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Materials used for bleaching and their effects on dental materials: a review

N.A. Nasr[1]

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[1] *Department of Dental biomaterial, Faculty of dentistry, Assiut University, Assiut, Egypt.*

* Corresponding author e-mail: *nermeen.ahmed@dent.aun.edu.eg*

Abstract: Over the years, bleaching agents were developed and new materials were introduced to facilitate the bleaching process for both the dentist and the patient. Several studies were made to evaluate the effect of such agents on different materials used in dentistry. This paper will describe different types of bleaching agents along with their possible effect on restorative materials.

Keywords: Bleaching**;** *Bleaching materials; Bleaching agents; Materials properties; Composite resin; Glass ionomer; Amalgam; bonding; Restorative materials.*

Tooth discoloration has been an ongoing problem affecting patients and making them seek treatment.Tooth discoloration can be intrinsic (affecting deeper layers of tooth structure), extrinsic (affecting outer tooth layer) or both. Causes of intrinsic tooth discoloration can be genetic conditions (amelogenesis imperfecta), systematic conditions (porphyria and jaundice), body byproducts (hemoglobin and bilirubin), trauma, restorative materials (amalgam restoration) and medications taken during tooth development (fluoride and tetracycline). Extrinsic tooth discoloration can be caused by chromogenic bacteria and plaque, tobacco and cigarettes, food and beverage, chemicals (chlorhexidine) and poor oral hygiene. Causes of both intrinsic and extrinsic discoloration can be either aging or fluorosis. Generally Extrinsic stains are easier to remove than intrinsic stains because intrinsic stains are stains that became incorporated inside tooth matrix. [1,4] Along the years, many advancements were made and many materials were discovered in order to solve this problem and get better results. the bleaching materials used will be discussed in this topic, along with the possible effects that bleaching materials may have on other materials used in dental field. [1, 2]

History of bleaching materials:

Non- vital tooth bleaching started as early as 1848 by using chloride of lime. Later, many materials were introduced as sodium hypochlorite solution and oxalic acid. In 1868, the first attempt to bleach vital tooth was made using oxalic acid and by 1911, hydrogen peroxide material was introduced with the possibility of using light or heating source along with it. In 1960, an orthodontist named Dr. Bill Klusmier introduced “over the counter” home bleach which contained 10% carbamide peroxide. Bleaching materials continued to develop. Nowadays,

there are home bleaching methods using lower concentrations and in office bleaching methods using higher concentrations. [3]

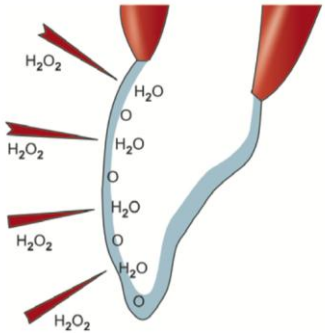
Composition of commercial bleaching materials:

1- Active ingredient:
Hydrogen peroxide, carbamide peroxide and sodium perborate.
2- Thickening agents
3- Surfactant
4- Carrier agent
5- Preservatives
6- Flavoring agents

1. Active ingredients:

1.1. Hydrogen peroxide: It is the most used material in bleaching agents. It is used in 5% to 35% concentrations.This range of concentrations is used according to method of use, stain severity and method of activation. Method of use affects concentration used as home bleaching uses low concentrations (5-10%) while in-office bleaching uses higher concentrations (30-35%); Stain severity affects the concentration used as lower concentrations are used for mild stains while high concentrations 30-35% are used for severe stains.[4] Method of activation affects the concentration of hydrogen peroxide used as new generation is introduced with low concentrations (3.5-15%) with semiconductor catalyst to potentate the oxidation reaction for in- office bleaching. This new generation is considered to be safer to use due to its lower concentrations.[14] Hydrogen peroxide was used in liquid form which is applied to the tooth, however it is now available in gel form. The gel form is preferred because it prolonged its shelf life and prevented its leakage from the tray. It is used in both in- office and home bleaching. [4]

Mechanism of action: Hydrogen peroxide divides into water and oxygen particles. Those unstable free radicals penetrates the tooth and remove the stain particles by attacking the double bonds. The break down of the double bonds results in smaller particles; This process affects the color absorption of the tooth and gives whiter appearance (fig.1) .[3]



Figure(1) The breakdown of hydrogen peroxide into water and oxygen particles that penetrates into the tooth structure causing oxidation of the pigments.

