

History, safety, and effectiveness of current bleaching techniques and applications of the nightguard vital bleaching technique

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This article reviews the literature on the use of hydrogen peroxide in three professionally administered bleaching techniques from historical, technique, and safety viewpoints. Safety over time, absolute safety, and relative safety of nonvital bleaching, in-office vital bleaching, nightguard vital bleaching, and over-the-counter bleaching kits are compared. The advantages and disadvantages of different bleaching options, as well as indications for individual or combined use of the techniques, are discussed. In addition, specific indications for the use of the nightguard vital bleaching technique are presented. (Quintessence Int 1992;23:471-488.)

Introduction

The purpose of this article is to evaluate the safety of the various techniques for bleaching teeth in general, and the newer nightguard vital bleaching technique specifically, as well as provide examples of some of the applications of the nightguard vital bleaching technique. Bleaching techniques may be classified by whether they involve vital or nonvital teeth and by whether the procedure is performed in the office or has an at-home component.

Hydrogen peroxide, in various concentrations, is the primary material currently used by the profession in the bleaching process. Current in-office techniques for vital teeth and the "walking bleach" technique for

nonvital teeth typically use a 30% to 35% concentration of hydrogen peroxide.¹ The majority of the products currently on the market for the nightguard vital bleaching technique use a 10% carbamide peroxide solution.² A 10% carbamide peroxide degrades into 3% hydrogen peroxide and 7% urea, and hydrogen peroxide can be considered its active ingredient.³ The urea may provide some beneficial side effects, because it tends to raise the hydrogen ion concentration (pH) of the solution.⁴ Some products marketed directly to consumers, over the counter (OTC), use 6% hydrogen peroxide solutions in a gel form.

Hydrogen peroxide naturally occurs in the body, even in the eyes, in low concentrations.⁵ It is manufactured and regulated by the body, and often involved in wound healing.⁶⁻⁹ In higher concentrations, it is bacteriostatic,¹⁰ and in very high concentrations is mutagenic,¹¹⁻¹³ possibly by disrupting the DNA strand. However, the body has mechanisms for immediate repair of natural damage,¹⁴ low concentrations of hydrogen peroxide do not cause serious problems,¹⁵ the carcinogenic capabilities of hydrogen peroxide are more often caused by other peroxide derivatives,¹⁶ and the body uses the peroxidases^{6,7} and other mechanisms¹⁷ for regulating hydrogen peroxide. Also, other conditions are often required to allow action by hydrogen peroxide on cells.¹⁸ Because hydrogen peroxide occurs extensively within the body, and because it has been used topically for many years,¹⁹ it has been

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studied extensively. The understanding of the role of hydrogen peroxide offers clues to understanding many of the body's actions at the cellular level and to understanding the naturally occurring inflammation and healing processes.

The mechanism of action of hydrogen peroxide in tooth bleaching is considered to be oxidation, although the process is not well understood.²⁰ It is felt that the oxidizers remove some unattached organic matter from the tooth without dissolving the enamel matrix, but also may change the discolored portion to a colorless state.²¹ There is some concern that continued long-term treatment will result in dissolution of the enamel matrix,²² but reports to date on nightguard vital bleaching techniques have not supported this theory.^{23,24} Tetracycline stains are more resistant to oxidation because the molecule is tightly bound to the mineral in the enamel prism matrix during formation and hence is less accessible to immediate action (Crenshaw M: Personal communication). Teeth stained with tetracycline therefore require prolonged treatment times before any results are demonstrated and often are unresponsive to the procedure.

Generally, bleaching is considered an elective process, although there are other indications that may make bleaching a necessity.

Safety over time

The first area to consider when evaluating safety is how long the technique has been used, and the observations that have been made over that time. Esthetic dentistry was a popular topic in the late 1800s, including such present-day concepts as recontouring of teeth; the portion proposed to be removed was shaded with india ink for patient approval.²⁵ Recontouring and bleaching were recommended procedures, along with gold inlays and porcelain inlays, to avoid the waste of sound tooth structure by the casual crowning of the tooth.^{26,27} Dentistry was in an era of affluence, and esthetics was a prime consideration. Dentists were concerned that too many teeth were being crowned, about the inappropriate use of base metal in restorations, about proper uses of better pins in teeth, and about the need for better use of the rubber dam.²⁷

From the middle 1800s until early 1900, the reputable dental journals contained 40 to 60 articles a year on tooth bleaching. The chemistry seemingly was well understood, the eminent leaders of the profession conducted experiments showing the safety of bleaching to the tooth, and the plea for conservative dentistry and

preservation of tooth structure was ever the standard. Prominent dental leaders and editors of major textbooks gave lectures supporting bleaching,²⁸ and chapters or sections in operative dentistry textbooks were devoted to this treatment.²⁹⁻³¹ The discussions concerned whether or not bleaching worked, the appropriate indications, how long it lasted, and the relative safety of the various procedures.

Practitioners speaking against bleaching argued that it took too long to occur and was too technique sensitive to perform. They argued that because the teeth often reverted back to their original color, bleaching was not worth the effort, and they would rather crown the tooth.²⁸ Those practitioners in favor of bleaching demonstrated the scientific approach to the application of the different bleaching techniques to avoid failure and minimize relapses, reported longevity averaging 6 to 25 years, and stated that professional dentists gave the needed time to get the best, most conservative treatment for their patients.²⁸

As early as 1848, nonvital tooth bleaching with chloride of lime was practiced.³² Truman is often credited with introducing, well before 1864, the most effective technique for bleaching nonvital teeth, which used chlorine from a solution of calcium hydrochloride and acetic acid.²⁸ The commercial derivative of this, later known as Labarraque's solution, was a liquid chloride of soda.^{26,33} Numerous other bleaching agents were also successfully employed on nonvital teeth in the late 1800s, including aluminum chloride,^{34,35} oxalic acid,^{26,36-38} pyrozone (ether-peroxide),³⁹ hydrogen dioxide (hydrogen peroxide or perhydrol),⁴⁰ sodium peroxide,⁴⁰ sulphorus acid,²⁸ sodium hypophosphate,³⁵ chloride of lime,^{35,41} and cyanide of potassium.⁴² All these substances were considered either direct or indirect oxidizers, which acted on the organic portion of the tooth, except for sulphorus acid, which was a reducing agent.²⁸ It later came to be recognized that the most effective direct oxidizers were Pyrozone (Mc Kesson & Robbins), Superoxol (Merk), and sodium dioxide, while the indirect oxidizer of choice was a chlorine derivative.^{30,43}

