

## MODERN CONCEPTS OF TEETH WHITENING – A NARRATIVE REVIEW

*Svitlana Boitsaniuk<sup>1</sup>*

*Orest Kochan*

*Department of Measuring Information Technology  
Lviv Polytechnic National University  
12 Stepana Bandery str, 12, Lviv, Ukraine, 79013*

*Mariana Levkiv<sup>1</sup>* ✉  
*levkiv@tdmu.edu.ua*

<sup>1</sup>*Department of Dental Therapy  
I. Horbachevsky Ternopil National Medical University  
1 Voli ave, Ternopil, Ukraine, 46001*

✉ **Corresponding author**

### **Abstract**

Whitening has been known since Biblical times. Nowadays, in the developed world, patients are placing a stronger interest in the aesthetic appearance of their teeth. As a result, public demand for aesthetic dentistry, including tooth whitening, has recently increased. Aesthetics of the teeth is of great importance to many patients.

**The aim is** to summarise and discuss the teeth whitening procedure, tools, materials, and methods, as well as its efficacy and safety. In addition, the paper aims to provide full and comprehensive information for dentists and their patients about the merits and perils of whitening.

**Methods.** Relevant literature from Scopus published in English was selected using the following search criteria “tooth OR teeth AND whitening OR bleaching” by 2022. In total, there were found 3840 papers. Then, we applied the inclusion and exclusion criteria to the selected scientific papers to choose the relevant ones.

**Results.** A comprehensive study of the available information related to means and products for teeth whitening was carried out. Whitening may be accomplished by the physical removal of the stain or a chemical reaction to lighten the tooth colour. The indications for appropriate use of tooth-whitening methods and products depend on the correct diagnosis of the discolouration. When used appropriately, tooth-whitening methods are safe and effective.

**Conclusions.** Tooth whitening is a form of dental treatment and should be completed as part of a comprehensive treatment plan developed by a dentist after an oral examination.

**Keywords:** abrasives, bleaching, dental floss, esthetics, hydrogen peroxide, mouthwash, toothpaste, teeth, tooth discolouration, whitening.

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### **1. Introduction**

A snow-white smile is an important detail of the image, which probably everyone has dreamed of at least once. The desire of patients to have an aesthetically perfect smile has led to the active development of such a direction in aesthetic dentistry as teeth whitening or bleaching [1–4].

Methods to improve the esthetics of dentition by tooth whitening are of interest to dentists, their patients, and the public. As the population’s dental awareness has grown, so has its demand for a natural (or preferably supernatural) smile. The inescapable fact is that patients are eager to have whiter and brighter smiles. The desire for whiter teeth is the strongest driving force in people’s quest for dental treatment [5–9].

A whitening process for teeth describes restoring the natural colour of teeth by removing stains from the tooth surface. Whiteners are cleaning agents found in some toothpaste and mouth rinses. Bleaching teeth refers to whitening teeth beyond their natural colour. While the ADA has defined the differences between teeth whitening and teeth bleaching, often, these terms are used interchangeably [10].

## 2. Materials and methods

For this review article, a narrative review style was performed using a comprehensive literature search within the Scopus database to identify any studies for whitening/bleaching techniques in dentistry. The search considered works published in Scopus from 3840 until 2022 (included) using the keywords ‘tooth OR teeth AND whitening OR bleaching’.

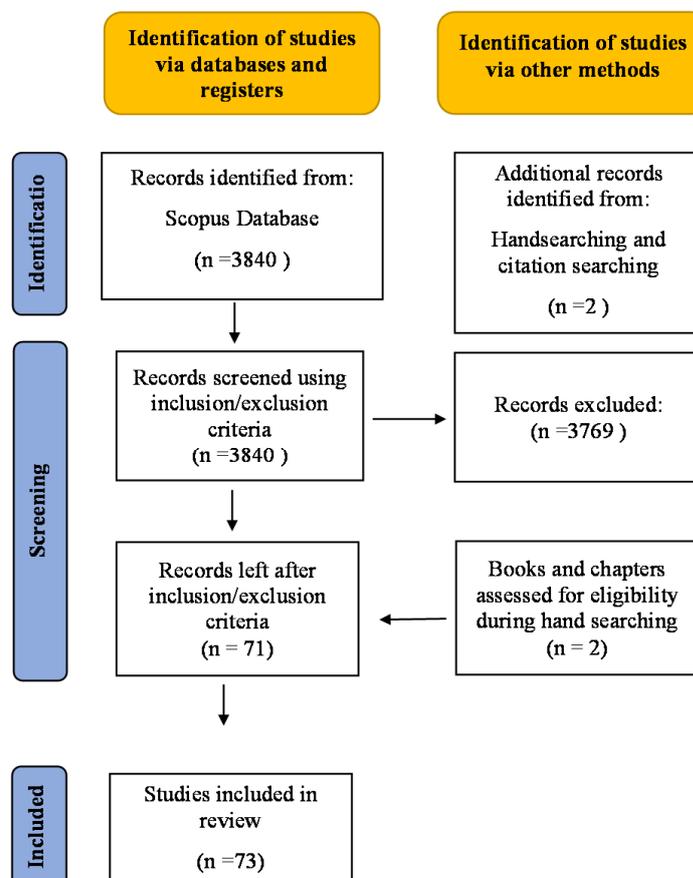
Only relevant literature from the electronic search was selected for the present review. The whitening/bleaching techniques of teeth, items, and strategies were interesting. The inclusion criteria are as follows: (i) use of existing commercial materials or their modifications in dental praxis; (ii) use of bleaching/whitening agents in esthetic dentistry; (iii) full-text journal articles indexed in Scopus written in English; (iv) books and book chapters written in English; (v) books and book chapters of highly rated publishers (Wiley, Elsevier and Springer) which appear in the references of the materials which meet our criteria but are not indexed in Scopus; (vi) case reports (clinical trials); (vii) randomised controlled studies. The exclusion criteria are as follows: (i) scientific papers written in a native language (not English); (ii) conference papers; (iii) articles with obsolete methods and tools from the modern point of view; (iv) editorials.