1.2. Carbamide peroxide: It is also known as urea hydrogen peroxide. It is used in concentrations from 3% to 45%. [4] Carbamide peroxide is available in gel form and can be supplied in syringe for ease of application since it can be used in home bleaching with low concentrations while high concentrations can be used in an in-office bleaching.

Mechanism of action: Carbamide peroxide breaks down to hydrogen peroxide and urea and thus is given the name urea hydrogen peroxide. The urea has many advantages which are stabilization of hydrogen peroxide and elevation of the PH (fig.2).[5]

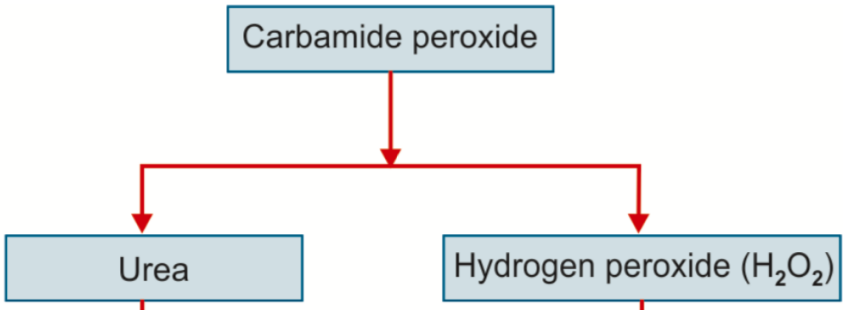


Figure (2) Carbamide peroxide mechanism of action by breaking down into urea and hydrogen peroxide.

1.3. Sodium perborate: sodium perborate powder is used with hydrogen peroxide due to their synergistic effect. Many recommended using such combination inside root canals in non- vital tooth bleaching.

Mechanism of action: Although sodium perborate does not contain hydrogen peroxide, it was found that when it breaks down, it releases hydrogen peroxide. Sodium perborate works more effectively with increasing the temperature over 55 ° c. To be able to be used in the temperature of the mouth, tetraacetylethylenedi- amine (TAED) organic activator is added to it. It should be noted that sodium perborate is banned in Europe and is considered as fetotoxic and cytotoxic material.[5]

2- Thickening agents: Carbopol (carboxypolymethylene) is the most used thickening agent used to increase the viscosity of the material and thus the material does not fall from tray. It also increases the time of oxygen release from the bleach material.

3- Surfactant: The surfactant is used to increase the efficacy of bleaching materials by increasing the wettability of the surface by them and so allow better diffusion of the materials inside the tooth.

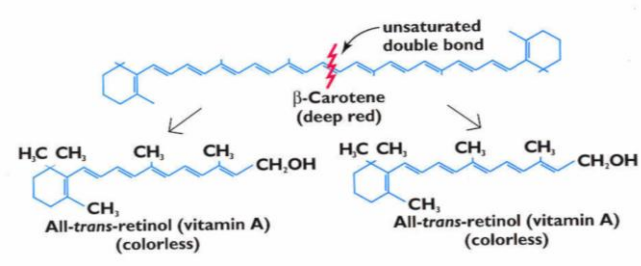
4- Carrier agent: Glycerin is used to help other ingredients to dissolve.

5- Preservatives: Sodium benzoate is used to prevent bacterial growth.

