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REVIEW ARTICLE

An Overview of Extrinsic Tooth Bleaching and its Impact on Oral Restorative Materials

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ABSTRACT

Aim: The aim was focused on compiling a comprehensive overview of the extrinsic tooth bleaching and its mechanisms including *in vitro* and *in vivo* measurement methods and analyzing factors affecting the efficacy of the bleaching process on restorative materials and tooth structures.

Background: The importance of tooth bleaching for patients has notably gained importance and been accompanied by a dramatic increase in the number of relevant products and procedures over the past two decades, with a concomitant rise in publications on this topic. Literatures have put forth that the mechanisms of tooth bleaching by peroxide agents occur by the diffusion of peroxide through the enamel to cause oxidation, and hence, lightening of colored species, particularly, within the dentinal regions.

Results: An electronic search was conducted across Ovid Medline, complemented by a manual search across individual databases, such as Cochrane, Web of Science databases, and Google Scholar for the purpose of literature analysis on the mentioned topic. The studies were reviewed and compared. This article summarizes the current scientific and clinical opinions through a brief review with regards to the preferred way of bleaching and its impact on restorative materials. There are controversies in terms of performing tooth bleaching. Regarding extrinsic tooth bleaching, certain literature have pointed out that the in-office method is being followed by a high number of dental practitioners, whereas it should be practiced based on selection of the right cases.

Conclusion: Based on previous findings, it is concluded that at-home bleaching technique appears to be the safest technique currently available, which is rapid, easy, and cheap. However, the correct selection of the cases is mandatory. The in-office method provides good outcomes, while it may be insufficient for correcting extreme discoloration. It should be considered that time and concentration are two crucial parameters that have a great influence on the successful bleaching process. These techniques are not entirely free from hazards, and therefore, using these agents under appropriate supervision and consultation with dental professionals is highly essential.

Clinical significance: In-office tooth bleaching is a great method for providing rapid tooth bleaching, while it is not as safe as the home bleaching method. With the presented data over the past two decades, at-home bleaching has also become an accepted and integrated procedure. However, long-term health risks are also associated with professional at-home tooth bleaching using 10% carbamide peroxide (CP) gels, which is equivalent to 3.5% H_2O_2. Hence, it is recommended that the latter method should be mindfully approached when preferring long-term bleaching processes.

Keywords: Carbamide peroxide, Hydrogen peroxide, Mechanism of tooth bleaching, Tooth bleaching.

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INTRODUCTION

Recently, there has been an increased demand for esthetic dentistry, particularly, tooth bleaching to improve the esthetic appearance and the tooth whiteness.[1,2] This process can be carried out through hydrogen peroxide (HP) directly or by using CP.[1] Certain studies have focused on the importance of tooth bleaching aspect. Compared with the restorative treatment process, bleaching, which is also called whitening, is the safest conservative approach for discolored teeth.[2,3]

Interestingly, both the terms "bleaching" and "whitening" are used confusingly by certain individuals. However, according to the Food and Drug Administration's definition, the former "is permitted to be used only when the teeth can be whitened beyond their natural color. This applies strictly to products that contain bleach—typically HP or CP."[4] The latter refers to removing debris and stain on tooth surfaces. In addition, any product, such as a toothpaste that cleans tooth surfaces is named a whitener. Whitening often enhances patients and encourages them to seek for further aesthetic treatment such as extrinsic tooth bleaching.[2]

It is crucial to diagnose correctly the intensity, type, and location of the tooth discolor to optimize the bleaching process and render it successful.[3] The process of bleaching can be used to overcome both extrinsic and intrinsic tooth colors.[5] The former may be due to drinking tea and coffee, smoking cigarettes, accumulation of plaque, and maintaining poor oral hygiene, while the

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latter may result from metabolic, inherited, iatrogenic, fluorosis, and aging processes. In addition, the internalized stain is another type of stain that enters the tooth surface through cracks.[6,7]

In general, bleaching is divided into intrinsic "non-vital" and extrinsic "vital" treatment modalities. The latter further subdivided into at-home (night guard, matrix, tray, and over-the-counter) and in-office (power bleaching, assisted-bleach technique, or waiting room surgery) techniques.[6,8,9] The former approach named walking bleaching, heat and light techniques or Shofu Hi-Lite.[5,6,8-11]

Among the bleaching ingredients, HP and CP are the most commonly used agents to remove stains and whiten tooth surfaces through different concentrations and time periods. However, HP is the most active ingredient agent of the two.[1,4,5,12,13]

This review article focuses on the tooth bleaching process and the impact of the mechanism on an individuals' teeth.

