Dentinal Hypersensitivity: A Review

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Introduction
Dentinal hypersensitivity is a common dental problem that is frequently encountered yet it is often under-reported by patients, or misdiagnosed by clinicians. This course will address the etiology, prevalence and diagnosis of dentinal hypersensitivity as well as review clinical evidence behind common treatments.

Conflict of Interest Disclosure Statement
• The author is a retired employee of P&G and does consulting work for P&G.

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Overview

This review will address the etiology of the condition commonly referred to as “dentinal hypersensitivity,” “dentine sensitivity,” “root sensitivity” or “tooth sensitivity.” More specifically, this course will re-view the prevalence and diagnosis of the condition as well as reviewing clinical evidence behind various popular home care products and in-office treatment options.

Learning Objectives

Upon completion of this course, the dental professional should be able to:

- Discuss the prevalence of dentinal hypersensitivity and common contributing factors.
- Explain the hydrodynamic theory, widely accepted as the cause for dentinal sensitivity.
- Discuss common diagnostic tools.
- List common ingredients used in at-home and in-office desensitizing products.
- Discuss the mode of action of common ingredients.
- Discuss the clinical evidence behind common treatment approaches including in-office treatments.

Prevalence

Dentinal hypersensitivity (DH) is a global oral health issue and a significant challenge for most dental professionals. Symptoms of dentinal hypersensitivity are generally reported by the patient and are difficult to describe and challenging to accurately diagnose because other dental diseases have to be ruled out first, such as dental caries, cracked-tooth syndrome, and defective restorations, among others. The most common symptom reported is a short, sharp transient pain arising from exposed dentin responding to one of several different stimuli: thermal, chemical, tactile, evaporative and osmotic (Figure 1).

The prevalence of dentinal hypersensitivity has been reported over the years in a variety of ways: 3.8% to 74.0% depending upon the population, study setting and study design, 1-14.3% of all dental patients, 2 between 8% and 57% of adult dentate population, 3 and up to 30% of adults at some time during their lifetime. 4 Among periodontal patients, the frequency is much higher (60%-98%). 5-7

Dentinal hypersensitivity has been shown to peak in 20 to 30 year olds and then rise again when in their 50s. 8 A more current study conducted in India by Sood et al, with 2051 subjects, found that the highest prevalence of DH occurred in 40-49 year old age group and the age group of 60-69 years showed minimum hypersensitivity. 9 These results further demonstrate the difficulty of diagnosing the condition and accurately reporting prevalence. The condition generally involves...
the facial surfaces near the cervical aspect of teeth and is very common in premolars and canines. Patients undergoing periodontal treatment are particularly susceptible to this condition, as mentioned above, because of the recession following periodontal surgery or loss of cementum following non-surgical periodontal therapy. In addition periodontal disease and improper brushing habits can also result in gingival recession accompanied by sensitive teeth. Dentinal hypersensitivity has been researched extensively through the years and many authors express an agreement that dentinal hypersensitivity is either under-reported by the dental patient population or under-diagnosed, and excludes the underserved population when estimating prevalence of the condition.

Theories
A variety of theories have been suggested to help explain the mechanism involved in the etiology of dentinal hypersensitivity. The transducer theory, the modulation theory, the “gate” control and vibration theory, and the hydrodynamic theory have all been presented and discussed throughout the years. The latter, “hydrodynamic theory,” developed in the 1960’s and based upon two decades of research, is now widely accepted as the cause of tooth sensitivity. Before explaining the “hydrodynamic theory” it is important to point out that none of these mechanisms full explain dentin hypersensitivity, indicating unexplained mechanisms are possibly responsible. The widely accepted hydrodynamic theory asserts that when the fluid within the dentinal tubules, absent of a smear layer, is subjected to thermal, chemical, tactile or evaporative stimuli, the movement of the fluid stimulates the mechanical receptors which are sensitive to fluid pressure, resulting in the transmission of the stimuli to the pulpal nerves (Figure 2) ultimately causing the pain response.

