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REVIEW ARTICLE

Tooth-bleaching procedures and their controversial effects: A literature review



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KEYWORDS

Bleaching;
Pre-bleaching;
Post-bleaching;
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Abstract *Aim:* 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.

Methods: The controversial issues about bleaching procedures and their effects are reviewed. Additionally, the consequences of pre- and post-bleaching on the bonding potential of composite resin restorations to tooth structure are discussed.

Conclusion: The overall goal of the paper is to help reduce risks for patients.

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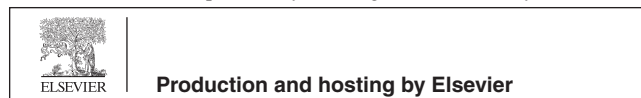
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1. History

The history of dentistry is comprised of many efforts undertaken to achieve an effective tooth-whitening method. Non-vital tooth bleaching began in 1848 with the use of chloride of lime (Dwinelle, 1850), and in 1864, Truman introduced the most effective technique for bleaching non-vital teeth, a method which used chlorine from a solution of calcium hydrochlorite and acetic acid (Kirk, 1889). The commercial derivative of this, later known as Labarraque's solution, was an aqueous solution of sodium hypochlorite (Woodnut, 1861; M'Quillen, 1868). In the late nineteenth century, many other bleaching agents were also successfully used on non-vital teeth (Haywood, 1992), including cyanide of potassium (Kingsbury, 1861), oxalic acid (Bogue, 1872), sulfurous acid (Kirk, 1889), aluminum chloride (Harlan, 1891), sodium hypophosphate (Harlan, 1891), pyrozone (Atkinson, 1892), hydrogen dioxide (hydrogen peroxide or perhydrol), and sodium peroxide (Kirk, 1893). All these substances were considered as either direct or indirect oxidizers acting on the organic portion of the tooth, except for sulfurous acid, which was a reducing agent (Kirk, 1889). Subsequently, it became known that the most effective direct oxidizers were Pyrozone, Superoxol, and sodium dioxide, while the indirect oxidizer of choice was a chlorine derivative (Franchi, 1950).

In fact, when Superoxol was introduced, it became the chemical substance used by most dentists, because of its high safety (Pearson, 1951). Pyrozone continued to be used effectively for non-vital teeth in the late 1950s and early 1960s (Pearson, 1958), as was sodium perborate (Spasser, 1961). In the late 1970s, Nutting began to use Superoxol instead of Pyrozone, for safety purposes, and later combined it with sodium perborate to attain a synergistic effect (Nutting, 1976). Moreover, he recommended the use of Amosan (Knox Mfg. Co., Tulsa, OK, USA), a sodium peroxyborate mono hydrate, because it is known to release more oxygen than sodium perborate. Also, he recommended that gutta-percha should be sealed before any procedure.

Vital teeth were also bleached as early as 1868, by means of oxalic acid (Latimer, 1868) or Pyrozone (Atkinson, 1892) and later with hydrogen peroxide (Fisher, 1911). In 1911, the use of

concentrated hydrogen peroxide with a heating instrument or a light source was regarded as an acceptable method in dental clinics (Fisher, 1911).

Furthermore, in the late 1960s, a successful home-bleaching technique was established when Dr. Bill Klusmier, an orthodontist, instructed his patients to use an "over-the-counter" oral antiseptic, Gly-Oxide (Marion Merrell Dow, Kansas City, MO, USA), which contained 10% carbamide peroxide delivered via a custom-fitting mouth tray at night. Dr. Klusmier found that this treatment not only improved gingival health but also whitened teeth (Haywood et al., 1990).

Subsequently, Proxigel (a mixture of 10% carbamide peroxide, water, glycerin, and carbopol) was marketed and replaced Gly-Oxide for orthodontic patients, because of its slow release of carbamide peroxide. Later on, the University of North Carolina clinically approved the clinical effectiveness of Proxigel. Then, Haywood and Heymann (1989) described a home-bleaching technique in their article, "Nightguard vital bleaching", and an at-home bleaching product "White and Brite™" (Omni International, Albertson, NY, USA) was introduced. Later, many other bleaching products and techniques have been introduced (Haywood, 1991).

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 (Greenwall et al., 2001).

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 (Haywood, 2000; Ontiveros, 2011).

2. Types of stains/discolorations

Many types of color problems may affect the appearance of teeth, and the causes of these problems vary, as does the speed with which they may be removed. Therefore, the causes of tooth staining must be carefully assessed for better prediction of the rate and the degree to which bleaching will improve tooth color, since some stains are more responsive to the

process than others (Haywood and Heymann, 1989; Jordan and Boksmann, 1984). Discolorations may be extrinsic or intrinsic.

2.1. Extrinsic stains

Extrinsic stains usually result from the accumulation of chromogenic substances on the external tooth surface. Extrinsic color changes may occur due to poor oral hygiene, ingestion of chromogenic food and drinks, and tobacco use. These stains are localized mainly in the pellicle and are either generated by the reaction between sugars and amino acids or acquired from the retention of exogenous chromophores in the pellicle (Viscio et al., 2000). The reaction between sugars and amino acids is called the “Millard reaction” or the “non-enzymatic browning reaction,” and includes chemical rearrangements and reactions between sugars and amino acids. The chemical analysis of stains caused by chromogenic food demonstrates the presence of furfurals and furfuraldehyde derivatives due to this reaction (Viscio et al., 2000).

