

Why We See Problems with Teeth Whitening: The Science of Whitening Part III – Whitening Sensitivity

by Rod Kurthy, DMD

Abstract

Teeth sensitivity, and even downright pain, is the single most common negative side effect of teeth whitening. Most dentists are confused by whitening sensitivity and do not know any of the science behind this phenomenon.

This article discusses the science behind what is actually causing whitening sensitivity and the reasons the most popular treatments are minimally effective. It discusses and describes the two types of whitening sensitivity encountered, and explanations for both, as well as the detrimental pulpal effects of using bleaching lights and lasers.

The science behind current methods attempting to control sensitivity are also discussed, as well as the reasons why they are minimally effective.

Educational Objectives

After reading this article, dental professionals will understand:

1. How sensitivity from whitening affects patients
2. The two distinctly different types of teeth sensitivity caused by teeth whitening
3. How peroxide whitening gels affect dentinal tubules and why
4. Why some patients experience whitening sensitivity and some do not
5. How chemical stabilizers in whitening gels increase whitening sensitivity
6. What affect bleaching lights and lasers have on the pulp during teeth whitening
7. Why dentists typically see higher whitening sensitivity when using bleaching lights and lasers
8. Current popular methods of reducing whitening sensitivity and why they are minimally effective

Parts I and II of this series appeared in the November and December 2012 issues of *Dentaltown Magazine*. To view the previous articles visit www.dentaltown.com/rodkurthy.

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“Hey Doc! I know you said that I might have a little sensitivity with my whitening, but this is ridiculous! I’m not doing this anymore, and I want my money back.” How often do you hear from people (both friends and patients) that teeth whitening “kills” their teeth? The most common negative side effect of both in-office and at-home whitening is, by far, teeth sensitivity, and sometimes downright pain.^{66-72,78} This is a common reason why patients are not compliant at home with their whitening, and the reputation of sensitivity is responsible for keeping many of our patients from accepting teeth whitening treatment.⁶⁶⁻⁷²

We’ve all heard claims of “no” sensitivity from whitening product companies, but most of us have found very little truth to those claims.⁷³⁻⁷⁷ We frequently hear recommendations from whitening gurus telling us how to lower sensitivity, but most of us find little or no benefit when we try those techniques.⁷³⁻⁷⁷ The majority of dentists don’t understand why whitening sensitivity occurs and many do not understand how and why various desensitizing products work.

Two Types of Whitening Sensitivity

As dentists, we typically find two distinctly different types of whitening sensitivity, apparently caused by two distinctly different mechanisms:⁷⁸

Type 1 – Typical Dental Hypersensitivity: Patients feel generalized discomfort of the teeth. Pulpals also overreact to various stimuli such as cold and teeth brushing.⁷⁸

Type 2 – Zingers: Zingers are those instantaneous sharp “electric shocks” that shoot down the length of anterior teeth with lightning speed, occurring without any obvious stimulus,

nearly bringing patients to their knees.⁷⁸ They last for a few seconds and are gone.

The physiology and causes of typical dental hypersensitivity have been understood for many years; however the causes of zingers have never been adequately addressed.⁷⁸ I will present my hypothesis regarding zingers below.

Typical Dental Hypersensitivity (DH)

DH is sometimes associated with genuine pathologic conditions such as caries, occlusal trauma, cracks in teeth, leakage under faulty restorations, etc. However our concern in this article is typical dental hypersensitivity due to teeth whitening.

Brännström’s Hydrodynamic Theory of Dental Hypersensitivity

The predominant theory of DH (Brännström) states that pulpal sensitivity is mediated by a “hydrodynamic mechanism.”^{16,17,66,79-81} A stimulus (thermal, mechanical, evaporative, osmotic or chemical) applied to dentin can increase the flow of dental tubular fluid within the dental tubules (either inward or outward).^{34,63,66,79-81,96} Flow of dental tubular fluid mechanically creates pressure or tension on the odontoblasts lining the pulp, resulting in deformation of the odontoblasts, which in turn cause distortion of the cell membranes of A-Delta nerve endings, which are intertwined throughout the layer of odontoblasts at the inner surface of the dentin (Fig. 2).^{66,80,82-86}

The term “hydraulic conductance” refers to the ease with which fluid flows through dental tubules.^{87,88} Obviously, the easier the fluid flows, the more and more often it flows, resulting in acute dental hypersensitivity.^{87,88}