History of Tooth Bleaching

A variety of approaches have been attempted for cleaning and whitening of patients' teeth.[14] The process emerged thousands of years ago using a simple toothbrush-like tool,[15] Miswak, which is a tooth-cleaning stick, is popular among diverse communities with various names such as "miswak, qisa, qesam, mastic and koyoji" in Arabic, Aramaic, Hebrew, Latin and Japanese languages, respectively. Other ancient cleaning ingredients used were ground seashells, ground bone, and eggshells.[16]

Bleaching was first described in 1864.[17] Then, in the late 1960s, researchers had observed that CP causes lightening of the teeth. Klusmier was the first person who described successful home bleaching.[6,17,18] The concept of bleaching further developed until in 1989, they described the night guard vital bleaching as a new approach. In addition, certain years later, they described 10% CP or (3.3% HP) in a mouth guard for whitening teeth.[19]

Nowadays, extrinsic stains can be removed through a combination of both in-office and at-home techniques.[20] Currently, patients are able to keep their teeth due to the decline in tooth caries and improvements in oral hygiene and periodontal tooth tissues, all consequences of excellent education programs. Recently, both HP and CP have been used for different age groups to preserve their tooth appearance cosmetically.[6,8,9]

Types, Causes, and Color Appearance of Tooth Stain

To justify the reason why extrinsic tooth bleaching is required, Table 1 gives a brief concept about the types, causes, and colors of external tooth stains.[6]

Table 1: Types, causes, and color of extrinsic stains

Types of stain	*Causes*	*Color produced*
Direct stains	Tea, coffee, and other foods	Brown to black
	Cigarettes/cigars	Yellow brown to black
	Plaque/poor oral hygiene	Yellow/brown
Indirect stains	Polyvalent metal salts and cationic antiseptics (e.g., chlorhexidine)	Black and brown

Certain other causes also play a major role in tooth staining, such as diet, chemicals, teeth injury, opaqueness, aging, tooth grinding, and smoking.[21] Therefore, bleaching has become a popular process among men and women.[21] However, young women prefer this treatment option compared to other age groups. Stain removal can be measured through three common techniques, namely, using the Minolta chroma meter, Lobene stain index, and color shade guide.[22]

Highly Effective Methods of Extrinsic Tooth Bleaching

It appears from the name of the method that these agents can be used for external applications wherein agents have to pass through the enamel, which acts as a semi-permeable membrane. Here, this article will focus on the evidence proving the effectiveness and impact of external tooth bleaching rather than explaining the practical steps involved in each method.[11,23]

A variety of techniques are available for the extrinsic approach; however, the most popular approach includes in-office (power bleaching)[8] and at-home (night guard) treatment modalities.[5,8] Usually, dentists in dental clinics use 15 to 35% HP during[5] immediate in-office procedures. However, at-home procedures are achieved using 10 to 15% CP.[5] At-home bleaching is cheaper, simpler, less complicated, and the patient has a chance to repeat the process several times at home.[14]

Certain studies evaluated that the lower concentration (at-home bleaching using 10–15% or sometime 10–20% CP) approach might be safer and better than the higher concentration (in-office bleaching of 15–35% HP). A number of researchers prefer the night guard technique as a first choice.[5,24] The American Dental Association confirms that low concentrations, i.e., 10% CP, is an effective and safe product agent. However, it should be kept in mind that frequent repetitions of this method may cause irreversible damage similar to effects of high concentration bleaching agents that use over shorter periods.[5]

Regarding the in-office approach, it has been suggested that 35% high concentration HP is convenient for cases that need immediate treatment and/or cases that

show resistance to treat teeth through the night guard (tray) approach.[5,17] On the contrary, it has been reported that the combination of in-office and night guard vital bleaching coud be more effective in certain cases, such as in individuals with severe discolored teeth.[11,25]

Currently, it has been reported that the issues of teeth discoloration which due to the drinks, foods, cigarette smoking, brown fluorosis-stained teeth, single dark tooth, and tetracycline-treated teeth can be bleached by using 10% CP.[24] In addition, the study suggested to follow-up patients, who presented with tetracycline stains, for about 2-6 months using the night guard treatment plan. However, certain cases show earlier positive response than the mentioned time.[24] After treatment accomplished, certain cases might show relapse after the first 2 weeks.[24] Later on, the whitened tooth color becomes stable for at least 1 to 3 years. Sometimes the cases show permanent color stability.[24]

It is worthy to note that over-the-counter home bleaching technique should be considered significantly in terms of efficacy and safety because markets provide the public with products with no supervision of dentists.[8,26] Therefore, it is strongly recommended that these agents need to be used by professionals or under the supervision of skillful dentists to avoid risk hazards.[8]

Microabrasion is also another method, which includes mechanical and chemical reactions depending on HP and hydrochloric acid.[5,24] It is suitable for removing superficial stains and localized discoloration of teeth or when there is accumulation of a high amount of stains on the irregular enamel surfaces.[27] Nevertheless, the efficacy of this method is relatively limited due to the stains and chromogens which may be deeply stained the tooth layers.[5]

