# WHITE PAPER

{KöR Whitening
Deep Bleaching™ System

## Solving Teeth Whitening Sensitivity

by Rod Kurthy, D.M.D.

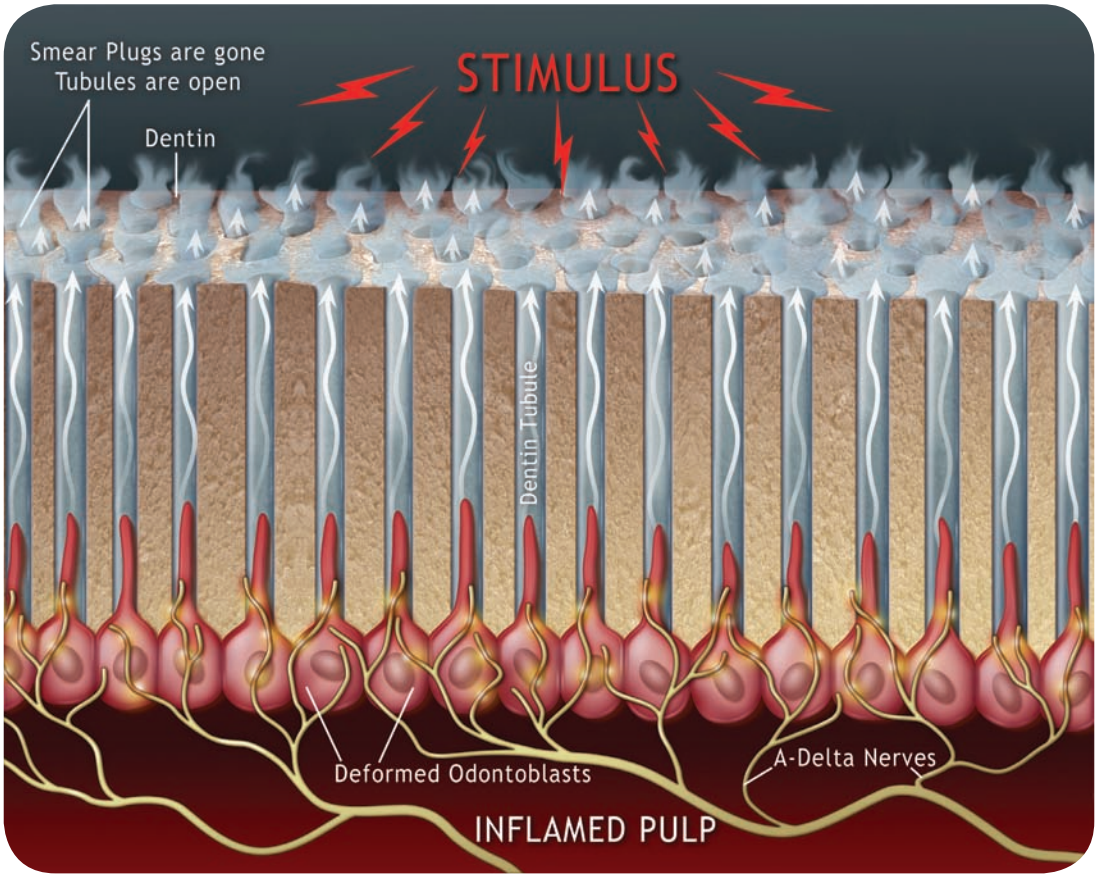


Illustration by Dr. Rod Kurthy and Andy Matlock

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# { Introduction }

*"Hey Doc,*
*I know you told me there might be a little sensitivity, but nobody told me whitening would hurt like heck! I can't do this. I just want my money back."*

Sensitivity (and sometimes downright pain) has been by far the most common negative side effect of teeth whitening – including both at-home and in-office whitening.[1,2,3,4,5,6,7] Millions of people have refrained from or discontinued whitening simply because of the discomfort.[1,2,3,4,5,6,7] As dentists, we hear this from people wherever we go, and especially in our dental practices.

Some attempts at eliminating sensitivity have resulted in whitening systems that didn't get teeth white. Some have resulted in whitening system claims of no sensitivity, when in fact sensitivity was not at all reduced.[8,9,10,11,12]

Recommended methods of preventing and treating bleaching sensitivity abound, yet when dentists try these methods, often they find little or no benefit.[8,9,10,11,12] The causes of bleaching sensitivity seem to be misunderstood by most, and methods of treating sensitivity are equally misunderstood.

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# { Causes of Bleaching Sensitivity }

Dentists providing whitening services have found two distinct types of bleaching sensitivity:

1) Typical Dentinal Hypersensitivity. Patients feel generalized discomfort of the teeth. Pulps also overreact to various stimuli such as cold and teeth brushing.

2) Zingers. Zingers are those instantaneous sharp "electric shocks" that shoot down the length of anterior teeth with lightening speed, nearly bringing patients to their knees. They last for a second or two and are gone.

The causes of Typical Dentinal Hypersensitivity are at least partially understood, however there is still speculation and controversy regarding the causes of zingers. We will present Dr. Rod Kurthy's hypothesis regarding zingers, which seems to have gained considerable attention by the dental community of late.