In addition, the retention of exogenous chromophores in the pellicle occurs when salivary proteins are selectively attached to the enamel surface through calcium bridges; consequently, a pellicle will form. At the early stage of staining, chromogens interact with the pellicle via hydrogen bridges. Most extrinsic tooth stains can be removed by routine prophylactic procedures. With time, these stains will darken and become more persistent, but they are still highly responsive to bleaching (Goldstein and Garber, 1995).

2.2. Intrinsic stains

Intrinsic stains are usually caused by deeper internal stains or enamel defects. They are caused by aging, ingestion of chromogenic food and drinks, tobacco usage, enamel microcracks, tetracycline medication, excessive fluoride ingestion, severe jaundice in infancy, porphyria, dental caries, restorations, and the thinning of the enamel layer.

Aging is a common cause of discoloration. Over time, the underlying dentin tends to darken due to the formation of secondary dentin, which is darker and more opaque than the original dentin, and when the overlying enamel becomes thinner. This combination often results in darker teeth.

Excessive fluoride in drinking water, greater than 1–2 ppm, can cause metabolic alteration in ameloblasts, resulting in a defective matrix and improper calcification of teeth (Dodson and Bowles, 1991).

Discoloration from drug ingestion may occur either before or after the tooth is fully formed. Tetracycline is incorporated into the dentin during tooth calcification, probably through chelation with calcium, forming tetracycline orthophosphate, which causes discoloration. Moreover, intrinsic stains are also associated with inherited conditions (e.g., amelogenesis imperfecta and dentinogenesis imperfecta) (Nathoo, 1997; Viscio et al., 2000). Blood penetrating the dentinal tubules and metals released from dental restorative materials also cause stains.

Intrinsic stains cannot be removed by regular prophylactic procedures. However, they can be reduced by bleaching with agents penetrating enamel and dentin to oxidize the chromogens. Tooth stains caused by aging, genetics, smoking, or cof-

fee are the fastest to respond to bleaching: Yellowish aging stains respond quickly to bleaching in most cases (Haywood, 2000), whereas blue–gray tetracycline stains are the slowest to respond to bleaching (Haywood, 1991), while teeth with brown fluorescence are moderately responsive (Haywood et al., 1994; Leonard et al., 2003).

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 (carboxypolyethylene) 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 (Rodrigues et al., 2007).
- (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 (Feinman et al., 1991). 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 $\text{H}^\cdot + \cdot\text{OOH}$ and 2^\cdotOH (hydroxyl radical), respectively (Kashima-Tanaka et al., 2003). Under photochemical reactions initiated by light or lasers, the

formation of hydroxyl radicals from hydrogen peroxide has been shown to increase (Kashima-Tanaka et al., 2003). Hydrogen peroxide is an oxidizing agent that, as it diffuses into the tooth, dissociates to produce unstable free radicals which are hydroxyl radicals ($\text{HO}\cdot$), perhydroxyl radicals ($\text{HOO}\cdot$), 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 (Dahl and Pallesen, 2003; Joiner, 2006; Minoux and Serfaty, 2008). 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 (Mello, 1967). 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 (Feinman et al., 1991). Vital bleaching via a long-term night guard can sometimes improve the color of tetracycline-stained teeth (Leonard et al., 2003).

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. (Berger et al., 2012).

4.1. Types of dental bleaching procedures

4.1.1. 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 (Kihn, 2007).

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 (Powell and Bales, 1991), and the peroxide will further be activated (or not) by heat or light for around one hour in the dental office (Sulieman, 2004). 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 (Sulieman, 2005b).

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 (Sulieman, 2005a).

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 (Leonard et al., 2003). 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% (Haywood, 1992).

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 (Langsten et al., 2002). Bailey and Swift (1992) 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 (Broome, 1998).

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 (Zantner et al., 2007). 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 (Kugel, 2003). However, these bleaching agents may be of highly questionable safety, because some are not regulated by the Food and Drug Administration.

4.1.2. 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 sodium perborate 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 (Setien et al., 2008).

5. Effects of the bleaching process

5.1. Effects on soft tissues

The more powerful in-office bleaching (30–35% hydrogen peroxide) can easily produce soft-tissue burns, turning the tissue white (Barghi and Morgan, 1997). 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 (Barghi, 1998). 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 (Li, 1997).

5.2. 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 (Howard, 1992; Pohjola et al., 2002). However, most reports in the literature have concluded that the use of low concentrations of hydrogen peroxide in tooth bleaching is still safe (Freedman, 1990; Reddy and Salkin, 1976; Shipman et al., 1971; Stindt and Quenette, 1989).

5.3. Effects of dental bleaching on tooth structure

There is still controversy over the effects of dental bleaching on the physical properties of enamel and dentin.