Berman describes this reaction as: “The coefficient of thermal expansion of the tubule fluid is about ten times that of the tubule wall. Therefore, heat applied to dentin will result in expansion of the fluid, and a cold stimulus will result in contraction of the fluid, both creating an excitation of the ‘mechano-receptor’.”

Based on the hydrodynamic theory, dentinal hypersensitivity is a transient tooth pain. In order to exhibit a response to the stimuli, the tubules would have to be open at the dentin surface as well as the pulpal surface of the tooth. Anatomically, the tubules in the area closest to the pulp chamber are wider, and the number of tubules per unit area increases almost two-fold from the outer surface to the pulp. The most important variable affecting the fluid flow in dentin is the radius of the dentinal tubules. If the radius is reduced by one-half, the fluid flow within the tubules falls to one-sixteenth of its original rate. Consequently, the creation of a smear layer or the occlusion of the tubules will significantly reduce sensitivity.

Diagnosis
The reason(s) for tubules to be exposed or open should be assessed during a visual examination of the teeth. Additionally, a detailed dietary history should be taken. Useful diagnostic tools are the air/water syringe (thermal), dental explorer (touch), percussion testing, bite stress tests, and other thermal tests such as an ice cube, and assessment of occlusion. Since dentinal hypersensitivity is essentially diagnosed by exclusion, a comprehensive dental

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Figure 2. Depiction of Brannstrom’s Hydrodynamic Theory.
Recessed areas may become sensitive due to the loss of cementum, ultimately exposing dentin. Probing depths, recessed areas (areas of gingival recession), and sensitivity reported by the patient must be accurately recorded and monitored to provide a reference for the patient’s disease activity over time.

**Treatments**
Treating dentinal hypersensitivity can be challenging for the dental professional because of the difficulty related to measuring the pain response as the response can often vary from patient to patient. In addition if the dentin exposure is due to personal habits, it may be difficult for patients to change their behavior(s). If the diagnosis confirms dentinal hypersensitivity in the absence of underlying diseases or structural problems of the tooth, then the following steps can be initiated:

1. remove the risk factors by educating the patient about dietary acids and other oral care habits;
2. recommend different toothbrushing methods, if appropriate;
3. initiate treatment by recommending a desensitizing agent for home use; and/or
4. applying topical desensitizing agents in-office.

In 1935, Grossman addressed the requirements for an ideal desensitizing agent as: rapidly acting with long-term effects, non-irritating to the pulp, painless and easy to apply without staining the tooth surface. These requirements still exist today when considering an ideal solution to dentinal hypersensitivity. There are various ways to classify treatments: first, they can be categorized based on their ingredients and/or mechanism of action.

There are two common approaches to treating dentinal hypersensitivity, nerve stabilization and tubule occlusion. Furthermore, treatment
options can be classified as either invasive or non-invasive in nature. Examples of invasive procedures administered in-office include gingival surgery, application of resin adhesive materials such as dentin bonding agents, or a pulpectomy. Dentifrices and other products for home use are non-invasive. Finally, treatments can be categorized based on whether they can be applied by the patient (over-the-counter) or require professional application. For the purposes of this CE course, the focus is on first line over-the-counter products as well as popular in-office treatments.

**Over-the-Counter Products**

Over-the-counter products for the treatment of tooth sensitivity are considered to be a simple and cost-effective first line of treatment for most patients. The primary at-home non-invasive treatment option has historically been anti-sensitivity dentifrices. The two most common ingredients are potassium nitrate, which interferes with the transmission of the nerve impulse, and stannous fluoride, which blocks dentinal tubules by forming a smear layer at the surface.