6- Flavoring agents: As peppermint, used to allow better patient acceptance. [3]

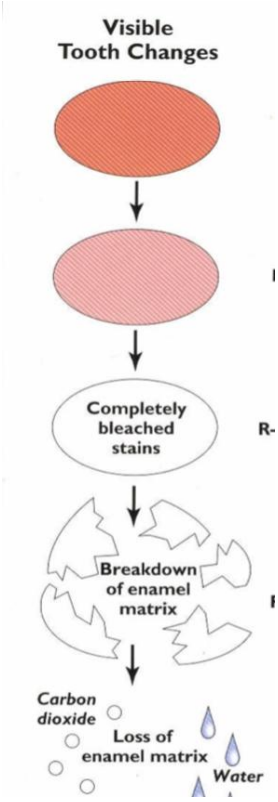
Pigment removal mechanism:

The process of pigment removal is through redox reaction, in which the hydrogen peroxide is oxidized forming free radicals. The free radicals released from the bleaching materials are unstable. They penetrate into organic matrix of the tooth structure and attack the bonds of the pigments to break the pigment into smaller structures that are colorless. An example can be beta carotene which is reduced by hydrogen peroxide free radicals into two colorless structures (fig.3).[6]



Figure(3) The reduction reaction of beta carotene into two smaller colorless structures

Saturation point: This occurs when all pigmented structures are changed into colorless ones. If bleaching material is left beyond this point, it will cause breakdown of the tooth structure which could lead to tooth brittleness and increase in porosity (fig.4).[6]



Figure(4) The saturation point is reached when all pigmented stains become colorless; Extended bleaching beyond this point will cause breakdown of the tooth matrix.

Techniques of bleaching:

Bleaching techniques can be classified into vital and non vital

For vital tooth:

- **Home bleaching:** Using 15% hydrogen peroxide or 1-10% hydrogen peroxide. A tray is made for the patient and the patient is instructed to put the material in the tray and wear the tray daily. Patient is called for checkups with the dentist to evaluate progress.

- **In-office bleaching**: There are 2 types, which are thermocatalytic and non thermocatalytic.

Thermocatalytic in-office bleaching is done using light source either conventional light or tungsten halogen light.

Apart from using heat to accelerate the radical release from hydrogen peroxide, there are methods that use light source in the presence of photosensitive agents or photocatalysts inside the bleaching materials that absorb the energy from the light/ laser and are activated to accelerate the hydrogen peroxide reaction(Photolytic reaction) and thus increase the amount of free radicals produced and the efficacy of bleaching material.[24]

Procedure: Teeth are isolated and polished. The bleaching material (30-35% hydrogen peroxide) is applied and the light is adjusted. Bleaching material is changed every 5 minutes and then finally removed.

Non-thermocatlytic in-office bleaching is done without the use of light source.

Procedure: teeth is isolated with rubber dam and then 30-35% hydrogen peroxide is applied for 5 minutes and then washed.[4]

- **Over the counter whitening products:**

As whitening kits, whitening tooth pastes, whitening chewing gum, whitening floss, whitening mouthwash,[5] whitening pens and whitening strips.Whitening pens release active oxygen that results in tooth whitening. Whitening strip is a flexible plastic that contains hydrogen peroxide or carbamide peroxide and is applied to the teeth by the patient; Since it is 2D strip, it can not be shaped according to the contours of teeth and so lacks precision. [25] Such materials may cause a lot of problems such as enamel erosion, loss of anatomy and tooth sensitivity because they are usually used by the patients without dentist supervision. The patient can overuse them or misdiagnose his condition.[5]

For non-vital tooth:

- **Thermocatalytic in-office bleach**

After tooth isolation, hydrogen peroxide and sodium perborate are used separately, or together and light source is applied.

- **Walking bleach (intracoronal bleach)**

Tooth is isolated and the coronal gutta percha of endodontically treated tooth is removed and then sodium perborate is applied inside the tooth. If the staining is severe 3% of hydrogen peroxide is used with sodium perborate. Temporary restoration is placed, and patient is recalled after 1-2 weeks. [4]

Factors affecting the bleaching agents efficacy:

1-Hydrogen peroxide concentration:

Using higher concentration of hydrogen peroxide leads to increase in its effect.

2- Temperature:
Every 10 ° c increase in temperature increases the rate of the bleaching chemical reaction by the double, however, the temperature increase should be within patient tolerance.

