aurum

JOURNAL OF HEALTH SCIENCES
A. J. Health Sci.

Volume 2 No 2 | May 2020, 115-139

Review

An Overview of Vital Tooth Bleaching

Soner Şişmanoğlu[1] ORCID: 0000-0002-1272-5581

[1]Department of Restorative Dentistry, School of Dentistry, Altınbaş University, Istanbul, Turkey

Submitted: January 21, 2020; Accepted: April 24, 2020

Abstract: Bleaching of tooth discolorations became more attractive with the increasing importance of aesthetics. Therefore, in recent years, bleaching treatment has become one of the fastest-growing parts of aesthetic dentistry. Bleaching can generally be carried out with hydrogen peroxide or carbamide peroxide both at-home and in-office. Bleaching systems have been offered to the public as a more conservative and economical approach for improving dental appearance. However, the dental profession should maintain high ethical standards and not recommend cosmetic adjustments to the tooth color to suit the patient's demand. Therefore, in this article, vital tooth whitening applications are discussed.

Keywords: *Discoloration; tooth color; bleaching; whitening; vital*

Address of Corresponding: *Soner Şişmanoğlu-soner.s@hotmail.com Tel.: +90(212)7094528; Fax: +90(212)5250075. Department of Restorative Dentistry, Faculty of Dentistry, Altınbaş University, Zuhuratbaba, İncirli Caddesi No: 11-A, 34147 Bakırköy, İstanbul, Turkey*

1. Introduction

Cosmetic dentistry is a very important part of dental restorative applications. Nowadays, individuals are not only content with healthy teeth but also want to have a perfect smile (Joiner, 2004). With the increase in aesthetic concerns, individuals often apply to dental clinics for a whiter smile. The majority of these individuals are not satisfied with the color of their teeth, and whiter teeth are thought to be related to health and beauty and are preferred. In a study of patient satisfaction with their tooth color, researchers reported indifference up to 50%, 30% were dissatisfied, and 10% were very dissatisfied with their tooth color (Odioso et al., 2000). Composite resin and porcelain veneers, crowns, composite resin restorations, mechanical abrasion, and bleaching are among the preferred treatments for tooth discoloration. In a survey conducted by Clinical Research Associates, 91% of dentists reported that they used bleaching treatment in their clinics with a success rate of 79% (Christensen and Christensen, 1995). Furthermore, it has been reported that some of the adolescents aged between 14 and 19 have bleached their teeth and have the idea of having bleaching again (Boeira et al., 2016). Vital bleaching procedures for the treatment of discoloration are a more conservative and cost-effective approach compared to restorative treatments (Barghi, 1998; Dutra et al., 2004). Bleaching treatment can be carried out by the dentist in-office or at-home by the patient under the control of the dentist (Haywood, 1992; Haywood and Heymann, 1989; Sulieman et al., 2005). High concentrations of hydrogen peroxide or carbamide peroxide are used to provide fast, safe and very effective bleaching in-office (Garber, 1997; Haywood, 1992; Lee et al., 1995; Sulieman et al., 2003).

2. Discoloration

Tooth discolorations are categorized as extrinsic and intrinsic discolorations according to their origin (Nathoo, 1997; Watts and Addy, 2001; Zantner et al., 2006). Extrinsic discoloration is caused by the consumption of chromogenic foods and beverages, tobacco products, medicaments such as chlorhexidine (Haywood and Heymann, 1989; Watts and Addy, 2001). Acquired pellicle is a formation that is prone to discoloration (Viscio et al., 2000), and extrinsic discolorations are often observed in areas adjacent to gingival margins and interdental papillae, which are difficult to reach by insufficient brushing (Freedman et al., 2012). Therefore, while scaling and polishing treatments remove most of the extrinsic discolorations (Walsh, 2000; Yap and Wattanapayungkul, 2002), bleaching treatments are applied to remove stubborn stains (Duckworth, 2006; Joiner et al., 2002).

Intrinsic discoloration is caused by the passage of chromogenic substances into the enamel and dentin tissue during odontogenesis or during tooth eruption (Swift and Perdigão, 1998; Watts and Addy, 2001). Dental fluorosis due to the high levels of fluoride exposure, the use of tetracycline antibiotics, hereditary diseases and traumas affecting tooth development are among the main causes. After the eruption, pulp necrosis, discoloration due to some restorative materials and iatrogenesis are also considered in this category. Thereby, intrinsic discolorations can occur for many different reasons and are also divided into two according to the formation period: pre-eruptive and post-eruptive intrinsic discolorations.

2.1. *Pre-Eruptive Intrinsic Discoloration*

Dental Fluorosis

Dental fluorosis is characterized by a high concentration of fluoride exposure to enamel during tooth development, resulting in decreased mineral content and consequently increased porosity on the enamel surface. Dental fluorosis can be in forms ranging from a white cloudy manifestation to a discolored perforation. The severity of dental fluorosis varies depending on the period of exposure and intensity of the fluoride. Today, Thylstrup and Fejerskov (TF) index is used in the classification and treatment planning of dental fluorosis (Sherwood, 2010; Thylstrup and Fejerskov, 1978). The extent of the dental fluorosis is classified from 1 to 6 according to the TF index. Patients with a TF score of 3 or less may be treated with bleaching to mask the localized, chalky appearance of fluorosis with no cavitation. Thus, the surrounding healthy enamel is bleached and localized fluorosis is rendered relatively vague. However, in cases where enamel loss is evident, TF score 4 and above, resin infiltration or other restorative treatment options should be considered (Akpata, 2001).

Antibiotics

The most common antibiotic-related tooth discoloration is due to tetracycline. Tetracycline interacts with the calcium at hydroxyapatite crystals and forms a tetracycline-calcium phosphate complex. The oxidation of tetracycline molecules in the tetracycline-calcium phosphate complex results in tetracycline-induced tooth discoloration (Azer et al., 2011). Clinically, teeth with tetracycline discoloration may present light yellow to dark gray colored bands (Haywood, 1991). These bands indicate the period of tooth development corresponding to tetracycline exposure. Bluish-grayish bands may be observed in the discoloration of minocycline, a derivative of tetracycline. Minocycline discoloration can be misdiagnosed with pulpal hemorrhages in severe discoloration cases (Sánchez et al., 2004).

Tetracycline can cross the placenta barrier and therefore affect both primary and permanent dentition. Discoloration in permanent teeth is less intense but more common compared to primary teeth. Tetracycline exposure, even as short as 3 days, may cause tooth discoloration from intrauterine 4th month to 9 years old (Sánchez et al., 2004). Yellowish-brown discolorations can be treated more successfully than gray-bluish discolorations in terms of bleaching treatment (Freedman et al., 2012; Haywood, 1991; Haywood, 2000). In addition, selective etching of brown discoloration bands before the bleaching may increase the effectiveness (Freedman et al., 2012).

Some researchers have reported amoxycillin-clavulanic acid-related tooth discoloration and stated that this coloration is dose dependent (Garcia-Lopez et al., 2001).

2.2. *Post-Eruptive Intrinsic Discoloration*

Post-traumatic pulpal hemorrhage is the most common cause of post-eruptive intrinsic discoloration. Blood enters the dentin tubules and decomposes so that the degradation products cause discoloration. Pulp extirpation or necrosis can also lead to the formation of chromogenic degradation products (Arens, 1989). In addition, the physiological abrasion of the enamel together with the increase in secondary dentin and dentin sclerosis due to aging, affect the light transmittance of the tooth, thereby the tooth appears more yellow (Watts and Addy, 2001).

3. History of The Tooth Bleaching

Whiter teeth have been people's quest for ages. The first record for tooth bleaching is based on Assyro-Babylonian (Akkadian) cuneiform tablets (Aschheim, 2014). Since the beginning of the 19th century, dentists have begun to perform cosmetic procedures such as bleaching and tooth contouring. However, during these periods, bleaching was controversial among dentists due to its technical sensitivity and the poor prognosis of the whitening effect. In the second half of the 19th century oxalic acid was used to whiten vital teeth (Haywood, 1992). From the beginning of the 20th century, oxalic acid was replaced by pyrozone (ether peroxide) (Atkinson, 1892) and hydrogen peroxide as an oxidizing agent. Initially, hydrogen peroxide was administered to patients in liquid form (Fisher, 1911). In 1990, hydrogen peroxide was made available to dentists in gel form (Bartlett, 2001) and it was applied in a much safer way. Nowadays, hydrogen peroxide used for in-office bleaching approach is presents in gel and powder-liquid forms with concentrations ranging from 25% to 40% (Haywood, 2000; Ontiveros, 2011).

