensitizing agents or varnishes. Additional relevant trials are still necessary and are certainly justified to evaluate its long-term benefits and cost-effectiveness [19,43]. Larger, high-powered RCTs with strict criteria have to be conducted in order to define the best laser settings when used for tooth desensitization after TB.

5. Conclusions

The findings of the current systematic review align with those of previous studies [40,41] on the subject, suggesting that the application of LLLT following in-office bleaching procedures has a positive effect on reducing tooth sensitivity. In addition, no adverse events have been reported in any study. Overall, these findings support the assertion that LLLT represents a viable and beneficial alternative for addressing post-bleaching sensitivity, offering both efficacy and safety in clinical practice.

Author Contributions: Conceptualization, S.D., D.D. and K.T.; methodology, P.G., C.N. and P.K.; software, P.K. and D.D.; validation, P.K., K.P. and S.D.; writing—original draft preparation, P.G., C.N. and P.K.; writing—review and editing, S.D., K.P., C.N. and D.D.; and supervision, K.T. and S.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Search strategy for each electronic database.

Electronic Databases	Search Strategy	Limitations	Final Search (15 May 2024)
PubMed	("dentin sensitivity" [MeSH Terms] OR ("dentin" [All Fields] AND "sensitivity" [All Fields]) OR "dentin sensitivity" [All Fields] OR ("tooth" [All Fields] AND "hypersensitivity" [All Fields]) OR "tooth hypersensitivity" [All Fields]) AND ("laser s" [All Fields] OR "lasers" [MeSH Terms] OR "lasers" [All Fields] OR "laser" [All Fields] OR "lasered" [All Fields] OR "lasering" [All Fields])	No	531
Scopus	(TITLE-ABS KEY ((dentin OR tooth) AND (hypersensitivity OR sensitivity)) AND TITLE-ABS-KEY (laser))	Title, abstract, keywords	1312
Science Direct	Title, abstract, keywords: [(tooth OR dentine) AND (sensitivity OR hypersensitivity)] AND (laser OR lasers)	Title, abstract, keywords	74
Google Scholar	allintitle: hypersensitivity laser tooth OR dentine OR sensitivity	Title	79
Web of science	518(abstract) AND laser (abstract)	Abstract	518
Ovid	(tooth sensitivity OR hypersensitivity) AND laser	All	133
BMJ evidence-based medicine	"(tooth sensitivity OR hypersensitivity) AND laser"	No	55
proQuest	title(tooth sensitivity OR hypersensitivity) AND title(laser)	Title	105
Greylit.org	tooth sensitivity and laser	No	0
Ethos British Library	tooth sensitivity and laser	No	1
Livivo	TI = (tooth (sensitivity OR hypersensitivity)) AND TI = laser	Title	30
Clinical trials gov	condition or disease:tooth hypersensitivity, other terms: laser	No	19
Meta register of controlled trials (https://trialsearch.who.int/)	tooth hypersensitivity and laser	No	18
Summary			2875

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