3- pH:
During storage, bleaching agents should be kept in acidic pH. The optimal pH for the reaction of the bleaching materials to take place is 9.5 to 10.8. In lower pH, bleaching materials tend to be less effective.[6] Due to its instability at alkaline pH, Hydrogen peroxide should be mixed with alkalizing solution just before use and therefore most of the bleaching materials comes in two syringes that require mixing.[15]

4- Time:
The effect of the bleaching materials is directly dependent on the amount of time it is exposed to the tooth.[6] Nevertheless, bleaching is done usually in three applications per one visit and the maximum time allowed is 15 -20 minutes per application. This may differ according to manufacture instructions.[16]

5- Method of activation:
Light activated bleaching materials result in increase in the free radicals produced by the bleaching material and so increase bleaching efficacy. [24]

Age restrictions of bleaching agents:
It was thought that bleaching is prohibited for children with deciduous teeth due to the large size of pulp chamber, however the american academy of pediatrics has approved the use of bleaching agents on both primary and mixed dentitions with lower concentrations of bleaching agents and under the supervision of a dentist.[18]

Contraindications of bleaching:
1- Emotional or psychological problems: loss of compliance.
2- Dentin hypersensitivity
3- Hypoplastic tooth: it will increase the color difference between the tooth structure and white spots.
4- Teeth with defective restorations.[4]
5- patients with photosensitive condition cannot undergo bleaching with light or laser. [25]
When Bleaching is contraindicated, several treatment options are available such as selective grinding of tooth (microabrasion), resin infiltration, composite restoration, veneers and full coverage crowns. [27]

Effect of bleaching materials on different dental materials properties:

1.Tooth structure:
Enamel: Erosion and loss of aprismatic layer was observed along with decrease in enamel surface hardness due to the degradation of enamel matrix by the bleaching materials. Decrease in calcium/ phosphorus ratio of enamel was also observed.

Dentin: Bleaching agents removed smear layer effectively from dentin, however, they left residue that affect the bonding of dentin with the adhesive and glass ionomer.[5] Bleaching agents and their thickening agents (carpabol) decreased surface hardness of dentin. [3]

Pulp: According to studies, bleaching materials can reach the pulp in 15 minutes and cause transient and reversible decrease in blood circulation to the pulp and glycerin present in bleaching materials can cause dehydration of tooth structure.[29] This can result in the patient feeling mild sensitivity after bleaching; This sensitivity increases with increasing the concentration of the bleaching agent used.[5]

Cementum: External root resorption and cervical resorption are reported to occur with non-vital tooth bleaching, but cementum is usually not affected by vital tooth bleaching.[5]

2.Composite resin:

Many studies were made on how the properties of composite resin restorative material were affected by the bleaching agents; Those studies had conflicting results, but they all agreed that some aspects of resin composite showed changes after bleaching.

Tensile strength: Microfilled composite resin showed decrease in tensile strength with bleaching while hybrid composite showed less significant change.This can be caused by the oxidative reactions of hydrogen peroxide that lead to degradation of polymer matrix and affect its cohesiveness and therefore composite resin having more concentration of resin matrix as in microfilled composite shows more degradation and decrease in tensile strength.[17]

Surface hardness: The effect of bleaching agents on surface hardness of composite resin is controversial. The depth of penetration of hydrogen peroxide is controlled by the concentration used and thus different concentrations of hydrogen peroxide have different impact on surface hardness.; For example, resin composite exposed to hydrogen peroxide with 14% concentration showed increase in hardness due to the fact that bleaching agent removed the surface layer and thus exposed more filler particles to the surface so the material showed increased surface hardness. On the other hand, resin composite exposed to 40% hydrogen peroxide showed decrease in surface hardness. This could be attributed to the release of the free radicals from bleaching agent causing debonding of filler and acceleration of the hydrolytic degradation.[7]