More recently, approaches have been simplified relying on 35% HP, used with a copolymer, NaF, CaF, and TiO_2 combination.[5] The main advantages of this technique are allowing the procedure to be carried out in the waiting room rather than as a chair-side approach, and there is also no need to protect gingiva.[5] Another contemporary method is using a disposable tray, which is prefilled with 9% HP, and offers inbuilt gingival protection.[6]

Overall, from the above-mentioned concepts, for each treatment approach, there are different controversies. It must be selected and decided upon judiciously as to which technique is appropriate to remove stains with better outcomes. However, the selection of the appropriate technique relies majorly on the operators' skill type and severity of the discolored teeth.[13,23] The results of bleaching usually depend on the causes and severity of stains.[5,23]

Bleaching Agents and Mechanism of Action

The mechanism of action of the bleaching process is based on usage of active ingredients, such as HP, which can be employed directly, or via chemical reactions from using sodium perborate or CP.[5,9,12,17,28-30] The HP is a strong oxidizing agent as it helps formation of reactive oxygen molecules, HP anions, and free radicals (FRs).[4] Carbamide peroxide is broken down to HP and urea by salivary enzymes.[11] For example, 3% HP and 7% urea are produced from breaking down of 10% CP.[23] Urea mainly acts as a stabilizer to provide a longer shelf life, slower release of the HP, and as a cariostatic.[31] Theoretically, it has been reported that urea breaks down further to give additional products, such as ammonia and carbon dioxide.[17] However, it is not clear about the amounts of ammonia and carbon dioxide formed during the bleaching process.[17] In addition, colored teeth are altered to noncolored one by the action of HP, oxidizing the organic constituents present in the inner enamel–dentin layers.[4]

In general, FRs are formed from the breaking down of HP. Therefore, they play a major role in the bleaching process by breaking down (C=C) bonds, which can be found in double-bonded organic tooth stains. Breaking down is carried out by anionic dissociation, photodissociation, or combining both.[9] Typically, lightening discolored teeth is achieved over hours or weeks based on dentists' or manufacturer's directions. It is considered that a high pH value (basic solution) facilitates the bleaching process.[17] This is due to the fact that the lower activation energy necessary to form FRs exists in a high pH solution compared with an acidic medium. It has been found that higher concentrations of bleaching agents with relatively longer time of application lead to faster whitening of teeth.[3] However, the frequent use of HP and CP agents beyond the required concentrations and extra applications are not free from potential risks. Therefore, using these agents under scientific guidelines is necessary.

$$Na_2[B_2(O_2)_2(OH)_4] + 2H_2O \longrightarrow 2NaBO_3 + 2H_2O_2 \quad (1)$$

$$H_2NCONH_2 \bullet H_2O_2 \xrightarrow[\text{in water}]{} H_2NCONH_2 + H_2O_2 \quad (2)$$

$$H_2O_2 \longrightarrow 2HO^{\bullet} \quad (3a)$$

$$HO^{\bullet} + H_2O_2 \longrightarrow H_2O + HO_2^{\bullet}$$

$$HO_2^{\bullet} \longleftrightarrow H^+ + O_2^{\bullet}$$

$$2H_2O_2 \longleftrightarrow 2H_2O + 2\{O\} \longleftrightarrow 2H_2O + O_2 \quad (3b)$$

$$H_2O_2 \longleftrightarrow H^+ + HOO^- \quad (3c)$$

The equations illustrate formation of hydrogen peroxide from sodium perborate (Eq. 1) and from carbamide peroxide (Eq. 2). Hydrogen peroxide forms free radicals like hydroxyl and perhydroxyl radicals, and superoxide anions (Eq. 3a), reactive oxygen molecules which are unstable and transformed to oxygen (Eq. 3b), and hydrogen peroxide anions (Eq. 3c).

Table 2: Factors affecting tooth bleaching

Factors	*Impact*
Bleaching type	Vital or nonvital bleaching
Concentration and time	10–15% CP or 15–35% HP either for 2 weeks, longer, or for 1 hour
Heat and light	Halogen, LED, UV, and plasma arc
Other factors	Plaque, pellicle on the tooth surface

LED: Light-emitting diode; UV: Ultraviolet

Ideal Properties and Factors Affecting Tooth Bleaching

Certain ideal properties, such as ease of application with optimum patient satisfaction, nonacidity, efficient and successfully lightening of teeth, nonirritating or dehydrating properties on soft/hard tissues, suitable peroxide concentrations, and the need to use limited quantities of the agents to provide maximum esthetic outcomes are crucial points that should be present in bleaching agents.[9] Certain parameters play a major role during the bleaching process. Table 2 shows the main factors.[28]

