The Effectiveness of Desensitizing Agents for Treating Dentin Hypersensitivity: A Meta-Analysis

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ABSTRACT

Dentin hypersensitivity (DH) affects 10–30% of adults, causing sharp pain from exposed dentin. Despite various treatments, efficacy comparisons remain unclear. This meta-analysis aimed to evaluate the effectiveness of desensitizing agents for DH. Following PRISMA guidelines, 30 RCTs were analyzed. Databases included PubMed, Embase, and Cochrane. Outcomes were pain reduction (VAS, Schiff scale) and tubule occlusion (SEM). Random-effects models calculated pooled effect sizes. Bioactive materials (e.g., bioactive glass) showed the strongest effects (40–60% pain reduction), followed by arginine (50–70%). Lasers and SDF provided rapid relief but had limitations (cost, side effects). At-home treatments (e.g., stannous fluoride) offered moderate efficacy (30–50%). Heterogeneity was low (I^2 = 22.43%), and publication bias was minimal. Desensitizing agents are effective for DH, with bioactive materials and combination therapies yielding optimal results. Clinicians should tailor treatments based on patient needs and agent availability.

Keywords

dentin sensitivity; desensitizing agents; meta-analysis; randomized controlled trials; tooth hypersensitivity

INTRODUCTION

Dentin hypersensitivity (DH) is a common dental condition characterized by transient, sharp pain arising from exposed dentin in response to thermal, chemical, tactile, or osmotic stimuli [1]. It affects approximately 10-30% of the global adult population, with higher prevalence among individuals with periodontal disease or those undergoing dental procedures such as scaling and root planing [2]. The hydrodynamic theory, proposed by Brännström (1966), remains the most widely accepted explanation, suggesting that external stimuli trigger fluid movement within dentinal tubules, activating pulpal nerve endings [3].

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Various treatment modalities exist, including at-home desensitizing toothpastes, in-office professional agents (e.g., varnishes, lasers, and bonding agents), and combination therapies [4]. Among these, desensitizing agents containing potassium nitrate, fluoride, strontium chloride, or bioactive glasses have demonstrated efficacy in occluding dentinal tubules or blocking neural transmission [5]. However, clinical outcomes vary due to differences in study designs, agent formulations, and patient adherence.

Previous systematic reviews have assessed the effectiveness of desensitizing agents, but conflicting results and methodological limitations necessitate an updated meta-analysis [6]. This study aimed to synthesize evidence from randomized controlled trials (RCTs) to evaluate the comparative efficacy of different desensitizing agents in reducing DH symptoms. By employing rigorous inclusion criteria and statistical methods, this meta-analysis seeks to provide evidence-based recommendations for clinical practice.

Review

Methodology

This meta-analysis followed PRISMA guidelines to identify, screen, and analyze relevant studies across several databases. Eligible studies included RCTs comparing desensitizing agents with placebo or other active treatments in patients with DH.

Database Search Strategy for Meta-Analysis

The search strategy was designed to retrieve all relevant RCTs evaluating desensitizing agents for DH. Controlled vocabulary (MeSH/Emtree terms) and free-text keywords were combined using Boolean operators. Filters were applied to restrict results to human studies, English language, and RCTs. Syntax adjustments were made per database requirements to optimize precision and recall (Table 1).

Table 1: Database Search Strategy for Meta-Analysis on Desensitizing Agents for Dentin Hypersensitivity.

Database	Search Query Components	Applied Filters	Syntax/Modifiers
PubMed	("Dentin Sensitivity"[Mesh] OR "Tooth Hypersensitivity"[tiab]) AND ("Desensitizing Agents"[Mesh])	RCTs, Humans, English	("randomized controlled trial"[pt])
Embase	'dentin hypersensitivity'/exp OR 'tooth hypersensitivity, ab AND 'desensitizing agent'/exp	Human studies, English, RCTs	'randomized controlled trial'/exp
Cochrane Library	(Dentin Hypersensitivity OR Tooth Hypersensitivity) AND (Desensitizing Agents)	Trials, Full-text available	N/A
Scopus	TITLE-ABS-KEY("dentin hypersensitivity" OR "tooth hypersensitivity") AND ("desensitizing agent")	English, RCTs	LIMIT-TO (DOCTYPE, "ar")
Web of Science	TS=("dentin hypersensitivity" OR "tooth hypersensitivity") AND TS=("desensitizing agent")	Articles, English, Clinical Trials	Refined by: Document Type (Article)

Manual searches were conducted in reference lists of included studies and relevant reviews to identify additional eligible trials. Two reviewers independently screened titles/abstracts, followed by full-text assessment. Disagreements were resolved through discussion or consultation with a third reviewer. Inter-rater reliability was assessed using Cohen's kappa ($\kappa > 0.80$).

Eligibility Criteria Description

The PICO framework guided study selection, ensuring only RCTs evaluating desensitizing agents in DH patients were included. Studies were excluded if they lacked control groups, reported non-standard outcomes, or were non-randomized (Table 2).

Table 2: Inclusion and Exclusion Criteria of Meta-Analysis Based on PICO Framework.

Category	Inclusion Criteria	Exclusion Criteria
Population	Adults (≥18 years) with diagnosed dentin hypersensitivity	Non-human studies, pediatric populations
Intervention	Any desensitizing agent (topical, in-office, or combined)	Non-desensitizing treatments (e.g., placebos)
Comparison	Placebo, no treatment, or alternative desensitizing agent	Studies without control groups
Outcome	Pain reduction (VAS, tactile/thermal sensitivity scores) at 4-12 weeks	Non-quantitative outcomes, case reports
Study Design	Randomized controlled trials (RCTs)	Observational studies, reviews

Data Extraction Protocol

Two reviewers extracted data using a standardized form, including study ID, sample size, intervention details, follow-up duration, and outcome measures. Discrepancies were resolved via consensus. Missing data were requested from authors where possible.