Bond strength

Torneck et al. (1991) discovered that the bond strength of freshly placed composite restoration made after bleaching is affected negatively by the bleaching materials. This could be attributed to the fact that newly bleached enamel has fewer, shorter and less defined resin tags in addition to the remaining oxygen on the surface of enamel causing inhibition of the polymerization to the resin composite.
It is therefore recommended to wait from 1 to 2 days up to 1 week following bleaching session before application of bond,[5] however, many recent studies suggested the use of ascorbic acid gel as antioxidant for 60 minutes after bleaching materials immediately showed improvement in bond strength. Although ascorbic acid can cause enamel erosion with prolonged exposure, the gel form of ascorbic acid slowed the rate of release of substance from the acid and thus allowed the use of ascorbic acid for longer times on tooth structure and increased its efficacy. (Kaya et al. 2008) .[19]

On the other hand, bond strength of an already existing composite restoration showed decrease after bleaching, which could be caused by the release of the free radicals which could attack the hybrid layer. The higher the concentration of the bleaching agent used, the higher the effect it has on the strength of the bond.[3]

Microleakage and bacterial adhesion: Increase in microleakage was observed in composite resin.[4] Microleakage should be differentiated from nanoleakage. Microleakage is the formation of gap between enamel/ dentin and restoration while nano leakage is nanoporosities formed within the hybrid layer even without marginal gap formation. [28]

Adhesion of salivary proteins was less after bleaching and this affects the adhesion of cariogenic bacteria to the tooth.[3]

Surface roughness and porosity: Composite resin showed increase in surface roughness and increase in surface porosities.[4] This is due to the softening of resin matrix and displacement of filler particles under the effect of the bleaching agent and the debonding of filler particles by the free radicals released (fig.5). [20]

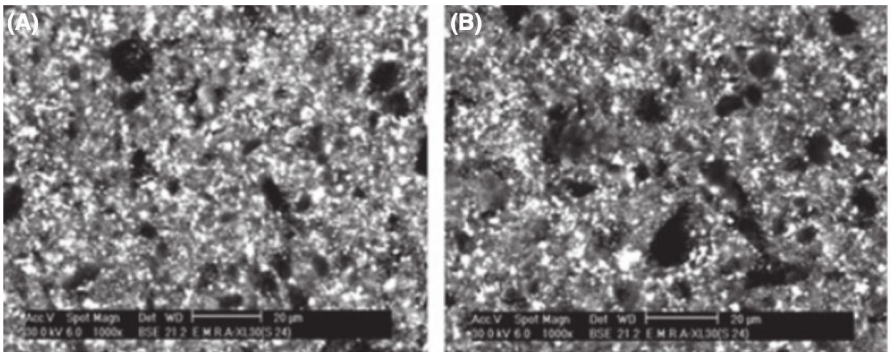


Figure (5) A) SEM of composite resin before bleaching. B) SEM of composite resin after bleaching showing increase in pores due to filler dislodgment.

Color stability: Color stability after bleaching was variable in different types of composite resin. This can be attributed to their different degrees of conversion and amount of fillers. The color stability of resin composite is dependent on the stability of its resin matrix. The color change of composite resin after bleaching is due to the oxidation of surface pigments. It is advisable to polish composite resin after bleaching to decrease the coloration that can be caused by the retention of microorganism to the rough surface caused by bleaching (fig.6).[3]

It should be noted that although these changes were detected, neither had real clinical impact.[5]

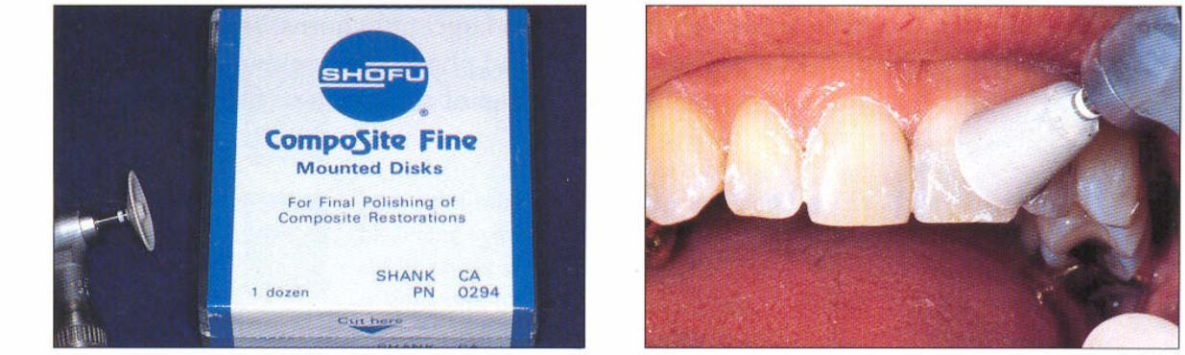


Figure (6) Polishing of composite resin following bleaching treatment is recommended to decrease the discoloration of composite restoration.