Recently, the term laser has been used among individuals. However, it is technically incorrect. Laser stands for light amplification by the stimulated emission of radiation. Most recently, in-office bleaching systems depend on halogen or light-emitted diodes or a combination of both.[32] Research has suggested that halogen rays would be an efficient source for tooth bleaching.[33]

Indications and Contraindications of Extrinsic Tooth Bleaching

Indications

Extrinsic tooth bleaching can be carried out in certain situations. For example, in a moderate discolored healthy tooth without significant structural defects, there is a good chance to bleach teeth with successful results.[34] Vital bleaching has been tried in certain cases, such as extremely discolored teeth; however, successful outcomes may be difficult to achieve.[5]

Other cases of discoloration can be distinguished such as an acquired stains, dentinogenesis, imperfecta,[5] fluorosis staining (mild, opaque, and pitting) types, tetracycline staining (1–4° staining) with the exception of severe cases, and lead poisoning.[5] Certain cases of discoloration due to physiological aging and, sometimes, post-traumatic discoloration (sclerotic dentin, but with vital pulp) can be treated by the extrinsic approach.[34]

Contraindications

In general, there are relative and absolute contraindications of vital bleaching. Relative contraindications include certain situations, such as very deep and prominent stains that cover the enamel–dentin layers.[36] The presence of several number of crowns, cervical lesions or incisal/occlusal attritions, and stains that are chiefly formed by amalgam ion release.[5]

Despite the above mentioned aspects, there are certain specific limitations while employing tray (night guard) bleaching, such as in cases of temporomandibular joint disorders, advanced periodontal disease, and presence of large number of amalgam fillings or temporary fillings (intermediate restorative material).[37] Recently, it has been suggested that certain cases need approaches to be used with caution, such as pregnancy gingivitis. However, it is not an absolute contraindication. Marginal leakage problems that may occur after bleaching may need to be taken care of.[5]

Regarding absolute contraindications, it is required to consider such cases. For instance, immature tooth tissues with large pulp horns, particularly, in patients under 15 to 16 years, hypersensitive tooth, and nonleak proof fillings (initial or recurrent caries) should be evaluated and treated precisely.[5] In addition, smoking should be avoided due to the possible interaction between cigarette ingredients and peroxide agents.[17]

Side Effects of Tooth Bleaching

Researchers have confirmed that there are numbers of crucial adverse effects that have been recognized after the bleaching process as shown in Table 3. Tooth sensitivity and gingival irritation are the most common adverse effects.[9] Sensitivity can be controlled by either passive or active treatment.[9] The former includes modifying the

Table 3: Effects associated with bleaching

Tissues	*Impact on tissues*
Gingivae (soft tissue)	Tissue sloughing
	Minor gingival irritation/ulceration
	Change in gingival texture
	Gingival soreness
Oral mucosa (soft tissue)	Sore throat
	Burning palate
	Unpleasant taste
Teeth (hard tissue)	Bleaching may occur in an uneven manner
	White spots may become more visible
	There may be a visible demarcation line between the color of the incisal tip and the cervical neck
Pain and sensitivity	Teeth may become sensitive, in particular, at the cervical margin, if gingival recession is present
Systemic	Mild laxative effect possibly due to the glycerin
	Free radicals formation during the bleaching process

frequency of application and bleaching time and also determine a convenient, concentration of the agent for patients. However, for the latter, the use of fluoride or potassium nitrate in a tray as a pretreatment choice or when symptoms occur is warranted.[9]

DISCUSSION

The process of tooth bleaching is a common process among most individuals. Therefore, stating the efficacy, effects, and biological safety is mandatory. Regarding efficacy, it has been reported that vital tooth bleaching using 10% CP night guard has the ability to whiten the tooth's surface to relatively two shades "2 folds."[38] Previously, the in-office approach was the most common approach and relied on the use of the acid-etch solution, 37% phosphoric acid. It was then followed using 30–35% HP with the aid of heat using lump or a contact instrument.[38]

Research, in a few instances, has reported that a number of dentists show priority for in-office technique due to the ease of monitoring and controlling the procedure.[38] However, recently, at-home approach has become a more popular option. It should be considered that it is difficult to predict results, such as degree of whitening, duration of treatment with number of required applications, response of stain for removal, and for how long the bleaching agents would remain effective.[38] It has been found that prolonged use of bleaching agents results in a chalky appearance, which is esthetically unacceptable.[39]

Regarding types of stain, moderate tetracycline discoloration shows acceptable outcomes after bleaching.[40] It has been found that the orange-brown to yellow color in older adults bleaches easily and faster than in teens and young adults.[38] Gray-blue stains are not easy to bleach, and moderate-to-severe dark colors have lesser response.[38] Researchers have suggested that neither at-home nor in-office can keep teeth white for life. Therefore, long-term follow-up would be necessary from 1 to 3 years.[6,30,35]