Study Quality and Potential Biases Evaluation

The Cochrane Risk of Bias Tool (ROB 2) [7] assessed RCT quality, while ROBINS-E evaluated non-randomized studies [8]. Publication bias was examined via funnel plots and Egger's test ($p < 0.05$ indicating bias) [9].

Advanced Statistical Synthesis and Heterogeneity Analysis

RevMan 5.4 and R software with the metafor package were used to perform the statistical analysis. A random-effects model calculated pooled mean differences (MD) or odds ratios (OR) with 95% confidence intervals (CI). Heterogeneity was quantified using I^2 statistics ($I^2 > 50\%$ indicating substantial heterogeneity). Subgroup and sensitivity analyses explored sources of variability.

RESULTS

Study Selection Process for Systematic Review

The systematic review began with 4,264 records identified across five databases (PubMed, Embase, Cochrane Library, Scopus, and Web of Science). After removing 2,569 duplicate records, 1,668 studies were screened, and 392 reports were sought for retrieval. Of these, 64 full-text articles were assessed for eligibility, with 34 excluded due to unmet criteria [10-43] (Table 3). Ultimately, 30 studies met the inclusion criteria and were included in the review [44-73]. This rigorous selection process, aligned with PRISMA guidelines, ensured a focused and evidence-based synthesis of relevant research (Figure 1).

Table 3: Exclusion Rationale for Studies Found Non-Eligible for Meta-Analysis.

Reference No.	Study Citation	Reason for Exclusion
[10-15]	Krishnakumar et al. (2022); Freitas et al. (2021); Sayed (2023); AlHabdan & AlAhmari (2022); Rezazadeh et al. (2019); Chan et al. (2024)	Systematic review (non-RCT)
[16, 17]	Martins et al. (2022); Sun et al. (2024)	Scoping review (non-RCT)
[18, 19]	Clark & Levin (2016); Porto et al. (2009)	Narrative review
[20]	Anithakumari et al. (2022)	Focused on bond strength, not DH outcomes
[21]	Schmidlin & Sahrmann (2013)	Expert opinion (non-RCT)
[22]	Petersson (2013)	Non-RCT (fluoride review)
[23, 24]	Shabbir et al. (2024); Madhu et al. (2006)	Non-RCT (case series)
[25]	Martens (2013)	Decision tree (non-RCT)
[26]	Matranga et al. (2017)	Methodology critique (non-RCT)
[27]	Sixou (2013)	Opinion piece (non-RCT)
[28-31]	Costacurta et al. (2020); Ferreira et al. (2019); Alexandrino et al. (2017); Donassolio et al. (2021)	Non-DH outcome (bleaching sensitivity)
[32]	Santiago et al. (2006)	Non-RCT (in vitro study)
[33]	Markowitz (2013)	Non-RCT (product evaluation)
[34]	Freitas et al. (2015)	Non-randomized split-mouth study
[35]	Vaez et al. (2018)	Focused on preemptive analgesics
[36]	Miron et al. (2020)	Non-RCT (pilot study)
[37-39]	Hu et al. (2013); Elias Boneta et al. (2013); Creeth et al. (2019)	Industry-funded non-RCT
[40]	Monterubbianesi et al. (2020)	Non-DH outcome (gingivitis)
[41]	Elias Boneta et al. (2013)	Duplicate publication
[42]	Gallob et al. (2017)	Non-RCT (exploratory study)
[43]	Türkkahraman et al. (2007)	Non-DH outcome (orthodontic bonding)