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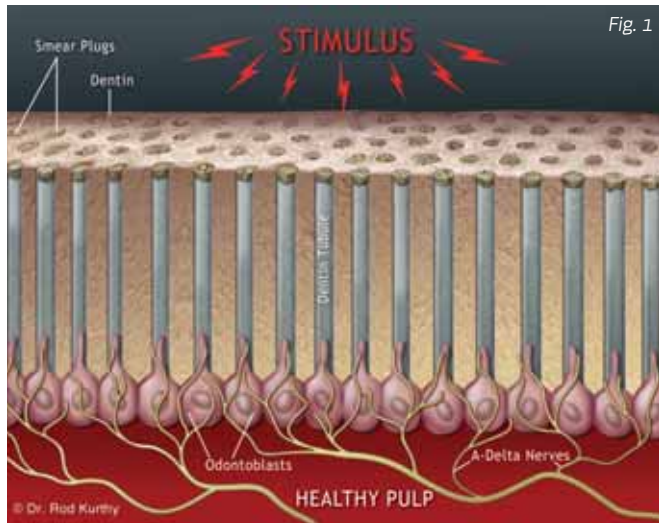


Fig. 1

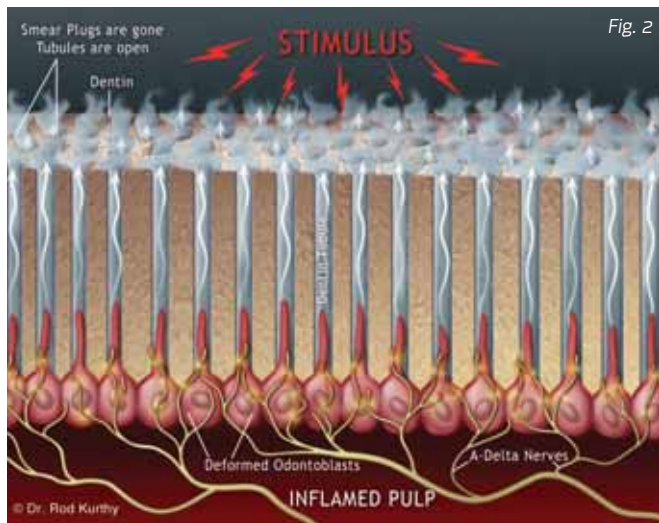


Fig. 2

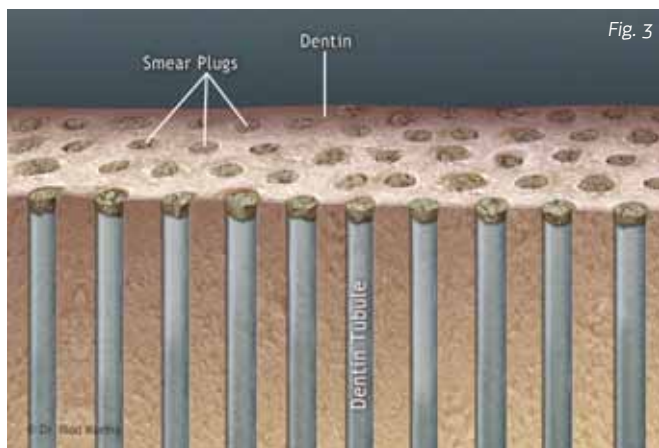


Fig. 3

Fig. 1: Smear plugs are present in dentinal tubular orifices. The stimulus applied to dentinal surface has no effect on tubular fluid flow because of smear plugs. The pulp is unaffected.

Fig. 2: Smear plugs have been lost, allowing the stimulus applied to dentinal surfaces to create outward tubular fluid flow, away from the pulp. Odontoblast processes are sucked deeper into dentinal tubules, causing deformation of the odontoblasts and surrounding A-Delta nerves, resulting in pain stimulation and inflammation.

Ideally, dentinal tubules should routinely have naturally formed smear plugs blocking or plugging the entrance (orifice) to the dentinal tubules,⁸⁷ thereby effectively reducing the tubular flow (conductance) (Fig. 1). When dentinal tubule smear plugs are lost, the hydraulic conductance increases a whopping 32-fold,^{87,89} resulting in potential for intense dentinal hypersensitivity (DH) (Fig. 2).