**Potassium Nitrate Dentifrice**

Potassium nitrate is known to interfere with the nerve impulse and is commonly found in desensitizing toothpaste. Potassium nitrate products raise the extracellular potassium ion concentrations and affect polarization. When the concentration is sustained over time, the synapse between nerve cells is blocked, the nerve excitation is reduced and the tooth is less sensitive to the stimuli. A number of studies, published since the early seventies, have investigated the use of potassium nitrate (KNO₃) as an effective active ingredient in treating dentinal hypersensitivity.

A four-week exposure time is widely used in these clinical trials because results have shown that this time is needed for 5% KNO₃ to exert its desensitizing effect. The use of a broadly accepted positive or negative control toothpaste formulation or product has been increasingly used over the years in comparative trials because the condition itself can appear to be self-resolving within the time scale of the study. Over time, investigators have chosen various methods to capture subjective responses; controlled reproducible stimuli and objective measurements are preferred.

In 2006, the Cochrane Collaboration published a systematic review of potassium nitrate toothpastes for the treatment of dentinal hypersensitivity based on clinical trials conducted up to the year 2005 involving KNO₃ toothpaste compared to non-KNO₃ toothpaste. This review focused on studies that incorporated similar methods in order to determine if KNO₃ is an effective agent in reducing dentinal hypersensitivity. The results were obtained by measuring tactile (Figure 5), thermal, and air blast stimuli as well as patients’ subjective assessment of pain during everyday life. The exposure periods ranged from six to eight weeks, reporting outcome measurements as a mean change from baseline. The meta-analysis included six studies, and all showed a significant effect on sensitivity assessed by air blast and tactile methods at the 6 to 8 week follow-up. However, there was no significant effect observed at the 6 to 8 week follow-up for the subjective assessment. The authors concluded the support for the efficacy of potassium nitrate toothpaste for dentinal hypersensitivity was based on a very small sample size, thus evidence of the effectiveness of KNO₃ is not clear, suggesting more clinical trials need to be conducted and published. There is no current research published to support a different conclusion than what is stated above even though new product lines are being marketed.

![Figure 5. Illustration of the Yeaple Probe.](image-url)
Some products that contain potassium nitrate include Sensodyne ProEnamel®, Crest® Sensitivity, Crest Sensi-Relief Plus Scope Toothpaste, Colgate® Sensitive Pro-Relief Enamel Repair Toothpaste, Arm & Hammer® Advanced Whitening Sensitive, Tom’s of Maine™ Maximum Strength Sensitive and Opalescence Whitening Sensitivity Relief Toothpaste.

Stannous Fluoride
Stannous fluoride has been shown to be effective in the prevention of dental caries, reduction of plaque formation, control of gingivitis and the suppression of breath malodor. Research also shows stannous fluoride is effective against dentinal hypersensitivity. The ADA has recognized the desensitizing properties of stannous fluoride by granting the ADA Seal of Acceptance to a non-aqueous stannous fluoride gel formulation (Gel-Kam) for the therapeutic prevention of sensitivity and caries as well as to Crest® PRO-HEALTH® toothpaste.

In situ research shows root dentin treated with stannous fluoride exhibits tubule occlusion at the surface by the formation of a smear layer (Figure 6). When the tubules are blocked, fluid flow is limited and the stimulation of the mechanoreceptors does not occur, thus preventing the pain response.

Stannous fluoride has been delivered via a mouth rinse, dentifrice, and gel for some time. Research by Thrash et al. in the 1990’s suggested there is a gradual decrease in sensitivity starting at two weeks and continuing throughout the 16-week period from initiation of treatment. Thrash and colleagues conducted a two-phase experimental design study comparing a 0.4% stannous fluoride gel to an aqueous 0.717% fluoride solution and a placebo to evaluate the effect of the products on hypersensitivity tooth pain and to determine the precise time of onset of any effect on dentinal hypersensitivity. Sensitivity to thermal stimuli was assessed prior to the first application and then at 2, 4, 8, and 16 week intervals after the initial application. The results indicated subjects who applied the 0.4% stannous fluoride gel reported significantly less sensitivity during the four to eight week period. The stannous fluoride gel resulted in the lowest mean threshold temperature compared to the other products.