5.3.1. 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 (Abouassi et al., 2011; Azrak et al., 2010; Ben-Amar et al., 1995; Bitter, 1992, 1998; Cadenaro et al., 2010; Ernst et al., 1996; Gurgan et al., 1997; Haywood et al., 1990; Hegedus et al., 1999; Hunsaker et al., 1990; Sa et al., 2013; Smidt et al., 2011; Sun et al., 2011; Titley et al., 1992; Xu et al.,

2011). Some studies have reported that bleaching did not significantly affect the enamel surface (Cadenaro et al., 2010; Ernst et al., 1996; Gurgan et al., 1997; Haywood et al., 1990; Hunsaker et al., 1990; Smidt et al., 2011; Sun et al., 2011). However, other investigations demonstrated morphological alterations in the bleached enamel surface: depressions, porosity, and increased depth of enamel grooves (Abouassi et al., 2011; Azrak et al., 2010; Ben-Amar et al., 1995; Bitter, 1992, 1998; Hegedus et al., 1999; Josey et al., 1996; Sa et al., 2013; Titley et al., 1992; Xu et al., 2011).

In a scanning electron microscopy (SEM) analysis, Haywood et al. (1990) reported no morphological changes in the enamel surface after the application of 10% carbamide peroxide bleaching. Titley et al. (1992) observed a slight increase in surface roughness, whereas Hunsaker et al. (1990) and Gurgan et al. (1997) reported no modification of surface roughness. Moreover, Ernst et al. (1996) reported slight, insignificant, or no changes on enamel surfaces under 3000× magnification and using 30% solutions of hydrogen peroxide.

In contrast, other studies have reported that dental bleaching might induce morphological alteration of enamel surfaces, such as increased porosity, shallow depressions, and slight erosion. Using atomic force microscopy, Hegedus et al. (1999) observed changes in the enamel surface after 28 h of bleaching with 10% carbamide peroxide and 30% hydrogen peroxide, and found that the sample's surface became more irregular and surface grooves became deeper after bleaching treatment. Azrak et al. (2010) conducted an *in vitro* study to assess the effects of bleaching agents on eroded and sound enamel specimens. They used enamel specimens prepared from human permanent anterior teeth incubated with different bleaching agents containing active ingredients such as 7.5% or 13.5% hydrogen peroxide or 35% carbamide peroxide, ranging in pH from 4.9 to 10.8. To induce erosive changes, enamel specimens were incubated for 10 h with apple juice. Then, pre-treated and untreated dental slices were incubated with one of the bleaching agents for 10 h. An optical profilometric device was used to measure surface roughness of all enamel specimens. Results indicated that exposure to an acidic bleaching agent (pH = 4.9) led to a higher surface roughness than treatment with a high peroxide concentration (pH = 6.15), and that bleaching agents with a high concentration of peroxide or an acidic pH can provoke surface roughness of sound or eroded enamel. Furthermore, Josey et al. (1996) examined the effect of a night-guard vital bleaching procedure on enamel surface morphology and the shear bond strength (SBS) of a composite resin luting cement to enamel. They used extracted human teeth which were bleached for 1 week with a vital bleaching product. The results of this study suggested that bleaching caused changes to the surface and subsurface layers of enamel. However, the SBS of composite resin luting cement to etched bleached enamel appeared to be clinically acceptable. Moreover, Bitter (1992, 1998) conducted two studies, the first of which examined the effects of bleaching agents on the enamel surface using SEM by comparison of treated with untreated enamel, and concluded that the treated surface showed increased surface change and porosity after the equivalent of 30 h of exposure to the bleaching agent (Bitter, 1992). The second study included an *in vivo* exposure of bleaching agents used to evaluate the short- and long-term effects on the enamel surface; the results were demonstrated by scanning electron microscopy (Bitter, 1998). In that study, he found that

exposure to the bleaching agents for 14 days created an alteration of the enamel surface and caused exposure of enamel prisms. In addition, a 21- to 90-day post-exposure SEM evaluation demonstrated an alteration of the surface enamel, indicating an exposure of the enamel prismatic layer, frequently to the depth of the enamel rods and possibly the dentin. However, this study lacked adequate controls, the patients' oral hygiene was not monitored, and compliance could have been poor, since the teeth were scheduled for extraction. Moreover, 35% carbamide peroxide bleaching agent was used, which is not acceptable because it is considered to be too high for long-term night-guard vital bleaching (Bitter, 1998).

Ben-Amar et al. (1995) used SEM to conduct an *in vitro* study to evaluate the effect of Opalescence home bleaching (10% carbamide peroxide) in a mouth guard on enamel surfaces and morphology. They found that bleaching created some enamel pitting because, since it contains hydroxyl radicals which are highly reactive, unstable, and will attack most organic molecules to achieve stability, the agent removed some of the organic components of the enamel, and thus could lead to changes in the mechanical properties of the enamel, such as changing the abrasion resistance of the enamel surface (Seghi and Denry, 1992).