Causes of Type 1 Whitening Sensitivity (Typical Dentinal Hypersensitivity)

Affects of an Acidic Diet

It is a fact that different people have different diameters of dentinal tubules^{87,90} and different amounts of flare of the orifices of those tubules.⁸⁷ Genetically, some have dentinal tubules twice the diameter of others.^{87,90} Acids not only decompose smear plugs and enlarge the inner diameter of the dentinal tubule, but they cause the orifice of the dentinal tubule to flare like a trombone (Fig. 3 & 4).^{87,89}

Low salivary pH and an acidic diet (frequent consumption of fruits and fruit drinks, sodas, sports drinks, acidic wine, etc.) have long-term negative effects on dentinal tubules by enlarging the diameter and flaring the orifice of dentinal tubules (Fig. 4).^{66,87,89} The larger the diameter of a tubule, and the more the orifice flares, the easier it is to dislodge the tubular plug, and the more difficult it is to re-plug the dentinal tubule.⁸⁷

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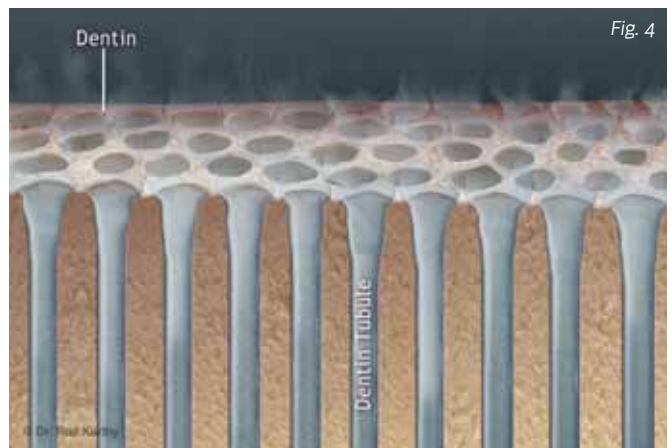


Fig. 4

Fig. 3: Smear plugs are present in dentinal tubular orifices. Tubules have not been enlarged by acid challenges.

Fig. 4: Chronic acid challenges from acidic fruits, juices, sodas, sports drinks, acidic wine, etc., have removed the smear plugs, enlarged the inner diameter of the dentinal tubules and flared the orifices of the tubules.

All illustrations by Dr. Rod Kurthy and Andrew Matlock

Fig. 5: The aggressive “oxygenation” phase of the whitening gel is dislodging smear plugs from the orifices of dentinal tubules. The higher osmolality whitening gel is osmotically drawing tubular fluid out of the tubules, initiating the hydrodynamic mechanism and creating sensitivity and discomfort.

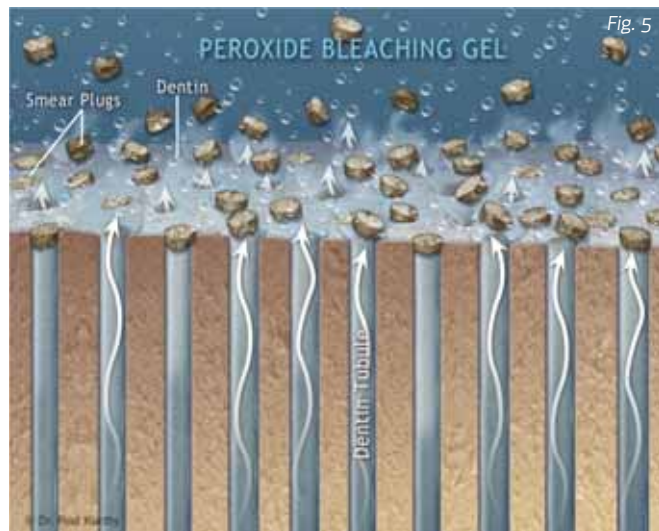


Fig. 6: The aggressive “oxygenation” of the whitening gel has removed smear plugs from the orifices of dentinal tubules. The higher osmolality whitening gel is osmotically drawing tubular fluid out of the tubules, causing sensitivity and discomfort initiated by the hydrodynamic mechanism.



We have long known that people who eat significant amounts of acidic foods have more sensitivity.^{66,87,89} It is no surprise that statistically, patients with dentinal hypersensitivity tend to have dentinal tubules that are twice the normal diameter^{87,90} and often have very flared orifices compared to those who do not experience hypersensitivity.⁸⁷

Peroxides Also Dislodge Smear Plugs

The aggressive “oxygenation” phase of any peroxide-based whitening system results in the physical removal of smear plugs (Fig. 5).^{123,124} Without smear plugs, hydraulic conductance of dentinal tubular fluid goes up 32-fold,^{87,89} and hyperosmotic whitening gels can now intimately contact tubular fluids.

Whitening Gels Create an Osmotic Gradient

All whitening gels are hypertonic, with osmolalities varying from 4,900mOsm/kg to 55,000mOsm/kg, compared to only 290mOsm/kg of dentinal tubular fluid.^{16,66} This means that whitening gels range from 17 to 190 times higher osmolality than dentinal tubular fluid.