## 1) Dentinal 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 with this paper is typical dentinal hypersensitivity due to teeth whitening.

### The Hydrodynamic Theory of Dentinal Hypersensitivity

The predominant theory of DH states that pulpal sensitivity is mediated by a "hydrodynamic mechanism".[1,13,14,15,16,17] A stimulus (thermal, mechanical, evaporative or osmotic/chemical) applied to dentin can increase the flow of dentinal tubular fluid within the tubules (either inward or outward).[1,13,14,15,18,19] Flow of tubular fluid mechanically creates pressure or tension on the pulp, resulting in deformation of the cell membranes of A-delta nerve endings, which are mainly located at the periphery of the pulp at the inner surface of the dentin.[1,14,20,21,22,23,24] (Fig. 2)

The term "hydraulic conductance" refers to the ease with which fluid flows through dentinal tubules.[25,26] Obviously, the easier the fluid flows, the more and more often it flows, resulting in acute dentinal hypersensitivity.[25,26]

Ideally, dentinal tubules should routinely have naturally-formed smear plugs blocking or plugging the entrance to the tubules,[25] thereby effectively reducing the tubular flow (conductance). (Fig. 1) When dentinal tubule smear plugs are lost, the hydraulic conductance increases a whopping 32-fold,[25,27] resulting in potential for intense dentinal hypersensitivity. (Fig. 2)