Historically, one limitation to the use of stabilized stannous fluoride has been the potential for temporary extrinsic tooth staining associated with the long-term use of these products. Due to advances in dentifrice technology, this occurrence has been mitigated by incorporating sodium hexametaphosphate, an advanced tartar control and whitening ingredient, in the formulation marketed as Crest® PRO-HEALTH® toothpaste.

In two randomized, double-blind clinical trials, this stabilized stannous fluoride toothpaste significantly reduced thermal and tactile sensitivity versus a negative control. More recently, He et al. demonstrated in two different randomized controlled clinical trials that twice daily brushing with the stabilized stannous fluoride dentifrice provides superior dentinal hypersensitivity improvement versus a marketed sodium fluoride dentifrice, and a dentifrice containing 8.0% arginine, calcium carbonate and sodium monofluorophosphate. The stannous fluoride dentifrice provided some relief after the first brushing relative to each control, with the benefit growing larger over the study period with twice daily use. When compared to sodium fluoride/triclosan dentifrice, there was a similar
outcome, superior dentinal hypersensitivity improvement with significant greater relief after two weeks and a larger benefit at eight weeks with twice daily brushing. In separate clinical research, this unique dentifrice provided significant extrinsic whitening relative to a positive control.

In addition to the product mentioned above, a 2-step system that includes stannous fluoride dentifrice as the first step and hydrogen peroxide whitening gel at the second step has been shown to provide significantly better sensitivity relief than potassium nitrate sodium fluoride dentifrice.

Bioactive Glass
Dentifrices containing desensitizing agents have been the most popular first-line treatment for sensitive teeth, but there are some drawbacks. It typically takes time (approximately 4 weeks) to experience relief and on-going use is required to maintain the benefit.

One such product is NovaMin, a synthetic mineral composed of calcium, sodium, phosphorus and silica releases deposits of crystalline, hydroxy-carbonate apatite which is structurally similar to tooth mineral composition. NovaMin is technically described as sodium calcium phosphosilicate.

Method of Action
The formation of bioglass reacts with the saliva in the mouth to form a protective layer of hydroxyapatite on the tooth, thereby, occluding dentin tubules. This layer prevents the discomfort that is tooth sensitivity.

A number of clinical studies investigating the efficacy of NovaMin for four and six weeks have been conducted. A product name you may be familiar with is Sensodyne Repair and Protect. An overview of the clinical evidence for the use of NovaMin to treat dental hypersensitivity was addressed by Gendreau et al. Clinical evidence supports the effectiveness of the 5% and 7.5% product twice daily brushing for pain relief from this malady.

In-office Treatments
Professional treatments are available for sensitivity cases that cannot be managed using over-the-counter products. Some in-office treatments include fluoride varnishes, prophylaxis pastes and laser treatments.

Fluoride Varnishes
The most popular in-office treatment is fluoride varnish, a resin-based fluoride. Various types are available. Fluoride varnish is primarily used to prevent tooth decay by entering the tooth enamel and making the tooth surface impenetrable. The mode of action involves calcium fluoride being deposited on the tooth surface with the formation of fluorapatite.

The varnish is applied after cleaning and drying the tooth surface. For caries protection, fluoride varnish is painted onto the tooth surfaces with a small brush. The varnish forms a sticky covering over the tooth and becomes hard as soon as saliva in the mouth touches it. Fluoride varnish prevents new cavities from forming and slows down or stops decay from progressing.