The greater the osmolality of the whitening gel, the stronger the osmotic gradient between the gel and tubular fluid, the stronger the osmotic “pull” on the dentinal tubular fluid,^{16,17,80,91-93} and the more discomfort is felt by the patient (Fig. 6).^{66,80,94,95,91}

Anhydrous and acidic pH whitening gels are more chemically stable,¹⁶ however both anhydrous and acidic gels have osmolalities that are up to 11 times higher than 100 percent aqueous and neutral pH gels.^{17,80,91-93} To avoid the costs of constant refrigeration, it is common for whitening product companies to use anhydrous gels and add acidifiers to lengthen the shelf life.¹⁶

The more acidic and the more anhydrous the whitening gel is, the stronger the osmotic gradient is,^{80,91-93} the more forceful the outward flow within the tubule is,^{16,80,91-93} and therefore the more acute the discomfort may be for the patient.^{16,17,66,80,91,94,95}

Furthermore, acid in whitening gels more aggressively removes existing smear plugs within dentinal tubules, fostering more tubular fluid flow and even more sensitivity.^{66,89}

Peroxide Becomes More Acidic as it Decomposes

As peroxide decomposes, in addition to the formation of oxygen, oxygen ions and radicals; hydrogen ions are thrown off.⁹⁶ Hydrogen ions create acidity (the designation pH refers to “potential of hydrogen,” and is a measure of the concentration of hydrogen ions).⁹⁶ This process can quickly cause an initially neutral gel to become acidic even down to a pH3, further causing the problems noted.

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Causes of Type 2 Whitening Sensitivity (Zingers)

During and/or soon after whitening, the patient may experience what feels like a sharp, immediate, intense “lightening bolt,” right down the length of an individual tooth.⁷⁸ This pain is Type 2 Whitening Sensitivity, which we commonly refer to as “zingers.” The patient may even describe this pain as a “crackling” electric shock. Zingers occur as immediate intense spontaneous pain sensations, with no apparent stimulus.⁷⁸ It feels as if it starts at the incisal edge, and extends the full length of the tooth.

Zingers occur in the smaller teeth – most often incisors and cuspids. They tend to occur in the same few teeth, over and over.

“The most common negative side effect of both in-office and at-home whitening is, by far, teeth sensitivity, and sometimes downright pain.”

Peroxide Enters the Pulp

It has been shown that molecular hydrogen peroxide (H₂O₂) may enter the pulp tissue during and after whitening (Fig. 7).^{66,97} Contrary to what many of us were taught years ago, enamel is not nearly impervious.⁶⁶ In fact, it is now considered a semi-permeable membrane.⁶⁶ Teeth often are formed with or acquire aberrations (little highways through tooth structure) allowing low molecular weight hydrogen peroxide to enter the pulp (Fig. 7).^{66,97}

Our Bodies Manufacture Hydrogen Peroxide

Our own bodies produce large amounts of hydrogen peroxide and other oxidative chemicals, primarily in the mitochondria, during oxygen metabolism every day.^{98-101,106} The average adult human body produces about 650mg of hydrogen peroxide per day via oxygen metabolism.¹⁰⁶ Two whitening

trays with reservoirs (with 16% carbamide peroxide) contain a total of only about 6.5mg of peroxide.¹⁰⁶ This means that our own bodies manufacture approximately 100 times more peroxide every day than the amount that is put into upper and lower whitening trays.

If this large amount of daily endogenous hydrogen peroxide were allowed to continuously break down to strongly Reactive Oxygen Species (ROS, such as free radicals) throughout our bodies, it would wreak havoc on our tissues.^{98,106} To protect against constant radical formation from the breakdown of peroxide, the body manufactures protective antioxidant enzymes including catalase,¹⁰²⁻¹⁰⁴ superoxide dismutase, hemoxygenase-1 and glutathione peroxidase.^{98,105-107}

In the presence of these antioxidant enzymes, hydrogen peroxide is forced to break down to only water and molecular oxygen, instead of ions and radicals.⁹⁸ This is precisely why hydrogen peroxide that enters the tooth pulp does not cause permanent damage.^{97,98,108}

Both gingival crevicular fluid and saliva contain high levels of peroxidase.^{16,39-42} To illustrate the effectiveness of peroxidase, salivary peroxidase alone can decompose 29mg of peroxide (4.5 times more than found in two whitening trays) per minute.¹⁰⁶ There is therefore little concern about swallowing minimal amounts of peroxide gels.¹⁰⁶