Regarding the effects of HP on hard tissues, such as enamel and dentin, certain studies have concluded that certain bleaching agents lead to alterations in the levels of sulfur, calcium, phosphorus, and potassium in the hard tissues.[41] Therefore, they may cause detrimental effects on the enamel–dentin layers, which is probably due to differences in the organic and inorganic constituents. Researchers have reported that the use of high concentration HP should be minimal as it causes microhardness of enamel–dentin layers significantly. For instance, the use of 30% HP shows this problem.[42]

Conversely, another study shows no significant change on enamel morphology when it has been exposed to 10% CP for 2 weeks. However, after 4 weeks, enamel hardness showed changes in terms of microhardness.[43] Another study recorded an initial significant alteration of enamel microhardness after the bleaching process, and then, remineralization of enamel was observed by the action of saliva and fluoride.[38]

Regarding pulp tissue, a study showed that both 10% CP and 35% HP may penetrate the pulp chamber and enhance pulp hypersensitivity. However, further studies are required to confirm the exact cause behind this process.[38]

Regarding safety issues and compatibility of peroxide bleaching agents, it must be remembered that the teeth whitening techniques have been used for more than 100 years. However, for the past two decades, concerns regarding safety during bleaching have increased significantly.[3] There are certain issues that may associate with FR oxygen by-products of HP metabolism, which may lead to biological tissue damage and oral cancer development. However, the exact mechanism is not well understood.[3,19,28,38] Certain studies have believed that the oxidation reaction of HP may enhance potential risk or even lead to carcinogenic activity, aging, stroke, liver problems, and/or other degenerative diseases.[9,44,45]

In addition, certain antioxidants, such as ascorbate, vitamin E, and glutathione encourage the body's defense mechanism against oxidation reactions and allow the system to remain healthy. However, a serious outcome may take place when the antioxidant capacity of the system is overwhelmed.[46] Another study has conducted that 10% CP may act as a tumor promoter in the presence of mutated cells. In addition, researchers believed that peroxide has a similar potential risk as that of smoking by stimulating cell division activity. For example, smokers may have a higher proliferation of the cell nuclear antigen, which is an indicator of cell proliferation, and increases in the basal and subbasal layers of epithelium, than nonsmokers.[29]

Regarding long-term exposure of peroxide, an *in vivo* animal study has shown that prolonged exposure of HP by itself may enhance pathological changes and may activate oral carcinogenesis associated with 9,10-dimethyl-1,2-benzanthracene, an analog of tobacco ingredient. It should be considered that animal studies cannot be generalized directly to human beings, but outcomes can be used to protect individuals from long-term exposure of HP, particularly, tobacco users.[38] To understand the exact concept behind this process, long-term *in vivo* scientific studies of human tissues are required.

Regarding short-term exposure, evidence suggests that HP may damage oral tissue when used chronically and cause severe tissue damage. A study has reported that 3% HP has shown certain detrimental results, such as delayed wound healing, leukoplakia, and ulcerations of labial mucosa and tongue with papillae erosion.[47] However,

it has been found that the short-term exposure shows reversible effects on enamel–dentin and pulp tissues.[38]

Regarding risk evaluation of external tooth bleaching, this can be divided into four stages: Risk characterization, hazard determination, dose–response correlation, and exposure assessment.[9] To assess the impact of bleaching agent, both safety factor (SF) and exposure (E) time should be calculated according to the following formula.[17]

SF = No observed adverse effect level/exposure

E = Amount of solution applied in the tray × concentration of HP × 25% ingested/Body weight (60 kg)

It has been reported that the minimum approved SF is 100. It should be considered that certain parameters reduce (SF) and increase (E), such as extended bleaching time per day, application of bleaching agents injudiciously, bleaching of both arches simultaneously, and overfilling tray during bleaching. Depending on the risk assessment, the exact safe concentrations with proper selection of the preparations are required to optimize patients' safety.[4,9,17]

Regarding the impact of bleaching process on dental restorative materials, the previous studies have focused on this matter and evaluated how the physical properties have been altered after exposing the dental materials to peroxide agents.[48] The detail of bleaching process impact on oral restorative materials has been argued in the following sections.

