TOOTH BLEACHING
A CRITICAL REVIEW

ABSTRACT

Present tooth-bleaching techniques are based upon hydrogen peroxide as the active agent. It is applied directly, or produced in a chemical reaction from sodium perborate or carbamide peroxide. More than 90% immediate success has been reported for intracoronal bleaching of non-vital teeth. Cervical root resorption is a possible consequence of internal bleaching and is more frequently observed in teeth treated with the thermo-catalytic procedure. When the external tooth-bleaching technique is used, the first subjective change in tooth color may be observed after 2-4 nights of tooth bleaching, and more than 90% satisfactory results have been reported. Tooth sensitivity is a common side-effect of external tooth bleaching observed in patients, but clinical studies addressing the risk of other adverse effects are lacking. This review article will help clinicians improve their understanding of the history of bleaching procedures, bleaching types, components, mechanisms, and their effects on soft tissue, tooth structures, resin composite, and bonding.

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INTRODUCTION

The history of dentistry is comprised of many efforts undertaken to achieve an effective tooth-whitening method. Tooth discoloration varies in etiology, appearance, localization, severity, and adherence to tooth structure. It may be classified as intrinsic, extrinsic, and a combination of both. Intrinsic discoloration is caused by incorporation of chromatogenic material into dentin and enamel during odontogenesis or after eruption. Exposure to high levels of fluoride, tetracycline administration, inherited developmental disorders, and trauma to the developing tooth may result in pre-eruptive discoloration.[1] After eruption of the tooth, aging, pulp necrosis, and iatrogenesis are the main causes of intrinsic discoloration. Coffee, tea, red wine, carrots, oranges, and tobacco give rise to extrinsic stain.[2] Wear of the tooth structure, deposition of secondary dentin due to aging or as a consequence of pulp inflammation, and dentin sclerosis affect the light-transmitting properties of teeth, [3] resulting in a gradual darkening of the teeth. Scaling and polishing of the teeth remove many extrinsic stains. For more stubborn extrinsic discoloration and intrinsic stain, various bleaching techniques may be attempted. Tooth bleaching can be performed externally, termed night guard vital bleaching or vital tooth bleaching, or intracoronallyin root-filled teeth, called non-vital tooth bleaching. The aims of the present paper are to review critically the literature on the biological aspects of tooth bleaching, including efficacy and side-effects of such treatments.

(II) History of Bleaching

Bleaching of discolored, pulpless teeth was first described in 1864 by Truman, and a variety of medicaments such as chloride, sodium hypochlorite, sodium perborate, and hydrogen peroxide has been used, alone, in combination, and with and without heat activation.[4] The "walking bleach" technique that was introduced in 1961 involved placement of a mixture of sodium perborate and water into the pulp chamber that was sealed off between the patient's visits to the clinician. The method was later modified and water replaced by 30-35% hydrogen peroxide, to improve the whitening effect. [5] The observation that carbamideperoxide caused lightening of the teeth was made in the late 1960s by an orthodontist who had prescribed an antiseptic containing 10% carbamide peroxide to be used in a tray for the treatment of gingivitis. The observation was communicated to other colleagues and must be regarded as the beginning of the night guard bleaching era.

The ''over-the-counter'' (OTC) bleaching agents were first launched in the United States in the 1990s, containing lower concentrations of hydrogen peroxide or carbamide peroxide and sold directly to consumers for home use.[6] Finally, the current in-office bleaching technique typically uses different concentrations of hydrogen peroxide, between 15% and 40%, with or without light and in the presence of rubber dam isolation.

3. Composition of commercial bleaching agents

Current bleaching agents contain both active and inactive ingredients. The active ingredients include hydrogen peroxide or carbamide peroxide compounds. However, the major inactive ingredients may include thickening agents, carrier, surfactant and pigment dispersant, preservative, and flavoring.

(a) Thickening agents:

Carbopol (carboxypolymethylene) is the most commonly used thickening agent in bleaching materials. Its concentration is usually between 0.5% and 1.5%. This high-molecular-weight polyacrylic acid polymer offers two main advantages. First, it increases the viscosity of the bleaching materials, which allows for better retention of the bleaching gel in the tray. Second, it increases the active oxygen-releasing time of the bleaching material by up to 4 times[7].

(b) Carrier:

Glycerin and propylene glycol are the most commonly used carriers in commercial bleaching agents. The carrier can maintain moisture and help to dissolve other ingredients.

c) Surfactant and pigment dispersant:

Gels with surfactant or pigment dispersants may be

more effective than those without them.[8] The surfactant acts as a surface-wetting agent which permits the active bleaching ingredient to diffuse. Moreover, a pigment dispersant keeps pigments in suspension.