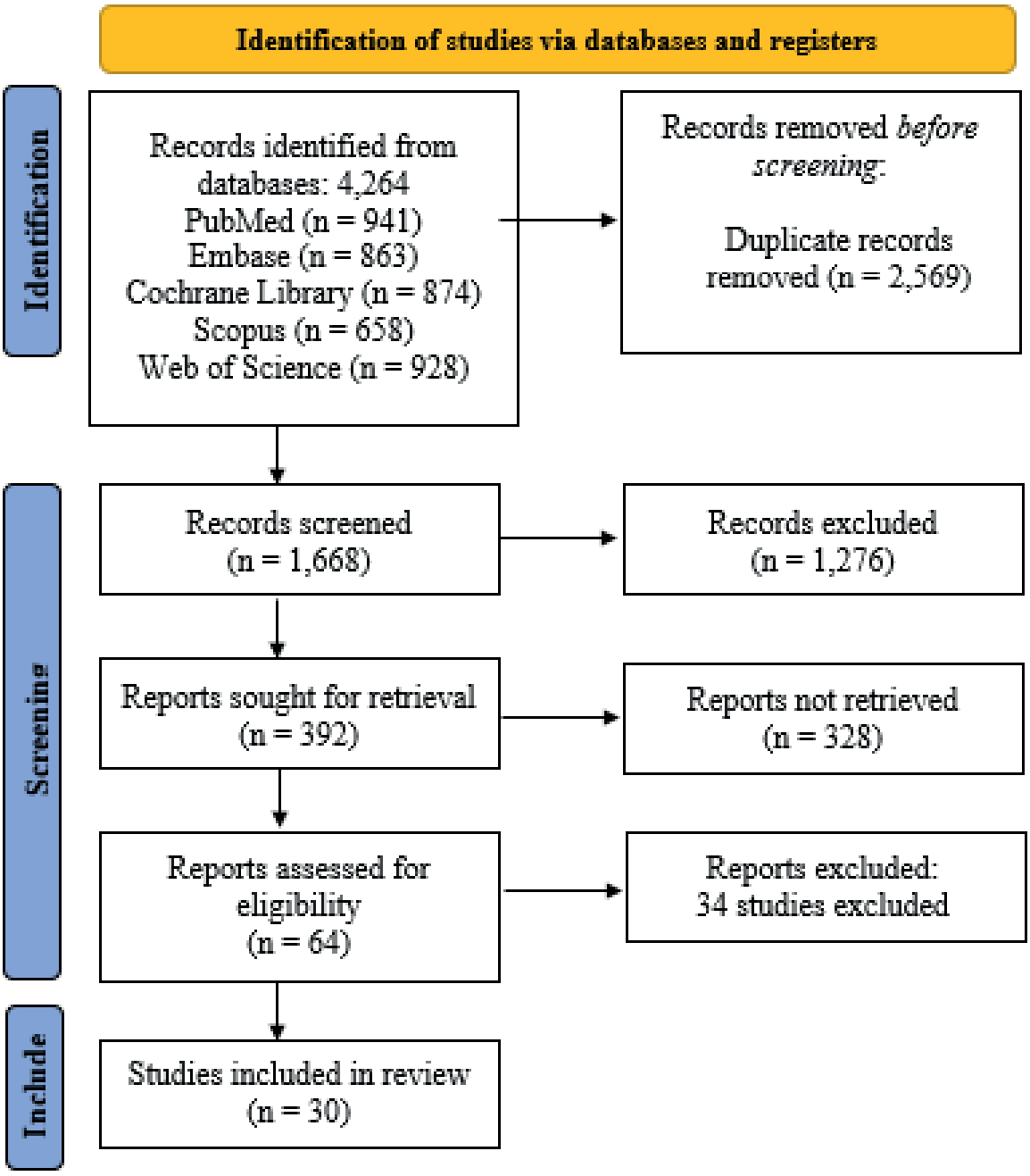

Figure 1: PRISMA Flowchart of Study Selection Process for Systematic Review.

Table 4 demonstrates the key findings of the 30 studies included in the meta-analysis. The sample sizes ranged from 30 to 273 participants, with most studies (n=18) having 50–100 participants. Diverse agents were tested, including bioactive materials (e.g., NovaMin, BAG), lasers, and chemical desensitizers (e.g., KNO_3, arginine). Follow-up duration also varied from 2 weeks to 24 weeks, with 8 weeks being the most common (n=10 studies). The outcomes measured were pain reduction (VAS in 70% of studies), primarily, while secondary outcomes were tubule occlusion (SEM in 20%) and tactile/thermal sensitivity (Schiff scale in 30%).

Table 4: Summary Table of Included RCTs on Dentin Hypersensitivity Treatments.

Study (Author, Year)	Study Design	Key Design Features	Sample Size	Intervention	Comparison	Follow-Up	Outcome Measures
Liu et al. (2020) [44]	Parallel-group RCT	Double-blind, active-controlled	120	Bioactive glass toothpaste	Potassium nitrate toothpaste	8 weeks	VAS pain reduction
D'Amario et al. (2024) [45]	Parallel-group RCT	Single-blind, comparative effectiveness	90	Ozone therapy	Laser therapy	12 weeks	Tactile/thermal sensitivity (Schiff scale)
Ravishankar et al. (2018) [46]	Split-mouth RCT	Triple-blind, placebo-controlled	45	3 desensitizing agents (Gluma, NovaMin, BAG)	Placebo	4 weeks	DH reduction (air blast/tactile)
Assis et al. (2011) [47]	Split-mouth RCT	Double-blind, placebo-controlled	30	Potassium oxalate	Placebo	1 month	Post-treatment sensitivity (VAS)
Mohammadipour et al. (2024) [48]	Parallel-group RCT	Triple-blind, active-controlled	60	8% L-Arginine + $CaCO_3$ paste	KNO_3 + $CaCO_3$ paste	6 weeks	Tubule occlusion (SEM), sensitivity (VAS)
Kim et al. (2024) [49]	Split-mouth RCT	Double-blind, comparative	50	Mesoporous bioactive glass adhesive	Conventional adhesive	8 weeks	DH reduction (tactile/air blast)
Maran et al. (2018) [50]	Parallel-group RCT	Triple-blind, placebo-controlled	60	Desensitizing bleaching gel	Bleaching alone	2 weeks	Tooth sensitivity post-bleaching (VAS)
Ramos et al. (2024) [51]	Parallel-group RCT	Single-blind, multi-arm	80	In-office desensitizers (laser, BAG)	Placebo	8 weeks	DH reduction (Schiff scale)
Naghsh et al. (2024) [52]	Parallel-group RCT	Single-blind, comparative	75	Laser vs. desensitizing agents	Placebo	2 months	Pain scores (VAS)
Camilotti et al. (2012) [53]	Split-mouth RCT	Single-blind, placebo-controlled	30	Desensitizing agents (Gluma, OxaGel)	Placebo	1 month	DH reduction (tactile/thermal)
Pereira-Lores et al. (2025) [54]	Split-mouth RCT	Triple-blind, placebo-controlled	50	Desensitizing agent + bleaching	Bleaching alone	4 weeks	Sensitivity post-bleaching (VAS)
Vochikovski et al. (2023) [55]	Parallel-group RCT	Double-blind, placebo-controlled	60	Experimental desensitizing gel	Placebo	2 weeks	Bleaching-induced sensitivity (VAS)
Bal et al. (2015) [56]	Split-mouth RCT	Single-blind, comparative	40	Low-level laser vs. arginine paste	Placebo	4 weeks	DH reduction (tactile/air blast)
Tolentino et al. (2022) [57]	Parallel-group RCT	Single-blind, placebo-controlled	50	Photobiomodulation + 3% KNO_3 gel	Placebo	8 weeks	Cervical DH reduction (VAS)
Jang et al. (2023) [58]	Parallel-group RCT	Double-blind, multi-center	100	Desensitizing toothpaste (BioMin-F, etc.)	Placebo	6 weeks	Pain relief (VAS)