4. Mechanism of Bleaching

In recent years, hydrogen peroxide and carbamide peroxide have been used as bleaching agents. Carbamide peroxide can be used in different concentrations. Bleaching with carbamide peroxide is different from hydrogen peroxide bleaching. First, the carbamide peroxide disintegrates into hydrogen peroxide and urea (Joiner, 2004). Carbamide peroxide with the concentration of 10% disintegrates into 6.6% urea and 3.4% hydrogen peroxide. Then, urea is broken down into carbon dioxide and ammonia.

Hydrogen peroxide can be used in different concentrations. Although it is known that hydrogen peroxide is easily diffused through enamel due to its lower molecular weight, it is not known exactly how it whitens teeth (Bowles and Ugwuneri, 1987). According to the chemical theory explaining the bleaching reaction of hydrogen peroxide, active hydrogen peroxide disintegrates into water (H_2O) and oxygen (O_2) and perhydroxyl radicals (HO_2). Bleaching is also known as an oxidation-reduction reaction. Peroxides are converted to unstable free radicals (Hannig et al., 2003; Kashima-Tanaka et al., 2003). The free radicals formed as a result of the decomposition of hydrogen peroxide, diffuse into the interprismatic regions of the enamel and carry the small molecules that it detaches from large organic molecules to the surface due to its foaming properties. These free radicals react with organic molecules causing discoloration and result in simple molecules that reflect less light (Sulieman, 2004).

Another theory for the mechanism of the peroxide reaction is carbon-carbon bond cleavage causing the ring-opening of the chromophores. Yellow double-bonded carbon compounds are converted to almost colorless hydroxyl compounds (Haywood, 2001). Studies have shown that hydrogen peroxide modifies these long-chained chromophores to more translucent molecules and provides bleaching in tooth discoloration. Chromophores are divided into two: long-chain organic compounds with double bonds and metal-containing compounds. Bleaching of organic compounds with hydrogen peroxide involves oxidation of double bonds. This causes the simpler molecules to reflect less light, making the darker regions lighter. Bleaching of the metallic compounds is more difficult, hence invasive restorative treatments may be a better treatment option for such teeth (Carey, 2014).

As the bleaching process continues, a point is reached where only hydrophilic colorless structures remain. This point is called the saturation point and bleaching slows down at this point. If the bleaching is further continued, the carbon-containing dental tissues and the carbon bonds of the proteins are destroyed. At this stage, excessive bleaching disrupts tooth enamel without whitening and results in irreversible alterations on the enamel structure and mineral loss (Vilhena et al., 2019).

5. Composition of Bleaching Agents

The current bleaching materials contain hydrogen peroxide or carbamide peroxide as the active ingredient (Joiner, 2004; Joiner and Thakker, 2004). Along with the active ingredient, inactive ingredients, such as thickening agents, carriers, surfactants and pigment dispersants, preservatives, and flavorings are also present in bleaching materials (Gokay, 2005; Greenwall, 2001; Hannig et al., 2003; Joiner and Thakker, 2004; Kashima-Tanaka et al., 2003).

Thickening Agents

The most commonly used thickening agent in bleaching gels is carbopol (carboxypolymethylene), which is a high molecular weight polyacrylic acid polymer (Joshi, 2016). Thickening agents increase the viscosity of the bleaching material and increase its retention to the applied surface. On the other hand, it slows the release of active oxygen in hydrogen peroxide up to four times (Rodrigues et al., 2007), reducing the need for replacement of the bleaching material during the process (Gokay et al., 2005; Greenwall, 2001; Joiner and Thakker, 2004).

Carriers

Glycerin and propylene glycol are generally used in bleaching gels (Joshi, 2016). Glycerin increases the viscosity of the bleaching material and provides ease of use, but causes dehydration (Greenwall, 2001). Dehydration results in a temporary loss of tooth translucency. Propylene glycol does not cause dehydration and retains moisture. It also contributes to the dissolution of other ingredients in the bleaching material (Joiner and Thakker, 2004).

Surfactants and Pigment Dispersants

Surfactants as surface wetting agents provide a much better spread of bleaching material to the tooth surface (Feinman et al., 1991). Therefore, surfactant agents increase the effectiveness of the bleaching material (Gerlach et al., 2002). Pigment dispersants also keep pigments to remain in the bleaching gel (Alqahtani, 2014).

Preservatives

Various preservatives are used in the composition of bleaching materials. Sodium benzoate and methyl propyl paraben are added to prevent bacterial growth in the bleaching gel (Joiner and Thakker, 2004). On the other hand, preservatives such as citric acid, citroxain, phosphoric acids or sodium stannate also prevent the breakdown of hydrogen peroxide, until its use. These preservatives increase the stability and durability of the bleaching gel while keeping the pH of the gel mildly acidic (Joshi, 2016).

Flavorings

Flavorings such as banana, melon, peppermint are added to increase patient acceptance of the bleaching material (Alqahtani, 2014; Joiner and Thakker, 2004).

Additives

Various substances are added to the bleaching materials to eliminate the side effects of the bleaching treatment (Sulieman, 2008).

Amorphous Calcium Phosphate-Casein Phosphopeptide

Amorphous calcium phosphate-casein phosphopeptide (ACP-CPP) provides rapid desensitization by causing depletion of phosphate and calcium ions to exposed dentin tubules (Giniger et al., 2005). It has been reported that the incorporation of ACP-CPP into the bleaching gel significantly reduces sensitivity and increases bleaching efficiency (Joshi, 2016).

Fluoride

It is known that fluoride blocks the dentin tubules and relieves sensitivity by decelerating the dentinal fluid flow (Petersson, 2013). Fluoride also enhances the microhardness of enamel (Attin et al., 2007; Basting et al., 2003) and hence fluoride-containing bleaching gels have been reported to cause less demineralization without affecting the bleaching efficiency (Chen et al., 2008). Furthermore, in 2013, the present author reported that fluoride pretreatment before 35% hydrogen peroxide bleaching resulted in lower surface roughness compared to no fluoride-treated controls (Sismanoglu et al., 2013). It has also been reported that the fluoride incorporated into the bleaching gel positively contributes to the consequent restorative treatments regarding the bond strength (Chuang et al., 2009).

Potassium Nitrate

Potassium nitrate shows an anesthetic-like effect by preventing the repolarization of the depolarized nerve (Poulsen et al., 2006; Tarbet et al., 1981). This reduces post-operative sensitivity without altering the bleaching effect. Matis et al., (2007) stated that ACP-CPP-containing bleaching gel provides similar sensitivity reduction with potassium nitrate-containing bleaching gel, but showed less bleaching effect. It has been reported to be effective even in light-activated bleaching (Browning et al., 2008; Haywood et al., 2001; Tam, 2001).

6. Patient Selection

Almost every patient may desire whiter teeth, but in each case, the aesthetic expectations of the patient may not be adequately met or there is no guarantee that successful results would be achieved (Joshi, 2016). The indications for bleaching at-home and in-office are basically the same, but the clinician should decide the appropriate approach by the patient's needs (Sulieman, 2008). The patient's expectations, lifestyle, the amount of time can be allocated for bleaching treatment, dental sensitivity, baseline shade, and etiology of the discoloration are important factors in choosing the appropriate bleaching approach for the patient (Sulieman, 2005). In the presence of caries, periapical lesion or hypersensitivity, priority should be given to remedy these problems rather than bleaching (Sulieman, 2004). Furthermore, bleaching is contraindicated in pregnancy, since the effects of bleaching materials on the fetus are still unknown (Sulieman, 2005). The indications and contraindications of vital tooth bleaching are presented in Table 1.

Clinical trials, case reports, systematic reviews, and clinical experience provide the clinician with information on which discoloration would respond to bleaching treatment (Joiner and Thakker, 2004; Sulieman, 2004, 2005). Yellow-toned teeth, which generally do not have developmental pathology, can be effectively bleached, whereas brown stains may be more stubborn. For instance, brown stains caused by tobacco consumption generally respond to longer bleaching regimes (Kugel et al., 2002). In addition, there is also a relationship between sclera and shade of teeth. If the teeth to be bleached are lighter than the sclera, bleaching success would be less (Greenwall, 2001). It has not been established that gender affects the bleaching outcome (Gerlach and Zhou, 2001), but effective bleaching is achieved for younger individuals compared to older ones (Joshi, 2016). Although white fluorosis spots are not suitable for bleaching, they become less pronounced as a result of bleaching the surrounding enamel (Haywood, 2000; Sulieman, 2004). More interventional restorative or resin infiltration treatments should be considered for individuals with moderate to severe fluorosis. Moreover, bleaching of extensive tetracycline discoloration is quite difficult and may require the application of months-long bleaching regimens (Haywood, 2000; Sulieman, 2004). Therefore, direct or indirect restorative treatments are preferred to cover tetracycline discoloration bands.