Figure 1

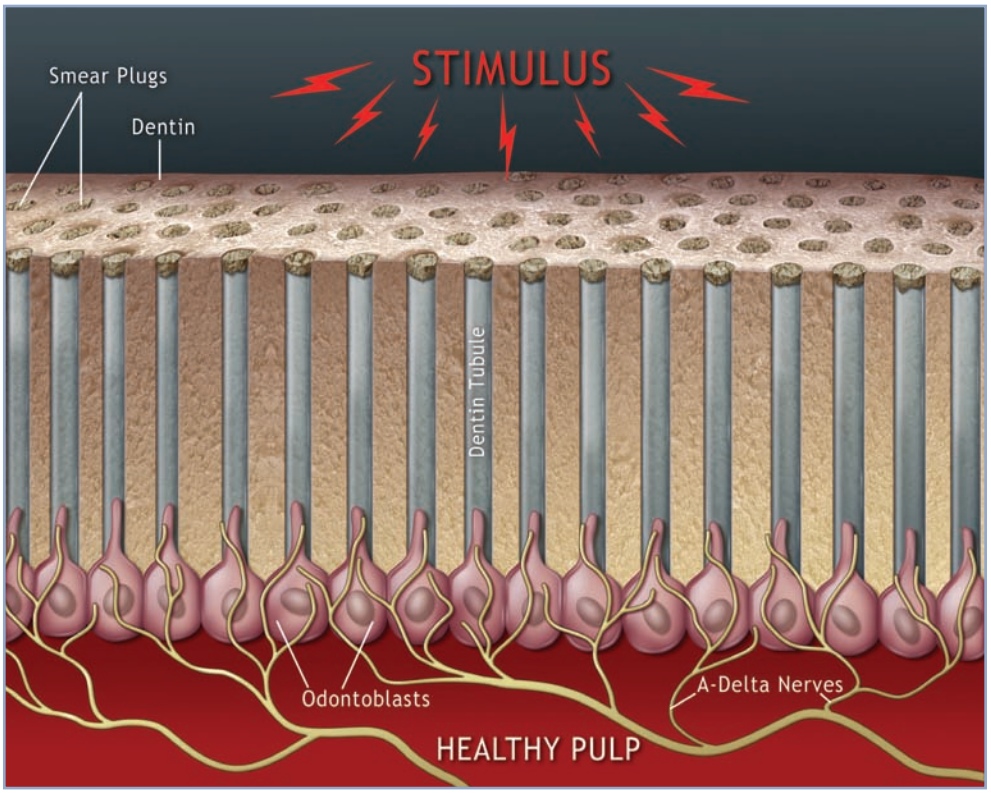


Illustration by Dr. Rod Kurthy and Andy Matlock

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

Figure 2

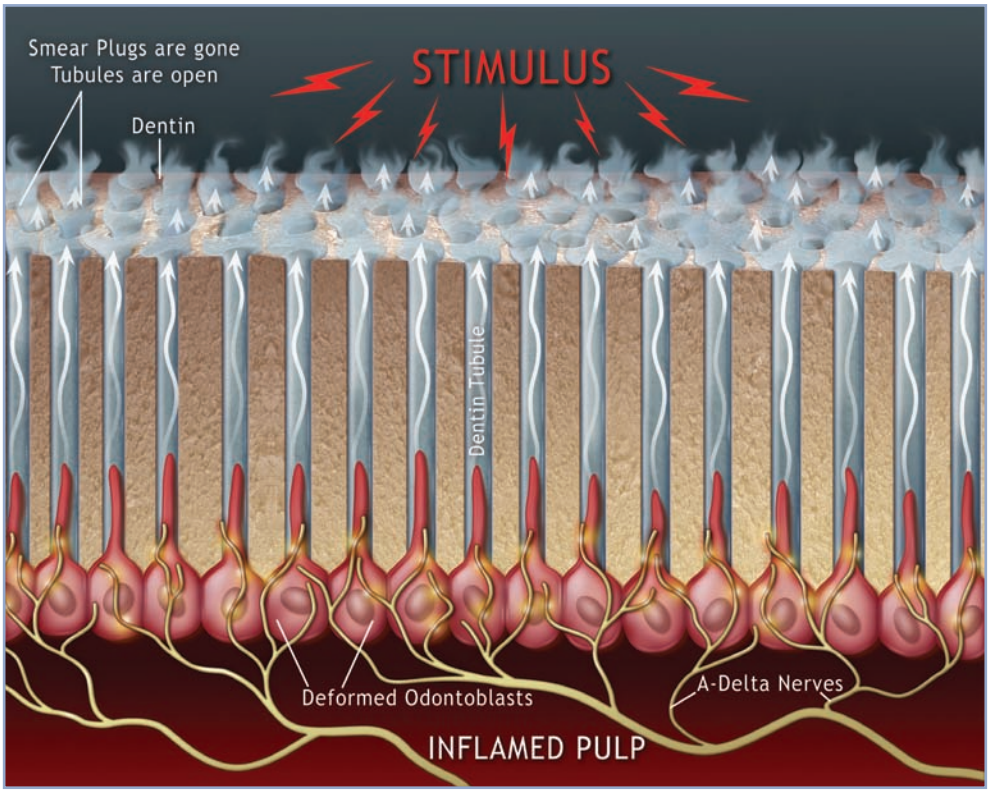


Illustration by Dr. Rod Kurthy and Andy Matlock

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

## Affects of an Acidic Diet

It is a fact that different people have different diameters of dentinal tubules[25,28] and different amounts of flare of the orifices of those tubules.[25] Genetically, some have dentinal tubules twice the diameter of others.[25,28] 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.[25,27] (Fig. 3 & 4)

### Figure 3

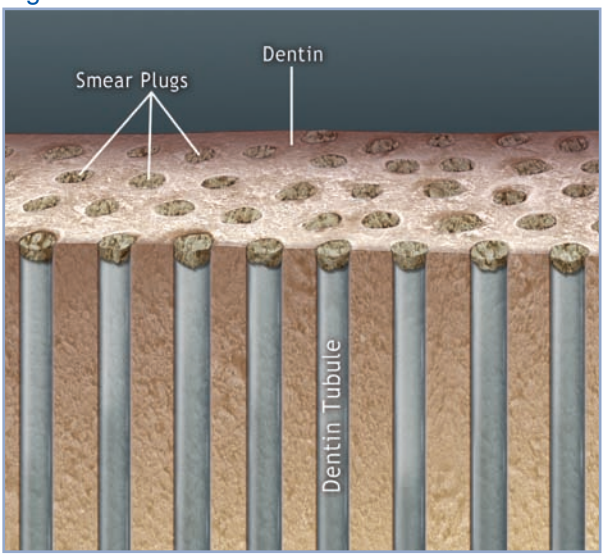


Illustration by Dr. Rod Kurthy and Andy Matlock

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

### Figure 4

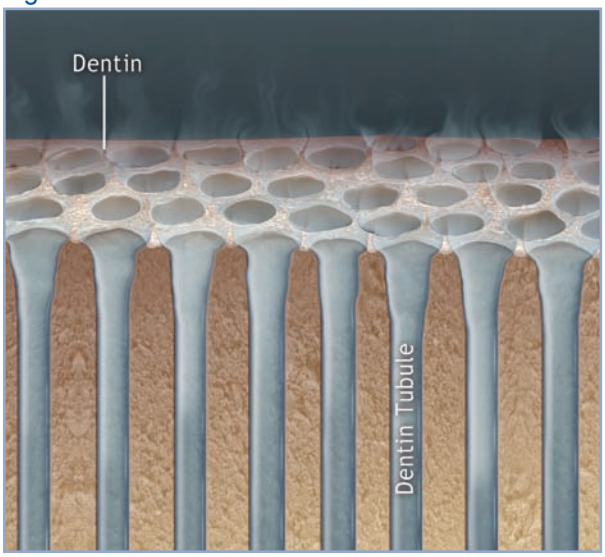


Illustration by Dr. Rod Kurthy and Andy Matlock

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.

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.[1,25,27] (Fig. 4) The larger the diameter of a tubule is, 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.[25]

We have long known that people who eat significant amounts of acidic foods have more sensitivity.[1,25,27] It is no surprise that statistically, patients with dentinal hypersensitivity tend to have dentinal tubules that are twice the diameter[25,28] and often have very flared orifices compared to those who do not experience hypersensitivity.[25]

## Peroxides Dislodge Smear Plugs

The aggressive "oxygenation" phase of any bleaching system results in the physical removal of smear plugs. (Fig. 5) Without smear plugs, hydraulic conductance of dentinal tubular fluid goes up 32 fold,[25,27] and bleaching gels can now intimately contact tubular fluids.