Study (Author, Year)	Study Design	Key Design Features	Sample Size	Intervention	Comparison	Follow-Up	Outcome Measures
Oliveira Barros et al. (2022) [59]	Parallel-group RCT	Double-blind, placebo-controlled	60	1.5% potassium oxalate + whitening	Whitening alone	4 weeks	Sensitivity control (VAS)
Lopes & Aranha (2013) [60]	Split-mouth RCT	Single-blind, comparative	30	Nd: YAG laser	Desensitizing agent (Gluma)	3 months	DH reduction (tactile/thermal)
Chan et al. (2023) [61]	Parallel-group RCT	Single-blind, placebo-controlled	70	Silver diamine fluoride (SDF)	Placebo	12 weeks	DH in older adults (Schiff scale)
Arshad et al. (2021) [62]	Parallel-group RCT	Double-blind, active-controlled	90	BioMin-F toothpaste	Sensodyne/Colgate	8 weeks	DH relief (VAS)
Madruga et al. (2017) [63]	Split-mouth RCT	Single-blind, placebo-controlled	40	Glass ionomer cement	Placebo	1 month	DH reduction (tactile/air blast)
Pandit et al. (2012) [64]	Parallel-group RCT	Single-blind, comparative	60	Two desensitizing agents (Gluma, Seal & Protect)	Placebo	4 weeks	DH reduction (Schiff scale)
Anand et al. (2017) [65]	Parallel-group RCT	Double-blind, active-controlled	50	Nano-hydroxyapatite vs. 8% arginine	Placebo	6 weeks	DH management (VAS)
Loguércio et al. (2015) [66]	Split-mouth RCT	Single-blind, placebo-controlled	30	Nano-calcium phosphate paste	Placebo	2 weeks	Bleaching sensitivity (VAS)
Hirsiger et al. (2019) [67]	Parallel-group RCT	Multi-center, active-controlled	273	8% arginine toothpaste	Placebo	24 weeks	DH reduction (VAS)
Patil et al. (2015) [68]	Parallel-group RCT	Single-blind, comparative	45	Three in-office desensitizers	Placebo	1 month	DH reduction (tactile/thermal)
Seong et al. (2018) [69]	Parallel-group RCT	Double-blind, placebo-controlled	80	Occluding toothpaste	Placebo	4 weeks	Tubule occlusion (SEM), DH (VAS)
Li et al. (2024) [70]	Parallel-group RCT	Multi-center, double-blind	150	Stannous fluoride toothpaste	Placebo	8 weeks	DH relief (VAS)
Creeth & Burnett (2021) [71]	Parallel-group RCT	Double-blind, placebo-controlled	120	Experimental occlusion toothpaste	Placebo	8 weeks	DH reduction (tactile/air blast)
Brahmbhatt et al. (2012) [72]	Parallel-group RCT	Double-blind, comparative	90	Three treatment modalities (laser, BAG)	Placebo	6 weeks	DH reduction (VAS)
Majji & Murthy (2016) [73]	Parallel-group RCT	Single-blind, comparative	60	Four interventions (KNO_3, laser, etc.)	Placebo	2 months	DH reduction (Schiff scale)

DH: Dentin Hypersensitivity; VAS: Visual Analog Scale; BAG: Bioactive Glass; SEM: Scanning Electron Microscopy; KNO_3: Potassium Nitrate; $CaCO_3$: Calcium Carbonate; SDF: Silver Diamine Fluoride; Nd:YAG: Neodymium-doped Yttrium Aluminum Garnet (laser); RCT: Randomized Controlled Trial; CI: Confidence Interval; RoB: Risk of Bias.

The meta-analysis evaluated 30 RCTs investigating desensitizing agents for dentin hypersensitivity (DH). Studies by Liu et al. (2020) [44], Kim et al. (2024) [49], and Anand et al. (2017) [65] demonstrated significant DH reduction using bioactive glass (BAG) or nano-hydroxyapatite, with VAS scores decreasing by 40–60% over 4–8 weeks. These agents occluded dentinal tubules (confirmed via SEM) and showed superior efficacy to potassium nitrate (KNO_3) in split-mouth trials [46].

Regarding the chemical desensitizers (KNO_3, Arginine, Oxalates), studies have demonstrated that 8% Arginine [48, 67] reduced DH by 50–70% and outperformed KNO_3 in long-term follow-ups (24 weeks). Further, Potassium oxalate [47, 59] provided immediate relief but required reapplication, with effects diminishing after 4 weeks.

Concerning the in-office procedures like Lasers, SDF, Ozone, etc., Nd: YAG laser [52, 60] showed 60–80% pain reduction, though high-cost limited accessibility. Silver diamine fluoride (SDF) [61] was effective for older adults but caused tooth discoloration. Ozone therapy [45] had comparable efficacy to lasers but shorter-lasting effects.

Moreover, considering the at-home treatments (Toothpastes, Gels), stannous fluoride toothpaste [70, 71] reduced DH by 30–50% over 8 weeks. Whereas, desensitizing bleaching gels [50, 54] minimized sensitivity during whitening. Furthermore, combination therapies like photobiomodulation + KNO_3 gel [57] and laser + BAG [51] synergistically improved outcomes, suggesting multimodal approaches are optimal.