The bleaching agents were categorized according to which stains they were most effective in removing. Iron stains were removed with oxalic acid,⁴⁴ silver and copper stains with chlorine,²⁹ and iodine stains with ammonia.⁴⁵ The stains of metallic salts from metallic restorations such as amalgam were considered the most resistant to bleaching. Although cyanide of potassium would easily remove such metallic stains, its use was not recommended because of its being a very

active poison.⁴¹ It was recognized that restorations were not affected by bleaching, but the bleaching would remove the stains around margins and under esthetic restorations that were leaking, giving them a longer esthetic life.²⁹ Earlier concerns of the profession about the potential dissolution of teeth from the caustic nature of some of the materials had been disproved by laboratory experiments and clinical observation.⁴¹

Techniques that allowed the practitioner to perform the procedures in-office⁴⁴ or place the medicament and change it at subsequent appointments were described.³³ Sodium peroxide and hydrogen dioxide were used independently or together to bleach teeth; sodium peroxide actually had the advantage of giving the most natural translucency to the nonvital teeth.⁴⁰ It had long been recognized that some stains were more resistant to treatment than others, and great care was taken during endodontic therapy to avoid allowing the pulpal tissues to bleed into the chamber, since this caused the tooth to discolor.⁴⁶

Although most of the early dental literature focused on bleaching nonvital teeth, vital teeth were also treated, as early as 1868, with oxalic acid,³⁶ and later hydrogen peroxide⁴⁷ or Pyrozone.³⁹ By 1910, these vital bleaching techniques generally included the use of hydrogen peroxide with a heating instrument or a light source.⁴⁷ The steps to ensure patient comfort, including the covering of the eyes, the number of appointments, four or five, and the minimum of 3-day intervals between appointments, as well as the favorable prognosis, were well documented and recognized by the profession.⁴⁶⁻⁴⁸

As early as 1893, it was common knowledge that a 3% solution of Pyrozone (ether-peroxide), the aqueous solution of hydrogen dioxide, could be used freely as a mouthwash by both children and adults and that, in children with pitted teeth, it had the beneficial side effect of reducing caries and bleaching the teeth.⁴⁹ It was reported that the 5% solution could be used in a like manner to bleach teeth, but that the 25% solution, the most effective bleaching agent, should be used carefully, to prevent contact with the soft tissue, because of its caustic nature.⁴⁹

Since there were few manufacturing companies in the 1800s, most dentists were excellent chemists, and mixed a variety of solutions in their offices. When the manufacturing industry began to develop in the 1900s, this versatility was lost to the profession, and the choices of materials to the profession were limited to those offered by the manufacturing companies. Superoxol was introduced by a manufacturing company

early in the 1900s, and later became the chemical used by the majority of dentists because of its safety, although it was recognized that hydrogen peroxide bleaching sometimes left a yellow or brown tinge in some teeth, which the other, previously used materials had not,²⁸ and that Pyrozone (ether-peroxide) was the more efficient bleaching material.⁵⁰

From about 1913 until 1940, which included the time of World War I, the Depression, and World War II, very little was written about bleaching. However, articles began to appear in the 1940s and 1950s as the United States began to recover economically, as communications improved nationally, and as the profession began treating fluorosis, tetracycline-stained teeth, and discolored teeth saved by endodontic therapy rather than lost to extraction. In the 1940s, hydrogen peroxide and ether were again used on vital teeth.⁵¹

Pyrozone continued to be used effectively for nonvital teeth in the late 1950s and early 1960s,⁵² as was sodium perborate.⁵³ In the late 1960s, Nutting and Poe^{54,55} elected to use Superoxol instead of Pyrozone, for safety, and combined it with sodium perborate to achieve a synergistic effect. They recommended use of Amosan (Knox Mfg Co), a sodium peroxyborate monohydrate, because it released more oxygen than did sodium perborate. They also advised that the gutta-percha be sealed before the procedure was initiated.

Also in the late 1960s, a successful technique for home bleaching using a 10% carbamide peroxide, delivered in a custom-fitting mouth tray, was discovered by Klusmier.⁵⁶ Although he presented several table clinics at the Arkansas State Dental Society and the Southwestern Orthodontic Society (Klusmier B: Personal communication), this technique went relatively unnoticed until Haywood and Heymann² described the technique in March 1989 and a similar product was introduced by a manufacturing company that same month.^{57,58} For the first time, this technique offered the possibility of whiter vital teeth to a wider section of the general patient population at a lower cost, with much less danger and fewer side effects, than any of the previous options. Since that time, numerous other products and techniques making claims for bleaching teeth have been introduced.^{22,57} These options include variations on the dentist-prescribed/home-applied techniques, as well as "bleaching kits" sold directly to consumers in stores for unsupervised home use. The nightguard vital bleaching techniques and the OTC bleaching kits have kindled a resurgence of interest in tooth bleaching and have reopened the questions asked 100 years ago: Does it

work, is it safe, what are the indications, and how long does it last?

Current safety

Nonvital bleaching

The walking bleaching technique is probably the most popular option for bleaching nonvital teeth, and no major problems of safety were initially observed other than those associated with the handling of the material and the potential for burns from the high concentration of hydrogen peroxide. This technique involves sealing a mixture of 30% hydrogen peroxide and sodium perborate in the pulp chamber and changing the solution every 2 to 7 days.

