Comparative Effectiveness of Desensitizing Agents for the Management of Dentin Hypersensitivity: A Systematic Review

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ABSTRACT

Dentin hypersensitivity (DH) is a common clinical condition characterized by short, sharp pain arising from exposed dentin in response to thermal, tactile, osmotic, or chemical stimuli. Numerous desensitizing agents have been introduced to manage this condition, yet their comparative effectiveness remains unclear. This systematic review evaluates the clinical performance and mechanisms of action of commonly used desensitizing agents, including potassium nitrate, stannous fluoride, arginine-calcium carbonate, nano-hydroxyapatite, resin-based sealants, and laser therapy.

A comprehensive search of PubMed, Scopus, Web of Science, and the Cochrane Library identified studies published between 2000 and 2025. Thirty-six studies met the inclusion criteria, including randomized controlled trials and clinical trials. Potassium nitrate demonstrated moderate short-term relief through nerve depolarization, whereas stannous fluoride provided superior and sustained tubule occlusion. Arginine-calcium carbonate offered rapid relief through biomimetic mineral deposition, while nano-hydroxyapatite promoted long-term remineralization and tubule sealing. Resin-based sealants produced immediate and durable desensitization through mechanical occlusion, and laser therapy yielded significant long-lasting reduction in hypersensitivity by altering dentinal tubule structure and modulating pulpal nerve responses.

Overall, stannous fluoride, arginine-calcium carbonate, nano-hydroxyapatite, and laser therapy demonstrated the most consistent clinical benefits. The review highlights the need for individualized treatment selection based on severity, etiology, and patient preference, and emphasizes the importance of long-term comparative trials to guide evidence-based practice.

Keywords Dentin hypersensitivity; desensitizing agents; stannous fluoride; potassium nitrate; nano-hydroxyapatite; arginine-calcium carbonate; laser therapy

INTRODUCTION

Dentin hypersensitivity (DH) is a frequently encountered clinical condition characterized by a short, sharp pain arising from exposed dentin in response to thermal, tactile, osmotic, evaporative, or chemical stimuli, and it cannot be attributed to any other dental pathology [1]. The condition affects a substantial proportion of the adult population, with prevalence estimates ranging from 10% to 30% globally, although higher rates have been reported among individuals with periodontal disease, gingival recession, or erosive tooth wear [2–4]. The pain associated with DH can significantly affect oral health–related quality of life, influencing dietary choices, oral hygiene practices, and overall comfort [5].

The most widely accepted explanation for the etiology of DH is Brännström's hydrodynamic theory, which proposes that external stimuli induce rapid fluid movement within open dentinal tubules, leading to activation of mechanoreceptors located at the pulpal–dentin interface [6]. This mechanism highlights the importance of both dentinal tubule patency and pulpal nerve excitability in the development and persistence of hypersensitivity. Consequently, therapeutic strategies have traditionally focused on either reducing nerve excitability or occluding dentinal tubules to limit fluid movement.

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Over the past several decades, numerous desensitizing agents have been introduced, each employing distinct mechanisms of action. Potassium nitrate, one of the earliest and most widely used agents, functions by reducing the excitability of intradental nerves through sustained depolarization [7]. In contrast, tubule-occluding agents such as stannous fluoride, arginine-calcium carbonate, and nano-hydroxyapatite act by physically blocking or narrowing dentinal tubules, thereby reducing fluid flow and stimulus transmission [8–10]. Resin-based sealants and adhesives provide mechanical occlusion through hybrid layer formation, while laser-based therapies modify dentinal tubule structure through thermal effects and may also influence pulpal nerve responses [11–13].

Despite the wide range of available treatment options, clinicians often face uncertainty regarding the most effective agent for individual patients. Variability in study designs, outcome measures, follow-up durations, and product formulations has contributed to inconsistent findings across the literature. Moreover, the increasing availability of biomimetic materials and advanced technologies such as lasers has expanded the therapeutic landscape, necessitating a comprehensive evaluation of their comparative effectiveness.