### Figure 5

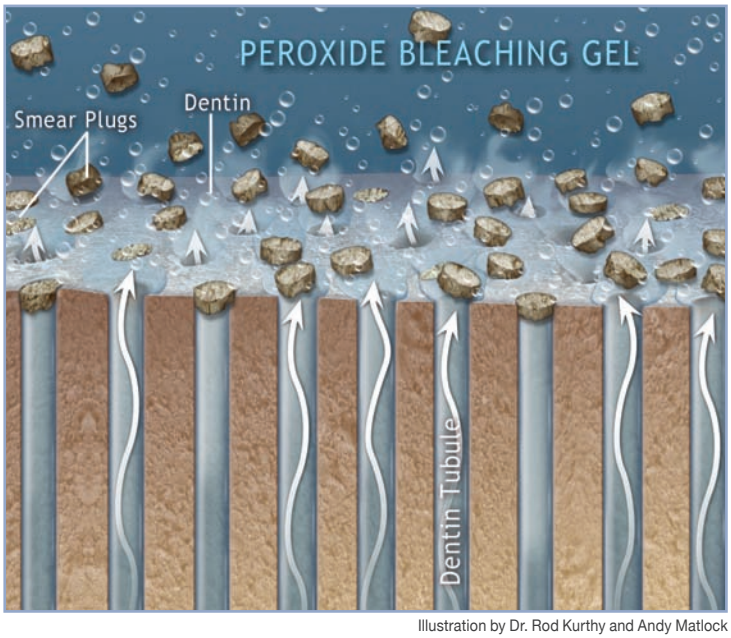


Illustration by Dr. Rod Kurthy and Andy Matlock

Fig. 5 – The aggressive "oxygenation" of the bleaching gel is dislodging smear plugs from the orifices of dentinal tubules. The higher osmolarity bleaching gel is osmotically drawing tubular fluid out of the tubules, initiating the hydrodynamic mechanism and creating sensitivity and discomfort.

Figure 6

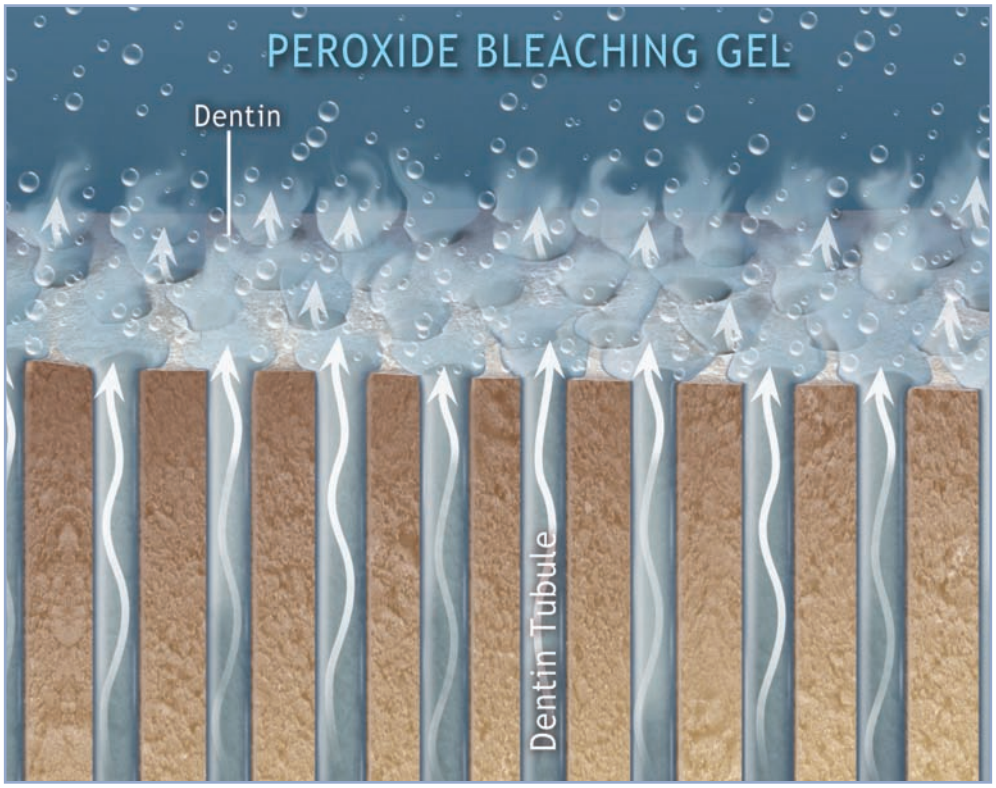


Illustration by Dr. Rod Kurthy and Andy Matlock

Fig. 6 – The aggressive "oxygenation" of the bleaching gel has removed smear plugs from the orifices of dentinal tubules. The higher osmolarity bleaching gel is osmotically drawing tubular fluid out of the tubules, causing sensitivity and discomfort initiated by the hydrodynamic mechanism.