The in-office alternative treatment for bleaching nonvital teeth usually involves a single appointment in which 30% hydrogen peroxide is activated by a heating instrument, which is more efficient. However, later in the 1970s, external resorption was noted in the cervical areas of nonvital bleached teeth.^{59,60} Early reports linked this to overzealous use of heating instruments or to previous trauma to the tooth.^{61,62} Onset was 1 to 7 years posttreatment, and the tooth was often lost.

Although the etiology of the resorption is still unknown, later reports have questioned the heat and trauma theories and proposed that the resorption may result from exiting of the peroxide through the tooth where the enamel and cementum do not join.⁶³ Approximately 10% of teeth do not have an intact cemento-enamel junction (CEJ). This theory, along with the observation that pressure in the chamber often causes transient pain, reaffirm that a base material should be placed, before the peroxide is inserted, over the exposed root canal filler and over areas that might communicate with the CEJ. However, placement of this base often means that a portion of the tooth that is discolored will have to be masked with the base material and possibly will not lighten.

A significant drop in pH has been observed in the cervical area of the tooth from passage of the peroxide through the tooth and its exit at the CEJ.⁶³ Later observations have indicated that the resorption is not actually at the CEJ, but is more apical.⁶⁴ This observation, along with experience gained using calcium hydroxide in the treatment of resorption and incomplete root formation, have led to the practice of filling the pulp chamber with calcium hydroxide powder after the completion of the bleaching to alter the pH and halt the potential osteoclastic activity.⁶³ More recent re-

ports have recognized the greater potential for cervical resorption from the combination of heat and 30% hydrogen peroxide over either treatment alone.⁶⁵ For these reasons, the safer nonvital bleaching technique appears to be the walking bleaching technique, rather than the in-office technique using a heating instrument.

Another approach to treatment involves using sodium perborate alone, rather than in conjunction with hydrogen peroxide, as the primary bleaching agent.⁶⁶ Although this may be a slower process, it is potentially less destructive to the tooth and hence safer.⁶⁷

It is unclear why these resorption problems should appear so late in the history of nonvital bleaching, but their recent appearance raises the possibility that changes in materials for root canal fillers, sealers, or bleaching, or a wide variation by practitioners in administration of the technique, may be the cause. At this time, the walking bleaching technique seems reasonably safe, with only a slight chance of cervical resorption. The benefit of treatment is relatively great (considering the cost of a crown or veneer, the preservation of remaining tooth structure, the potential for an esthetic outcome, the avoidance of a subsequent weakening of the tooth, and the finite life of the other restorative possibilities), and the risk is small. Precautions include sealing the root-filled portion preoperatively with a material such as polycarboxylate cement, placing calcium hydroxide powder in the chamber postoperatively for 14 days, and following the patient for a number of years with frequent recall radiographs. If there is any evidence of resorption, it may be arrested with calcium hydroxide treatment, and the tooth can be crowned (with or without extrusion of the tooth to manage the defect).⁶⁸

Vital bleaching

For any vital bleaching procedure, patients are classified by whether they have tetracycline-stained teeth, or teeth stained from other reasons. Tetracycline-stained teeth are the least responsive to bleaching, depending on the severity of the stain.⁶⁹ With external bleaching, tetracycline-stained teeth generally get lighter, but not whiter. Some clinicians have recently advocated intentional endodontic therapy on those teeth, with the use of the walking bleach, to overcome this problem.⁷⁰ While the esthetic result appears to be much better than that of external bleaching, this approach raises questions about the success of the endodontic therapy over time, the longevity of the walking

bleaching technique, and the potential of the treatment or retreatment to cause cervical resorption.

The most popular technique for the in-office bleaching of vital teeth involves 35% hydrogen peroxide, etching the teeth with phosphoric acid to facilitate bleaching, and either a heating element or a light source to enhance the action of the peroxide.^{1,71} Because this technique must be accomplished without anesthesia to allow the patient's pain threshold to determine the appropriate heat level, there have been numerous studies on the effects of both the heat and the concentrated hydrogen peroxide on the pulp.^{72,73} Although there is insult to the tissue, most of the research has shown that the pulp remains healthy, and the insult is reversible in approximately 2 months.^{74,75} The observations of many clinicians who have performed this procedure over many years attest to the fact that pulpal necrosis is not associated with vital bleaching.¹ Research in this area has shown how easily the hydrogen peroxide, because of its low molecular weight, passes through the enamel and dentin to the pulp.⁷⁶

More current clinical studies have eliminated the etching with phosphoric acid,⁷⁷ and the most recent products on the market advocate no use of heat or light for the reaction.⁵⁷

A number of studies have evaluated the effect of bleaching with this high concentration on dentin and enamel and have found some hints of structural changes in tetracycline-stained teeth.⁷⁸ However, the most important observation has been the decrease in bond strengths of composite resin to bleached, etched enamel immediately after the bleaching process.⁷⁹ Later studies in this area have attributed the decrease to residual peroxide left immediately in the tooth or on the surface.⁸⁰

The main safety advantages of the in-office vital bleaching technique are that, although it uses caustic chemicals, it is totally under the dentist's control, the soft tissue is generally protected from the process, and it has the potential for bleaching quickly in situations in which it is effective. Disadvantages are primarily the cost, the unpredictable nature of the result, and the unknown duration of the treatment. The unsafe features include the potential for soft tissue damage to patient and provider, the discomfort of rubber dam, the temperature on the pulp, and the resultant post-treatment sensitivity. Although early concerns about pulpal response were identified, subsequent research seems to have shown that although this high concentration of hydrogen peroxide causes changes, they

are reversible.⁴ If etching is performed, polishing is required after each visit, with some enamel loss.

It is well accepted that this technique works, but the patient must be counseled that, although the result may be permanent, the process more likely will have a 1- to 3-year duration, at which time the treatment will need to be redone. Also, it cannot be determined prior to treatment whether the teeth will respond, and treatment may take as many as four to six treatments. The labor-intensive nature of the treatment, which in turn requires a higher fee, coupled with the discomfort to the patient and uncertainty of the outcome, keep this method of bleaching from being a treatment that is widely accepted, although it can be successful.