Regarding the impact on amalgam, certain studies confirmed that HP and CP affect the surface properties, such as microhardness, roughness, and elution. A study reported that there is no significant enhancement of metal ion release from amalgam with 10% CP.[1] Conversely, another study have found an increase of metal ion release when the amalgam surface has been exposed to various concentrations of HP (1, 3, 10, and 30)%.[48] Another literature confirmed the similar outcome using 10% CP. However, the amount of metal ion release has shown no significant health hazard.[49]

Certain factors may play a major role in increasing the mercury release, such as old amalgam, unpolished rough surfaces, and low pH of bleaching agents. For instance, a research has reported that mercury release is time-dependent and significantly higher in old amalgam restorations than in fresh amalgam. In addition, it reveals that mercury release is pH-dependent and higher in unpolished amalgam.[50]

Regarding microhardness and roughness of amalgam, certain studies have shown no significant changes.[1,49] A case report study has linked the chipping of the amalgam surface with green color after bleaching with 10% CP.[48] It has been reported that dentists have to check amalgam margins for marginal integrity to prevent risks of ion release and inhibit green color by removing amalgam, especially near the esthetic zone, before starting the bleaching process.[48]

Regarding the impact on composite resin, a significant color change has been reported with nanohybrid and packable composites after treatment with 15% CP, while another study recorded surface alterations with 35% HP when a low density microfilled composite was used.[48] In addition, studies have reported that after bleaching the composite, surface hardness significantly decreased. This phenomenon was recorded in both deep and superficial layers. Therefore, it should be considered that bleaching agents may weaken adhesive bonding in the deep layer of composites and may result in bond failure between tooth substrate and composite materials.[13,48] Furthermore, another study confirmed a significant decrease in microhardness after using different peroxide concentrations.[48]

Interestingly, occlusal marginal restorations are not affected after bleaching with 20% CP of class I composite restoration. Therefore, there is no chance of marginal leakage. The similar outcome was found when studies on 20% CP and 35% HP for class V composite resin were made; however, for class II restorations, further studies are required.[48]

Recently, it has been found that 15% CP increased surface roughness of composite after bleaching, which may result in accumulation of plaque. The composites might keep their color, at the same time, enamel shows susceptibility to color change after bleaching process. In addition, it has been found that bleached composites release fewer bisphenol A glycidyl methacrylate and urethane dimethacrylate than the unbleached type. Further, it has been reported that bleached composites may stain more easily than nonbleached one after accomplished process.[48] Regarding impacts on glass ionomer cement (GIC) and resin-modified GIC (RMGIC), studies have shown that 15% CP and 35% HP cause significant reduction in surface hardness of RMGIC.[47] Although a significant color change has been recorded with conventional GIC, after using 15% CP for 4 weeks, it returned to the pretreatment condition after 2 weeks. In general, color changes may be associated with GIC and MGIC after exposing to bleaching agents. Hence, it is recommended to replace an old filling with a new one to keep restorations with esthetic surface texture.[47]

A further impact on compomer dental restorative materials has confirmed that 10 to 15% CP shows a significant change in surface properties, such as color change, increased surface roughness, porosity, dissolution, and crack formation. In addition, the surface is prone to take the color of Coca-Cola, red wine, coffee, and tea after bleaching with 15% CP. Therefore, it is recommended to polish or replace compomer after bleaching process.[47,51]

The impact on ormocer has shown a significant color change when exposed to 10% CP or 35% HP. Hence, after bleaching, it requires new restoration. However, it does not show a significant change in microhardness after exposure to 35% HP. Studies have shown that a low amount release of bisphenol-A is associated with bleached ormocer in comparison to nonbleached one. It has been concluded that bleaching of ormocer is not associated with the risk of health hazard, while it causes potential color change of restored teeth.[19,47,51]

Studies have shown the impact of bleaching process on porcelain.[47] Literatures have concluded that different concentrations of HP and CP influences on surface hardness with microhardness of porcelain materials. Dentists have to instruct patients to avoid bleaching of ceramic restorations. In particular, those of the anterior esthetic zone.[4,47]

Regarding the public satisfaction after teeth bleaching, certain studies have focused on this aspect. For example, a study has found that in the UK 28% of adults are dissatisfied with their discolored teeth, while this number is reported to be greater 34% among the US population.[28]

Another study reported change in outcomes among the UK and the US populations; 12 to 15% and 17 to 21% respectively. However, still, the percentage in the USA shows a higher dissatisfaction rate than the UK. In addition, in China, this figure was found to be about 52.5%. This difference may be due to better and rapid improvements of oral health promotion in the UK than in the US or China.[13]

Further, a research has shown that 28% among the UK population and 50% in the United States were dissatisfied with their discolored teeth. Another literature has reported that the American population spends more than $1 million for home bleaching annually,[8] this reflects patients' demand toward the aesthetic concern.

CONCLUSION

Depending on the previous outcomes, it can be concluded that at-home bleaching technique appears to be the safest technique currently available, which is rapid, easy, and cheap. However, the correct case selection mandatory. The in-office method provides acceptable outcomes, while it may be insufficient for extreme discoloration. It should be considered that time and concentration are two crucial parameters that have a great role in the successful bleaching process. These techniques are not free from hazards; therefore, using these agents under supervision and consultation is of great concern.