## Bleaching Gels Create an Osmotic Gradient

All bleaching gels are hypertonic, with osmolarities varying from 4,900 mOsm/kg to 55,000 mOsm/kg, compared to only 290 mOsm/kg of dentinal tubular fluid.[1,16] This means that bleaching gels range from 17 to 190 times higher osmolarity than dentinal tubular fluid.

The greater the osmolarity of the bleaching gel, the stronger the osmotic gradient between the gel and tubular fluid, the stronger the osmotic "pull" on the dentinal tubular fluid,[14,16,17,29,30,31] and the more discomfort is felt by the patient.[1,14,32,33,29] (Fig. 6)

Anhydrous and acidic pH bleaching gels are more chemically stable,[16] however both anhydrous and acidic gels have osmolarities that are up to eleven times higher than 100% aqueous and neutral pH gels.[14,17,29,30,31] To avoid the costs of constant refrigeration, it is common for bleaching product companies to use anhydrous gels and add acidifiers to lengthen the shelf life.[16]

The more acidic and the more anhydrous the bleaching gel is, the stronger the osmotic gradient is,[14,29,30,31] the more forceful is the outward flow within the tubule,[14,16,29,30,31] and therefore the more acute the discomfort may be for the patient.[1,14,16,17,29,32,33]

Furthermore, acid in bleaching gels more aggressively removes existing smear plugs within dentinal tubules, fostering more tubular fluid flow and even more sensitivity.[1,27]

## 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.[34] Hydrogen ions create acidity (the designation pH refers to "potential of Hydrogen", and is a measure of the concentration of hydrogen ions).[34] This process can quickly cause an initially neutral gel to become acidic even down to a pH 3, further causing the problems noted above.

## 2) Zingers

During and/or soon after bleaching, the patient may experience what feels like a sharp, immediate, intense "lightening bolt", right down the length of an individual tooth. The patient may even describe this pain as a "crackling" electric shock. This tends to be spontaneous, for no apparent reason. It feels as if it starts at the incisal edge, and extends fully into 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.

### Peroxide Enters the Pulp

It has been shown that molecular hydrogen peroxide ($H_2O_2$) may enter the pulp tissue during and after bleaching.[1,35] (Fig. 7) Contrary to what many of us were taught years ago, enamel is not nearly impervious.[1] In fact, it is now considered a semi-permeable membrane.[1] Teeth often are formed with or acquire aberrations (little highways through tooth structure) that allow the low molecular weight hydrogen peroxide to enter the pulp.[1,35] (Fig. 7)

### 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.[36,37,38,39,40] The adult human body produces about 650mg of hydrogen peroxide per day via oxygen metabolism.[37] Two bleaching trays with reservoirs, with 16% carbamide peroxide contain a total of only 6.5mg of peroxide.[37] This means that our own bodies manufacture approximately 100 times more peroxide every day than the amount that is put into upper and lower bleaching trays.

If this large amount of daily endogenous hydrogen peroxide were allowed to continuously break down to strongly reactive oxygen species (such as free radicals) throughout our bodies, it would wreak havoc on our tissues.[36,37] To protect against constant radical formation from the breakdown of peroxide, the body manufactures protective anti-oxidant enzymes including Catalase,[41,42,43] superoxide dismutase, hemoxygenase-1 and glutathione peroxidase.[36,44,45,46]