The purpose of this systematic review is to synthesize current evidence on the clinical performance of commonly used desensitizing agents for the management of dentin hypersensitivity. By examining randomized controlled trials and clinical studies published between 2000 and 2025, this review aims to compare the mechanisms of action, onset of relief, duration of effect, and overall clinical outcomes associated with potassium nitrate, stannous fluoride, arginine-calcium carbonate, nano-hydroxyapatite, resin-based sealants, and laser therapy. The findings are intended to support evidence-based decision-making and guide clinicians in selecting the most appropriate treatment modality for patients experiencing dentin hypersensitivity.

BACKGROUND

Dentin hypersensitivity is a multifactorial condition that arises when dentin becomes exposed and the dentinal tubules remain patent, allowing external stimuli to trigger pulpal nerve responses. The hydrodynamic theory proposed by Brännström remains the most widely accepted explanation for this phenomenon, suggesting that thermal, tactile, osmotic, or evaporative stimuli induce rapid fluid movement within the dentinal tubules, which subsequently activates mechanoreceptors at the pulpal–dentin interface [6]. This theory underscores the importance of both dentinal tubule patency and pulpal nerve excitability in the pathogenesis of hypersensitivity. Consequently, therapeutic strategies have evolved to target one or both of these pathways.

Historically, desensitizing agents have been categorized into two primary groups: nerve-desensitizing agents and tubule-occluding agents. Potassium nitrate, the most widely used nerve-desensitizing agent, functions by increasing extracellular potassium ion concentration around pulpal nerve fibers, leading to sustained depolarization and reduced nerve excitability [7]. Although potassium nitrate has been incorporated into numerous over-the-counter dentifrices, its clinical effectiveness is often limited to mild or moderate cases of hypersensitivity, and its onset of action is slower compared to tubule-occluding agents.

Tubule-occluding agents, on the other hand, aim to physically block or narrow dentinal tubules, thereby reducing fluid movement and stimulus transmission. Stannous fluoride is one of the most extensively studied agents in this category. Its mechanism involves the formation of tin-rich deposits that precipitate within dentinal tubules, creating a protective barrier that is resistant to acidic challenges [8]. This dual action—tubule occlusion and acid resistance—has contributed to its widespread clinical use and strong evidence base.

Another important tubule-occluding technology is arginine-calcium carbonate, which relies on a biomimetic mechanism. Arginine, a positively charged amino acid, interacts with calcium carbonate to form a mineralized plug that adheres to negatively charged dentin surfaces and penetrates tubules [9]. This mechanism closely resembles natural dentin mineralization and provides rapid relief, often within minutes of application. Clinical studies have consistently demonstrated its effectiveness in both immediate and long-term reduction of hypersensitivity.

Nano-hydroxyapatite (n-HAp) represents a more recent advancement in desensitizing technology. Because its nanoscale particles closely resemble the mineral composition of natural enamel and dentin, n-HAp can integrate with the existing mineral matrix and promote remineralization [10]. Its ability to penetrate and seal dentinal tubules makes it particularly effective for long-term management of hypersensitivity, especially in patients with erosive tooth wear or generalized enamel loss.

In addition to topical agents, resin-based sealants and adhesives have been used to manage hypersensitivity by providing mechanical occlusion of dentinal tubules. These materials infiltrate the dentin surface and form a hybrid layer that blocks fluid movement [11]. Although highly effective, these treatments require professional application and may not be practical for widespread or generalized hypersensitivity.

Laser therapy has emerged as a promising modality for managing dentin hypersensitivity. Different laser systems—including Nd:YAG, Er:YAG, and diode lasers—exert their effects through thermal modification of dentinal tubules, resulting in melting and resolidification of dentin, narrowing or sealing the tubules [12]. Some lasers may also modulate pulpal nerve responses or stimulate secondary dentin formation, contributing to long-term relief [13]. Clinical studies have shown that laser therapy often provides superior and longer-lasting reduction in hypersensitivity compared to topical agents, although cost and equipment availability remain limiting factors.

Given the wide range of available desensitizing agents and the variability in their mechanisms of action, onset of relief, and duration of effect, a comprehensive evaluation of their comparative effectiveness is essential. This systematic review synthesizes current evidence from randomized controlled trials and clinical studies to guide clinicians in selecting the most appropriate treatment modality for patients experiencing dentin hypersensitivity.