(d) Preservative:

Methyl, propylparaben, and sodium benzoate are commonly used as preservative substances. They have the ability to prevent bacterial growth in bleaching materials. In addition, these agents can accelerate the breakdown of hydrogen peroxide by releasing transitional metals such as iron, copper, and magnesium.

(e) Flavoring:

Flavorings are substances used to improve the taste and the consumer acceptance of bleaching products. Examples include peppermint, spearmint, wintergreen, sassafras, anise, and a sweetener such as saccharin.

4. Mechanism of tooth bleaching

The mechanism of bleaching by hydrogen peroxide is not well understood. In-office and home bleaching gels contain hydrogen peroxide or its precursor, carbamide peroxide, as the active ingredient in concentrations ranging from 3% to 40% of hydrogen peroxide equivalent. Hydrogen peroxide bleaching generally proceeds via the perhydroxyl anion(HO_2^-). Other conditions can give rise to free radical formation, for example, by homolytic cleavage of either an O-H bond or the O-O bond in hydrogen peroxide to give H^- + OOH^- and $2OH^-$ (hydroxyl radical), respectively. [9] Under photochemical reactions initiated by light or lasers, the formation of hydroxyl radicals from hydrogen peroxide has been shown to increase. Hydrogen peroxide is an oxidizing agent that, as it diffuses into the tooth, dissociates to produce unstable free radicals which are hydroxyl radicals (HO^-), perhydroxyl radicals (HOO^-), perhydroxyl anions (HOO^-), and superoxide anions (OO^-), which will attack organic pigmented molecules in the spaces between the inorganic salts in tooth enamel by attacking double bonds of chromophore molecules within tooth tissues.[10,11] The change in double-bond conjugation results in smaller, less heavily pigmented constituents, and there will be a shift in the absorption spectrum of chromophore molecules; thus, bleaching of tooth tissues occurs. In the case of tetracycline-stained teeth, the cause of discoloration is derived from photo-oxidation of tetracycline molecules available within the tooth structures.[12] The bleaching mechanism in this case takes place by chemical degradation of the unsaturated quinone-type structures found in tetracycline, leading to fewer colored molecules. Vital bleaching via a long-term night guard can sometimes improve the color of tetracycline-stained teeth.[13] More recently, amorphous calcium phosphate (ACP) has been added to some of the tooth whitening products, to reduce sensitivity, reduce the demineralization of enamel through a remineralization process after whitening treatments, and add a lustrous shine to teeth. A study proved that the bleaching treatments promoted increased sound enamel demineralization, while the addition of Ca ions or ACP did not prevent/reverse the effects caused by the bleaching treatment in both conditions of the enamel. Early artificial caries induced by pH cycling model were not affected by the bleaching treatment, regardless of the type of bleaching agent.[14]

Types of dental bleaching procedures

Vital tooth bleaching

There are three fundamental approaches for bleaching vital teeth: in-office or power bleaching, at-home or dentist supervised night-guard bleaching, and bleaching with over-the-counter (OTC) products.[15] First, in-office bleaching utilizes a high concentration of tooth-whitening agents (25–40% hydrogen peroxide). Here, the dentist has complete control throughout the procedure and has the ability to stop it when the desired shade/effect is achieved. In this procedure, the whitening gel is applied to the teeth after protection of the soft tissues by rubber dam or alternatives [16] and the peroxide will further be activated (or not) by heat or light for around one hour in the dental office [17]. Different types of curing lights including; halogen curing lights, Plasma arc lamp, Xe–halogen light (Luma Arch), Diode lasers (both 830 and 980 nm wavelength diode lasers), or