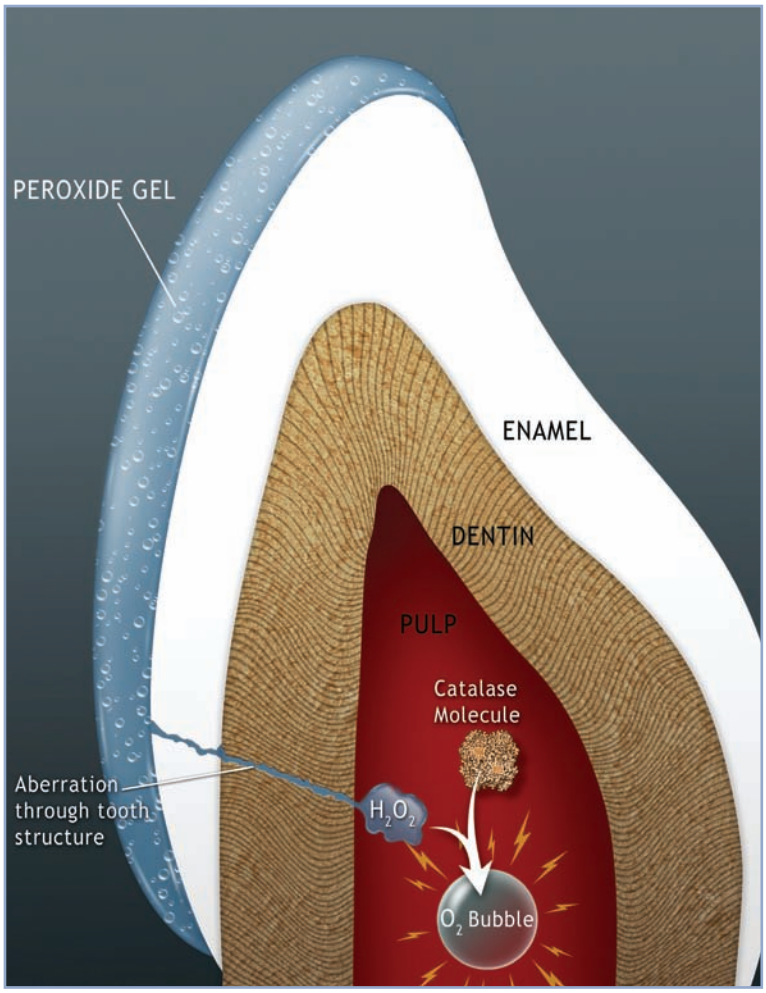


Illustration by Dr. Rod Kurthy and Andy Matlock

Figure 7

Fig. 7 – Molecular hydrogen peroxide may enter the pulp during and after bleaching through developmental or acquired aberrations through the enamel and dentin. The anti-oxidant enzyme Catalase present in the pulp breaks down the 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 neurons of the pulp, creating a sharp painful "zinger" that lasts only seconds before the intrapulpal pressure dissipates.

In the presence of these anti-oxidant enzymes, hydrogen peroxide is forced to break down to **only** water and molecular oxygen, instead of ions and radicals.[36] This is precisely why hydrogen peroxide that enters the tooth pulp does not cause permanent damage.[35,36,47]

Both gingival crevicular fluid and saliva contain high levels of peroxidase.[16,48,49,50,51] To illustrate the effectiveness of peroxidase, salivary peroxidase alone can decompose 29mg of peroxide (4.5 times more than found in two bleaching trays) per minute.[37] There is therefore no concern about swallowing peroxide gels.[37]

Catalase, which is always found in the dental pulp,[35,41,42,43,44,45,52,53] is a very efficient enzyme molecule, and each Catalase molecule is capable of instantly breaking down several million molecules of hydrogen peroxide to water and molecular oxygen.[54]

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 anti-oxidative enzymes such as Catalase[43,44,45] and peroxidases within tissues and tissue fluids, which decompose the hydrogen peroxide to water and oxygen upon contact.

### Dr. Rod Kurthy's Hypothesis of Zinger-Type Bleaching Sensitivity Etiology:

Molecular hydrogen peroxide ($H_2O_2$) enters the pulp during and after bleaching through developmental or acquired aberrations in enamel and dentin.[1,35] When hydrogen peroxide comes into contact with pulpal Catalase, the hydrogen peroxide is decomposed to water and oxygen gas upon contact,[35,36,43,44,45] forming an intrapulpal oxygen bubble. (Fig. 7)

Because the pulp is housed in a rigid chamber incapable of expanding, the instantaneous expansion caused by the formation of a bubble creates a very significant spike in intrapulpal pressure.[14] This significant and instantaneous spike in pressure deforms the membranes of pulpal neurons, resulting in instant acute pain.[14] (Fig. 7) The pressure quickly dissipates and equalizes, the deformation of the pulpal neurons ceases, and pain is gone. This hypothetic model perfectly describes the "zinger" type event.

## Pulpal Inflammation Caused by Bleaching Lights and Lasers

Bleaching lights and lasers have been found to have no positive effect on teeth whitening results.[55,56,57,58,59,60,61] When combined with higher concentration hydrogen peroxide, bleaching lights and lasers were found to enhance pain[16,17] and Substance P formation within the pulp, resulting in significantly higher pulpal inflammation and pain[14,62] than when no lights or lasers were used.[63] Substance P is a neuropeptide released by pain transmitting neurons to communicate with each other. Its function is to cause pain and inflammation.[14,62,63]

A popular UV bleaching light was found to be the greatest offender in increasing the release of Substance P.[63] The next greatest offender was the diode laser.[63]

# { Current Desensitizing Methods }

There are two general categories of desensitizing product action:

1) Occlusion of dentinal tubules – By occluding (plugging) dentinal tubules, movement of intratubular fluid flow is prevented, and sensitivity is therefore prevented or ceased[1,14,64] [treating the cause of sensitivity]. (Fig. 1)

2) Neuronal suppression – Chemical effect on pulpal neurons reducing the ability of pulpal neurons to fire[1] [treating the symptoms of/masking sensitivity].

## Unsuccessful attempts of reducing/eliminating sensitivity

### Modifying bleaching gels

Several companies have altered bleaching gels with intent to reduce sensitivity. What dentists have found is: 1) these gels did reduce sensitivity, but also did not whiten teeth well, or 2) the claims of reduced sensitivity were false.[8]

### 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 bleaching, during bleaching, and after bleaching has had some level of success, although rather minimal and unpredictable.[66,67]

### ACP

Amorphous Calcium Phosphate has primarily been discussed regarding remineralization of enamel, not dentin. The growth of inorganic hydroxyapatite within the highly organic matrix of dentin is highly questionable.[12,68,69]

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 bleaching.[12,68,69]

### Potassium Nitrate

Potassium nitrate does not occlude tubules and does not reduce tubular flow.[70] It is theorized that it may reduce nerve excitability (inhibit re-polarization of pulpal neurons),[1] however the efficacy of potassium nitrate, having been around for decades, has not been strongly supported in the literature.[1,9,66,67,70,71,72,73,74] To have an effect, potassium nitrate must migrate through dentinal tubules into the pulp,[1] which takes extended time.