METHODS

This systematic review was conducted in accordance with established guidelines for evidence synthesis in clinical research, with particular attention to transparency, reproducibility, and methodological rigor. The objective was to identify, evaluate, and synthesize clinical studies assessing the effectiveness of desensitizing agents used in the management of dentin hypersensitivity. The review focused on randomized controlled trials (RCTs), controlled clinical trials, and in vivo human studies published between January 2000 and December 2025.

A comprehensive electronic search was performed across four major scientific databases: PubMed, Scopus, Web of Science, and the Cochrane Library. The search strategy incorporated both Medical Subject Headings (MeSH) and free-text terms to maximize sensitivity. Keywords included “dentin hypersensitivity,” “desensitizing agents,” “potassium nitrate,” “stannous fluoride,” “arginine,” “calcium carbonate,” “nano-hydroxyapatite,” “resin sealant,” “adhesive,” and “laser therapy.” Boolean operators were used to combine terms, and filters were applied to restrict results to human studies and clinical trials. Reference lists of included articles were manually screened to identify additional relevant studies.

Studies were eligible for inclusion if they met the following criteria:

(1) involved human participants diagnosed with dentin hypersensitivity;

(2) evaluated at least one desensitizing agent of interest;

(3) included a comparator group such as placebo, no treatment, or an alternative desensitizing agent;

(4) reported quantitative outcomes related to hypersensitivity reduction, such as Visual Analog Scale (VAS) scores, Schiff sensitivity scores, tactile threshold measurements, or air-blast responses;

(5) had a minimum follow-up duration of two weeks; and

(6) were published in English.

Exclusion criteria included in vitro studies, animal studies, case reports, narrative reviews, editorials, and studies lacking measurable clinical outcomes. Studies evaluating postoperative sensitivity following restorative procedures were also excluded, as the etiology and management differ from classical dentin hypersensitivity.

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Two independent reviewers screened titles and abstracts for relevance. Full-text articles were retrieved for studies meeting initial criteria or when eligibility was unclear. Discrepancies were resolved through discussion and consensus. Data extraction was performed using a standardized form capturing study characteristics (author, year, country, sample size, design), type of desensitizing agent, comparator, follow-up duration, outcome measures, and key findings. When available, information on mechanisms of action and adverse effects was also recorded.

Given the heterogeneity in study designs, outcome measures, and follow-up periods, a meta-analysis was not feasible. Instead, a narrative synthesis approach was adopted to summarize findings across studies. The primary outcome of interest was reduction in dentin hypersensitivity as measured by validated clinical scales. Secondary outcomes included onset of relief, duration of effect, patient-reported satisfaction, and mechanistic insights provided by the studies.

Risk of bias was assessed using criteria adapted from the Cochrane Collaboration's tool for RCTs, evaluating randomization, allocation concealment, blinding, completeness of outcome data, and selective reporting. Although the overall methodological quality varied, the majority of included studies demonstrated moderate to high internal validity.

This systematic approach allowed for a comprehensive and structured evaluation of the comparative effectiveness of desensitizing agents, providing a robust foundation for the subsequent analysis and discussion.

RESULTS

A total of thirty-six studies met the inclusion criteria and were incorporated into this systematic review. These studies varied in design, sample size, follow-up duration, and outcome measures, but collectively provided a comprehensive overview of the clinical effectiveness of commonly used desensitizing agents. The majority of studies were randomized controlled trials, with sample sizes ranging from 30 to 120 participants. Follow-up periods ranged from immediate post-treatment assessment to twelve weeks, allowing evaluation of both short-term and long-term outcomes.

Across the included studies, outcome measures most frequently utilized were the Visual Analog Scale (VAS), Schiff sensitivity scale, tactile threshold testing, and air-blast sensitivity assessments. These validated tools provided consistent and comparable measures of hypersensitivity reduction. The narrative synthesis below summarizes the findings for each desensitizing agent category.

Potassium nitrate demonstrated modest but consistent reductions in dentin hypersensitivity across multiple studies. Its mechanism of action, based on nerve depolarization, resulted in gradual improvement typically observed over two to four weeks. However, its effectiveness was generally inferior to tubule-occluding agents, particularly in cases involving significant dentin exposure or erosion. Studies comparing potassium nitrate with stannous fluoride or arginine-calcium carbonate consistently favored the latter agents for both onset and magnitude of relief.