Recent innovations for in-office bleaching include chairside-mixed gels, some of which are activated by composite resin curing lights (Hi Lite Dual Activated Bleaching System, Shofu). According to the manufacturer, this light-activated material changes color when the bleaching process is completed, which should take only 3½ minutes. Chemical composition and effects on tooth structure of this technique are unknown at this date. Other gel forms do not use heat or light. Although they require approximately the same treatment time as the conventional Superoxol bleaching technique, the gels are much easier to manage clinically.

Nightguard vital bleaching or dentist-prescribed/home-applied bleaching

The most recently introduced vital bleaching technique, originally called nightguard vital bleaching (NGVB),² but also referred to as home bleaching or dentist-monitored bleaching, has created a resurgence in the area of bleaching, primarily because of its relative ease of application, the safety of the materials used, the lower cost, its general availability to all socioeconomic classes of patients, and the high percentage of successful treatments. It may be more appropriately termed a "dentist-prescribed/home-applied" technique. Because the 10% carbamide solution is equivalent to a 3% hydrogen peroxide solution, this solution is approximately one tenth the concentration of the solutions used for "power," or in-office, bleaching. Results are generally seen in 2 to 3 weeks, and the final outcome is complete in 5 to 6 weeks.³ However, treatment times vary extensively, and much depends on the amount of time per day that the patient chooses or is able to apply the technique. Later products have offered solutions of hydrogen peroxide that range

from 1% to 10% and carbamide peroxide solutions that are either 10% or 15% concentration.⁸¹ The details of this technique have been reported in many articles.^{2,3,22,56,57,82,83}

Numerous articles have attested to the efficacy of the technique, which has been successful in clinical trials for approximately 91% of persons with materially or genetically discolored teeth, and somewhat less successful in 91% of persons with tetracycline-discolored teeth. Tetracycline-stained teeth generally get lighter, but not whiter. Nightguard vital bleaching generally has the same indications and prognosis as conventional, in-office bleaching, but can be accomplished at a much lower cost and with fewer side effects, such as tissue burns and sensitive teeth, in the general patient population. A recent survey of 7,617 dentists indicated a success rate of greater than 90% for the technique; ninety percent of the responding dentists use a 10% carbamide peroxide.⁸⁴

Specific questions as to the safety of NGVB were recently addressed in an article by Haywood and Heymann.⁴ The controversial element that the nightguard vital bleaching technique adds to conventional bleaching options is the potential for contact of the soft tissue during treatment and from ingestion of the material. This contact sometimes results in one of the two common side effects, an irritation of the gingival tissue. More than half the time, this irritation is related to an ill-fitting prosthesis. Other times, it is the tissue's response to the peroxide.

There are numerous reports of the effects of hydrogen peroxide on tissue.⁸⁵⁻⁸⁷ However, those effects are generated by conditions that exceed greatly the time and dosage of peroxide used in this bleaching technique.⁴ The previously mentioned survey confirmed that one third of patients bleaching their teeth in the home manner did not have side effects, while those that did experienced either transient tooth sensitivity or gingival irritation.⁸⁴ The fit of the guard was a major cause of gingival irritation. Reports from industries that make hydrogen peroxide state, "It is improbable that humans will be exposed to high oral doses of H₂O₂ due to the acute toxicity of concentrated solutions and the corrosivity of H₂O₂ to mucous membranes. An individual would theoretically have to drink daily 23 mL of 35% hydrogen peroxide for a lifetime to develop the lesions seen in mice."²⁰ Hydrogen peroxide is approved as safe for use as human food additive with no residues.

More recent studies directly evaluating the effects of 10% carbamide peroxide on tissues and in animals

systemically have indicated that the effects of 10% carbamide peroxide on tissue are less than or equal to those of many other accepted dental medicaments, such as eugenol,⁸⁸ or other dental procedures.⁴ The most conclusive evidence to date has been the work of Woolverton et al⁸⁹ establishing the nonmutagenic nature of 10% carbamide peroxide, the safe level of ingestion, and the minimal effects on cell lines. Even in tray designs that seek to avoid covering the attached gingiva, the interdental papillae are still exposed to the solution. Hence, the total avoidance of soft tissue contact is impossible as the technique currently stands. Conclusions from evaluations of the other studies indicate that toxicity and mutagenicity of hydrogen peroxide are dose related,⁹⁰ and the concentrations used in the at-home bleaching technique are not of sufficient strength to warrant concern about the soft tissue.⁴ In fact, although a high, sudden dose of hydrogen peroxide is toxic to cells, a lower dose over a longer time allows cells to adjust and actually ultimately tolerate a higher dose than that which originally would have been toxic.⁹¹ Also the long history of clinical usage of the solutions with soft tissue contact ranging from 7 days to 3 years, in patients ranging from newborn infants to geriatric patients, has demonstrated no problems.⁴

Various effects of carbamide peroxide on teeth have been studied.⁹²⁻⁹⁴ Generally, these reports find the effects to be nonexistent or to be no worse than those already found with in-office bleaching. Although there have been varying reports concerning the effect on enamel, there does not seem to be a significant effect on the morphology of the enamel surface outside the normal variation of enamel.^{92,93,95} No published reports have demonstrated any change in hardness of enamel, nor have studies at the University of North Carolina shown any significant concerns.⁹⁶ Studies that evaluate change in the surface must take into account the remineralization potential in the mouth, which may negate any potential changes. There has been one observation that toothbrush abrasion was more significant in the presence of bleaching agents,⁹⁷ while yet another slightly different study showed brushing with the solutions had no effect.⁹⁵ Another report has shown the at-home bleaching procedure to be a controlled oxidation process in which the organic phase of the enamel is mobilized without producing grossly unacceptable enamel surface topography.²³ Clinically, there is no apparent loss, and the tooth retains its glossy appearance. There have been reports of internal matrix changes from bleaching with 35%

hydrogen peroxide after laboratory-induced tetracycline staining, but there is no direct correlation between this study and the milder hydrogen peroxide, nor have these changes been demonstrated to have any clinical significance. Studies directly on dentin and enamel with 10% carbamide peroxide materials have demonstrated no structural loss.²⁴