Metal halide (Zoom) light can be used to activate the bleaching gel or accelerate the whitening effect. The in-office treatment can result in significant whitening after only one treatment, but many more may be needed to achieve an optimum result. Second, at-home or dentist-supervised night-guard bleaching basically involves the use of a low concentration of whitening agent (10–20% carbamide peroxide, which equals 3.5–6.5% hydrogen peroxide). In general, it is recommended that the 10% carbamide peroxide be used 8 h per day, and the 15-20% carbamide peroxide 3–4 h per day. This treatment is carried out by the patients themselves, but it should be supervised by dentists during recall visits. The bleaching gel is applied to the teeth through a custom-fabricated mouth guard worn at night for at least 2 weeks. This technique has been used for many decades and is probably the most widely used. The at-home technique offers many advantages: self administration by the patient, less chair-side time, high degree of safety, fewer adverse effects, and low cost. Despite the fact that patients are able to bleach at their own pace, this at-home bleaching technique, with its various concentrations of bleaching materials and regimens, has become the gold standard by which other techniques are judged. However, it is by no means without disadvantages, since active patient compliance is mandatory and the technique suffers from high dropout rates In addition, color change is dependent on diligence of use, and the results are sometimes less than ideal, since some patients do not remember to wear the trays every day. In contrast, excessive use by overzealous patients is also possible, which frequently causes thermal sensitivity, reported to be as high as 67% . A 35% concentration of hydrogen peroxide is recommended by some clinicians for in-office dental bleaching, followed by at-home bleaching with gels containing 10%, 15%, or 20% carbamide peroxide.[18]

Bailey and Swift showed that higher-concentration bleaching agents can produce more peroxide radicals for bleaching, resulting in a faster whitening process. However, this rapid process of bleaching may increase the side-effects of tooth sensitivity, gingival irritation, throat irritation, and nausea.

Finally, over-the-counter (OTC) bleaching products have increased in popularity in recent years. These products are composed of a low concentration of whitening agent (3–6% hydrogen peroxide) and are self-applied to the teeth via gum shields, strips, or paint-on product formats. They are also available as whitening dentifrices, pre-fabricated trays, whitening strips, and toothpastes.[19] They should be applied twice per day for up to 2 weeks. OTC products are considered to be the fastest growing sector of the dental market. However, these bleaching agents may be of highly questionable safety, because some are not regulated by the Food and Drug Administration.

Non-vital tooth bleaching

There are numerous non-vital bleaching techniques used today, for example, walking bleach and modified walking bleach, non-vital power bleaching, and inside/outside bleaching. The walking bleach technique involves sealing a mixture of sodium perborate with water into the pulp chamber of the affected tooth, a procedure that is repeated at intervals until the desired bleaching result is achieved. This technique is modified with a combination of 30% hydrogen peroxide and sodiumperborate sealed into the pulp chamber for one week; this is known as modified walking bleach. In internal non-vital power bleaching, hydrogen peroxide gel (30–35%) is placed in the pulp chamber and activated either by light or heat, and the temperature is usually between 50° and 60°C maintained for five minutes before the tooth is allowed to cool for a further 5 min. Then, the gel is removed, the tooth is dried, and the 'walking bleach technique' is used between visits until the tooth is reviewed 2 weeks later to assess if further treatment is needed. Finally, the inside/outside bleaching technique is a combination of internal bleaching of non-vital teeth with the home bleaching technique.[20]

Effects of the Bleaching process

Local side-effects

Tooth sensitivity

Tooth sensitivity is a common side-effect of external tooth bleaching. Data from various studies of 10%

carbamide peroxide indicate that from 15 to 65% of the patients reported increased incidence of tooth sensitivity (from 67 to 78%) was reported after in-office bleaching with hydrogen peroxide in combination with heat. Tooth sensitivity normally persists for up to 4 days after the cessation of bleaching but a longer duration of up to 39 days has been reported . In a clinical study that compared two different brands of 10% carbamide peroxide bleaching agent, 55% of the patients reported tooth sensitivity and/or gingival irritation, and 20% of those who experienced side-effects terminated the treatment due to discomfort. The mechanisms that would account for the tooth sensitivity after external tooth bleaching have not yet been fully established.

In vitro experiments have shown that peroxide penetrated enamel and dentin and entered the pulp chamber [21] and that the penetration of restored teeth was higher than that of intact teeth. The amount of peroxide detected in the pulp chamber was related to the concentration of hydrogen peroxide in the preparations applied, [22] and also varied among different brands of bleaching agents with the same declared concentration of carbamide peroxide.

Effects on soft tissues

The more powerful in-office bleaching (30–35% hydrogen peroxide) can easily produce soft-tissue burns, turning the tissue white. In general, these tissue burns are reversible with no long-term consequences if the exposure to the bleaching material is limited in time and quantity.

Rehydration and application of an antiseptic ointment quickly return the color to the tissue. Therefore, it is very important to protect soft tissues with a rubber dam or other measures to prevent tissue burns. In addition, soft-tissue irritation has been reported with at-home bleaching. This irritation is most likely due to an ill-fitting tray rather than to the bleaching agent itself.