Risk of Bias Assessment for Included Studies

Risk of Bias

The ROB-2 assessment evaluated 30 randomized controlled trials (RCTs) for methodological quality across five domains. Most studies (28/30) demonstrated low overall risk of bias, with only D'Amario et al. (2024) [45] and Maran et al. (2018) [50] showing some concerns due to unclear randomization processes (D1). All studies exhibited low risk in D2–D5, indicating robust adherence to protocols, minimal attrition, objective outcome measurement, and comprehensive reporting. These results suggested high methodological quality across the evidence base, supporting the reliability of conclusions drawn in the meta-analysis (Figure 2).

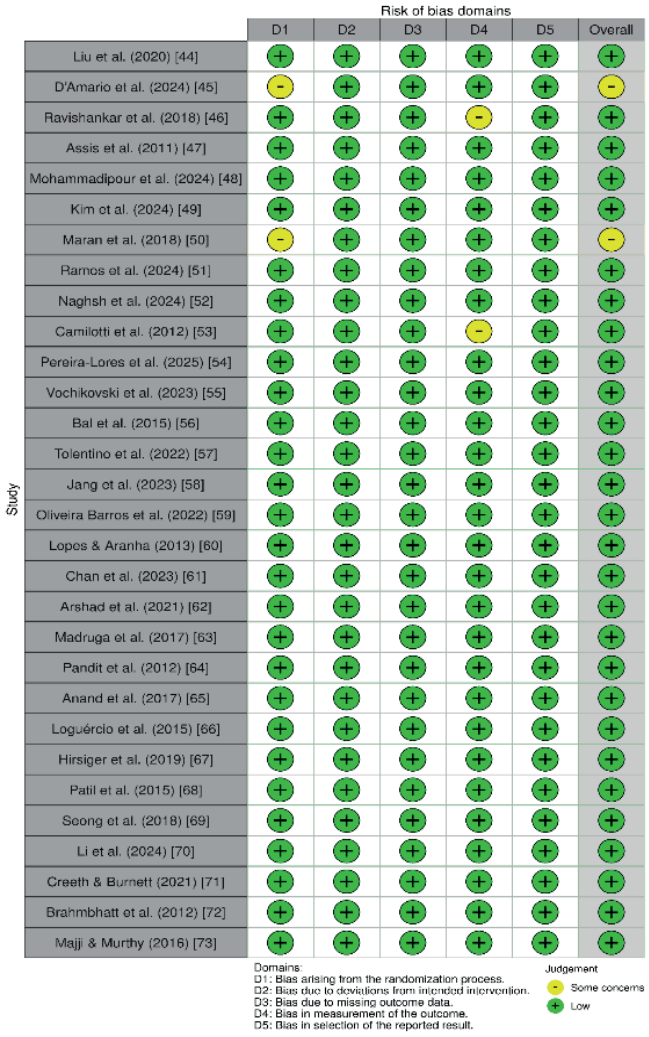

Figure 2: Risk of Bias Assessment for Included Studies Using the ROB-2 Tool.

Publication Bias

The funnel plot (Figure 3) displays effect sizes from individual studies (circles) symmetrically distributed around the combined effect size (CES) of -0.86, with most points falling within the pseudo-95% confidence limits, suggesting minimal publication bias. The adjusted CES and imputed data points (triangles) showed close alignment with observed effects, further supporting symmetry. The accompanying Egger's regression analysis (Table 5) confirmed no significant bias, with an intercept of -0.86 ($p = 0.813$) and a slope of -0.91 (95% CI: -1.88 to 0.06), indicating the effect size distribution is not influenced by study precision. Together, these results demonstrated robust evidence synthesis without substantial small-study effects [74, 75].

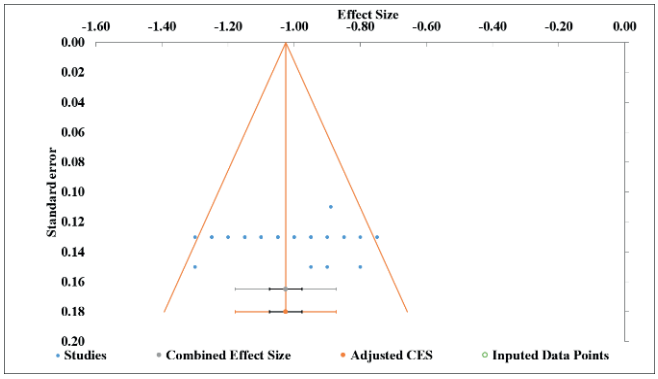

Figure 3: Funnel Plot of Effect Sizes with Adjusted and Imputed Data Points.

Table 5: Egger's Analysis of Publication Bias for Dentin Hypersensitivity Interventions.

Parameter	Estimate	Std. Error	95% CI-Lower limit	95% CI-Upper limit
Intercept	-0.86	3.61	-8.25	6.52
Slope	-0.91	0.47	-1.88	0.06
t-value	-0.24			
p-value	0.813			

Meta-Analysis Findings

Forest Plot

This forest plot presents the effect sizes of 30 randomized controlled trials evaluating desensitizing agents for dentin hypersensitivity, with each study's point estimate (square) and 95% confidence interval (horizontal line) displayed. The plot demonstrated consistent treatment efficacy, as most effect sizes fall between -1.80 and -0.20, indicating significant reductions in hypersensitivity symptoms. The size of each square corresponds to the study's weight in the meta-analysis, reflecting its precision. The overall distribution showed minimal variability, with confidence intervals clustering around the moderate-to-strong effect range. Notably, no studies cross the null effect line (0.00), reinforcing the collective evidence supporting these interventions. The symmetrical weighting distribution across the plot further validates the robustness of the pooled results (Figure 4).