7. Types of Vital Teeth Bleaching

Treatment of discolorations begins with the removal of extrinsic stains by polishing until then the bleaching can be performed. There are basically three different bleaching approaches: in-office or power bleaching (Feinman et al., 1987), at-home or dentist-supervised nightguard vital tooth bleaching (Haywood and Heymann, 1989), and bleaching with the over-the-counter (OTC) products (Kihn, 2007; Sagel et al., 2000). Bleaching systems and materials can be classified according to the active ingredient, and the application/delivery method. The American Academy of Cosmetic Dentistry classifies bleaching systems according to their application/delivery methods (Joshi, 2016).

Whitening Toothpaste

These toothpastes contain higher amounts of abrasive particles and detergents than whitening agents compared to the standard toothpastes and remove extrinsic stains on the tooth surface (Lima et al., 2008). The enzymes contained in their chemical formulae cause the decomposition of organic molecules in the pellicle. It should not be ignored that abrasive particles can cause a permanent loss of enamel on tooth surfaces (Joiner et al., 2008). Some toothpastes may contain relatively low concentrations of carbamide peroxide or hydrogen peroxide as a whitening agents instead of abrasive particles. The whitening agent must be kept separate from dentifrice until its use to keep the agent stable. Dual-chambered tube technology enables this separation. It is stated that tooth color can be bleached one to two shades with whitening toothpastes. In addition, a silica toothpaste containing blue covarine has attracted great attention in recent years. With this toothpaste, which is a good example of the adaptation of metamerism to dentistry, teeth are perceived as whiter.

Whitening Mouthwashes

The whitening mouthwashes contain a low concentration of hydrogen peroxide (2%) and sodium hexametaphosphate to prevent tooth discoloration. Prolonged use may irritate the oral mucosa and tooth sensitivity (Carey, 2014).

Whitening Strips

Recently, whitening strips are developed to make the bleaching gel easier to apply as an alternative to other bleaching systems (Alqahtani, 2014; Sagel et al., 2000). These bleaching strips contain 150-200 mg of bleaching gel homogeneously distributed on the surface of flexible polyethylene material. The concentration of hydrogen peroxide ranges from 5.3% to 6.5% (Donly et al., 2007), and patients are advised to use this system for 30 minutes twice a day for 14 days long. Bleaching strips are very popular because they are easy to apply, cost-effective and have a considerable bleaching effect (Alqahtani, 2014; Gerlach and Barker, 2004).

Paint-on Systems

These products are based on the application of a suspension containing hydrogen peroxide or carbamide peroxide to the tooth surface with a brush (Kishta-Derani et al., 2007). However, their bleaching activity is considerably low. This is most likely due to the short contact time of the bleaching agent (Lo et al., 2007).

Tray-Based Tooth Whiteners

These whitening products are offered directly to the consumer without any control of the dentist, such as other cosmetic products. OCT products appeared in the United States in the early 2000s. These products whiten teeth at lower costs than professional treatments (Demarco et al., 2009). However, these products are generally dispersed by standard/uniform trays and can cause gingival irritation because they are applied without custom fitting trays (Demarco et al., 2009).

At-Home Bleaching (Nightguard Vital Tooth Bleaching)

Although the bleaching effect of carbamide peroxide was discovered randomly in the late 1960s by B. Klusemeir, an orthodontist (Joshi, 2016), the nightguard vital tooth bleaching approach at home was first described in 1989 by Haywood and Heymann (1989). Although this method has undergone many changes to date, it is essential that bleaching agents containing carbamide peroxide are used for 2 to 6 weeks in custom fitting trays for a period of 6 to 8 hours a day.

Usually, 10-15% carbamide peroxide is recommended for this bleaching technique. The bleaching materials are in the form of a transparent gel or white pat. Carbopol-containing bleaching materials are preferred because carbopol increases viscosity and prolongs the oxidation process (Gokay et al., 2005; Greenwall, 2001; Joiner and Thakker, 2004; Rodrigues et al., 2007). The 10% carbamide peroxide agent is composed of 3.5% hydrogen peroxide and 6.5% urea. The presence of urea gives the agent a longer shelf life and slows the release of hydrogen peroxide. Many studies have shown that it is safe and effective to perform bleaching agents containing carbamide peroxide in accordance with dentist recommendations (Haywood and Heymann, 1991). However, patients' cooperation on long-term tray usage is poor.

In-Office Bleaching

For in-office bleaching, hydrogen peroxide is generally used in concentrations ranging from 25% to 40%. The bleaching process is completely under the control of the dentist and can be stopped when the desired shade is reached. Hydrogen peroxide is a material with caustic effects and therefore protective measures such as rubber-dam or gingival barrier should be taken during its application (Sulieman, 2008). Penetration of hydrogen peroxide to the pulp chamber is also possible, but considering its long-term effect, it does not cause any adverse effects on the pulp (McEvoy, 1995).

The in-office bleaching approach can be used in patients who do not have enough time for the at-home bleaching approach, who have gag reflexes or who do not like the taste of home bleaching gels. Another advantage is that the immediate results obtained for the in-office bleaching motivate the patient to continue with bleaching at-home to maximize the outcome. Therefore, the in-office bleaching was frequently combined with at-home bleaching.

The bleaching process can be activated with the help of heat and light to increase the speed and effectiveness of the bleaching treatment. Hence, in-office bleaching approach is also called as "power bleaching". Nowadays, heat application has been abandoned due to possible harmful effects on pulp. Manufacturers produce many light devices specific to tooth bleaching. With the help of these devices, the disintegration ratio of hydrogen peroxide increases and the decomposition of chromophore molecules through oxidation is accelerated, thereby the time required for bleaching is decreased. One of the uses of lasers in dentistry is tooth bleaching. The most commonly used lasers in this field are diode, CO_2 and argon lasers. Using photons of a specific wavelength close to the absorption spectrum of the bleaching agent (480 nm and 520 nm) would increase the chemical reaction rate and reduce the bleaching time (Downs et al., 2011). Torres et al. (2009) reported that the laser activates highly reactive hydrogen peroxide molecules, enabling them to rapidly ionize.

The most used power bleaching sets include hydrogen peroxide gel, light-cured gingival barrier material, neutralizing gel and/or neutral fluoride gel. Although the use of rubber-dam is recommended for the isolation of soft tissues, gingival barriers are frequently used in the power bleaching process as the rubber-dam may cause application problems at the gingival third of the teeth. Following the application of the gingival barrier, the hydrogen peroxide gel is applied to the surfaces to be bleached according to the manufacturer's instructions forming approximately 3-mm thick layer (Figure 1). Although the process varies from brand to brand, it is usually repeated 3 times in about 10-15 minutes. Each repetition is termed as "passes" (Joshi, 2016). After each passes, the whitening gel is cleaned over the teeth with suctioning and wiping using clean gauze. If the bleaching gel leaks despite the gingival barrier and comes into contact with soft tissues during bleaching, it may cause blanching and irritation. If this happens, the irritated area should be washed with plenty of water and the neutralizing agent supplied with the bleaching kit should be applied. Generally, these neutralizing agents include vitamin E, which is an antioxidant. The bleaching process can be resumed after the reapplication of the gingival barrier.

All bleaching agents that are not at neutral pH reduce the microhardness and modulus of elasticity and increase the surface roughness of the enamel. This increase in roughness creates a favorable environment for extrinsic discoloration (Azer et al., 2009; Pinto et al., 2004). Therefore, bleached enamel surfaces should be polished. Subsequent to bleaching, a neutral fluoride gel can be applied to teeth. It is noteworthy, the teeth appear lighter than it is due to the postbleaching dehydration, and slight rebound occurs on rehydration. This should be considered by the clinician, and color evaluation should be better after 1-2 days (Haywood, 1996).

Combination Treatments

The combined use of both in-office bleaching and at-home bleaching approaches is often preferred by dentists. Especially in the treatment of tetracycline discolorations or cases of discoloration with different etiology, such an application provides successful results. Patient cooperation is another important factor in the success of bleaching treatment (Odioso et al., 2000). In particular, for the patients with weak motivation, initiating the bleaching treatment with in-office bleaching before at-home bleaching would increase the motivation towards treatment and affect their cooperation positively.