A more recent study, by Smidt et al. (2011), evaluated the morphologic, mechanical, and chemical effects of three carbamide peroxide bleaching agents on human enamel *in situ* using Nitewhite (16% carbamide peroxide, Discus Dental, Philips Oral Healthcare, Stamford, CT, USA), Polanight (16% carbamide peroxide), and Opalescence (15% carbamide peroxide, Ultradent, South Jordan, UT, USA). They found that enamel surfaces showed no mechanical, morphologic, or chemical changes after bleaching with any of the three different carbamide peroxide agents, and this may be attributed to the protective effects of saliva, which provided dilution, buffering capacity, and a supply of Ca and P ions for tooth remineralization. Using profilometric and SEM analyses of epoxy resin replicas of upper right incisors at baseline (control), and after each bleaching treatment with a 38% hydrogen peroxide whitening agent, applied four times at one-week intervals, Cadenaro et al. (2010) conducted an *in vivo* study to test the effect of a hydrogen peroxide in-office whitening agent on enamel. Results demonstrated that the application of a 38% hydrogen peroxide in-office whitening agent did not change enamel surface roughness, even after multiple applications. However, Xu et al. (2011) investigated the influence of pH values of bleaching agents on the properties of the enamel surface using four groups treated with 30% hydrogen peroxide solutions with different pH values: HP3 group (pH = 3.0), HP5 group (pH = 5.0), HP7 group (pH = 7.0), and HP8 group (pH = 8.0). SEM investigation and micro-Raman spectroscopy were used to evaluate enamel surface morphological and chemical composition alterations and detected obvious enamel surface alterations in the neutral or alkaline bleaching solutions.

Abouassi et al. (2011) examined changes in the micromorphology and microhardness of the enamel surface after bleaching with two different concentrations of hydrogen peroxide and carbamide peroxide, using bleaching gels containing 10% or 35% carbamide peroxide, or 3.6% or 10% hydrogen peroxide, respectively, for two hours every second day over a period of 2 weeks. They found that application of carbamide

peroxide and hydrogen peroxide showed only small quantitative and qualitative differences. In addition, they found that the influence of the bleaching procedure on the morphology and hardness of the enamel surface depended on the concentrations of the active ingredients.

Furthermore, a study by Sun et al. (2011) investigated the effects of acidic and neutral 30% hydrogen peroxide on human tooth enamel in terms of chemical structure, mechanical properties, surface morphology, and tooth color and concluded that neutral 30% hydrogen peroxide had the same efficiency in tooth bleaching and caused less deleterious effects on enamel than did the acidic 30% hydrogen peroxide. Finally, Sa et al. (2013) demonstrated that in-office bleaching agents with low pH values could induce enamel morphology alterations under *in vitro* conditions, and that the presence of natural human saliva could eliminate the demineralization effect caused by low pH.

5.3.2. Effects on Enamel surface hardness and wear resistance

Enamel surface hardness and wear resistance after dental bleaching have also been investigated in the literature. Some studies (Araujo Fde et al., 2010; Potočnik et al., 2000; Sasaki et al., 2009) showed no effects, while others (Azer et al., 2009; de Arruda et al., 2012) showed significant decreases in hardness and fracture resistance. Sasaki et al. (2009) studied the effect of home-use bleaching agents containing 10% carbamide peroxide and 7.5% hydrogen peroxide on enamel microhardness and surface micromorphology. They concluded that these bleaching agents may change the surface micromorphology of enamel, although no changes in microhardness were detected. Potočnik et al. (2000) evaluated the effect of 10% carbamide peroxide on the human enamel subsurface layer in terms of microhardness, microstructure, and mineral content. They found that 10% carbamide peroxide caused clinically insignificant local microstructural and chemical changes in enamel. In contrast, Azer et al. (2009) examined the nanohardness and elastic modulus of human enamel after treatment with tray and strip bleaching systems. They exposed human enamel samples to five different bleaching agents. Results showed that the nanohardness and elastic modulus of human enamel were significantly decreased after the application of home-bleaching systems.

Moreover, Araujo Fde et al. (2010) investigated the effects of various light sources on the microhardness of human dental enamel following treatment with an in-office vital bleaching agent (35% hydrogen peroxide) using enamel slabs subjected to hardness testing after four time periods (baseline and after 1, 7 and 14 days). Enamel slabs were then divided into five groups according to the light source treatment: Group LA (35% hydrogen peroxide + argon laser unit); Group HA (35% hydrogen peroxide + halogen light-curing unit); Group LED (35% hydrogen peroxide + LED-laser unit); Group OX (35% hydrogen peroxide + no light source unit); and Group CO (control: saliva only). Results indicated that the different light sources tested did not significantly affect the microhardness of human enamel following treatment with 35% hydrogen peroxide.

In addition, de Arruda et al. (2012) studied the microhardness and histomorphology of bovine enamel after using 35% hydrogen peroxide. The specimens in this study were adapted to removable devices that were used by individuals undergoing

a dental caries challenge. It was concluded that 35% hydrogen peroxide enhanced the reduction in hardness and histomorphologic changes in the enamel surfaces exposed to cariogenic challenge.

5.3.3. 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., 2007; Cakir et al., 2011; Düschner et al., 1997; Efeoglu et al., 2005; Goo et al., 2004; Lee et al., 2006; Rotstein et al., 1996; Tezel et al., 2007). Al-Salehi et al. (2007) 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. (2005) 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 50 µm below the enamel surface. Therefore, they recommended that the application of bleaching agents should be carefully considered in patients susceptible to caries and tooth wear. In another two studies, Rotstein et al. (1996) and Tezel et al. (2007) proved that a concentrated bleaching agent caused a significant loss of calcium from the enamel surface. In a more recent study, Cakir et al. (2011) concluded that the use of home bleaching agents (10%, 20%, and 35% carbamide peroxide) could affect the chemical composition of dental hard tissues, whereas the change in the chemical composition of enamel and dentin was not affected by the carbamide peroxide concentration of the bleaching systems used.