It is predicted that the future trends of tooth bleaching would mainly include using activating agents to increase the effect of HP and natural enzymes present in human saliva. Future technologies will focus more on home-bleaching agents. The reasons being saving patients and dentists' time, cost-effectiveness, ease of use at-home, and portability. Finally, it is also predicted that bleaching approaches would become further digitalized than today's options.

REFERENCES

1. Al-Salehi SK, Hatton PV, Miller CA, McLeod C, Joiner A. The effect of carbamide peroxide treatment on metal ion release from dental amalgam. Dent Mater 2006 Oct;22(10): 948-953.
2. Kihn PW. Vital tooth whitening. Dent Clin North Am 2007 Apr;51(2):319-331.
3. Majeed A, Farooq I, Grobler SR, Rossouw RJ. Tooth-bleaching: a review of the efficacy and adverse effects of various tooth whitening products. J Coll Physicians Surg Pak 2015 Dec;25(12):891-896.
4. Kwon SR, Wertz PW. Review of the mechanism of tooth whitening. J Esthet Restor Dent 2015 Sep-Oct;27(5):240-257.
5. Sulieman MA. An overview of tooth-bleaching techniques: chemistry, safety and efficacy. Periodontol 2000 2008;48: 148-169.
6. Hattab FN, Qudeimat MA, al-Rimawi HS. Dental discoloration: an overview. J Esthet Dent 1999;11(6):291-310.
7. Duron A. Which foods actually stain your teeth...and which don't. Todays FDA 2016;28(4):12-15.
8. Thickett E, Cobourne MT. New developments in tooth whitening. The current status of external bleaching in orthodontics. J Orthod 2009 Sep;36(3):194-201.
9. Dahl JE, Pallesen U. Tooth bleaching—a critical review of the biological aspects. Crit Rev Oral Biol Med 2003;14(4): 292-304.
10. Attin T, Paqué F, Ajam F, Lennon AM. Review of the current status of tooth whitening with the walking bleach technique. Int Endod J 2003 May;36(5):313-329.
11. Alqahtani MQ. Tooth-bleaching procedures and their controversial effects: a literature review. Saudi Dent J 2014 Apr;26(2):33-46.
12. Haywood VB. Nightguard vital bleaching: current concepts and research. J Am Dent Assoc 1997 Apr;128 (Suppl):19S-25S.
13. Joiner A, Hopkinson I, Deng Y, Westland S. A review of tooth colour and whiteness. J Dent 2008;36 (Suppl 1):S2-S7.
14. Perdigão J, Baratieri LN, Arcari GM. Contemporary trends and techniques in tooth whitening: a review. Pract Proced Aesthet Dent 2004 Apr;16:185-192.
15. Connelly T. The history of the toothbrush: from 5000 BC to present. 2011. https://www.huffingtonpost.com (Accessed Jun 22, 2017).
16. Norton MR, Addy M. Chewing sticks versus toothbrushes in West Africa. A pilot study. Clin Prev Dent 1989 May-Jun;11(3):11-13.
17. Margeas R. New advances in tooth whitening and dental cleaning technology; 2014. Available from https://www.dentalacademyofce.com (Accessed Aug 18, 2017).
18. Haywood VB. Nightguard vital bleaching and in-office bleaching. Contemp Esthet Rest Pract 1998 Jul/Aug;78-81.
19. Goldberg M, Grootveld M, Lynch E. Undesirable and adverse effects of tooth-whitening products: a review. Clin Oral Investig 2010 Feb;14(1):1-10.