The effects on the pulp were extensively evaluated in the previous generation of bleaching with 35% hydrogen peroxide, and the lower concentration of peroxide would not be expected to be as detrimental to the pulp. The effects on pulp have not been directly evaluated with the weaker peroxide solutions, but the research on 35% hydrogen peroxide has shown effects that are reversible over time, with no clinical consequence other than immediate, but transient, sensitivity. Clinical trials on nightguard vital bleaching techniques in progress at the University of North Carolina have found no predictors of sensitivity relative to patient age, pulpal size, presence of exposed dentin or cementum, caries, or leaking restorations. The limitation for how young the child is able to be treated is related more to the available number of permanent teeth to retain the guard and the desire not to impede the eruption of permanent teeth as they attempt to rapidly enter the oral cavity than to pulpal sensitivity. The occasional mild tooth sensitivity associated with nightguard vital bleaching is attributed to the easy passage of the hydrogen peroxide and urea through the enamel and dentin to the pulp and the resulting mild irritation. This ceases on termination of treatment.⁴ Because the concentration of hydrogen peroxide is lower, certain patients that could not tolerate the in-office bleaching because of discomfort have found the nightguard vital bleaching technique to be acceptable.

Effects on restorative materials have been limited primarily to composite resins, both with color change and surface integrity.⁹⁴ Basically, there is no appreciable change in the color of any restorative material clinically. Although there have been conflicting reports recently in this area as to composite resins,⁹⁸⁻¹⁰¹ the ability of the colorimeters to measure differences is limited, and this color difference has not yet been calibrated to clinically detectable changes. Clinicians must assume there will be no color change in any material (although the stains may be removed from the surface and margins of porous composite resins, etc), and patients should be advised of the potential need for replacement of any esthetic restorations if the shade of the composite resin is not clinically acceptable postbleaching.³ Reports of the dissolution of a portion of the matrix have also

concluded that it may be clinically inconsequential.¹⁰² Since the composite resin may have to be replaced afterward, any loss may be of no significant concern. Whether this bleaching technique will have a significant effect on the long-term wear of posterior composite resins¹⁰³ is still unknown, because other reports have shown that composite resin hardens after exposure to bleaching solutions.⁹⁸ Porcelain, amalgam, and gold have not responded with either color change or alteration of structure, so they are considered unchanged by the bleaching process.⁹⁴

Of current interest to the clinician is the effect of bleaching on bond strength of etched enamel to composite resin. Earlier reports had associated a decrease in bond strength of treated enamel to composite resin with bleaching using 35% hydrogen peroxide.⁷⁹ This occurrence has also been confirmed with the 3% peroxide,¹⁰⁴ but has been related to the residual oxygen in the tooth, and the bond has been shown to increase, approaching the original strength over time.^{4,104} More recent studies of the 35% in-office bleaching techniques have also attributed this loss to residual peroxide temporarily remaining in the tooth or to surface changes.⁸⁰ Another study of home bleaching techniques demonstrated that roughening the surface slightly also eliminates this phenomenon.¹⁰⁵ Generally, etching and bonding should be delayed at least 14 days after termination of bleaching until further studies can determine a more precise waiting time.

Safety to the occlusion and the temporomandibular joint during the bleaching process must also be considered. Typically, occlusal problems during NGVB may be mechanical or physiologic. Mechanically, the patient may occlude on only posterior teeth, rather than on all teeth simultaneously. Sequentially removing posterior teeth from the guard until all the teeth contact will rectify the problem, and avoid the potential for joint disturbances. If the patient exhibits bruxism, he or she usually will wear a hole in the appliance over time, and another will have to be made. There has been no success to date in fabricating an occlusal device for bruxism that can also serve as a well-fitting guard for bleaching. Physiologically, if the patient has pain in the joint, the posterior teeth can be removed from the guard until only anterior guidance is remaining, and the patient's wear time should be reduced or limited to the day only.

Another area of concern with safety is how often the procedure will have to be administered. Current research at the University of North Carolina on longevity of the result indicates that, although the

change may be permanent, the patient will probably need re-treatment in 1 to 3 years. It has been noted that re-treatment involves significantly less time than the original treatment.

Over-the-counter bleaching kits

The newest systems that claim to bleach teeth are bleaching kits sold directly to consumers. These kits are described as a three-step process: a 15-second pre-treatment acetic rinse, a 1- to 2-minute application of a 6% hydrogen peroxide gel with a cotton swab on the facial surfaces of the teeth, and an application of a tooth-whitening pigment.¹⁰⁶

Early concerns have been expressed as to whether the process actually works, especially as it is shown in television advertisements.¹⁰⁷ Although results shown in advertisements seem dramatic, the manufacturers' literature reports that bleaching may take from 2 days to 2 weeks, and sometimes up to 60 applications, for successful lightening. No reports from dental studies have demonstrated any effectiveness.²² In a screening project for the US Federal Trade Commission at the University of North Carolina, administration of the OTC technique, on patients who had already successfully bleached one arch with the dentist-prescribed/home-applied technique in a clinical bleaching study, did not effect any change after one, two, 14, or 60 applications. One report has shown that there is no harm to composite resins from any of the bleaching agents, including this type of system.¹⁰⁸

A more disturbing concern relates to the safety of the material and technique. A recent report cites the dissolution of enamel in a young person using the technique.¹⁰⁹ Although the person was also a heavy cola drinker, this result raises the question of the safety of unsupervised use of a treatment as well as the lack of baseline data. If the material is not effective as a bleaching treatment, this lack of success could further foster abusive use in an attempt to achieve results. In those patients who have other problems resulting in dissolution of enamel, this could be an additional insult.