In contrast, Goo et al. (2004) demonstrated that mineral loss caused by dental bleaching was not a threat to teeth. In addition, Lee et al. (2006) showed that the amount of calcium lost from teeth after 12 h of bleaching treatment was similar to that lost from teeth exposed to a soft drink or juice for a few minutes. These studies concluded that changes in the chemical composition of enamel were slight and not clinically significant.

5.3.4. Effects on dentin

Little has been published about the influence of dental bleaching on dentin structure compared with enamel. Zalkind et al. (1996) used SEM to reveal changes in dentin surface morphology. Pecora et al. (1994) found that dentin microhardness decreased after the application of a 10% carbamide peroxide agent for 72 h. In a study conducted by Basting et al. (2003), results showed that the thickening agent (carbopol and/or glycerin), not just the 10% carbamide peroxide, caused a decrease in dentin microhardness. In addition, Tam et al. (2005) concluded that direct exposure to 10% carbamide peroxide caused a significant decrease in the flexural strength and flexural modulus of bovine dentin. Faraoni-Romano et al. (2008) studied the effects of low and highly concentrated bleaching agents on microhardness and surface roughness of bovine enamel and root dentin and proved that while bleaching did not change enamel microhardness and surface roughness, it affected root dentin in terms of microhardness, which seems to be dependent on the bleaching agent used. Moreover, Lewinsein et al. (1994) showed a decrease in the microhardness of dentin following exposure to a 30% solution

of hydrogen peroxide at pH 3, while Tam et al. (2007) found that *in vitro* fracture resistance of dentin was reduced after the prolonged use of bleaching products applied directly to dentin. In another study, Engle et al. (2010) conducted an investigation of the effect of the interaction among bleaching, erosion, and dentifrice abrasivity on enamel and dentin. They indicated that bleaching with 10% carbamide peroxide did not increase the erosive and abrasive wear of enamel. However, it might change dentin's abrasive wear, depending on erosive and abrasive challenges.

5.4. Effects of dental bleaching on composite resin restorations

5.4.1. 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 (Polydorou et al., 2006). 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 (Bailey and Swift, 1992; Türker and Biskin, 2003). 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 (Schemehorn et al., 2004). In addition, cracking was also observed in microfilled specimens after application of 10% carbamide peroxide for a period of four weeks (Bailey and Swift, 1992). Also, a study was set to compare the superficial texture of nanocomposites with that of microhybrid composites after different bleaching protocols (Wang et al., 2011). The authors used Filtek Supreme, Filtek Z350 (3M ESPE, Dental Products, St. Paul, MN, USA), and Grandio (Voco, Cuxhaven, Germany) nanocomposites and compared them with Opallis (FGM Produtos odontológicos, Joinville, SC, Brazil) and Filtek Z250 (3M ESPE, Dental Products, St. Paul, MN, USA) (control microhybrid composites) using three different bleaching agents: 35% hydrogen peroxide Whiteness HP (WHP), 35% Whiteness HP MAXX (WMAXX) and 16% carbamide peroxide Whiteness Standard (WS). The results showed that surface roughness alteration was material- and time-dependent. While WHP treatment significantly altered the Filtek Supreme composite over time, when WMAXX was used, Grandio displayed the most significant alterations in surface roughness throughout the evaluation period, which was not observed for the other nanocomposites. When WS was used, over time, Filtek Z250 presented significant surface alterations that were not seen in the nanofilled materials. In this context, it should also be mentioned that salivary proteins adsorbed onto the surfaces of composite materials decrease after bleaching with peroxide-containing agents, which is suggested to have an influence on bacterial adhesion of cariogenic bacteria, such as *Streptococcus sobrinus* and *Streptococcus mutans*, but not *Actinomyces viscosus* (Steinberg et al., 1999).

As for the effect of bleaching on surface microhardness of composites, there is a controversy about the impact of low-concentration 10–16% carbamide peroxide gels on surface microhardness of restorative composite materials. In some

investigations, softening of composite resins was associated with the application of at-home bleaching gels (Bailey and Swift, 1992; Lima et al., 2008; Türker and Biskin, 2002). Other investigations revealed no significant changes in hardness (Garcia-Godoy et al., 2002; Nathoo, 1997; Polydorou et al., 2007) or even an increase in surface hardness (Campos et al., 2003; Türker and Biskin, 2003) due to the application of at-home bleaching gels. In-office tooth whiteners (35% carbamide peroxide or 35% hydrogen peroxide) were not reported to have significant effects on the hardness and tensile strength of composite materials (Cullen et al., 1993; Yap and Wattanapayungkul, 2002). Using the Knoop hardness test, Hannig et al. (2007) reported a significant decrease in the surface hardness of bleached composite resins (Tetric Flow, TetricEvoCeram; Ivoclar Vivadent, Schaan, Liechtenstein), not only on superficial surfaces, but also in the deeper layers of the filling materials. These results were related to the high oxidation and degradation of the resinous matrix in the composites (Taher, 2005).