Catalase, which is always found in the dental pulp,^{97,102-106,109,110} is a very efficient antioxidant enzyme molecule, and each catalase molecule is capable of instantly breaking down several million molecules of hydrogen peroxide to water and molecular oxygen.¹¹¹

A common example of the effects of catalase and peroxidase that most have observed is the bubbling seen when liquid hydrogen peroxide is poured into a cut. Hydrogen peroxide bubbles immediately upon contact with exposed bodily tissues and fluids. This reaction is due to the antioxidant enzymes such

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as catalase¹⁰⁴⁻¹⁰⁶ and peroxidases within tissues and tissue fluids, which decompose the hydrogen peroxide to water and oxygen upon contact. Of course the released oxygen forms the bubbles we see.

Dr. Rod Kurthy's Hypothesis of Zinger-Type 2 Whitening Sensitivity Etiology:

- Fact: Molecular hydrogen peroxide (H₂O₂) enters the pulp during and after whitening through developmental and/or acquired aberrations in enamel and dentin (Fig. 7).^{66,97}
- Fact: Catalase is always present in the dental pulp (Fig. 7).^{97,102-106,109,110}
- Fact: When hydrogen peroxide comes into contact with catalase, hydrogen peroxide is forced to instantly break down to molecular oxygen (O₂) and water (Fig. 7).¹¹¹
- Fact: Pulp is enclosed inside rigid tooth structure, which is incapable of expanding (Fig. 7).
- Fact: A-Delta neurons in the pulp respond/react to distortion caused by pressure and specifically cause a sharp sensation.^{66,72,80,82-86}

Kurthy Hypothesis: According to the given facts, when hydrogen peroxide enters the pulp, it would come into contact with catalase antioxidant enzyme. The result would be an immediate breakdown of hydrogen peroxide into water and oxygen (Fig. 7).

The oxygen would instantly cause the formation of a bubble(s) within the pulp. Given that the pulp is housed in the rigid pulp chamber and canals, the formation of a bubble would cause an immediate spike in intrapulpal pressure (Fig. 7).

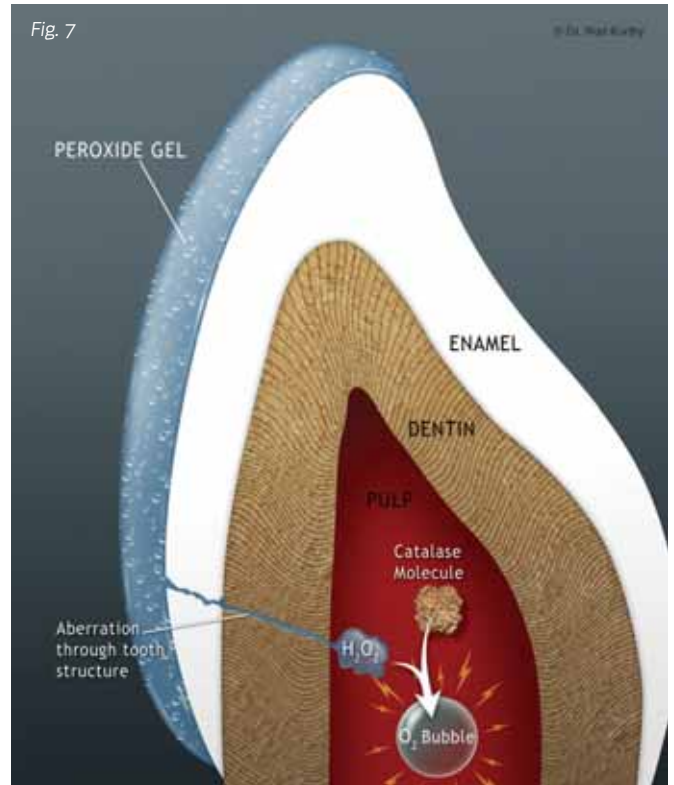
An instantaneous spike in intrapulpal pressure would distort pulpal A-Delta neurons, causing them to instantly fire. Given that the instant increase in intrapulpal pressure would affect all neurons in the pulp, the simultaneous firing of virtually all pulpal A-Delta neurons would occur.

Large numbers of A-Delta neurons firing simultaneously would cause an immediate, intense stabbing or electrical shock sensation occurring throughout the entire tooth.

Once the intrapulpal pressure would dissipate, the neurons would no longer be distorted and the pain sensation would abruptly stop.