3. Amalgam restoration:

The effect of bleaching on amalgam restorations is mainly due to active oxidation process by the bleaching agents and microstructure changes within the amalgam.[8]

Surface hardness: No significant change in surface hardness of amalgam was detected after bleaching.[9]

Color stability:
Bleaching materials changed color of amalgam from black back to silver due to removal of the surface film of corrosion products formed [26]. Some amalgam showed greenish discoloration due to their copper composition.[5]

Corrosion:
Although studies made on the effect of the bleaching agents on amalgam restorations placed in the oral cavity suggested that bleaching agents caused increased release of mercury and other corrosive substances from the amalgam, they were found to be within the limit accepted by the world health organization.Unpolished amalgam showed more release of mercury compared to polished amalgam restoration, so it was recommenced to polish amalgam restorations and apply varnish before bleaching in order to limit the release of mercury.[10]

4. Dental alloys:
Corrosion: Bleaching agents have the same effect on dental alloys as on amalgam. They cause corrosion of the dental alloys, except noble alloys. It is also advisable to polish dental alloys before bleaching application to limit the release of the corrosive products.[8] A study made on different dental alloys showed that, except for gold alloys, all dental alloys (Ni–Cr–Mo, titanium) were liable to corrosion with bleaching agents. The rate of corrosion increased with increasing the concentration of bleaching agents used. The materials known for their passive layer were not able to maintain stable passive layer and the layer is usually destructed when exposed to bleaching agents due to high ion concentrations.[21]

5 Ceramics:
Surface hardness: Decrease in surface hardness was observed; this could be due to the decrease of SiO_2 that forms the matrix and thus affects the hardness.[22]
Color stability: Ceramics containing polymers showed color changes due to the polymer lacking chemical stability and thus is liable to color change when exposed to bleaching agents. Glazed porcelain showed no color change unlike unglazed porcelain.[11]

6. Provisional restoration:
Surface properties: Provisional materials showed cracking and swelling with hydrogen peroxide but appear to be unaffected by carbamide peroxide.[5]

Color stability: Methacrylate based provisional material showed orange discoloration with bleaching materials; On the other hand, bis- acryl composite based provisional materials showed no discoloration.[8]

7. Polymodified resin composite (compomer) and Glass ionomer cement:

Strength and hardness: Mechanical properties of glass ionomer such as compressive strength and hardness seem to decrease with bleaching agents;[12] This could be due to the alteration of glass iono-

mer matrix as it begins to erode when exposed to bleaching agents and the glass particles start to dislodge. Softening of glass ionomer occurs due to failure of bonds by the free radicals released from bleaching agents.[23]

Color stability: Color change with bleaching agents was also observed in compomers.[8] Glass ionomers shows the most noticeable color change of all esthetic restorative materials because it naturally lacks color stability due to the poly acid content and due to the degradation of its metal polyacrylate salts by the bleaching materials.[13]

Degradation and fluoride release: Bleaching agents with high concentrations used on compomers induced softening to the surface with surface degradation and increased fluoride release, however with smaller concentrations, there were no apparent changes in compomer nor glass ionomer.[8]

CONCLUSION

Bleaching materials, although advantageous for patients complaining from unappealing tooth discoloration, can cause many deleterious effects on other materials used in dentistry. Those changes can compromise their mechanical, physical or biological properties. Care and understanding of the chemistry of bleaching materials are necessary in order to prevent or decrease these effects to increase the durability of such materials and allow the patients to be satisfied with their teeth shade.

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