20. Martos J, Kinalski M. Combined in-office and take-home bleaching in vital teeth. J Rest Dent 2014;2(3):149-153.
21. Nakonieczna-Rudnicka M, Bachanek T, Madejczyki M, Grajewskai I, Kobylecka E. Teeth whitening versus the influence of extrinsic factors on teeth stains. Przegl Lek 2015; 72(3):126-130.
22. Haywood VB. Current status of nightguard vital bleaching. Compend Contin Educ Dent (Suppl) 2000;S10-S17.
23. Joiner A. The bleaching of teeth: a review of the literature. J Dent 2006 Aug;34(7):412-419.
24. Croll TP. Enamel microabrasion for removal of superficial dysmineralization and decalcification defects. J Am Dent Assoc 1990 Apr;120(4):411-415.
25. Mountouris G, Mantzavinos Z, Michou H. Discolorations: a new method of bleaching discolored vital teeth. (Preliminary study). Odontostomatol Proodos 1990 Jun;44(3):195-206.
26. Ghalili KM, Khawaled K, Rozen D, Afsahi V. Clinical study of the safety and effectiveness of a novel over-the-counter bleaching tray system. Clin Cosmet Investig Dent 2014 Feb;6:15-19.
27. Sarrett DC. Tooth whitening today. J Am Dent Assoc 2002 Nov;133(11):1535-1538.
28. Naik S, Tredwin CJ, Scully C. Hydrogen peroxide tooth-whitening (bleaching): review of safety in relation to possible carcinogenesis. Oral Oncol 2006 Aug;42(7):668-674.
29. Haywood VB. Frequently asked questions about bleaching. Compend Contin Educ Dent 2003 Apr;24(4A):324-338.
30. Kugel G, Ferreira S. The art and science of tooth whitening. J Mass Dent Soc 2005 Winter;53(4):34-37.
31. Joshi S. An overview of vital teeth bleaching. J Interdiscip Dent 2016;6(1):3-13.
32. Magne P. Megabrasion: a conservative strategy for the anterior dentition. Pract Periodontics Aesthet Dent 1997 May;9(4):389-395.
33. Liang S, Sa Y, Jiang T, Ma X, Xing W, Wang Z, Wang Y. In vitro evaluation of halogen light-activated vs chemically activated in-office bleaching systems. Acta Odontol Scand 2013 Sep;71(5):1149-1155.
34. Fearon J. Tooth whitening: concepts and controversies. J Ir Dent Assoc 2007 Autumn;53(3):132-140.
35. Tay LY, Kose C, Herrera DR, Reis A, Loguercio AD. Long-term efficacy of in-office and at-home bleaching: a 2-year double-blind randomized clinical trial. Am J Dent. 2012;25(4):199-204.
36. Rostein I, Cohenca N, Mor C, Moshonov J, Stabholz A. Effect of carbamide peroxide and hydrogen peroxide on the surface morphology and zinc oxide levels of IRM fillings. Endod Dent Traumatol 1995 Dec;11(6):279-283.
37. Craig BJ, Supeene L. Tooth whitening: efficacy, effects and biological safety. Pro Sci J 1999 Nov/Dec;33(6):169-174.
38. Rotstein I, Dankner E, Goldman A, Heling I, Stabholz A, Zalkind M. Histochemical analysis of dental hard tissues following bleaching. J Endod 1996 Jan;22(1):23-25.
39. Santos HM, Borges AB, Pucci CR, Torres CR. Efficacy of bleaching treatment on demineralized enamel treated with resin infiltration technique. World J Dent 2012 Oct-Dec;3(4):279-283.
40. Suchetha AK, Mundinamane DB, Apoorva SM, Bhat D, Govindappa L. All about dental stains: a review (Part I). Ann Dent Spec 2016 Apr-Jun;4(2):41-46.
41. Lewinstein I, Hirschfeld Z, Stabholz A, Rotstein I. Effect of hydrogen peroxide and sodium perborate on the microhardness of human enamel and dentin. J Endod 1994 Feb;20(2): 61-63.
42. Shannon H, Spencer P, Gross K, Tira D. Characterization of enamel exposed to 10% carbamide peroxide bleaching agents. Quintessence Int 1993 Jan;24(1):39-44.
43. Li Y. Toxicological considerations of tooth bleaching using peroxide-containing agents. J Am Dent Assoc 1997 Apr;128 (Suppl):31S-36S.
44. Goldstein GR, Kiremidjian-Schumacher L. Bleaching: is it safe and effective? J Prosthet Dent 1993 Mar;69(3):325-328.
45. Floyd RA. Role of oxygen free radicals in carcinogenesis and brain ischemia. FASEB J 1990 Jun;4(9):2587-2597.
46. Rees TD, Orth CF. Oral ulcerations with use of hydrogen peroxide. J Periodontol 1986 Nov;57(11):689-692.
47. El-Murr J, Ruel D, St-Georges AJ. Effects of external bleaching on restorative materials: a review. J Can Dent Assoc 2011;77:b59.
48. Al-Salehi SK, Hatton PV, McLeod CW, Cox AG. The effect of hydrogen peroxide concentration on metal ion release from dental amalgam. J Dent 2007 Feb;35(2):172-176.
49. Rotstein I, Avron Y, Shemesh H, Dogan H, Mor C, Steinberg D. Factors affecting mercury release from dental amalgam exposed to carbamide peroxide bleaching agent. Am J Dent 2004 Oct;17(5):347-350.
50. Hannig C, Duong S, Becker K, Brunner E, Kahler E, Attin T. Effect of bleaching on subsurface micro-hardness of composite and a polyacid modified composite. Dent Mater 2007 Feb;23(2):198-203.
51. Attin T, Hannig C, Wiegand A, Attin R. Effect of bleaching on restorative materials and restorations—a systematic review. Dent Mater 2004 Nov;20(9):852-861.