Because aberrations allowing hydrogen peroxide to enter the tooth are more common in the smaller anterior teeth, and because larger aberrations are found in some teeth and not in

Fig. 7: Kurthy Zinger Hypothesis: Molecular hydrogen peroxide may enter the pulp during and after whitening through developmental and/or acquired aberrations through the enamel and dentin. The anti-oxidant enzyme Catalase present in the pulp breaks down hydrogen peroxide to water and molecular oxygen. The formation of oxygen creates an instantaneous bubble in the pulp, immediately increasing the intrapulpal pressure, aggressively distorting and stimulating the A-Delta neurons of the pulp, creating a sharp painful "zinger" that lasts only seconds before the intrapulpal pressure dissipates.



others, zingers are typically felt in the same few anterior teeth over and over.

This hypothetical model perfectly describes the zinger-type event felt by many whitening patients.

Pulpal Pain and Inflammation Caused by Bleaching Lights and Lasers

Bleaching lights and lasers have been shown to have no genuine positive effect on teeth whitening results.^{48,55-60} Yet dentists and clinical studies have routinely found that patients experience significantly more discomfort, and sometimes outright intense pain, when bleaching lights and lasers have been used.^{16,17,49,112}

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The dental community has commonly speculated that the cause of discomfort seen when using bleaching lights and lasers is due to increases in pulpal temperature because of lights and lasers, and/or dehydration caused by bleaching lights and lasers. But these factors have been shown not to create pulpal discomfort.¹¹²

When combined with higher concentration hydrogen peroxide, photon energy from bleaching lights and lasers was found to significantly enhance Substance P formation within the pulp,⁴⁹ resulting in considerably higher pulpal inflammation and pain than when no lights or lasers were used.^{16,17,49,62,80} Substance P is a neuropeptide released by pain transmitting neurons to communicate with each other. Its function is to cause pain and inflammation.^{49,62,80}

Given the current knowledge that bleaching lights and lasers are of no long-term value in teeth whitening results,^{48,55-60} in addition to the proven findings that bleaching lights and lasers, in combination with high concentration peroxide, does cause transient “harm” to the pulp,^{16,17,49,112} dentists are obliged to consider these findings before subjecting their patients to this much higher potential for pain without any genuine benefit.

Current Desensitizing Methods

There are two general categories of desensitizing product action:

Occlusion of dentinal tubules: By occluding (plugging) dentinal tubules, movement of intratubular fluid flow in dentinal tubules is prevented, and sensitivity is therefore prevented or ceased (treating the cause of sensitivity) (Fig. 1).^{66, 80,113}

Neuronal suppression: Chemical effect on pulpal neurons reducing the ability of pulpal neurons to fire (treating the symptoms of/masking sensitivity).⁶⁶

Unsuccessful Attempts of Reducing/ Eliminating Sensitivity

Modifying Whitening Gels

Several companies have altered whitening gels with intent to reduce sensitivity. What dentists have often found is: 1) these

gels did reduce sensitivity, but did not whiten teeth well, or 2) the claims of reduced sensitivity were false.⁷³

Fluorides

Stannous and sodium fluoride combine with salivary calcium to create a precipitation of insoluble calcium fluoride within dentinal tubules.⁶⁵ The process of occlusion of tubules via use of fluoride requires extended treatment times and often never fully occludes tubules or cures sensitivity completely. Most dentists have not had remarkable results because of the very slow process of precipitation.

Use of fluorides in trays, as well as brushing with prescription strength fluoride for several weeks prior to whitening, during whitening, and after whitening has had some level of success, although rather minimal and unpredictable.^{115, 116}

ACP

Amorphous Calcium Phosphate (ACP) has primarily been discussed regarding remineralization of enamel, not dentin. Remineralization requires a nearly 100 percent inorganic substrate framework on which to “grow” additional hydroxyapatite. The growth of inorganic hydroxyapatite within the highly organic matrix of dentin is highly questionable.^{77,117,118}

Even if ACP were to actually promote mineralized formations within dentinal tubules, this process would not be immediate. The action of ACP in enamel is more of a “growth of hydroxyapatite” instead of a rapid occlusion of tubules.

Use of ACP has not been met with wide-spread reports of desensitizing success with whitening.^{77,117,118}

Potassium Nitrate

Potassium nitrate does not occlude tubules and does not reduce tubular flow.¹¹⁹ It is theorized that it may reduce nerve excitability (inhibit re-polarization of pulpal neurons),⁶⁶ however the efficacy of potassium nitrate, having been around for decades, has not been strongly supported in the literature.^{66,74,114-116,119-122} To have an effect, potassium nitrate must migrate through dentinal tubules into the pulp,⁶⁶ which takes some time.