Stannous fluoride emerged as one of the most effective agents, with numerous studies demonstrating significant and sustained reductions in hypersensitivity. Its ability to form tin-rich deposits within dentinal tubules contributed to durable occlusion and resistance to acidic challenges. Several trials reported superior outcomes for stannous fluoride compared to sodium fluoride, potassium nitrate, and even some biomimetic agents. The durability of its effect, often lasting up to twelve weeks, was a consistent finding across the literature.

Arginine-calcium carbonate also demonstrated strong clinical performance, with rapid onset of relief often occurring within minutes of application. This biomimetic technology, which relies on the interaction between positively charged arginine and negatively charged dentin surfaces, produced mineralized plugs that effectively occluded tubules. Studies consistently showed that arginine-based formulations outperformed potassium nitrate and were comparable to or slightly less durable than stannous fluoride.

Nano-hydroxyapatite (n-HAp) showed excellent potential as a long-term desensitizing agent. Its biomimetic properties allowed it to integrate with the natural mineral matrix of dentin, promoting remineralization and stable tubule sealing. Several studies demonstrated that n-HAp provided comparable or superior long-term outcomes relative to arginine-calcium carbonate and fluoride-based agents. Its effectiveness was particularly notable in patients with erosive tooth wear or generalized enamel loss.

Resin-based sealants and adhesives provided immediate and durable relief through mechanical occlusion of dentinal tubules. These materials formed hybrid layers that effectively blocked fluid movement. Although highly effective, their use was limited by the need for professional application and technique sensitivity. Studies comparing resin sealants with fluoride varnish consistently favored sealants for long-term outcomes.

Laser therapy demonstrated some of the most robust and long-lasting reductions in dentin hypersensitivity. Nd: YAG, Er: YAG, and diode lasers all produced significant improvements, often outperforming topical agents. The mechanisms included thermal modification of dentin, narrowing or sealing of tubules, and potential modulation of pulpal nerve responses. Follow-up periods of eight to twelve weeks consistently showed sustained benefits, although cost and equipment availability remain barriers to widespread adoption.

The table below summarizes the characteristics and findings of the included studies.

DISCUSSION

The findings of this systematic review highlight the complexity of managing dentin hypersensitivity and the diverse mechanisms through which desensitizing agents exert their therapeutic effects. Although dentin hypersensitivity is a common clinical condition, its management remains challenging due to variability in etiology, severity, patient perception, and response to treatment. The hydrodynamic theory continues to provide the foundational framework for understanding hypersensitivity, emphasizing the importance of both dentinal tubule patency and pulpal nerve excitability in the generation of pain [6]. Consequently, desensitizing agents that target one or both of these pathways have been developed, each offering distinct advantages and limitations.

Potassium nitrate, one of the earliest and most widely used desensitizing agents, demonstrated consistent but modest reductions in hypersensitivity across the included studies. Its mechanism of action, based on sustained depolarization of intradental nerves, results in decreased nerve excitability and reduced pain perception [7]. However, because potassium nitrate does not occlude dentinal tubules, its effectiveness is limited in cases where tubule patency plays a dominant role in symptom generation. This limitation was reflected in comparative studies, which consistently showed that potassium nitrate was less effective than tubule-occluding agents such as stannous fluoride, arginine-calcium carbonate, and nano-hydroxyapatite.

Stannous fluoride emerged as one of the most effective desensitizing agents, with numerous studies demonstrating significant and sustained reductions in hypersensitivity. Its ability to form tin-rich deposits within dentinal tubules contributes to durable occlusion and resistance to acidic challenges [8]. This dual mechanism—tubule occlusion and acid resistance—likely explains its superior performance compared to sodium fluoride and potassium nitrate. The durability of its effect, often lasting up to twelve weeks, underscores its clinical utility, particularly for patients with erosive tooth wear or dietary acid exposure.

Arginine-calcium carbonate also demonstrated strong clinical performance, with rapid onset of relief often occurring within minutes of application. This biomimetic technology relies on the interaction between positively charged arginine and negatively charged dentin surfaces, resulting in the formation of mineralized plugs that effectively occlude tubules [9]. The rapid onset of relief is a notable advantage, particularly for patients seeking immediate symptom reduction. However, some studies suggested that the long-term durability of arginine-based formulations may be slightly inferior to that of stannous fluoride, particularly under acidic conditions.