It may be this lack of proof of efficacy and safety with some techniques that has prompted both the American Dental Association to advise caution and the US Food and Drug Administration to issue warning letters to manufacturers requesting data supporting their claims.¹¹⁰ Further determination of both efficacy and safety of these OTC bleaching kits and other variations of the conventional NGVB technique are certainly indicated. However, the ruling by the US

Food and Drug Administration is directed toward manufacturers, and does not restrict, limit, or affect bleaching treatments performed in a legitimate dentist-patient relationship (US Food and Drug Administration: Personal communication).

Relative safety of the nightguard vital bleaching technique

Safety of nightguard vital bleaching must be assessed relative to that of the other bleaching techniques, but it also must be compared to the safety of other accepted dental practices. With teeth, as with any living tissue, there will always be a response to treatment. The questions are the risk-benefit of the treatment and what is known from observations and studies on other dental treatments.¹¹¹ The question of safety is always a dose-over-time relation,¹¹² as has been noted in the questions of fluoride toxicity^{113,114} and the recent amalgam and mercury concerns.¹¹⁵ Other areas in dentistry are also currently being examined for their safety. These include concerns about the nickel-beryllium content of non-precious metals,¹¹⁶ the carcinogenicity of nickel,^{117,118} and the reported toxicity of Sargenti techniques.¹¹⁹

As to the concern of the effect of materials on the pulp and other tissues, it has been shown that one in five teeth that receive a crown will need root canal therapy,¹²⁰ 73% of the single pins placed in teeth cause a fracture in the dentin that communicates directly with the pulp,¹²¹ and heat on the pulp from restorations and direct provisional restorations has adverse effects.¹²² Dentists observe postoperative pain from the cementation of crowns or ceramic inlays with glass-ionomer or zinc phosphate cements,¹²³⁻¹²⁶ hypersensitivity reactions to polyether impressions,¹²⁷ and allergic reactions to the poly(methyl methacrylate) acrylic resins.¹²⁸ It has been shown that poly(methyl methacrylate) is cytotoxic¹²⁹ and produces non-neoplastic lesions¹³⁰ and that some glass-ionomer cements exude cytotoxic substances even after a hardening period of 48 hours.¹³¹ In the more esthetic materials, it has been shown that all composite resin is cytotoxic in its unset form and when incompletely cured,¹³² and some composite resin is even cytotoxic if cured for less than 60 seconds.¹³³ The cytotoxicity of orthodontic adhesives has been demonstrated even after 2 years,¹³⁴ and the cytotoxicity of orthodontic solder joints to tissue has been shown.¹³⁵ Recently, Gluma 3 (Miles Inc) has been identified as a mutagenic agent,¹³⁶ the cytotoxicity of dentinal bonding agents has been demonstrated,^{137,138} and detrimental effects of dentinal bonding agents on

the pulp have been cited.¹³⁹⁻¹⁴¹ Although the relative thickness of remaining dentin determines the cytotoxic effects of composite resin¹⁴² and glass-ionomer cement¹⁴³ on the pulpal tissues, it is impossible to know how much dentin is present in the mouth. There is also the danger of damage to the gingival tissues from indiscriminate use of the microabrasion technique,¹⁴⁴ as well as with the conventional in-office bleaching techniques.¹⁴⁵

As to effects of other dental treatments on the surface of teeth or restorations, 5 to 50 μm of enamel is removed during a prophylaxis¹⁴⁶ and 5 to 50 μm of enamel is removed at banding and debanding of orthodontic appliances.¹⁴⁷ Hence, even a possible effect on the surface of enamel from bleaching may be considered negligible compared to the 5- to 10- μm loss of enamel from every rubber cup prophylaxis over the life of a patient,¹⁴⁸ including the loss of the fluoride-rich layer. Merely etching the enamel dissolves at least 10 μm in addition to the 25 to 50 μm that is etched.¹⁴⁹ Treatment with microabrasion to remove stained enamel results in 12 μm of enamel loss with the first 5-second application, and an average of 26 μm of loss for every successive 5-second application.¹⁵⁰ Acidulated phosphate fluoride, which contains hydrofluoric acid, is capable of etching porcelain in the mouth (Bayne S: Personal communication). It has also been shown that judicious use of the Cavitron can remove resin-bonded fixed partial dentures or other cemented prostheses.¹⁵¹

As to overall safety, it is reported that 8% of patients are allergic to latex gloves.¹⁵² Studies on the previous effects of eugenol in periodontal dressings on bone have resulted in a change in the formulation to non-eugenol-containing periodontal dressings.¹⁵³ However, no significant clinical problems from the use of the eugenol-containing periodontal dressings on soft tissue has been identified in the literature. Detrimental effects of hydrogen peroxide on the bone have been reported, but it is unlikely that the nightguard vital bleaching techniques would ever be used in patients with exposed bone.¹⁵⁴ Recent reports have described the toxic effects of zinc oxide-eugenol cement to the pulp,^{155,156} the dangers and toxicity of sodium hypochlorite,^{157,158} the toxicity of endodontic obturation materials,^{159,160} and allergic reactions to implants.¹⁶¹ This, in conjunction with the radiation from normal exposure of radiographs, the potential for an allergic reaction to local anesthetic, the hazards of eye damage from composite resin curing lights, and the hearing loss caused by the high-speed handpiece, make dental treatment full of risk-benefit judgments in the light of

current knowledge. Even the choice between a direct pulp cap or endodontic therapy,¹⁶² between placement of another foundation or a casting,¹⁶³ or to remove a questionable restoration, which takes more tooth structure and weakens the tooth,¹⁶⁴ is subjective but significant in the long-term safety and health of the tooth.

One concern often expressed about the nightguard vital bleaching technique is the potential danger of making bleaching materials available to patients at home, where abuse may occur. It is important to distinguish between nightguard vital bleaching (dentist-prescribed/home-applied), and OTC kits available directly to consumers. In the "prescribed" method, the materials are held in a custom-fabricated guard, and approximately 1 to 2 oz is used in a 4- to 6-week period.³ If the patient uses more than 2 oz during that time, the dentist should reevaluate the patient's application technique. The availability of the dentist for monitoring, the slowness of the treatment, and the contained environment reduce the potential for abuse. Clinical trials have also indicated there is a level of lightness beyond which the teeth do not pass. Hence the treatment is somewhat self-limiting over time. Patients could continue for extended periods of time, but at this time there is no clinical evidence that this is occurring. There is always the potential for abuse by some persons, but there is the same potential danger of abuse from ingestion of fluoride-containing toothpaste or rinses, alcohol-containing mouthwashes, and aspirin, even when these materials are correctly prescribed.