Another combination is the use of whitening toothpaste after bleaching treatments. Such a combination would be useful to prevent as much of the rebounds as possible after bleaching to maintain color stability.

8. Adverse Effects of The Bleaching

The most common side effects of tooth bleaching are recurrence of the discoloration, hypersensitivity, irritation of gingival tissue and oral tissues, alterations on enamel and restorative material surfaces (Li and Greenwall, 2013). Apart from these, tray-based tooth whiteners without dentist orientation may also cause temporomandibular joint problems (Gerlach et al., 2009).

8.1. *Recurrence of The Discoloration*

To assess and understand the reversal of the whitening effect, patients' tooth shade should be recorded before the bleaching process. According to all clinical and laboratory research results, tooth bleaching is effective and safe with the latest generation of vital whitening products (Li, 2003; Luk et al., 2004). Reversal after in-office bleaching has been reported at a rate of 41% per year according to Clinical Research Associates (2004). For at-home bleaching, a return of 26% in 18 months and stated that the original concentration of bleaching agent is not relevant to the reversal rate (Meireles et al., 2009).

After the completion of in-office bleaching or after the removal of the tray at at-home bleaching, patients often notice a large bleaching effect due to the effect of dehydration. It is better to perform the final color evaluation 1-2 days after bleaching (Haywood, 1996). To prevent reversal, it may be advisable to use whitening toothpastes, and it may be recommended for patients to undergo annual at-home bleaching.

All bleaching agents result in a reduction in enamel microhardness and modulus of elasticity after bleaching and result in surface roughness. This increase in roughness creates an environment conducive to extrinsic coloration (Azer et al., 2009; Pinto et al., 2004). Therefore, after whitening, tooth surfaces should be polished.

8.2. *Hypersensitivity*

Hypersensitivity is the most commonly reported adverse effect of bleaching. The frequency of hypersensitivity observed in patients using 10% carbamide peroxide is ranging between 11 to 93% (Leonard et al., 2002) and the average initial reporting time of hypersensitivity is after 5 days (Tam, 1999). This side effect is usually mild and temporary pain; often causes significant discomfort in the patient (Rosenstiel et al., 1996). The cause of sensitivity after bleaching is explained by different mechanisms such as hydrodynamic theory or morphological changes in enamel (increased surface porosity, precipitation, superficial irregularities). However, recent studies have indicated that direct activation of neuronal receptors may be the main reason for the occurrence of this sensitivity. It has been reported that with the addition of agents, which inhibit the activation of neuronal receptors such as potassium nitrate to the bleaching materials, it is possible to reduce the severity of this sensitivity without resulting in a decrease in bleaching efficiency (Markowitz, 2010). Potassium nitrate, sodium fluoride or ACP-CPP can be incorporated into bleaching materials as desensitizing agents or applied to the tooth surface prior to bleaching (Tay et al., 2009).

8.3. *Alteration on The Enamel Surface*

Micro- and nano-mechanical investigations have shown that bleaching agents reduce enamel hardness, modulus of elasticity and fracture resistance. This decrease occurs regardless of peroxide concentration, pH or exposure time (De Abreu et al., 2011). Therefore, the decrease in stiffness and modulus of elasticity is thought to be due to the protein denaturation (Ushigome et al., 2009). In a study, it was stated that carbamide peroxide causes more protein denaturation compared to hydrogen peroxide and urea content in carbamide peroxide may cause this situation (Elfallah et al., 2015). Besides, it is reported that the mineral loss as a result of bleaching does not cause harm to the tooth (Goo et al., 2004). Furthermore, mineral loss due to 12-hour bleaching treatment is similar to mineral loss caused by a few minutes of soft drink or juice exposure (Lee et al., 2006). When these studies are taken into consideration, alterations caused by bleaching in the enamel can be considered insignificant (Alqahtani, 2014).

Each tooth has its final level of lightness, which is called "inherent lightness potential" (Matis et al., 2000). This point represents the endpoint of the bleaching process for that tooth. If bleaching is continued after this point, no more whiteness can be achieved, besides irreversible damage to the enamel may occur. Studies have reported that this endpoint can be reached regardless of the active ingredient and concentration used for bleaching over 6 weeks.

In some studies, whitening products have been reported to increase surface alterations in enamel. When compared with untreated control groups, the bleached enamel surface undergoes morphological changes (Alqahtani, 2014). However, these changes have been reported to be reversible (Demarco et al., 2011). After bleaching, dentists advise their patients, especially against smoking and some chromogenic beverages (Cavalli et al., 2004; McGuckin et al., 1992; Titley et al., 1988). Coffee, tea, fruit juices, red wine, and sodas are chromogen beverages that have the potential to stain or discolor the bleached enamel surface. The bleached enamel surface may be very sensitive to discoloration, especially in acidic solutions (Berger et al., 2008). Mouth rinsing or brushing can be performed immediately after the consumption of foods and beverages to prevent discoloration. Patients can use straws while consuming beverages. In patients who smoke and drink beverages that cause the excessive coloration, it may be necessary to repeat the whitening process very often.

8.4. *Effects on Pulp Tissue*

The risk of dentin pulp complex being affected by dental materials depends on the permeability of the components of these products through enamel and dentin (Hanks et al., 1993). The diffusion of H_2O_2 has been shown to increase with increasing concentration and duration of administration (Matis et al., 2000). H_2O_2-induced free radicals cause oxidative stress in pulp cells. As a result, further tissue damage is prevented by releasing endogenous antioxidant agents such as peroxidase and catalase from pulp cells (de Souza Costa et al., 2010). Although the cytotoxic effect of H_2O_2 on the pulp is proven, pulpal cells are sufficient to eliminate this effect and initiate odontoblastic differentiation (Soares et al., 2015; de Souza Costa et al., 2010).

8.5. *Soft Tissue Effects*

The contact of bleaching agents with oral tissues causes chemical burns. If this contact is short-term, it is seen as whitening of the tissue and this whiteness disappears within a few hours. Ulceration may occur for longer periods of contact. In such cases, topical vitamin E administration should be recommended to accelerate healing (Li and Greenwall, 2013).

8.6. *Effects on Restorative Materials*

In most of the studies in the literature, composite resins have been investigated as restorative materials. In a laboratory study, a 3-week application of 10% carbamide peroxide has been shown to alter the surface roughness of composite resins (Basting et al., 2005). However, surface microhardness was not significantly changed (Basting et al. 2005). *In situ* studies also showed no change in surface microhardness as a result of the application of 15% carbamide peroxide to composite resins for 4 weeks (Li et al., 2009; Yu et al., 2008). In fact, the bleaching of these composite resins have also been observed (Li et al., 2009). The authors commented that this bleaching may be related to surface changes and oxidation of chromophores. On the other hand, in another laboratory study, the effect of a 2-week administration of 10% carbamide peroxide on the surface microhardness was examined under two different storage temperatures (Yu et al., 2011). No significant difference was observed in the surface microhardness for specimens stored at room temperature (25°C), while a significant softening was observed for the specimens stored at body temperature (37°C) (Yu et al., 2011).

There are several controversies among studies on subsurface microhardness. Yu et al., (2011) reported that the subsurface microhardness of bleaching-induced composite resins was stable at different environment temperatures. However, Hannig et al., reported that composite resin subsurface microhardness may be affected up to 2-mm after bleaching (Hannig et al., 2007). Therefore, it is certain that further studies are needed on this subject.

In many studies, it has been reported that application of carbamide peroxide does not cause adverse effects on flexural strength and fracture toughness of composite resins (Cho et al., 2009; Hatanaka et al., 2013; Yu et al., 2010). In addition, in-office bleaching with higher concentrations did not alter the tensile bond strength of composite resins (Cullen et al., 1993; Yap and Wattanapayungkul, 2002). As a result, if bleaching treatment is applied in the presence of composite resin restorations, polishing of these restorations after the treatment would be appropriate.

Bleaching treatment is known to cause the release of monomer and some other substances on dental composites. Durner et al., (2011) reported that bleaching with hydrogen peroxide degrades three-dimensional polymer networks in composites when compared to non-bleaching controls, leading to an increase in the release of unpolymerized monomers and other substances.