Systemic effects

There is more concern about the possible adverse effects of home-bleaching agents, although their concentrations are far below those of in-office bleaching agents, because the latter are controlled by the dentist. Occasionally, patients report gastrointestinal mucosal irritation, e.g., a burning palate and throat, and minor upsets in the stomach or intestines. However, most reports in the literature have concluded that the use of low concentrations of hydrogen peroxide in tooth bleaching is still safe.[23,24]

Effects on Enamel surface morphology and texture

Many studies in the literature have investigated the effects of bleaching on enamel morphology and the surface texture morphological alteration of the enamel surface - increased porosity of the superficial enamel structure, demineralization and decreased protein concentration, organic matrix degradation, modification in the calcium: phosphate ratio, and calcium loss - thereby supporting the hypothesis that bleaching agents are chemically active components potentially able to induce substantial structural alterations in human dental enamel.

Effects on enamel chemical composition

Regarding the effect of dental bleaching on enamel chemical composition, many studies examined it by measuring the changes in constituent enamel elements Al-Salehi et al [25] found that tooth-bleaching agents might adversely affect tooth structure by demonstrating that, with increasing hydrogen peroxide concentrations, ion release from both enamel and dentin increased, and that microhardness of enamel decreased significantly with bleaching. Moreover, Efeoglu et al used micro-computerized tomography to evaluate the effect of 10% carbamide peroxide applied to enamel. Results indicated that this was found to cause demineralization of the enamel extending to a depth of 50μm below the enamel surface.[26] Therefore, they recommended that the application of bleaching agents should be carefully considered in patients susceptible to caries and tooth wear.

Effects of dental bleaching on composite resin restorations.

Surface properties and microhardness

Most studies addressing the effects of bleaching agents on the surface properties of composite showed that the effect of bleaching on the surface texture is material- and time-dependent [28]. In some SEM studies and profilometric analyses, it was shown that 10-16% carbamide peroxide bleaching gels may lead to a slight, but statistically significant, increase in surface roughness and numbers of porosities of microfilled and hybrid composite resins [28].

However, in another SEM study, it was concluded that the application of 6% hydrogen peroxide gel to a hybrid composite in a cycling protocol, with intermittent storage in saliva, could modify or weaken the impact of the hydrogen peroxide by formation of a surface-protective salivary layer on the restorative material.[29]

Genotoxicity and Carcinogenicity of Bleaching Agents

The genotoxicity of hydrogen peroxide and of tooth whiteners containing carbamide peroxide has been evaluated. The consensus arising from these evaluations was that direct contact with hydrogen peroxide induced genotoxic effects in bacteria and cultured cells.

When hydrogen peroxide was administered to bacteria or cultured cells in the presence of catalase or other metabolizing enzymes, the effect was reduced or abolished. Testing of hydrogen peroxide for systemic genotoxic effects in animals revealed no evidence of in vivo mutagenicity. Since hydroxy radicals, perhydroxyl ions, and superoxide anions formed from hydrogen peroxide are capable of attacking DNA, the genotoxic potential of hydrogen peroxide is dependent on the accessibility of free radicals to target DNA.[30] This may explain why hydrogen peroxide induces geno toxicity in the presence of metabolizing enzymes neither in vitro nor in vivo. Tooth whiteners containing carbamide peroxide were mutagenic in certain bacterial strains and non mutagenic in the presence of additional activating enzymes.[31] Several in vivo studies addressing the formation of micronuclei in bone marrow cells and sister chromatide exchange after exposure to carbamide-peroxide containing products revealed no genotoxic effects.[32]

SUMMARY

The increasing demand for tooth bleaching has driven many manufacturers and researchers to develop bleaching products to be used either in the dental office or at home. However, as with any dental procedure, bleaching involves risks. For that reason, this review article is provided to help clinicians improve their information about the bleaching process and their understanding of the controversial issues regarding the effects of bleaching on teeth, resin composite, and bonding, to help reduce the risks to patients. To minimize the risks, the involvement of dental professionals, the prevention of using of OTC bleaching products and the reduction of overused of bleaching products are necessary.

In addition to that interval of 2 weeks post-bleaching procedure is found to be adequate to avoid adverse effects on the polymerization. The need for bleaching solely to achieve a "perfect" smile and a youthful look is thus questioned. We urge the dental profession to maintain high ethical standards and not to recommend performing cosmetic adjustment of tooth color just to comply with the demand of the patient. We advocate a more selective use of tooth bleaching and a limitation on its use to patients for whom such treatment could be professionally justified.

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