Potassium nitrate has been unpredictable, seemingly effective on some, partially effective on some, and ineffective on some.[1,74] Though potassium nitrate may reduce sensitivity in some individuals, it simply masks pulpal inflammation and does not eliminate it.

### Addition of Desensitizers to Bleaching Gels

Some bleaching gels are manufactured with fluoride, potassium nitrate and/or ACP mixed into the bleaching gels.[9,10,12] Studies have not shown reduction of sensitivity from the addition of these substances into bleaching gels.[8,9,10,11,12]

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

Potassium nitrate must migrate through the dentinal tubule to the pulp to have any positive benefit.[1] Bleaching gels create an osmotic gradient resulting in flow within the dentinal tubules AWAY from the pulp.[1,14,29,30,31] For potassium nitrate to reach the pulp during bleaching, it would have to move through the tubule against the outward flow (like trying to swim upstream).[14,29,30,31] Potassium nitrate mixed within the chemistry of bleaching gel has been shown to be ineffective.[8,9]

The chemical and aggressive oxygenation environment during bleaching; 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 bleaching, but not when mixed into the bleaching gel itself.[8,11,12]

## { Solutions to Bleaching Sensitivity }

Solutions to teeth whitening sensitivity includes the following:

1. Creation of bleaching gels with the lowest osmolarity possible, to reduce the osmotic gradient between bleaching gel and dentinal tubular fluid, thereby reducing intratubular flow and sensitivity.[1,14,15,29,30,31]
    a) Bleaching gels should not only be aqueous,[16] but 100% aqueous. To extend shelf life and gel stability during storage, constant refrigeration must be used instead of the use of anhydrous gels.
    b) Bleaching gels should be entirely neutral or even slightly alkaline.[16,27] To extend shelf life and gel stability during storage, constant refrigeration must be used instead of adding acidifiers to bleaching gels.

2. Prevention of dentinal hypersensitivity during bleaching with rapid, aggressive occlusion of dentinal tubules, before and after each bleaching activity instead of treating symptoms after they occur. Reinforcement of tubular smear plugs immediately prior to bleaching, and rapid, aggressive replacement of any smear plugs lost during the oxygenation of bleaching immediately after each bleaching session results in predictability of success.[14, 25,64]

3. Prevention of zinger type bleaching sensitivity with rapid, aggressive occlusion of enamel and dentin aberrations before, and after each bleaching activity.

4. Use of desensitizer before and/or after bleaching, but not mixed in with the bleaching gel itself.[8,9,10,11,12]

5. Avoidance of bleaching lights or lasers. Numerous studies have proven the ineffectiveness of lights and lasers.[56,55,57,58,59,60,61] With the ability to predictably accelerate bleaching gels via pH and chemical acceleration,[59,60] there is no need to consider the use of potentially harmful bleaching lights or lasers.[14,16,17,62,63]

6. Use of buffering agents to stabilize the neutral pH of bleaching gels during decomposition in the mouth, preventing the natural tendency of peroxides to rapidly become acidic.

## { KöR Whitening Sensitivity Solutions }

Dr. Rod Kurthy's Evolve Dental Technologies is the first teeth whitening company to refrigerate a full line of bleaching gels from the instant of manufacture until received by the dental office. Stabilization via refrigeration adds overhead cost for Evolve Dental Technologies, however this allows the bleaching gels to be formulated with the lowest osmolarity possible by using 100% aqueous gels and no acid content whatsoever.

The obvious benefit is the lowest possible osmotic gradient between the KöR Whitening gels and the dentinal tubular fluid, the least amount of intratubular fluid flow, and therefore the least potential for sensitivity.[1,14,15,29,32,33]

Dr. Kurthy's research indicates that rapid profound closure of dentinal tubules, immediately before and after whitening procedures, results in the most predictable bleaching sensitivity control possible. (Figs. 8 & 9)

Figure 8

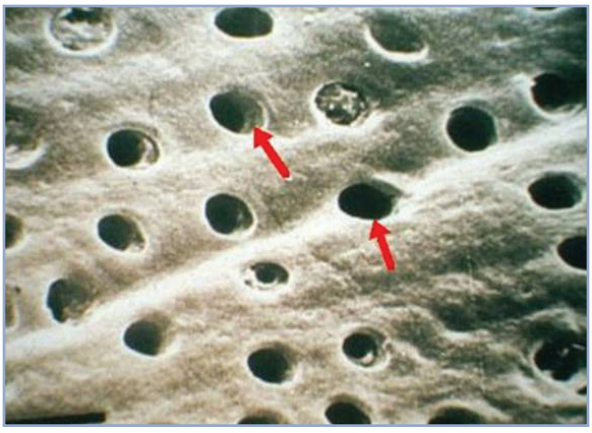

Fig. 8 – SEM photograph showing opened dentinal tubular orifices. Hydraulic conductance is 32 times greater than occluded tubules, tubular fluids are exposed to various stimuli capable of creating tubular fluid flow, resulting in tooth sensitivity and pain.