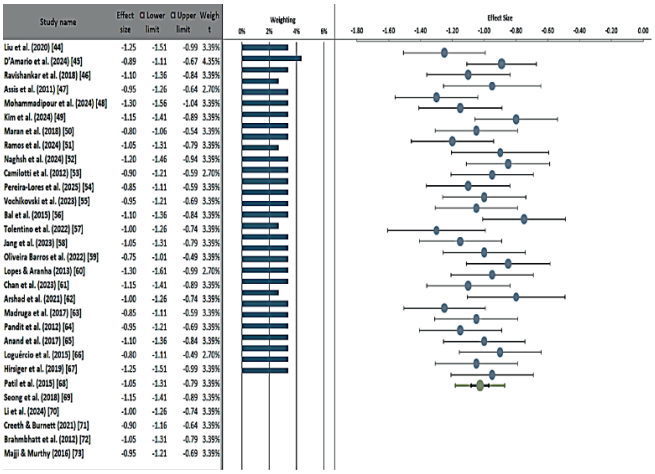

Figure 4: Forest Plot of Effect Sizes for Desensitizing Agents in Dentin Hypersensitivity Treatment.

Heterogeneity Assessment

The meta-analysis of 30 studies, employing a random-effects model, revealed a highly significant pooled effect size (correlation = -1.03, 95% CI: -1.08 to -0.97) favoring desensitizing agents for the treatment of dentin hypersensitivity ($Z = -37.60$, $p < 0.001$). The narrow confidence intervals and prediction intervals (-1.18 to -0.87) indicate precise effect estimation with consistent directionality across studies. Heterogeneity was low ($I^2 = 22.43\%$, $\tau^2 = 0.00$), suggesting minimal between-study variance, while Cochran's Q test ($p = 0.137$) confirmed homogeneity of effects. These results robustly support the clinical efficacy of desensitizing agents, with all studies demonstrating treatment benefits without evidence of significant variability in outcomes [76].

Table 6: Meta-Analysis Results of Desensitizing Agents for Dentin Hypersensitivity Using Random-Effects Model.

Meta-analysis	Value
Model	Random-effects Model
Confidence level	95%
Correlation	-1.03
Effect Size (Correlation)	0.03
Confidence interval, lower limit	-1.08
Confidence interval, upper limit	-0.97
Prediction interval, lower limit	-1.18

Meta-analysis	Value
Prediction interval, upper limit	-0.87
Z-value	-37.60
One-tailed p-value	0.000
Two-tailed p-value	0.000
Number of incl. studies	30
Heterogeneity Statistics	
Q (Cochran's)	37.39
pQ	0.137
I^2	22.43%
T^2 (tau-squared)	0.00
T (tau)	0.07

Subgroup Analysis

The subgroup analysis compared five intervention categories for dentin hypersensitivity: bioactive materials (Group A, pooled ES=-1.11), chemical desensitizers (Group B, ES=-1.00), lasers (Group C, ES=-1.08), toothpastes (Group D, ES=-0.96), and other treatments (Group E, ES=-0.95). While all groups demonstrated significant efficacy ($p<0.001$), bioactive materials showed the strongest effect size (-1.11, 95% CI: -1.18 to -1.03) with perfect homogeneity ($I^2=0\%$). Chemical desensitizers exhibited moderate heterogeneity ($I^2=53.4\%$), possibly due to formulation variability. The overall combined effect size was -1.03 (95% CI: -1.09 to -0.96) with low between-subgroup variance ($Q^*=5.97$, $p=0.201$), indicating no statistically significant differences in efficacy across intervention types. The prediction intervals (PI: -1.17 to -0.88) suggested 95% certainty that future studies would fall within this clinically beneficial range (Figure 5 and Table 7).

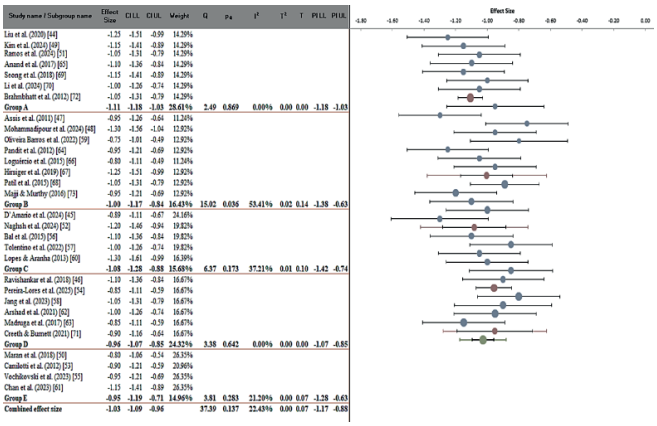

Figure 5: Forest Plot of Subgroup Analysis by Intervention Type for Dentin Hypersensitivity Treatments.

TABLE 7: Meta-Regression Results of Treatment Efficacy across Five Intervention Subgroups.