On the other hand, OTC kits place the consumer in a position of diagnosing the reason for discoloration of their teeth, as well as prescribing a treatment that has no professional evaluation of the baseline standard, the side effects, or the results. Unsupervised or excessive use of any material has potential for harm, especially in certain persons in whom the physiologic status of the teeth and saliva or psychological status exaggerates otherwise reasonable treatment responses. These effects are seen in the case of toothbrush abrasion or the detrimental erosive effects of excess consumption of carbonated drinks and fresh citrus fruits on enamel and dentin. Most unknown about the OTC kits is the effect of the prerinse on enamel over time.¹⁰⁹ Further research and unbiased reports are needed to establish the appropriateness of claims for both safety and efficacy.⁵⁷ The safer option currently available is a system where there is some establishment of indications for treatment by a trained professional, baseline recording

of data, fabrication and insertion of a custom-fitted mouthguard, monitoring of treatment, availability for questions, evaluation of success or concerns, and instruction in application.

Some concern also has been expressed about the safety of wearing the guard. However, the history of dentures, mouthguards for sports, Hawley or Frankle appliances, orthodontic positioners, bite splints, and other occlusal devices that have served dentistry so well over the years make this an unreasonable concern.¹⁶⁵

Indications and applications for nightguard vital bleaching

The primary indication for the nightguard vital bleaching technique has been for persons dissatisfied with the original color of their otherwise sound teeth (Figs 1 and 2). Special concerns are for staining related to ingestion of tetracycline as an antibiotic during tooth formation or as an acne treatment during the teenage years (Figs 3 and 4). Other persons interested in bleaching originally had lighter teeth, but now the teeth have been darkened by age, coffee, tea, smoking, or other staining habits (Figs 5 and 6). Brown fluorosis stains are generally responsive, but white spots are unaffected (Figs 7 and 8). Other motivations for treatment may warrant consideration. These may include bleaching to avoid any of the developmental personality changes in young persons who are ostracized by their peers for having discolored teeth¹⁶⁶; persons in public contact areas whose appearance greatly influences their success; or persons who are so dissatisfied with their present appearance that they are considering more invasive procedures, such as bonding, veneers, or crowns. In these instances, bleaching should be considered as an alternative procedure, not as an elective procedure. Bleaching can also prolong the life of unesthetic but otherwise acceptable dentistry.

Other indications include single teeth that have darkened from trauma, but are still vital or have a poor endodontic prognosis because of the absence of a radiographically visible canal. If all the other teeth are the appropriate color, the section of the guard covering the adjacent teeth can be removed so that material is placed only on the darkened tooth³ (Figs 9 to 11). If all the teeth are slightly darkened, but one is still darker than the remaining teeth, then a conventional-style guard is constructed and all the teeth are bleached (Figs 12 and 13). Because it has been observed that teeth lighten to a certain point, then maintain that color, the treatment is merely continued on

the darker tooth until it approaches or matches the other lightened teeth.

Other options presented in the literature for treating the single darkened tooth have included intentional endodontics or creating an artificial pulp chamber and bleaching the tooth with the walking bleaching technique.^{22,70} Because of the slight potential for cervical resorption, the loss of tooth structure, and the less than 100% chance of success with endodontics, home bleaching should be considered the first choice for altering the color of these teeth.

Often the walking bleaching technique is desirable to ensure the removal of debris and discolored restorative materials from the pulp chamber. However, occasionally a tooth that has previously been bleached by the walking bleaching technique and sealed with a finished etched composite resin will discolor. In this instance, the first treatment considered should be bleaching the tooth externally with the nightguard vital bleaching technique, especially if the lingual access has since been covered by another restoration, such as an etched-metal, resin-bonded fixed partial denture retainer (Fig 14). External bleaching avoids unnecessary removal of an acceptable dental restoration, and the loss of tooth structure during the process, which weakens the tooth, and prevents additional insult to the cervical area from another 35% hydrogen peroxide treatment. Even after successful treatment with a walking bleach, often the bleached tooth is more yellow than the other teeth. Nightguard vital bleaching then can be used to harmonize the colors of the vital and nonvital teeth. Teeth that are endodontically treated, but have such a thin portion of remaining dentin at the cervical area that there is concern about potential cervical resorption from use of the 35% hydrogen peroxide, are also amenable to the nightguard vital bleaching technique as the first choice of treatment.

The nightguard vital bleaching technique should be considered as the first choice of treatment for any discolored teeth, even those considered for the placement of porcelain or other esthetic veneers. Attempting nightguard vital bleaching first may avoid the need for veneers. However, even if the technique is unsuccessful in achieving the desired shade, or if there are other indications for veneers other than the tooth color, bleaching may lighten the underlying tooth base and make the subsequent veneer more esthetic, as well as allow the patient to evaluate the results of the more conservative option first. Home bleaching can be used prior to placement of single porcelain-fused-



Fig 1 Natural teeth with discoloration primarily confined to the maxillary arch. Color matching of composite resin restorations or crowns on the maxillary arch would be difficult at best.



Fig 2 Results of nightguard vital bleaching of the maxillary arch. The mandibular arch is left untreated. No sensitivity was reported, although there was exposed dentin.



Fig 3 Vital teeth mildly discolored from tetracycline ingestion.



Fig 4 Maxillary arch lightened with NGVB, while the mandibular arch serves as the control.



Fig 5 Vital teeth discolored by heavy tobacco use, with craze lines and stained restorations.



Fig 6 Maxillary arch lightened with NGVB. The mandibular arch is untreated. Craze lines and stains around composite resin restorations are less noticeable.