Figure 9

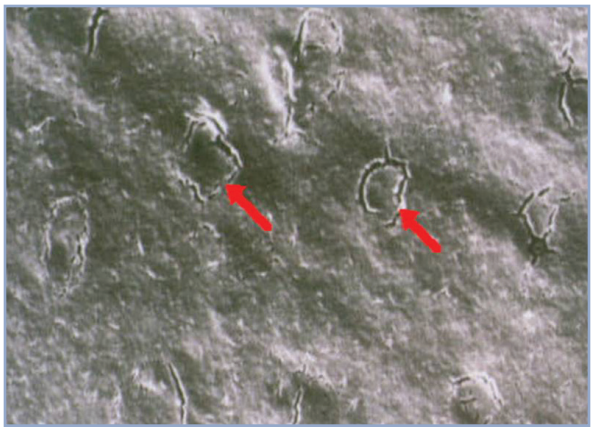

Fig. 9 – SEM photograph showing dentinal tubular orifices closed by Evolve Dental Technologies' KöR desensitizers. Hydraulic conductance has been eliminated and tubular fluids are prevented from contact by stimuli, including bleaching gels, resulting in the reduction or prevention of sensitivity.

## HEMA Based Desensitizing

KöR Desensitizer is a HEMA (hydroxyethyl methacrylate) based desensitizer. HEMA is a hydrophilic dentin bonding derivative – a resin primer. HEMA based desensitizers bind with proteins within dentinal tubules to form organic plugs within the tubules.[1,75,76] The result is immediate and profound.[1,75,77,78,79,80,81,82]

HEMA based desensitizers have a long history of successful, immediate desensitizing via occlusion of dentinal tubules,[1,75,77,78,79, 80,81,82] and are well supported by years of research.[77,78,79,75,80,81,82] HEMA based desensitizers provide rapid, aggressive plugging and re-plugging of tubules,[1,75,77,78,79,75,80,81,82] with no reduction in whitening effectiveness whatsoever. (Fig. 11)

KöR Desensitizers are used in the dental practice immediately before and after any in-office bleaching session. They are not mixed in with the bleaching gels. Desensitizer is also included with all at-home whitening kits, dispensed to patients to use daily after each at-home bleaching to re-plug any tubules that may have been opened by the oxygenation process of bleaching.[75]

Dr. Kurthy's split-arch clinical trials confirmed that use of KöR Desensitizer occludes both dentinal tubules and enamel/dentin aberrations, resulting in a decrease of both bleaching sensitivity and bleaching zingers by 90%, and showed no reduction in whitening effectiveness whatsoever. (Figs. 10 & 11)

Figure 10

Fig. 10 – Participant in desensitizer clinical testing – before hitening.

Figure 11

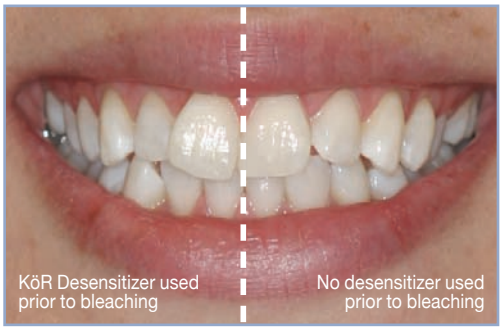


Fig. 11 – After whitening. KöR Desensitizer was used on the patient's right side immediately prior to the whitening procedure. No desensitizer was used on the patient's left side prior to bleaching. KöR Desensitizer did not impede whitening – whitening results are identical on both sides.

KöR Desensitizer also contains sodium fluoride. Sodium fluoride not only enhances the desensitizing effect, but has been shown to promote remineralization and increased enamel surface microhardness[83,84] after bleaching. Remineralization may promote the filling of natural surface voids in enamel opened by the oxygenation phase of bleaching,[83] (see KoR Solving Teeth Whitening Frustrations White Paper) which may not only increase enamel surface microhardness,[83,84] but result in an even whiter result and less potential for relapse of bleaching.

With the use of a revolutionary Dual-Accelerated Tri-Barrel Hydremide™ Peroxide technology, the KöR in-office bleaching gels are chemically accelerated in two distinctly different ways, maximizing the effectiveness of the gels without the potentially negative pulpal effects of a bleaching light or laser.

This Tri-Barrel approach also enables the use of buffering agents that not only maintain a constant neutral pH throughout the whitening procedure, but maintain the rapid effectiveness of the gels throughout the procedure. Remember, acidic pH stabilizes the bleaching gel, and therefore slows its effectiveness. By maintaining a neutral pH throughout the breakdown of peroxide on the teeth, the bleaching gel instability is maintained and whitening continues to progress quickly throughout the procedure.

There is currently no effective whitening system that can claim "no sensitivity", however with the meticulous scientific approach discussed in this paper, both the incidence and severity of bleaching related sensitivity has been greatly reduced by the KöR desensitizing approach, and in the majority of cases virtually eliminated.

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