Moreover, in 2013, the present author reported the results of an *in vitro* study (Alqahtani, 2013) conducted to assess the effect of a 10% carbamide peroxide bleaching agent on the microhardness of four types of direct resin-based restorative materials [Microhybrid resin composite (Z250) (3M ESPE, St. Paul, MN, USA), a nanofilled resin composite (Z350) (3M ESPE, St. Paul, MN, USA), a silorane-based low-shrink resin composite (P90) (3M ESPE, Seefeld, Germany), and a hybrid resin composite (Valux Plus) (3M ESPE, St. Paul, MN, USA)]. The author divided specimens from each material into three groups, selected one group as a control group (non-treated with bleaching agent), and treated the other two groups with the bleaching agent for 14 days (Group A) and for 14 days followed by immersion in artificial saliva for 14 days (Group B). In addition, the top surfaces of the specimens were exposed to the Vickers hardness test with a load of 300 g. Results showed a general reduction of Vickers hardness values of treated groups compared with the control group for each material used; however, this reduction was minimal, and there was no significant difference between groups in Z250, whereas the other three materials (Z350, P90, and Valux Plus) demonstrated a significant decrease of Vickers hardness of treated groups compared with the control group.

5.4.2. Color changes

For standardized and reproducible evaluation of color changes of restorative materials, colorimeters are used for analysis of $L^*a^*b^*$ values according to the CIELAB system. Under oral conditions, ΔE^* color differences have been reported to be objectionable only when higher than 3.3 or 3.7 (Buchalla et al., 2002; Inokoshi et al., 1996). The application of 10% hydrogen peroxide or heated 30% hydrogen peroxide resulted in composite color changes which were presumably clinically detectable with ΔE^* ranging between 2 and 11 for the different materials and shades tested (Canay and Cehreli, 2003). In contrast, the use of 10% carbamide peroxide gel led to color changes of composite resins less than $\Delta E^* 2$, and these were comparable with color changes of unbleached samples stored in water only (Monaghan et al., 1992). Using a spectrophotometer, Li et al. (2009) found significant changes in the color of nanohybrid and packable composite resins after bleaching with 15% carbamide peroxide. Another study found that this

difference was especially noticeable when a high peroxide concentration (35%) was used on low-density resins such as microfilled composite resin (Hubbezoğlu et al., 2008). The authors attributed these results to the volume of resin matrices and filler type.

Generally, alterations in the color of restorative materials have been attributed to oxidation of surface pigments and amine compounds, which have also been indicated as responsible for color instability of restorative materials over time. Differences in color change between and among different materials might be a result of different amounts of resin and different degrees of conversion of the resin matrix. For the above-mentioned reasons, more color change was found in chemically cured than in light-cured composites, and this difference can be mainly attributed to the composition of the matrix phase, especially the activator system (Inokoshi et al., 1996). Color stability of light-cured composites can be explained by the stability of its resin matrix.

Yu et al. (2009) found that bleached composite resins stain more easily than unbleached ones. The authors suggested that this staining could be caused by alterations in the surfaces of the bleached restorations. However, two studies found that bleaching can remove stains from the external surface of a composite restoration (Fay et al., 1999; Villalta et al., 2006), and another showed that bleaching with 10–15% hydrogen peroxide is more effective than polishing for removing stains and restoring the original color of the composite resin (Turkun and Turkun, 2004). However, at a minimum, polishing of restorations after bleaching is advisable, since the increased surface roughness is held to be responsible for increased adherence of certain cariogenic microorganisms to the outer surfaces of tooth-colored restorative materials after contact with different bleaching agents, as assessed by Mor et al. (1998).

5.4.3. Effects on marginal quality and microleakage

Two studies using the dye penetration test reported that, in extracted teeth restored with composite restorations, post-operative contact with 35% hydrogen peroxide or 10–16% carbamide peroxide gel could adversely affect the marginal seal at both dentin and enamel margins (Crim, 1992; Ulukapi et al., 2003). In contrast, another study found no increased microleakage rates, at least at enamel margins (White et al., 2008). In that study, White et al. found that bleaching teeth with Class I composite restorations with 20% carbamide peroxide did not affect the occlusal margins of the restorations, and therefore did not cause microleakage.

Polydorou et al. (2009) studied the amount of monomer released from a bleached composite resin (Ceram X). They indicated that less Bis-GMA (bisphenol A-glycidyl dimethacrylate) and less UDMA-2 (urethane dimethacrylate) were released from composite resin restorations than from unbleached control samples, while the released concentration of TEGDMA (triethylene glycoldimethacrylate) molecules was similar to that of the control group. In a recent study, Ajami et al. (2012) evaluated the effects of Oral-B (OB), Listerine (LN), and Rembrandt Plus (RM) mouthrinses on microleakage of composite resin restorations bonded with two adhesive systems (Excite and Clearfil SE Bond) after bleaching with 10% carbamide peroxide. They demonstrated that microleakage with Excite was significantly higher than that with Clearfil SE Bond. In addition, they found that microleakage with OB was higher

than that with LN. However, there were no significant differences in microleakage between LN and RM and between RM and OB. In addition, with the Excite adhesive system, microleakage with OB was higher than that with LN and RM. They concluded that the use of some mouthrinses, such as OB, after bleaching can increase post-restoration microleakage of resin composite restorations bonded with etch-and-rinse adhesive systems.

5.4.4. Effects on the bonding of composite resin restorations to tooth structure

The effects of dental bleaching on the bonding potential of composite resin restorations to tooth structure can be divided into the effects of pre- and post-operative bleaching on the bonding of composite resin restorations to the tooth structure.