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Potassium nitrate has been unpredictable, seemingly effective on some, partially effective on some, and ineffective on some.^{66,114} Though potassium nitrate may reduce sensitivity in some individuals, it simply masks pulpal inflammation.

Addition of Desensitizers to Whitening Gels

Some whitening gels are manufactured with fluoride, potassium nitrate and/or ACP mixed into the whitening gels.^{74,75,77} Studies have not shown reduction of sensitivity from the addition of these substances into whitening gels.⁷³⁻⁷⁷

Precipitation of calcium fluoride requires access to salivary calcium, which is excluded by whitening gel. Any effect by fluoride and ACP is a slow “growth” type process, which is interrupted by the aggressive chemistry and oxygenation process of peroxide whitening gels, as well as the outward flow of dentinal tubular fluid during whitening.

Potassium nitrate must migrate through the dentinal tubule to the pulp to have any positive benefit.⁶⁶ Whitening gels create an osmotic gradient resulting in flow within the dentinal tubules away from the pulp.^{66,80,91-93} For potassium nitrate to reach the pulp during whitening, it would have to move through the tubule against the outward flow (like trying to swim upstream).^{80,91-93} Potassium nitrate mixed within the chemistry of whitening gel has been shown to be ineffective.^{73,74}

The chemical and aggressive oxygenation environment during whitening, as well as the outward flow of dentinal tubular fluid, is not conducive to the intended results of desensitizers of any type. Use of desensitizers is effective only before and/or after whitening, but not when mixed into the whitening gel itself.^{73,76,77} ■

Watch for the fourth and final part of “Why We See Problems with Teeth Whitening: The Science of Whitening” in the February issue of *Dentaltown Magazine*, where you will learn the science-based solutions to the common whitening sensitivity problems discussed.

[Editor’s Note: If you have questions or would like to learn more, please contact Dr. Kurthy at rod@evolvedental.com or call 866-763-7753]

Author’s Bio

Dr. Rod Kurthy practices in Mission Viejo, California. He graduated with highest honors from Fairleigh Dickinson University School of Dentistry in 1978, and completed a GP residency at Newark Beth Israel Medical Center.



Dr. Kurthy’s 35 years of research and development include laser and surgical periodontal bone regeneration; endodontic surgery, including bone regeneration and repair of resorptive lesions; teeth whitening; teeth sensitivity; and development of several cosmetic techniques and impression techniques, to name a few. His first participation in periodontal research was in 1976, and teeth whitening in 1977.

He is an international lecturer and author of five popular clinical and dental marketing books. He is the recipient of awards and accolades including the Mosby Scholarship Award; FDU Prosthodontics and Pediatric Dentistry Awards; the Omicron Kappa Upsilon Gold Key Award; a commendation from the Chief Attorney of the United States Department of Defense for his role in supporting patients’ rights in disputes with insurance carriers; and in March, 2005, he was selected as the most respected member of Dentaltown.com by more than 60,000 of his peers.

Kurthy has authored numerous articles; is frequently interviewed by dental journals and consumer magazines; has appeared numerous times on the covers of several widely-read dental journals in the USA; has been featured six times on national tape interview series; and is a consultant to magazines such as *People Magazine* and has been a feature writer for *Oxygen Women’s Fitness* magazine. He has been interviewed and featured numerous times in national media, and has been the personal dentist for the United States Men’s World Cup Soccer Team. Most recently, Kurthy has been widely known for his KÖR Whitening Deep Bleaching System.

Disclosure: Dr. Kurthy discloses that he has a financial interest in KÖR Whitening Deep Bleaching System.