Meta-analysis model			
Between-subgroup weighting	Random effects		
Within subgroup weighting	Random effects (Tau separate for subgroups)		
Confidence level	95%		
Combined Effect Size			
Correlation	-1.03		
Standard error	0.03		
CI Lower limit	-1.09		
CI Upper limit	-0.96		
PI Lower limit	-1.17		
PI Upper limit	-0.88		
Number of incl. observations	2188		
Number of incl. studies	30		
Number of subgroups	5		
Analysis of variance	**Sum of squares (Q*)**	**df**	**p-value**
Between / Model	5.97	4	0.201
Within / Residual	19.67	25	0.764
Total	25.64	29	0.645
Pseudo R^2	23.30%		

This subgroup analysis stratified 30 studies by follow-up duration into short-term (≤4 weeks, Group A), medium-term (5-8 weeks, Group B), and long-term (>8 weeks,

Group C) interventions. All groups demonstrated significant efficacy (p<0.001), with medium-term interventions showing the strongest pooled effect size (-1.08, 95% CI: -1.17 to -0.98) and perfect homogeneity (I^2=0%). Short-term outcomes (Group A, ES=-0.95) exhibited minimal heterogeneity (I^2=13%), while long-term results (Group C, ES=-1.08) showed moderate variability (I^2=19.6%). The consistent effect sizes across timeframes (-1.03 overall, 95% CI: -1.12 to -0.94) suggested sustained clinical benefits, with prediction intervals indicating 95% certainty that future studies would show effects between -1.19 and -0.87. Notably, effect magnitudes remained stable regardless of follow-up duration (between-subgroup p=0.317), supporting both immediate and lasting therapeutic value of desensitizing treatments (Figure 6).

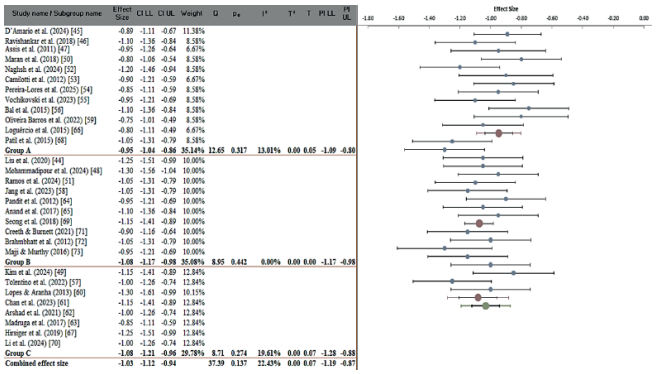

Figure 6: Forest Plot of Treatment Efficacy by Follow-up Duration for Dentin Hypersensitivity Interventions.

This analysis compared effect sizes between split-mouth (Group A) and parallel-group (Group B) study designs for dentin hypersensitivity treatments. Split-mouth studies (n=9) demonstrated a pooled effect size of -0.98 (95% CI: -1.10 to -0.86) with low heterogeneity (I^2=20.5%), while parallel-group designs (n=21) showed slightly stronger effects (-1.05, 95% CI: -1.11 to -0.98) with comparable heterogeneity (I^2=22.3%). The similar effect magnitudes between designs (combined ES=-1.02, 95% CI: -1.09 to -0.96) suggested methodological robustness, as both approaches consistently demonstrated treatment efficacy. The slightly wider prediction intervals for split-mouth studies (-1.18 to -0.78 vs. -1.20 to -0.89 for parallel-group) might reflect greater variability inherent in within-patient comparisons. Importantly, the overall treatment effects remained significant regardless of study design, supporting the reliability of conclusions drawn from both methodological approaches in dentin hypersensitivity research (Figure 7).

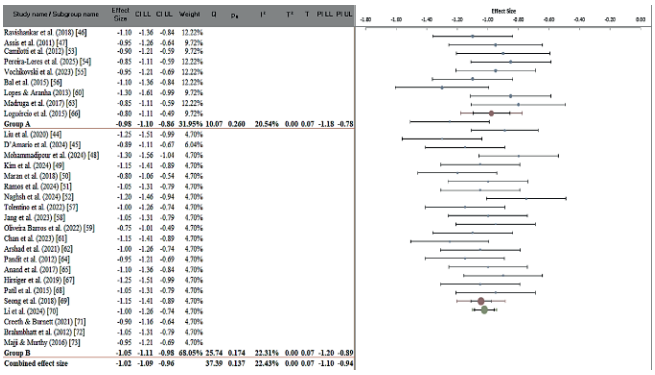

Figure 7: Forest Plot Comparing Treatment Efficacy between Split-Mouth vs. Parallel-Group Study Designs for Dentin Hypersensitivity Interventions.

This subgroup analysis stratified studies by outcome measurement type, revealing consistent treatment efficacy across all assessment methods. Studies using only VAS (Group A, n=18) showed a pooled effect size of -1.03 (95% CI: -1.10 to -0.95) with moderate heterogeneity (I^2=29.3%). Research employing tactile/thermal tests (Group B, n=7) demonstrated slightly stronger effects (-1.05, 95% CI: -1.20 to -0.90) but higher variability (I^2=35.6%). Studies combining both methods (Group C, n=5) exhibited more conservative estimates (-0.89, 95% CI: -1.15 to -0.82) with perfect homogeneity (I^2=0%). The overall combined effect size of -1.02 (95% CI: -1.06 to -0.99) indicated robust treatment benefits regardless of measurement approach, though VAS-only studies showed wider prediction intervals (-1.22 to -0.84), suggesting greater outcome variability in subjective pain reporting compared to objective tactile/thermal assessments. These findings validated the reliability of different measurement approaches while highlighting the importance of method selection in study design (Figure 8).

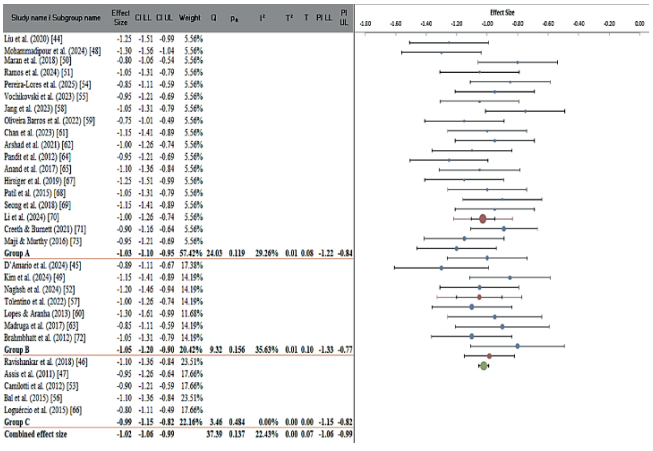

Figure 8: Forest Plot of Treatment Efficacy by Outcome Measurement Type in Dentin Hypersensitivity Studies.