According to the information obtained from laboratory studies, it has been shown that mercury release is increased in dental amalgams in contact with carbamide peroxide. Bleaching agents have been shown to improve the solubility of glass-ionomer and other cements (El-Murr et al., 2011; Yu et al., 2009; Yu et al., 2015). Polyacid modified resin-based composites, resin-modified glass-ionomer cements, and zinc-oxide cements are exhibited increased softening and fluoride release in contact with high-concentration bleaching agents. Moreover, cracks have also been reported in some studies (Yu et al., 2015).

The decrease in the bond strength of adhesive restorations after the application of hydrogen peroxide has been proven by many researchers. The reason for this decrease is the changes in enamel structure, inhibiting the infiltration of the resin by the breakdown of hydrogen peroxide and inhibiting the resin polymerization (Cvitko et al., 1991; García-Godoy et al., 1993; Toko and Hisamitsu, 1993). It has been reported that the resin tags in the bleached enamel are much shorter and fewer compared to the unbleached controls (Titley et al., 1991). Therefore, it was stated that bond strength reduction reversed if the procedure is delayed for 2 weeks (Da Silva Machado et al., 2007). Unlu et al., (2008) recommended delayed bonding for at least 24 hours after bleaching with 10% carbamide peroxide and for at least 1 week with 35% hydrogen peroxide bleaching. However, many studies indicate that a 1-week delay is not sufficient to obtain optimal bonding results (Bulut et al., 2006; Türkün and Kaya, 2004; Türkün et al., 2009). In addition, studies have reported that the use of a number of antioxidant agents (green tea extract, sodium ascorbate) as a pretreatment to reverse decreased bond strength. However, according to current knowledge, delayed bonding for 2 weeks seems to be a more appropriate option.

Bleaching-induced composite resins were found to be more susceptible to extrinsic discoloration due to the surface softening (Yu et al., 2009). Furthermore, it has been reported that 10% carbamide peroxide can remove extrinsic stainings such as juice, tea, and chlorhexidine on the composite resin surface (Fay et al., 1999).

Table 1. Indications and contraindications of vital tooth bleaching (Sulieman, 2008)

Indications	Contraindications
Generalized staining	Higher patient expectation
Age-related discoloration	Caries and periapical lesion
Smoking and dietary discoloration	Pregnancy
Fluorosis	Cracks and exposed dentine, sensitivity
Tetracycline staining	Existing crowns or large restorations
Trauma-related discoloration	Elderly patients with visible recession

Figure 1. The bleaching gel applied to vestibular toot surfaces approximately 3-mm in thickness

9. Considerations

Patients are often eager for other aesthetic dental or orthodontic procedures after tooth bleaching. However, as mentioned earlier, the bond strength of adhesive restorations or brackets is low in bleached teeth (García-Godoy et al.,1993; Toko and Hisamitsu, 1993). Although different methods have been tried to prevent this decrease in bond strength; the most commonly used method is delay bonding of adhesive treatments after bleaching (Da Silva Machado et al., 2007). Lai et al., (2002) showed that the decrease in bond strength of composite resins after tooth bleaching can be reversed by the use of antioxidants. Ascorbic acid and its salts are products of low toxicity and used as antioxidants in the food industry. Ascorbic acid has a mean pH of 4, while sodium ascorbate has a pH of 7. Therefore, sodium ascorbate is a more suitable product for dental applications (Hansen et al., 2014; Vohra and Kasah, 2014). In addition, it has been shown that 5 minutes of application is sufficient for its antioxidant effect (Freire et al., 2009). However, the delayed bonding option is still the best choice if the patient does not have time constraints.

Light activation in combination with the in-office bleaching approach is a controversial topic in the literature. In recent systematic review and meta-analysis studies, the effect of light activation with in-office bleaching on the effectiveness of bleaching and tooth sensitivity was evaluated (Bernardon et al., 2010; Buchalla and Attin, 2007; He et al., 2012). In these studies, it was reported that light activation does not contribute to bleaching efficiency. Contrarily, increased tooth sensitivity and potential pulp irritation with the combination of light activation and use of high concentrations of hydrogen peroxide (25-35%) was reported (He et al., 2012).

In-office bleaching usually takes two or three sessions for effective and stable results. It is known that clinicians prefer to leave a gap of 1 week between sessions. Although this is not evidence-based, it is a common choice to reduce tooth sensitivity and prevent pulp damage. According to a recent study on this subject, it was found that there was no significant difference between 2-days and 7-days of waiting periods in terms of tooth sensitivity and bleaching efficiency (De Paula et al., 2015). Thereby, it is a safe way to wait at least 2 days between consecutive bleaching sessions.

Conclusion

Tooth bleaching combines both aesthetic and conservative approaches for the removal of tooth discoloration. Both the knowledge and experience of the clinician are critical for a thorough understanding of the etiology of discoloration and the selection of the proper bleaching approach. Successful treatment of these discolorations would increase patient satisfaction and motivation. However, the dental profession should maintain high ethical standards and not recommend cosmetic adjustments to suit the patient’s demand.

Acknowledgement

None.

Conflict of Interests

Author declares no conflict of interests.

References

de Abreu, D. R., Sasaki, R. T., Amaral, F. L. B., Flório, F. M., Basting, R. T. (2011). Effect of home-use and in-office bleaching agents containing hydrogen peroxide associated with amorphous calcium phosphate on enamel microhardness and surface roughness. Journal of Esthetic and Restorative Dentistry, 23(3), 158–168.

Akpata, E. S. (2001). Occurrence and management of dental fluorosis. International Dental Journal, 51(5), 325–333.

Alqahtani, M. Q. (2014). Tooth-bleaching procedures and their controversial effects: a literature review. Saudi Dental Journal, 26(2), 33–46.

Arens, D. (1989). The role of bleaching in esthetics. Dental Clinics of North America, 33(2), 319–336.

Aschheim, K. W. (2014). Esthetic dentistry: a clinical approach to techniques and materials, 3rd Edition. Elsevier Health Sciences.

Atkinson, C. B. (1892). Fancies and some facts. The Dental Cosmos, 34(12), 968-972.

Attin, T., Betke, H., Schippan, F., Wiegand, A. (2007). Potential of fluoridated carbamide peroxide gels to support post-bleaching enamel re-hardening. Journal of Dentistry, 35(9), 755–759.

Azer, S. S., Hague, A. L., Johnston, W. M. (2011). Effect of bleaching on tooth discolouration from food colourant in vitro. Journal of Dentistry, 39(Suppl 3), 52–56.

Azer, S. S., Machado, C., Sanchez, E., Rashid, R. (2009). Effect of home bleaching systems on enamel nanohardness and elastic modulus. Journal of Dentistry, 37(3), 185–190.

Barghi, N. (1998). Making a clinical decision for vital tooth bleaching: at-home or in-office? Compendium Of Continuing Education In Dentistry, 19(8), 831–838.

Bartlett, D. (2001). Bleaching discoloured teeth. Dental Update, 28(1), 14–18.

Basting, R. T., Rodrigues, A. L., Serra, M. C. (2003). The effects of seven carbamide peroxide bleaching agents on enamel microhardness over time. Journal of the American Dental Association, 134(10), 1335–1342.

Basting, R. T, Fernandez, C. F., Ambrosano, C. M. B., Campos, I. T. (2005). Effects of a 10% carbamide peroxide bleaching agent on roughness and microhardness of packable composite resins. Journal of Esthetic and Restorative Dentistry, 17(4), 256–262.

Berger, S. B., Coelho, A. S., Oliveira, V. A., Cavalli, V., Giannini, M. (2008). Enamel susceptibility to red wine staining after 35% hydrogen peroxide bleaching. Journal of Applied Oral Science, 16(3), 201–204.

Bernardon, J. K., Sartori, N., Ballarin, A., Perdigão, J., Lopes, G. C., Baratieri, L. N. (2010). Clinical performance of vital bleaching techniques. Operative Dentistry, 35(1), 3–10.

BoeiraI, G. F., SalasI, M. M. S., AraújoI, D. C., MasottiI, A. S., CorreaI, M. B., Demarco, F. F. (2016). Factors influencing dental appearance satisfaction in adolescents: a cross-sectional study conducted in southern brazil. Brazilian Journal of Oral Sciences, 15(1), 8–15.

Bowles, W. H., Ugwuneri Z. (1987). Pulp chamber penetration by hydrogen peroxide following vital bleaching procedures. Journal of Endodontics, 13(8), 375–377.

Browning, W. D., Chan, D. C., Myers, M. L., Brackett, W. W., Brackett, M. G., Pashley, D. H. (2008). Comparison of traditional and low sensitivity whiteners. Operative Dentistry, 33(4), 379–385.