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Post-test

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1. The most common negative side effect of both in-office and at-home whitening is:
 - a. gingival sensitivity and inflammation.
 - b. teeth sensitivity.
 - c. etching of the surfaces of the teeth.
 - d. a and c
2. According to Brännström's Hydrodynamic Theory of Dentinal Hypersensitivity, dentinal sensitivity:
 - a. is caused by flow of dentinal tubular fluid within the dentinal tubules toward the pulp.
 - b. is caused by flow of dentinal tubular fluid within the dentinal tubules away from the pulp.
 - c. is caused by flow of dentinal tubular fluid within the dentinal tubules toward or away from the pulp.
 - d. is not caused by flow of dentinal tubular fluid within the dentinal tubules.
3. Which of the following statements is false?
 - a. Different people have different diameters of dentinal tubules.
 - b. Different people have different amounts of flair of the dentinal tubule orifices.
 - c. Studies have shown that statistically, patients with dentinal hypersensitivity tend to have dentinal tubules that are half the normal diameter.
 - d. Genetically, some have dentinal tubules twice the diameter of others.
4. The common methods used to lengthen the shelf life of whitening gels are the use of anhydrous base and addition of acidifiers to whitening gels. Which statement is true:
 - a. An anhydrous base raises the osmolality of whitening gels, creating more sensitivity; however, the addition of acidifiers to the gel neutralizes this effect and reduces sensitivity.
 - b. Adding acidifiers raises the osmolality of whitening gels, creating more sensitivity; however, use of an anhydrous base neutralizes this effect and reduces sensitivity.
 - c. Both anhydrous base and the addition of acidifiers raise osmolality and increase sensitivity.
 - d. Neither an anhydrous base nor the addition of acidifiers to whitening gels has any impact on teeth sensitivity.
5. Which of the following statements is true?
 - a. As hydrogen peroxide decomposes it becomes weaker and more neutral (pH).
 - b. As hydrogen peroxide decomposes it becomes weaker and more alkaline.
 - c. As hydrogen peroxide decomposes, breaking down to only water and molecular oxygen, it also throws off hydrogen ions, becoming steadily more acidic.
 - d. As hydrogen peroxide decomposes, breaking down to ions and radicals, it also throws off hydrogen ions, becoming steadily more acidic.
6. Select the false statement regarding Type 2 Whitening Sensitivity (Zingers).
 - a. Feel like a sharp, immediate intense "lightning bolt", right down the length of an individual tooth
 - b. Are typically triggered by cold foods and beverages
 - c. Occur with no apparent stimulus
 - d. Typically occur in the smaller anterior teeth and tend to occur in the same few teeth, over and over
7. According to the Kurthy Hypothesis of Zinger-Type 2 Whitening Sensitivity etiology:
 - a. perhydroxyl radicals given off by peroxide travel through dentinal tubules to the pulp and cause immediate firing of the A-Delta neurons in the pulp.
 - b. hydrogen ions given off by peroxide travel through tooth aberrations into the pulp and cause instant simultaneous firing of the A-Delta neurons in the pulp.
 - c. molecular hydrogen peroxide travels through tooth aberrations into the pulp, enters the pulp, comes into contact with catalase enzyme, which causes instant breakdown of hydrogen peroxide into water and molecular oxygen, forming a bubble in the pulp.
 - d. molecular hydrogen peroxide travels through dentinal tubules into the pulp, enters the pulp, comes into contact with catalase enzyme, which causes instant breakdown of hydrogen peroxide into water and molecular oxygen, forming a bubble in the pulp.
8. Select the following true statement regarding bleaching lights and lasers.
 - a. The combination of photon energy from bleaching lights and lasers, plus high concentration hydrogen peroxide results in excessive production of Substance P in the pulp, resulting in additional moderate and severe sensitivity.
 - b. Bleaching lights and lasers cause additional whitening sensitivity due to evaporative dehydration.
 - c. Bleaching lights and lasers cause additional whitening sensitivity due to elevation of pulpal temperature.
 - d. b and c
9. Select the following true statement regarding the fact that molecular hydrogen peroxide from whitening gel does enter the pulps of teeth.
 - a. Hydrogen peroxide releases free radicals in the pulp, which may create long-term damage to the pulp. This is why whitening is not recommended to be used more than just once.
 - b. Catalase is an antioxidant enzyme found in the pulp, which forces hydrogen peroxide to break down only to water and molecular oxygen, instead of free radicals. This protects the pulp from true long-term damage.
 - c. Hydrogen peroxide in the pulp breaks down to hydrogen ions, causing the pH of the pulp to elevate, but does not appear to cause long term damage.
 - d. Hydrogen peroxide in the pulp breaks down to hydrogen ions, causing the pH of the pulp to lower, but does not appear to cause long term damage.
10. Select the following true statement regarding teeth desensitizing methods.
 - a. Stannous and sodium fluoride combine with salivary calcium to create a precipitation of insoluble calcium fluoride, instantly plugging the orifices of dentinal tubules.
 - b. ACP must have a nearly 100 percent inorganic substrate framework on which to "grow" additional hydroxyapatite. The growth of inorganic hydroxyapatite within the highly organic matrix of dentin is highly questionable.
 - c. Potassium nitrate slowly plugs dentinal tubules by aggregating in the dentinal tubular orifice.
 - d. ACP has been shown to create hydroxyapatite crystals in the dentinal tubule orifice, instantly plugging the orifice.

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