Many practitioners have begun using fluoride varnish as a desensitizing agent by applying the varnish to the exposed area to seal the dentin surface. Pashley et al., evaluated a series of commercial cavity varnishes and reported that all cavity varnishes tested decreased dentin permeability by 20 to 50%. In 2012, Camilotti et al. conducted a randomized, split-mouth clinical trial in 42 patients (252 teeth) presenting with dentin hypersensitivity to thermal changes in the mouth. The treatment groups were 4 fluoride varnishes (Duraphat, Fluorniz, Duofluorid XII, and Fluorphat), a neutral fluoride (Flutop), a potassium oxalate gel (Oxa-gel) and a placebo which were all applied 3 different times with a time interval of one week between applications. Sensitivity reduction using air blast and clinical probing was evaluated at the end of 1 week, 2 weeks, 3 weeks and 30 days after the last application. The 4 fluoride varnish groups and the oxalate gel group had significantly lower pain scores compared to placebo at the 30-day reassessment; there were no significant differences between the 5 groups. The neutral fluoride group was not significantly different from placebo, nor was it significantly different from Fluoriniz, Duoluorid XII, or Oxa-gel.

Fluoride varnish is easy to apply, low-cost and generally safe to use in the mouth, but should
not be used if there is an allergy to one of the ingredients in the varnish.

**Prophylaxis Pastes**

Prophylaxis pastes with desensitizing agents are another professional treatment used for the relief of sensitivity. One example is paste containing 8% arginine (Pro-Argin), calcium carbonate, and 1450 ppm fluoride as sodium monofluorophosphate (Colgate Sensitive Pro-Relief). Arginine, an amino acid naturally present in saliva, is reported to work in conjunction with calcium carbonate and phosphate to occlude dentinal tubules.\(^70\)-\(^76\)

Results from a 12-week clinical trial showed that 8% arginine-containing prophylaxis paste was statistically significantly more effective in reducing dentinal hypersensitivity than a control pumice prophylaxis paste (NuPro) immediately following application and after 4 weeks. No statistically significant differences were noted between treatment groups post-scaling and after 12 weeks.\(^70\)

In some markets outside the US, arginine is available in over-the-counter dentifrice and mouthrinse products.

Another prophylaxis paste for hypersensitivity relief contains sodium calcium phosphosilicate, marketed under the name of NovaMin\(^\circledast\).\(^77\),\(^78\) Sodium calcium phosphosilicate occludes the dentinal tubules by forming a protective hydroxyapatite-like layer on the dentin surface. A number of clinical studies investigating the efficacy of NovaMin\(^\circledast\) for the relief of dentinal hypersensitivity have been conducted.\(^79\)-\(^82\)

Neuhaus et al., conducted a randomized, controlled, double-blind, parallel study with three treatment groups - sodium calcium phosphosilicate prophylaxis paste, with and without fluoride, and a control group - in 151 subjects meeting dentinal hypersensitivity entrance criteria.\(^83\) Tactile and air blast assessments were completed at baseline and day 28. The results indicate that after a single professional application of sodium calcium phosphosilicate prophylaxis paste, hypersensitivity was significantly reduced immediately and 28 days after scaling and root planing procedures. The effect was independent from the presence of fluoride in the paste.

**Lasers**

Four different kinds of light amplification by stimulated emission of radiation (lasers) have been used for the treatment of dentinal hypersensitivity with effectiveness ranging from 5.2 to 100%, depending on the laser type and parameters used.\(^84\) The most common are: Nd-YAG (neodymium:yttrium-aluminum-garnet), GaAlas (gallium/aluminum/arsenide) and Erbium-YAG (yttrium-aluminum-garnet) lasers.\(^85\)-\(^88\) The mechanism of action of lasers in treating hypersensitivity is not very clear, but it has been proposed that the lasers coagulate the proteins inside the tubules and block the movement of fluid.

A 2011 systematic review of lasers for the treatment of sensitivity found only 3 randomized clinical trials for inclusion. The authors concluded that laser therapy can reduce dentinal hypersensitivity-related pain, but there is only weak evidence for its effectiveness and the placebo effect has to be taken into account.\(^89\)

**Conclusion**

Dentinal hypersensitivity is a common problem that effects many dental patients. When a patient presents with dentinal hypersensitivity symptoms, they should be examined and informed of the treatment options available to alleviate the problem. The patient plays a role in this process since their daily habits may be contributing to the problem, and if not changed the condition may persist.