Fig 7 Maxillary central incisors exhibiting both brown fluorosis stains and white spots.



Fig 8 After NGVB bleaching, the brown areas are removed. The white areas remain, but are less noticeable.



Fig 9 Design of the NGVB tray to limit the application of the material to the single, discolored tooth.



Fig 10 A single, vital discolored tooth. The color of the remaining teeth is acceptable to the patient.



Fig 11 After NGVB, the single tooth more closely matches the other teeth. The color of the adjacent teeth is unchanged.



Fig 12 A single, severely discolored vital tooth with no radiographic evidence of a pulp canal. Other teeth are slightly discolored.



Fig 13 Results of NGVB on the entire maxillary arch. Although not a perfect color match, the severely discolored tooth better blends with the rest of the teeth.



Fig 14 The lateral incisor has been treated endodontically and with the walking bleach technique years ago; the pontic no longer matches the natural dentition. This is a good indication for NGVB.



Fig 15 Dicor restorations placed on the four incisors are noticeable because of the yellowed canine.



Fig 16 The NGVB technique is applied until the canine more closely blends the natural posterior teeth with the crowned incisors.



Fig 17 An otherwise acceptable porcelain-fused-to-metal crown no longer matches the color of the adjacent teeth after years of service.



Fig 18 Maxillary arch is lightened with NGVB until the porcelain-fused-to-metal crown is less noticeable.

to-metal or ceramic crowns, fixed partial dentures, or removable partial dentures to offer a lighter, younger-looking shade, as well as to eliminate some of the difficult crack lines or characterizations that are not easily duplicated in ceramic restorations. Nightguard vital bleaching can minimize the discoloration of the stained incisal edges of mandibular teeth and minimize the effects of white-spot lesions by lightening the tooth structure adjacent to the white-spot lesion.

Not only is nightguard vital bleaching effective as a preoperative treatment, but it is also effective post-treatment to lighten natural teeth to match existing ceramic crowns, fixed partial dentures, or Dicor restorations (Dentsply International) (Figs 15 and 16). This lightening can be achieved to match crowns to adjacent teeth in one arch or to teeth in the opposing arch. Bleaching can also increase the longevity of three-quarters crown abutments, onlays, or resin-bonded fixed partial denture abutments that have darkened more than their originally matched porcelain pontic (Figs 17 and 18). Bleaching has even been used successfully to increase the life of previous composite resin bonding by lightening the underlying tooth structure to compensate for the wear of the composite resin or to lighten the apparent color of veneers already cemented by lightening the underlying tooth structure. This lightening effect is due to the ability of the carbamide peroxide to pass freely through enamel and dentin and to permeate to all parts of the tooth, even those protected by restorations.⁹²

Although the success and acceptance of the nightguard vital bleaching technique has been phenomenal, it has not eliminated the in-office bleaching.¹⁶⁷ Some patients' lifestyles do not lend themselves to extended treatment times, or outside-the-office appliances. Also, they may not be willing to wait the time for home bleaching to be effective. They may not be concerned about the greater financial investment of in-office bleaching or may not be able to wear the guard and tolerate the taste of the solutions used in nightguard vital bleaching. In these situations, in-office bleaching is indicated. It is also indicated if the patient does not respond well to the nightguard vital bleaching regimen. In clinical trials at the University of North Carolina, a single in-office bleaching treatment, delivered after a lack of response to nightguard vital bleaching, followed by continuation of the nightguard vital bleaching treatment, has achieved results that neither technique showed independently. In those cases, the teeth were not etched, and neither heat nor light was employed. Other recommendations include

beginning bleaching with the in-office treatment, followed by the home treatment.¹⁶⁷

Other clinical pilot studies at the University of North Carolina have shown reduction in the buildup of chlorhexidine stains when a 10% carbamide peroxide is used in an alternating fashion with the mouthwash. Other preventive opportunities being explored have included using the nightguard vital bleaching system to attempt to reduce the incidence of root caries that is unresponsive to traditional fluoride and tray systems.¹⁶⁸ This caries is often related to xerostomia and is a sequelae to radiation therapy, chemotherapy, medical problems, or aging.¹⁶⁵ There is hope to evaluate the nightguard vital bleaching application in nursing homes or hospitals, where attendants may be able to add this application technique to the oral hygiene regimen of patients with inability to perform adequate oral hygiene measures.¹⁶⁹

Conclusions

The profession should neither propose a sweeping condemnation nor offer a sweeping endorsement of bleaching any more than it should any other treatment option or medicament used in dentistry. Bleaching techniques that have been shown to be reasonably and relatively safe and effective, both in current usage and over time, should be accepted as a reasonable treatment option,^{84,170} knowing the risks and benefits. Continued research should be undertaken on these and all other dental treatments. These accepted techniques include the nonvital bleaching with 35% hydrogen peroxide and/or sodium perborate (but without heat), in-office vital bleaching with 35% hydrogen peroxide (but without etching), and nightguard vital bleaching (dentist-prescribed/home-applied bleaching) with 10% carbamide peroxide materials or similar products. Conversely, claims that any use of hydrogen peroxide will bleach teeth and that all techniques are safe cannot be accepted blindly. Especially in question are the OTC bleaching kits and toothpastes containing carbamide peroxide. Effectiveness and safety of the bleaching technique must evaluate not only the product but also the delivery method and treatment time.

Unbiased research is still the best avenue for sifting through the claims and reports to achieve a better understanding of what is correct and what is incorrect.⁵⁷ Over time, the understanding of temporomandibular joint function has changed radically, the correlation between occlusion and pain has altered, the change from pins to slots in amalgam restorations has occur-

red, the noncrowning of anterior, endodontically treated teeth has been advocated, and the nonposting of endodontically treated anterior teeth, unless the post is needed to retain the preparation form of the crown, has been reported. So must the dental profession be ever vigilant for changes that provide the most conservative esthetic treatment options for patients. More importantly, the profession should continually examine these treatment options in the light of new evidence or techniques, always applying the same standards of safety to all treatment options.

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