5.4.4.1. The effects of pre-operative dental bleaching on the bonding potential of composite resin restorations to tooth structure. The reduction in bond strength of adhesive restorations to tooth structure after dental bleaching has been investigated widely in the literature. Some authors attributed the decrease in bond strength to the presence of residual peroxide on the tooth surface, which interferes with the resin bonding and prevents its complete polymerization (Dishman et al., 1994). Others mentioned that vital bleaching will alter the protein and mineral content of the superficial layers of enamel, which may be responsible for reduced bond strength (Perdigão et al., 1998).

Titley et al. (1991) reported that, in the SEM evaluation of bleached specimens, large areas of enamel surface were resin-free and tags were poorly defined and fragmented and penetrated to a lesser depth when compared with those in the unbleached control groups. In another study, SEM examination of resin and bleached enamel interfaces displayed a porous and granular view with a 'bubbly' appearance (Titley et al., 1992).

To improve the bond strength of previously bleached teeth, different methods have been proposed in the literature. Some studies reported the effectiveness of 10% sodium ascorbate in reversing the compromised bond strength of enamel previously bleached with 10% carbamide peroxide when bonded to resin composite (Kaya and Turkun, 2003; Kimyai and Valizadeh, 2006, 2008; Turkun et al., 2009). Lai et al. (2002) found that surface treatment with an antioxidant (sodium ascorbate) can immediately reverse the compromised bond strength of teeth bleached with hydrogen peroxide or teeth treated with sodium hypochlorite.

Moreover, in a study conducted by Feiz et al. (2011), it was suggested that the application of sodium ascorbate as an antioxidant could significantly increase the bond strength of composite resin to bleached dentin, while the use of calcium hydroxide as a buffering agent did not affect bond strength. In another study, Dabas et al. (2011) studied the effects of different concentrations of hydrogel of sodium ascorbate (10% and 20%) on the bond strength of bleached enamel for various periods of time (30, 60, 120 min) and concluded that sodium ascorbate hydrogel application following bleaching increased the resin-enamel bond strength, and that this was directly proportional to its duration of application. However, there was no difference in bond strength with an increase in the concentration of sodium ascorbate hydrogel. Furthermore, Danesh-Sani and Esmaili (2011) demonstrated that delaying

the bonding procedure by one week after bleaching reduced the compromised SBS of composite resin and resin-modified glass ionomer. Furthermore, applying 10% sodium ascorbate hydrogel in the treatment of bleached enamel surfaces reversed the compromised SBS and might be an alternative to delayed bonding, especially when restoration can be completed immediately after bleaching. In addition, other recent studies found that the method of application and the chemical composition of the adhesives could affect the efficacy of antioxidant as a reducing agent (Khoroushi and Aghelinejad, 2011; Khoroushi and Saneie, 2012). Khoroushi and Saneie (2012) compared the SBS of three different adhesives: OptiBond FL (OFL; three-step etch & rinse), OptiBond Solo Plus (OSP; two-step etch & rinse), and OptiBond All-in-One (OA; one-step self-etch) (Kerr, Orange, CA, USA) on bleached enamel immediately after bleaching, bleached then delayed for one week, and bleached then an antioxidizing agent applied. Results showed that: for OFL, SBS of the sodium ascorbate group was significantly higher than that of the unbleached control group; for OSP, the sodium ascorbate group had no statistically significant difference from the unbleached control group; and for OA, the SBS was significantly lower than that of the unbleached control group. In addition, it was suggested that, in the etch-and-rinse adhesives, the use of sodium ascorbate is more appropriate than delayed bonding; however, in the self-etching adhesive under study, there was no difference between the two methods (Khoroushi and Saneie, 2012). Moreover, they reported that the chemical composition of some adhesives is more compatible with sodium ascorbate, to compensate for the reduced bond strength after bleaching.

In many studies, bonding resin composite after home bleaching with 10% carbamide peroxide was compared with the use of either etch-and-rinse or self-etch adhesives (Adebayo et al., 2007; Gurgan et al., 2009; Moule et al., 2007). These studies proved that the SBS of bleached enamel was best when etch-and-rinse adhesives were used. Furthermore, Sung et al. (1999) proposed the use of dental adhesives containing organic solvents to enhance bond strength. They suggested that the use of an alcohol-based bonding agent (OptiBond) will result in less-compromised composite bond strength when the restorative treatment is to be completed immediately after bleaching (10% carbamide peroxide, Nite White Whitening System), while Montalvan et al. (2006) concluded that the SBS did not differ between the acetone- or ethanol-based adhesives 24 h post-bleaching with 35% hydrogen peroxide (Opalescence Xtra, Ultradent). On the contrary, Niat et al. (2012) indicated that the acetone-based adhesive (One Step) had a higher bond strength than did the alcohol-based adhesive (Single Bond).

Some investigators demonstrated that catalase or catalase-like substances can be used as effective adjuncts after bleaching treatment to decrease the residual hydrogen peroxide on the bleached teeth (Kum et al., 2004). However, they reported that catalase presently is not a practical agent to be used clinically, because of its short shelf life, need for refrigeration, and its sensitivity to air. Other investigators mentioned that α -tocopherol formulated in solution results in a significant increase in the bond strength of bleached enamel (Sasaki et al., 2009). However, they mentioned that a period of at least 1 week after the bleaching treatment is still recommended before bonding procedures can precede.