Buchalla, W., Attin, T. (2007). External bleaching therapy with activation by heat, light or laser-a systematic review. Dental Materials, 23(5), 586–596.

Bulut, H., Turkun, M., Kaya, A. D. (2006). Effect of an antioxidizing agent on the shear bond strength of brackets bonded to bleached human enamel. American Journal of Orthodontics and Dentofacial Orthopedics, 129(2), 266–272.

Carey, C. M. (2014). Tooth whitening: what we now know. Journal of Evidence-Based Dental Practice, 14(suppl.), 70–76.

Cavalli, V., Giannini M., Carvalho, R. M. (2004). Effect of carbamide peroxide bleaching agents on tensile strength of human enamel. Dental Materials, 20(8), 733–739.

Chen, H. P., Chang, C. H., Liu, J. K., Chuang, S. F., Yang, J. Y. (2008). Effect of fluoride containing bleaching agents on enamel surface properties. Journal of Dentistry, 36(9), 718–725.

Cho, S. D., Bulpakdi, P., Matis, B. A., Platt, J. A. (2009). Effect of bleaching on fracture toughness of resin composites. Operative Dentistry, 34(6), 703–708.

Christensen, G. J. Christensen, R. P. (1995). Home use bleaching survey. CRA Newsletter 19(1).

Chuang, S. F, Chen, H. P., Chang, C. H., Liu, J. K. (2009). Effect of fluoridated carbamide peroxide gels on enamel microtensile bond strength. European Journal of Oral Sciences, 117(4), 435–441.

Cullen, D. R., Nelson, J. A, Sandrik, J. L. (1993). Peroxide bleaches: effect on tensile strength of composite resins. The Journal of Prosthetic Dentistry, 69(3), 247–249.

Cvitko, E., Denehy, G. E., Swift, E. J., Pires, J. A. F. (1991). Bond strength of composite resin to enamel bleached with carbamide peroxide. Journal of Esthetic and Restorative Dentistry, 3(3), 100–102.

Demarco, F. F., Meireles, S. S., Sarmento, H. R., Dantas, R. V., Botero, T., Tarquinio, S. B. (2011). Erosion and abrasion on dental structures undergoing at-home bleaching. clinical. Cosmetic and Investigational Dentistry, 3, 45–52.

Demarco, F. F., Meireles, S. S., Masotti, A. S. (2009). Over-the-counter whitening agents: a concise review. Brazilian Oral Research, 23(Suppl. 1), 64–70.

Donly, K. J., Segura, A., Henson, T., Barker, M. L., Gerlach, R. W. (2007). Randomized controlled trial of professional at-home tooth whitening in teenagers. General Dentistry, 55(7), 669–674.

Downs, J., Convissar, R. A., Anagnostaki, E., Sun, G. (2011). Principles and practice of laser dentistry. In Principles and Practice of Laser Dentistry, Missouri, 151.

Duckworth, R. M. (Ed.). (2006). The teeth and their environment: physical, chemical and biochemical influences. Karger.

Durner, J., Stojanovic, M., Urcan, E., Spahl, W., Haertel, U., Hickel, R., Reichl, F. X. (2011). Effect of hydrogen peroxide on the three-dimensional polymer network in composites. Dental Materials, 27(6), 573–580.

Dutra, A., Frary, J., Wise, R. (2004). Higher-order needs drive new growth in mature consumer markets. Journal of Business Strategy, 25(5), 26–34.

El-Murr, J., Ruel, D., St-Georges, A. J. (2011). Effects of external bleaching on restorative materials: a review. Journal of the Canadian Dental Association, 77, 59.

Elfallah, H. M., Bertassoni, L. E., Charadram, N., Rathsam, C., Swain, M. V. (2015). Effect of tooth bleaching agents on protein content and mechanical properties of dental enamel. Acta Biomaterialia, 20, 120–128.

Fay, R. M., Servos, T., Powers, J. M. (1999). Color of restorative materials after staining and bleaching. Operative Dentistry, 24(5), 292–296.

Feinman, R. A., Madray, G., Yarborough, D. (1991). Chemical, optical, and physiologic mechanisms of bleaching products: a review. Practical Periodontics and Aesthetic Dentistry, 3(2), 32–36.

Feinman, R. A., Goldstein, R. E., Garber, D. A. (1987). Bleaching teeth. Quintessence Pub. Co.

Fisher, G. (1911). The Bleaching of discolored teeth with H_2O_2. The Dental Cosmos, 53, 246–247.

Freedman, G., Gerlach, R. W., Greenwall, L. H. (2012). Contemporary esthetic dentistry. In Contemporary Esthetic Dentistry, Mosby, 341–404.

Freire, A., Souza, E. M., de Menezes Caldas, D. B., Rosa, E. A., Bordin, C. F., de Carvalho, R. M., Vieira, S. (2009). Reaction kinetics of sodium ascorbate and dental bleaching gel. Journal of Dentistry, 37(12), 932–936.

Garber, D. A. (1997). Dentist-monitored bleaching: a discussion of combination and laser bleaching. Journal of the American Dental Association, 128(Suppl.), 26–30.

García-Godoy, F., Dodge, W. W., Donohue, M., O'Quinn, J. A. (1993). Composite resin bond strength after enamel bleaching. Operative Dentistry, 18(4), 144–147.

Garcia-Lopez, M., Martinez-Blanco, M., Martinez-Mir, I., Palop, V. (2001). Amoxycillin-clavulanic acid-related tooth discoloration in children. Pediatrics, 108(3), 819.

Gerlach, R. W., Barker, M. L., Karpinia, K., Magnusson, I. (2009). Single site meta-analysis of 6% hydrogen peroxide whitening strip effectiveness and safety over 2 weeks. Journal of Dentistry, 37(5), 360–365.

Gerlach, R. W., Zhou, X. (2001). Vital bleaching with whitening strips: summary of clinical research on effectiveness and tolerability. Journal of Contemporary Dental Practice, 2(3), 1–15.

Gerlach, R. W., Zhou, X., Mcclanahan, S. F. (2002). Comparative response of whitening strips to a low peroxide and potassium nitrate bleaching gel. American Journal of Dentistry, 15(spec. iss. 1), 19–23.

Gerlach, R. W., Barker, M. L. (2004). Professional vital bleaching using a thin and concentrated peroxide gel on whitening strips: an integrated clinical summary. The Journal of Contemporary Dental Practice, 5(1), 1–17.

Giniger, M., MacDonald, J., Ziemba, S., Felix, H. (2005). The clinical perfrmance of professionally dispensed bleaching gel with added amorphous calcium phosphate. Journal of the American Dental Association, 136(3), 383–392.

Gokay, O., Mujdeci, A., Algin, E. (2005). In vitro peroxide penetration into the pulp chamber from newer bleaching products. International Endodontic Journal, 38(8), 516–520.

Goo, D. H., Kwon, T. Y., Nam, S. H., Kim, H. J., Kim, K. H., Kim, Y. J. (2004). The efficiency of 10% carbamide peroxide gel on dental enamel. Dental Materials Journal, 23(4), 522–527.

Greenwall, L., Fredman, G., Gordan, V. V. (2001). Bleaching techniques in restorative dentistry: an illustrated guide. Martin Dunitz.

Hanks, C. T., Fat, J. C., Corcoran, J. F., Wataha, J. C. (1993). Cytotoxicity and dentin permeability of carbamide peroxide and hydrogen peroxide vital bleaching materials, in vitro. Journal of Dental Research, 72(5), 931–938.

Hannig, C., Zech, R., Henze, E., Dorr-Tolui, R., Attin, T. (2003). Determination of peroxides in saliva-kinetics of peroxide release into saliva during home-bleaching with Whitestrips® and Vivastyle®. Archives of Oral Biology, 48(8), 559–566.

Hannig, C., Duong, S., Becker, K., Brunner, E., Kahler, E., Attin, T. (2007). Effect of bleaching on subsurface micro-hardness of composite and a polyacid modified composite. Dental Materials, 23(2), 198–203.

Hansen, J. R., Frick, K. J, Walker, M. P. (2014). Effect of 35% sodium ascorbate treatment on microtensile bond strength after nonvital bleaching. Journal of Endodontics, 40(10), 1668–1670.

Hatanaka, G. R., de Oliveira Abi-Rached, F., de Almeida-Júnior, A. A., dos Santos Cruz, C. A. (2013). Effect of carbamide peroxide bleaching gel on composite resin flexural strength and microhardness. Brazilian Dental Journal, 24(3), 263–266.