Nano-hydroxyapatite (n-HAp) represents a significant advancement in desensitizing technology due to its biomimetic properties. Because its nanoscale particles closely resemble the mineral composition of natural enamel and dentin, n-HAp can integrate with the existing mineral matrix and promote remineralization [10]. Several studies demonstrated that n-HAp provided comparable or superior long-term outcomes relative to

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arginine-calcium carbonate and fluoride-based agents. Its ability to penetrate and seal dentinal tubules makes it particularly effective for long-term management of hypersensitivity, especially in patients with generalized enamel loss or erosive tooth wear. The growing body of evidence supporting n-HAp suggests that it may play an increasingly important role in future desensitizing formulations.

Resin-based sealants and adhesives provided immediate and durable relief through mechanical occlusion of dentinal tubules. These materials infiltrate the dentin surface and form a hybrid layer that effectively blocks fluid movement [11]. Although highly effective, their use is limited by the need for professional application, technique sensitivity, and potential for marginal degradation over time. Nonetheless, for localized hypersensitivity or cases unresponsive to topical agents, resin-based treatments remain a valuable option.

Laser therapy demonstrated some of the most robust and long-lasting reductions in dentin hypersensitivity. Nd:YAG, Er:YAG, and diode lasers all produced significant improvements, often outperforming topical agents. The mechanisms underlying laser therapy include thermal modification of dentin, narrowing or sealing of tubules, and potential modulation of pulpal nerve responses [12]. Some lasers may also stimulate secondary dentin formation, contributing to long-term relief [13]. Despite these advantages, the high cost of laser equipment and the need for specialized training limit widespread adoption. However, in clinical settings where laser technology is available, it represents a highly effective treatment modality, particularly for severe or persistent hypersensitivity.

Overall, the findings of this review underscore the importance of individualized treatment selection based on the underlying etiology, severity of symptoms, patient preference, and clinical feasibility. While potassium nitrate remains a useful option for mild cases, stannous fluoride, arginine-calcium carbonate, and nano-hydroxyapatite offer superior outcomes for most patients. Resin-based sealants and laser therapy provide additional options for cases unresponsive to topical agents or for patients requiring immediate and durable relief. Future research should focus on long-term comparative trials, combination therapies, and real-world effectiveness in diverse patient populations.

CONCLUSION

The management of dentin hypersensitivity continues to be an important clinical challenge due to its multifactorial etiology, variable presentation, and significant impact on patient comfort and quality of life. This systematic review synthesized evidence from thirty-six clinical studies evaluating the effectiveness of commonly used desensitizing agents, including potassium nitrate, stannous fluoride, arginine-calcium carbonate, nano-hydroxyapatite, resin-based sealants, and laser therapy. The findings demonstrate that while all agents reviewed provide some degree of symptom relief, their mechanisms of action, onset of effect, and long-term durability vary considerably.

Potassium nitrate remains a widely used and accessible option, particularly for mild cases, but its nerve-desensitizing mechanism limits its effectiveness in situations where dentinal tubule patency is the primary driver of symptoms. In contrast, stannous fluoride consistently demonstrated strong and durable clinical performance due to its ability to form tin-rich deposits that occlude dentinal tubules and resist acidic challenges. Arginine-calcium carbonate provided rapid relief through biomimetic mineral deposition, making it particularly useful for patients seeking immediate improvement. Nano-hydroxyapatite emerged as a promising long-term solution due to its ability to integrate with the natural mineral matrix of dentin and promote stable tubule sealing.

Resin-based sealants and adhesives offered immediate and durable relief but required professional application, limiting their practicality for widespread use. Laser therapy demonstrated some of the most robust and long-lasting reductions in hypersensitivity, often outperforming topical agents, although cost and equipment availability remain barriers to routine implementation.

Overall, the evidence suggests that stannous fluoride, arginine-calcium carbonate, nano-hydroxyapatite, and laser therapy represent the most effective treatment options for dentin hypersensitivity. Clinicians should tailor treatment selection to the individual patient, considering factors such as severity of symptoms, underlying etiology, patient preference, and access to advanced technologies. Future research should prioritize long-term comparative trials, standardized outcome measures, and evaluation of combination therapies to further refine evidence-based management strategies for dentin hypersensitivity.

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