In addition, Vidhya et al. (2011) concluded that the use of grape seed extract (oligomeric proanthocyanidin complexes

[OPCs]), after bleaching with 38% hydrogen peroxide and prior to bonding procedures on enamel, completely neutralizes the deleterious effects of bleaching and significantly increases bond strength.

Since the reduction in bond strength after dental bleaching has been shown to be reversible, the best method, according to the literature, is to postpone the bonding procedure for a period of time after tooth bleaching, which varies in many studies from 24 h to one week, 2 weeks, or even up to 4 weeks (Bulut et al., 2006; Turkun and Kaya, 2004; Turkun et al., 2009).

5.4.4.2. The effects of post-operative dental bleaching on the bonding potential of composite resin restorations to tooth structure. Most available research in the current literature has focused on the preoperative influence of bleaching gels on adhesion of composites to enamel. However, few studies have dealt with the influence of bleaching gels on the adhesive bond of previously prepared composite restorations. This effect was analyzed by different methods, including measurement of bond strength (Barcellos et al., 2010; Cavalli et al., 2005; Dudek et al., 2012), fracture toughness (Far and Ruse, 2003), and microleakage (Crim, 1992; Polydorou et al., 2009; White et al., 2008). In fact, the oxygen radicals released from peroxide bleaching materials are known for their high reactivity and nonspecific nature and may have side-effects on tooth tissues (in terms of affecting tooth chemical structure due to reduction in the Ca/P ratio, enamel microhardness, dentin permeability, and surface morphology) (Attin et al., 2009; Tam et al., 2007), restorative materials (in terms of affecting their surface microhardness, color changes, surface properties, and marginal integrity) (Hannig et al., 2007; Türker and Biskin, 2003; Wattanapayungkul and Yap, 2003), and the bond between them, which is usually the most susceptible to degradation. It was reported that these peroxide radicals are supposed to damage the dental substrate bond to resin tags – in other words, the hybrid layer – which is mainly responsible for the mechanisms of adhesion between teeth and resin composites (Nakabayashi et al., 1982).

Cavalli et al. (2005) applied a bleaching agent containing 10% carbamide peroxide over composite-tooth interfaces bonded with two adhesive systems applied to enamel and dentin with Single Bond (SB) and Clearfil SE Bond (CB). Results indicated that bleaching significantly affected bond strength of CB to enamel, but no influence on bond strength to dentin was noted for both adhesive systems. Moreover, Far and Ruse (2003) assessed the effects of carbamide peroxide concentration and length of exposure on fracture toughness of existing composite-dentin interfaces with 11%, 13%, 16%, and 21% carbamide peroxide, and conducted tests after 1, 2, and 3 weeks, representing a cumulative exposure of 14, 42, and 70 h. Results suggested that cumulative exposure to a bleaching agent for 70 h significantly decreased interfacial fracture toughness, regardless of the concentration. For the 16% and 21% concentrations, a significant reduction was observed after 42 h. It was concluded that bleaching could adversely affect the interfacial fracture toughness of dentin-resin composite adhesive interfaces.

Barcellos et al. (2010) evaluated the effect of bleaching gel containing 10%, 15%, and 20% carbamide peroxide on the bond strength of dental enamel or dentin and resin composite restorations. Results showed that carbamide peroxide bleaching agents could significantly affect the micro-tensile bond strength (μ TBS) between the restoration and dental

structure. In addition, for groups in which the restoration was placed on enamel substrate, the control subgroup showed higher bond strength values when compared with subgroups subjected to bleaching with 15% and 20% carbamide peroxide. For groups with restorations in the dentin substrate, the control showed higher bond strength values compared with the subgroup treated with 20% carbamide peroxide. The conclusion was that the damage caused to the restoration-dental structure bond strength by the bleaching agents is augmented by the increase in carbamide peroxide concentration, and that the resin composite bond to dentin was less sensitive to this adverse effect than was the bond to enamel substrate.

In a more recent study, Dudek et al. (2012) investigated the effect of peroxide bleaching gel on the durability of the adhesive bond among composite material, enamel, and dentin created with the etch-and-rinse adhesive Gluma Comfort Bond (GLU) and with the self-etch adhesives Clearfil SE Bond (CLE), Adper Prompt (ADP), and iBond (IBO). They used a microhybrid composite (Charisma). After 25 eight-hour cycles of bleaching with a 20% carbamide peroxide bleaching gel (Opalescence PF 20), the SBS was tested and compared with that of one-day and two-month control specimens stored in water. Results demonstrated that the bleaching gel significantly decreased the bond strength on both enamel and dentin for the simplified single-step self-etch adhesives ADP and IBO and markedly affected the fracture patterns of ADP specimens at the periphery of their bonded area. They concluded that the durability of adhesive restorations can be detrimentally influenced by carbamide peroxide bleaching, and that different adhesives show various levels of sensitivity to the bleaching gel.

6. 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.

Finally, Clinicians should inform their patients about the possible changes that may occur on their dental restorations during bleaching procedure as well as the possibility of replacement of the bleached restorations at the end of bleaching treatment.

Ethical statement

This review article does not require ethical approval.

Conflict of interest

The author of this manuscript has no conflict of interest to declare.

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