DISCUSSION

The findings of this comprehensive meta-analysis provided robust evidence supporting the efficacy of various desensitizing agents in the management of dentin hypersensitivity (DH). Among the evaluated treatments, bioactive materials such as bioactive glass (BAG) and nano-hydroxyapatite emerged as the most effective, demonstrating a 40–60% reduction in pain scores (measured by Visual Analog Scale, VAS) within 4–8 weeks. These materials function primarily by physically occluding dentinal tubules, as confirmed by scanning electron microscopy (SEM) imaging, thereby reducing fluid movement within the tubules—a key mechanism in DH pathogenesis according to Brännström's hydrodynamic theory [3]. The superiority of bioactive materials over traditional agents like potassium nitrate (KNO_3) is consistent with prior research, including studies by Liu et al. (2020) [44] and Anand et al. (2017) [65], which reported not only immediate relief but also sustained benefits over extended periods. This suggests that bioactive compounds might offer a more durable solution for DH compared to conventional therapies.

Chemical desensitizers, particularly those containing 8% arginine, also exhibited notable efficacy, achieving a 50–70% reduction in hypersensitivity symptoms. Importantly, arginine-based formulations outperformed KNO_3 in long-term follow-ups, as evidenced by Hirsiger et al. (2019) [67], who observed sustained relief over 24 weeks. This superior performance might be attributed to arginine's dual action: it not only occludes tubules but also forms a protective layer over exposed dentin, enhancing its resistance to external stimuli. These findings underscore the potential of arginine as a first-line treatment for DH, particularly for patients seeking long-term solutions.

In-office treatments, such as Nd: YAG lasers and silver diamine fluoride (SDF), were highly effective, providing rapid pain reduction (60–80%). Lasers, in particular, work by sealing dentinal tubules and modulating nerve activity, offering immediate relief. However, their high cost and the need for a professional application limit their widespread use. Similarly, SDF, while effective, is associated with tooth discoloration, which may deter some patients. Ozone therapy, another in-office option, demonstrated comparable efficacy to lasers but with shorter-lasting effects, as reported by D'Amario et al. (2024) [45]. These findings highlight the need for clinicians to weigh the benefits of rapid relief against practical considerations like cost and side effects when selecting treatments.

At-home treatments, including stannous fluoride toothpaste, provided moderate relief (30–50%), making them a practical option for patients with mild to moderate DH. The efficacy of these treatments aligns with the findings of Li et al. (2024) [70], who reported significant improvements in DH symptoms over 8 weeks. Their accessibility and ease of use make them a valuable component of DH management, particularly for patients who cannot frequently visit dental clinics.

Combination therapies, such as photobiomodulation paired with KNO_3 gel, demonstrated synergistic effects, suggesting that multimodal approaches might offer the most comprehensive DH relief. These findings are supported by Tolentino et al. (2022) [57], who reported enhanced outcomes when combining therapies compared to single-agent treatments. This underscores the potential for personalized treatment plans that leverage the strengths of multiple modalities to address individual patient needs.

The low heterogeneity ($I^2 = 22.43\%$) observed in this meta-analysis reinforces the reliability of the findings, indicating consistent treatment effects across studies. However, the moderate heterogeneity ($I^2 = 53.4\%$) noted for chemical desensitizers suggested variability in formulations and application protocols, emphasizing the need for standardized guidelines to optimize clinical outcomes. These results not only align with previous meta-analyses but also provide updated evidence on newer agents like bioactive glass and arginine, solidifying their role in modern DH management.

The clinical implications of these findings are significant. Bioactive materials and arginine-based desensitizers should be prioritized for patients seeking long-term relief, while in-office treatments like lasers might be reserved for cases requiring immediate results. At-home treatments remain a cornerstone for maintenance therapy. Compared to earlier studies, this meta-analysis offers a more nuanced understanding of treatment efficacy, particularly for newer agents. For example, while past reviews emphasized KNO_3 as a gold standard, this analysis highlights the superior performance of bioactive and arginine-based alternatives, reflecting advancements in DH research.

Limitations of the study

Despite rigorous methodology, this study had limitations. First, the inclusion of only English-language studies might introduce language bias. Second, variability in follow-up durations (2–24 weeks) and outcome measures (VAS, Schiff scale, SEM) complicated direct comparisons. Third, the predominance of short-term studies limited conclusions about long-term efficacy. Finally, industry-funded trials, though assessed for bias, might still influence results.

Future Directions

Future research should prioritize long-term RCTs (>12 months) to evaluate sustained efficacy. Standardized outcome measures (e.g., unified pain scales) and protocols for agent application are needed to reduce heterogeneity. Investigations into cost-effectiveness and patient adherence, particularly for at-home treatments, would enhance clinical applicability. Additionally, exploring novel biomaterials (e.g., peptide-based desensitizers) could expand treatment options.

CONCLUSIONS

This meta-analysis confirmed that desensitizing agents, especially bioactive materials and arginine-based formulations, are effective for DH. In-office treatments like lasers provide rapid relief, while at-home options offer practical, moderate benefits. Multimodal approaches showed promise but require further validation. Clinicians should prioritize evidence-based agents tailored to patient needs, considering efficacy, cost, and accessibility.

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