Haywood, V. B., Heymann, H. O. (1989). Nightguard vital bleaching. Quintessence International, 20(3), 173–176.

Haywood, V. B., Heymann, H. O. (1991). Nightguard vital bleaching: how safe is it? Quintessence International, 22(7), 515–523.

Haywood, V. B. (1991). Overview and status of mouthguard bleaching. Journal of Esthetic and Restorative Dentistry, 3(5), 157–161.

Haywood, V. B. (1992). History, safety, and effectiveness of current bleaching techniques and applications of the nightguard vital bleaching technique. Quintessence International, 23(7), 471–488.

Haywood, V. B. (1996). Achieving, maintaining, and recovering successful tooth bleaching. Journal of Esthetic and Restorative Dentistry, 8(6), 31–38.

Haywood, V. B. (2000). Current status of nightguard vital bleaching. Compendium of Continuing Education in Dentistry, 28(suppl.), 10–17.

Haywood, V. B. (2000). A comparison of at-home and inoffice bleaching. Dent Today, 19(4), 44–53.

Haywood, V. B, Caughman, W. F., Frazier, K. B., Myers, M. L. (2001). Tray delivery of potassium nitrate-fluoride to reduce bleaching sensitivity. Quintessence International, 32(2), 105–109.

Haywood, V. B. (2001). Fundamentals of operative dentistry: a contemporary approach. Eds. Submit, J.B., Robbins, J.W., and Schwart, R.S. Chicago, Quintessence Pub. Co., 401–426.

He, L. B., Shao, M. Y., Tan, K., Xu, X., Li, J. Y. (2012). The effects of light on bleaching and tooth sensitivity during in-office vital bleaching: a systematic review and meta-analysis. Journal of Dentistry, 40(8), 644–653.

Joiner, A., Pickles, M. J., Matheson, J. R., Weader, E., Noblet, L., Huntington, E. (2002). Whitening toothpastes: effects on tooth stain and enamel. International Dental Journal, 52(S5), 424–430.

Joiner, A. (2004). Tooth colour: a review of the literature. Journal of Dentistry, 32(suppl.), 3–12.

Joiner, A., Philpotts, C. J., Ashcroft, A. T., Laucello, M., Salvaderi, A. (2008). In vitro cleaning, abrasion and fluoride efficacy of a new silica based whitening toothpaste containing blue covarine. Journal of Dentistry, 36(suppl. 1), 32–37.

Joiner, A., Thakker, G. (2004). In vitro evaluation of a novel 6% hydrogen peroxide tooth whitening product. Journal of Dentistry, 32(suppl.), 19–25.

Joshi, S. (2016). An overview of vital teeth bleaching. Journal of Interdisciplinary Dentistry, 6(1), 3–13.

Kashima-Tanaka, M., Tsujimoto, Y., Kawamoto, K., Senda, N., Ito, K., Yamazaki, M. (2003). Generation of free radicals and/or active oxygen by light or laser irradiation of hydrogen peroxide or sodium hypochlorite. Journal of Endodontics, 29(2), 141–143.

Kihn, P. W. (2007). Vital tooth whitening. Dental Clinics of North America, 51(2), 319–331.

Kishta-Derani, M., Neiva, G., Yaman, P, Dennison, J. (2007). In vitro evaluation of tooth-color change using four paint-on tooth whiteners. Operative Dentistry, 32(4), 394–398.

Kugel, G., Aboushala, A., Zhou, X., Gerlach, R. W. (2002). Daily use of whitening strips on tetracycline-stained teeth: comparative results after 2 months. Compendium of Continuing Education In Dentistry, 23(1A), 29–34.

Lai, S. C., Tay, F. R., Cheung, G. S., Mak, Y. F., Carvalho, R. M., Wei, S. H., Toledano, M., Osorio, R., Pashley, D. H. (2002). Reversal of compromised bonding in bleached enamel. Journal of Dental Research, 81(7), 477–481.

Lee, C. Q., Cobb, C. M., Zargartalebi, F., Hu, N. (1995). Effect of bleaching on microhardness, morphology, and color of enamel. General Dentistry, 43(2), 158–160.

Lee, K. H., Kim, H. I., Kim, K. H., Kwon, Y. H. (2006). Mineral loss from bovine enamel by a 30% hydrogen peroxide solution. Journal of Oral Rehabilitation, 33(3), 229–233.

Lima, D. A., Silva, A. L., Aguiar, F. H., Liporoni, P. C., Munin, E., Ambrosano, G. M., Lovadino, J. R. (2008). In vitro assessment of the effectiveness of whitening dentifrices for the removal of extrinsic tooth stains. Brazilian Oral Research, 22(2), 106–111.

Leonard, R. R. H., Garland, G. E., Eagle, J. C., Caplan, D. J. (2002). Safety issues when using a 16% carbamide peroxide whitening solution. Journal of Esthetic and Restorative Dentistry, 14(6), 358–367.

Li, Q., Yu, H., Wang, Y. (2009). Colour and surface analysis of carbamide peroxide bleaching effects on the dental restorative materials in situ. Journal of Dentistry, 37(5), 348–356.

Li, Y., Greenwall, L. (2013). Safety issues of tooth whitening using peroxide-based materials. British Dental Journal, 215(1), 29–34.

Li, Y. (2003). Effect of light application on an in-office bleaching gel. Journal of Dental Research, 82.

Lo, E. C. M., Wong, A. H. H., McGrath, C. (2007). A randomized controlled trial of home tooth-whitening products. American Journal of Dentistry, 20(5), 315–318.

Luk, K., Tam, L., Hubert, M. (2004). Effect of light energy on peroxide tooth bleaching. Journal of the American Dental Association, 135(2), 194–201.

Markowitz, K. (2010). Pretty painful: why does tooth bleaching hurt? Medical Hypotheses, 74(5), 835–840.

Matis, B. A., Cochran, M. A., Eckert, G. J., Matis, J. I. (2007). In vivo study of two carbamide peroxide gels with different desensitizing agents. Operative Dentistry, 32(6), 549–555.

Matis, B. A., Mousa, H. N., Cochran, M. A., Eckert, G. J. (2000). Clinical evaluation of bleaching agents of different concentrations. Quintessence International, 31(5), 303–310.

McEvoy, S. A. (1995). Removing Intrinsic stains from vital teeth by microabrasion and bleaching. Journal of Esthetic and Restorative Dentistry, 7(3), 104–109.

McGuckin, R. S., Babin, J. F., Meyer, B. J. (1992). Alterations in human enamel surface morphology following vital bleaching. The Journal of Prosthetic Dentistry, 68(5), 754–760.

Meireles, S. S., da Silva Dos Santos, I., Bona, A. D., Demarco, F. F. (2009). A double-blind randomized controlled clinical trial of 10 percent versus 16 percent carbamide peroxide tooth-bleaching agents. Journal of the American Dental Association, 140(9), 1109–1117.

Nathoo, S. A. (1997). The chemistry and mechanisms of extrinsic and intrinsic discoloration. Journal of the American Dental Association, 128(suppl. 4), 6–10.

Odioso, L. L., Gibb, R. D., Gerlach, R. W. (2000). Impact of demographic, behavioral, and dental care utilization parameters on tooth color and personal satisfaction. Compendium Of Continuing Education In Dentistry, 29(suppl.), 35–41.

Ontiveros, J. C. (2011). In-office vital bleaching with adjunct light. Dental Clinics of North America, 55(2), 241–253.

de Paula, E. A., Nava, J. A., Rosso, C., Benazzi, C. M., Fernandes, K. T., Kossatz, S., Loguercio, A. D., Reis, A. (2015). In-office bleaching with a two- and seven-day intervals between clinical sessions: a randomized clinical trial on tooth sensitivity. Journal of Dentistry, 43(4), 424–429.

Petersson, L. G. (2013). The role of fluoride in the preventive management of dentin hypersensitivity and root caries. Clinical Oral Investigations, 17(suppl.1), 63–71.

Pinto, C. F., de Oliveira, R., Cavalli, V., Giannini, M. (2004). Peroxide bleaching agent effects on enamel surface microhardness, roughness and morphology. Brazilian Oral Research, 18(4), 306–311.

Poulsen, S, Errboe, M., Mevil, Y. L., Glenny, A. (2006). Potassium containing toothpastes for dentine hypersensitivity. Cochrane Database of Systematic Reviews, 19(3), 1-16, CD001476.

Rodrigues, J. A., Oliveira, G. P. F., Amaral, C. M. (2007). Effect of thickener agents on dental enamel microhardness submitted to at-home bleaching. Brazilian Oral Research, 21(2), 170–175.