The initial cause of dentinal hypersensitivity, in the majority of cases, is recessed gingiva with the exposure of dentinal tubules. Once the tubules are exposed the patient is susceptible to pain in response to thermal, tactile, or osmotic stimuli. Desensitizing treatments should be delivered systematically.

Prevention and over-the-counter treatments, including desensitizing toothpastes, are a good place to start and can later be supplemented with in-office treatments if needed.
Course Test Preview
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1. The prevalence of dentinal hypersensitivity has been reported over the years in a variety of ways; as 
   a. between 8% and 57% of the adult dentate population
   b. 14.3% of all dental patients
   c. up to 30% of adults at some time during their lifetime
   d. All of the above.

2. Dentinal hypersensitivity has been shown to peak in 20 to 30 year olds and then rise again when in their 
   a. 40s
   b. 50s
   c. 60s
   d. 70s

3. Dentinal hypersensitivity has been researched extensively through the years and many authors express an agreement that dentinal hypersensitivity is 
   a. under-reported by the dental patient population
   b. under-diagnosed
   c. A or B
   d. neither A nor B

4. The “hydrodynamic theory” is widely accepted as the cause of tooth sensitivity.
   a. True
   b. False

5. Assumptions of the hydrodynamic theory conclude that when the fluids within the 
   a. hydroxyapatite
   b. cementum
   c. dentinal tubules
   d. periodontal ligaments
   are subjected to temperature changes or physical osmotic changes, the movement stimulates a nerve receptor sensitive to pressure, which leads to the transmission of the stimuli.

6. Various stimuli that are reported to cause the transmission of sensation are 
   a. cold
   b. hot
   c. osmotic
   d. All of the above.

7. The most important variable affecting the fluid flow in dentin is the pH of the stimulus.
   a. True
   b. False
8. A comprehensive dental examination will ultimately rule out other underlying conditions for which sensitivity is a symptom, such as the following EXCEPT:
   a. cracked tooth
   b. fractured restoration
   c. intrinsic tooth stain
   d. dental caries

9. The response to stimuli ____________
   a. is relatively constant among patients
   b. varies from patient to patient
   c. can be predicted based on gender
   d. is directly correlated to the patient's age

10. One of the most common reasons a dental patient would have exposed dentinal tubules is:
    a. fluorosis
    b. interproximal plaque
    c. class II malocclusion
    d. gingival recession

11. Invasive treatments may include all the following EXCEPT:
    a. application of resins
    b. use of home care OTC products
    c. pulpectomy
    d. gingival surgery

12. Over-the-counter desensitizing dentifrices are considered to be simple, cost-effective and an efficacious first line of treatment for most patients.
    a. True
    b. False

13. Stannous fluoride is a most widely available desensitizing toothpaste active ingredient. It works by ____________.
    a. occluding dentinal tubules by forming a smear layer at the surface
    b. numbing the surrounding tissue
    c. blocking the synapse between nerve cells, reducing nerve excitation and associated pain
    d. None of the above.

14. The following are are examples of in-office treatments:
    a. prophylaxis pastes with a desensitizing agent
    b. fluoride varnishes
    c. lasers
    d. All of the above.
References


79. Elias Boneta AR, Ramirez K, Naboa J, et al. Efficacy in reducing dentine hypersensitivity of a regimen using a toothpaste containing 8% arginine and calcium carbonate, a mouthwash containing 0.8% arginine, pyrophosphate and PVM/MA copolymer and a toothbrush compared to potassium and negative control regimens: An eight-week randomized clinical trial. J Dent. 2013 Mar;41 Suppl:S42-49.


About the Author

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