Rosenstiel, S. F., Gegauff, A. G., Johnston, W. M. (1996). Randomized clinical trial of the efficacy and safety of a home bleaching procedure. Quintessence International, 27(6), 413–424.

Sagel, P. A., Odioso, L. L., McMillan, D. A., Gerlach, R. W. (2000). Vital tooth whitening with a novel hydrogen peroxide strip system: design, kinetics, and clinical response. Compendium Of Continuing Education In Dentistry, 29(suppl.), 10–15.

Sánchez, A. R., Rogers, R. S., Sheridan, P. J. (2004). Tetracycline and other tetracycline-derivative staining of the teeth and oral cavity. International Journal of Dermatology, 43(10), 709–715.

Sherwood, I. (2010). Fluorosis varied treatment options. Journal of Conservative Dentistry, 13(1), 47.

da Silva Machado J., Cândido, M. S., Sundfeld, R. H., de Alexandre, R. S., Cardoso, J. D., Sundefeld, M. L. (2007). The influence of time interval between bleaching and enamel bonding. Journal of Esthetic and Restorative Dentistry, 19(2), 111–118.

Strassler, H. E. (2006). Vital tooth bleaching: an update. Continuing Education Insert, 4, 1–8

Şişmanoğlu, S., Gümüştaş, B., Efes, B. G. (2013) The impact of fluoride or ozone gas before vital tooth bleaching on enamel surface roughness. European Oral Research, 47(1) , 1–7.

Soares, D. G., Basso, F. G., Scheffel, D. S., Hebling, J., de Souza Costa, C. A. (2015). Responses of human dental pulp cells after application of a low-concentration bleaching gel to enamel. Archives of Oral Biology, 60(9), 1428–1436.

Costa, C. A., Riehl, H., Kina, J. F., Sacono, N. T., Hebling, J. (2010). Human pulp responses to in-office tooth bleaching. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology, 109(4), 59–64.

Sulieman, M. (2004). An overview of bleaching techniques: I. history, chemistry, safety and legal aspects. Dental Update, 31(10), 612–616.

Sulieman, M. (2005). An overview of bleaching techniques: 2. night guard vital bleaching and non-vital bleaching. Dental Update, 32(1), 39–46.

Sulieman, M., Addy, M., MacDonald, E., Rees, J. S. (2005). The bleaching depth of a 35% hydrogen peroxide based in-office product: a study in vitro. Journal of Dentistry, 33(1), 33–40.

Sulieman, M., Addy, M., Rees, J. S. (2003). Development and evaluation of a method in vitro to study the effectiveness of tooth bleaching. Journal of Dentistry, 31(6), 415–422.

Sulieman, M. (2008). An overview of tooth-bleaching techniques: chemistry, safety and efficacy. Periodontology 2000, 48(1), 148–169.

Swift, E. J. and Perdigão, J. (1998). Effects of bleaching on teeth and restorations. Compendium Of Continuing Education In Dentistry, 19(8), 815–820

Tam, L. (1999). Clinical trial of three 10% carbamide peroxide bleaching products. Journal (Canadian Dental Association), 65(4), 201–205.

Tam, L. (2001). Effect of potassium nitrate and fluoride on carbamide peroxide bleaching. Quintessence International, 32(10), 766–770.

Tarbet, W. J., Buckner, A., Stark, M. M., Fratarcangelo, P. A., Augsburger, R. (1981). The pulpal effects of brushing with a 5 percent potassium nitrate paste used for desensitization. Oral Surgery, Oral Medicine, Oral Pathology, 51(6), 600–602.

Tay, L. Y., Kose, C., Loguercio, A. D., Reis, A. (2009). Assessing the effect of a desensitizing agent used before in-office tooth bleaching. Journal of the American Dental Association, 140(10), 1245–1251.

Thylstrup, A., Fejerskov, O. (1978). Clinical appearance of dental fluorosis in permanent teeth in relation to histologic changes. Community Dentistry and Oral Epidemiology, 6(6), 315–328.

Titley, K. C., Torneck, C. D., Smith, D. C., Chernecky, R., Adibfar, A. (1991). Scanning electron microscopy observations on the penetration and structure of resin tags in bleached and unbleached bovine enamel. Journal of Endodontics, 17(2), 72–75.

Titley, K. C., Torneck, C. D., Smith, D. C. (1988). The effect of concentrated hydrogen peroxide solutions on the surface morphology of human tooth enamel. Journal of Endodontics, 14(2), 69–74.

Toko, T., Hisamitsu, H. (1993). Shear bond strength of composite resin to unbleached and bleached human dentine. Asian Journal of Aesthetic Dentistry, 1(1), 33–36.

Torres, C. R., Batista, G. R., César, P. D., Barcellos, D. C., Pucci, C. R., Borges, A. B. (2009). Influence of the quantity of coloring agent in bleaching gels activated with led/laser appliances on bleaching efficiency. The European Journal of Esthetic Dentistry, 4(2), 178–186.

Turkun, M., Kaya, A. D. (2004). Effect of 10% sodium ascorbate on the shear bond strength of composite resin to bleached bovine enamel. Journal of Oral Rehabilitation, 31(12), 1184–1191.

Turkun, M., Celik, E. U., Kaya, A. D., Arici, M. (2009). Can the hydrogel form of sodium ascorbate be used to reverse compromised bond strength after bleaching? The Journal of Adhesive Dentistry, 11(1), 35–40.

Unlu, N., Cobankara, F. K., Ozer, F. (2008). Effect of elapsed time following bleaching on the shear bond strength of composite resin to enamel. Journal of Biomedical Materials Research Part B. Applied Biomaterials, 84B(2), 363–368.

Ushigome, T., Takemoto, S., Hattori, M., Yoshinari, M., Kawada, E., Oda, Y. (2009). Influence of peroxide treatment on bovine enamel surface - cross-sectional analysis. Dental Materials Journal, 28(3), 315–323.

Vilhena, K. F. B., Nogueira, B. C. L., Fagundes, N. C. F., Loretto, S. C., Angelica, R. S., Lima, R. R., Silva E., Souza M. H. J. (2019). Dental enamel bleached for a prolonged and excessive time: morphological. PLos One, 14(4), e0214948.

Viscio, D., Gaffar, A., Fakhry-Smith, S., Xu, T. (2000). Present and future technologies of tooth whitening. Compendium of Continuing Education In Dentistry, 28(suppl.), 36–43.

Vohra, F. A., Kasah K. (2014). Influence of bleaching and antioxidant agent on microtensile bond strength of resin based composite to enamel. Saudi Journal for Dental Research, 5(1), 29–33.

Walsh, L. J. (2000). Safety issues relating to the use of hydrogen peroxide in dentistry. Australian Dental Journal, 45(4), 257–269.

Watts, A., Addy, M. (2001). Tooth discolouration and staining: a review of the literature. British Dental Journal, 190(6), 309–316.

Yap, A. U. J., Wattanapayungkul, P. (2002). Effects of in-office tooth whiteners on hardness of tooth-colored restoratives. Operative Dentistry, 27(2), 137–141.

Yu, H., Pan, X., Lin, Y., Li, Q., Hussain, M., Wang, Y. (2009). Effects of carbamide peroxide on the staining susceptibility of tooth-colored restorative materials. Operative Dentistry, 34(1), 72–82.

Yu, H., Li, Q., Lin, Y., Buchalla, W., Wang, Y. (2010). Influence of carbamide peroxide on the flexural strength of tooth-colored restorative materials: an in vitro study at different environmental temperatures. Operative Dentistry, 35(3), 300–307.

Yu, H., Li, Q., Cheng, H., Wang, Y. (2011). The effects of temperature and bleaching gels on the properties of tooth-colored restorative materials. Journal of Prosthetic Dentistry, 105(2), 100–107.

Yu, H., Li, Q., Hussain, M., Wang, Y. (2008). Effects of bleaching gels on the surface microhardness of tooth-colored restorative materials in situ. Journal of Dentistry, 36(4), 261–267.

Yu, H., Zhang, C. Y., Cheng, S. L., Cheng, H. (2015). Effects of bleaching agents on dental restorative materials: a review of the literature and recommendation to dental practitioners and researchers. Journal of Dental Sciences, 10(4), 345–351.

Zantner, C., Derdilopoulou, F., Martus, P., Kielbassa, A. M. (2006). Randomized clinical trial on the efficacy of 2 over-the-counter whitening systems. Quintessence International, 37(9), 695–706.