(1) The search was carried out in the Scopus database using the keywords ‘tooth OR teeth AND whitening OR bleaching’. In total, 3840 records were found.

(2) Three co-authors analysed 3840 records for compliance with the inclusion and exclusion criteria. In total, 3769 records were deleted, i.e., 71 records remained.

(3) In the reference lists of these 71 articles, we found 2 relevant books and sections of books by highly rated publishers (Wiley, Elsevier, and Springer or affiliated with them).

(4) To the 71 records from Scopus, we added 2 books and chapters of books. That is 73 records in total. All selected records were distributed among all authors for reading the full-text articles and preparing the manuscript. The procedure is shown in **Fig. 1** in the PRISMA flowchart.



**Fig. 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram

### 3. Result

#### 3. 1. History of clinical development and evolution of the procedure

##### *Ancient civilisations and teeth whitening*

The desire for whiter teeth is not completely a recent phenomenon. Even Biblical times, white dentition was considered attractive, youthful, and desirable. In third-century bc Greece, Theophrastus wrote that it was "considered a virtue to shave frequently and have white teeth".

The ancient Egyptian culture placed a strong emphasis on personal appearance. Pharaohs were fascinated by the idea of achieving white teeth, and they used a special toothpaste that contained wine vinegar, pumice stone, and ground oxen hooves. While this abrasive and acidic mixture may have whitened teeth, it likely caused serious damage to the tooth enamel [7, 10].

The ancient Romans also loved white smiles. They used chew sticks to get rid of plaque on their teeth. There are even documents to indicate that they used urine (due to its ammonia content) to keep dental stains at bay (Fig. 2) [11–15].

### The evolution of modern whitening

Initial Attempts at Bleaching:	Successful Non-Vital Bleaching:	Modern Techniques:
<ul style="list-style-type: none"> <li>• 1877 – Chapple – oxalic acid;</li> <li>• 1888 – Taft calcium – hypochlorite;</li> <li>• 1884 – Harlan – hydrogen dioxide;</li> <li>• 1895 – Electrical currents.</li> </ul>	<ul style="list-style-type: none"> <li>• 1958 – Pearson – intrapulpal bleach;</li> <li>• 1967 – Nutting and Poe – walking bleach;</li> <li>• 1978 – Superoxol heat and light.</li> </ul>	<ul style="list-style-type: none"> <li>• 1989 – Munro – outpatient tooth whitening;</li> <li>• 1990s – General use of in – office vital bleaching;</li> <li>• 1995 – Yarborough – laser-assisted bleaching.</li> </ul>

Fig. 2. The evolution of modern whitening techniques

#### 3. 2. Classification of whitening procedures

Bleaching procedures can be classified as follows:

Internal (or nonvital) bleaching. The active agent is placed within the pulp chamber by the dentist (in-office bleaching) and can be left in its place between appointments ("walking bleaching") as well. [16–19].

External (or vital) bleaching. The active agent is placed in contact with the tooth surface. Despite its name, vital bleaching can be performed only on endodontic-treated teeth. Vital bleaching can be further divided into at-home bleaching (with self-application of the bleaching agent by the patient as instructed by the dentist) and in-office bleaching (in which the dental team performs the bleaching procedure at the dental chair) [20–23].

Bleaching with over-the-counter products [24, 25].

**Table 1** Summarises the indications for use and the adverse effects of tooth-whitening methods [26].

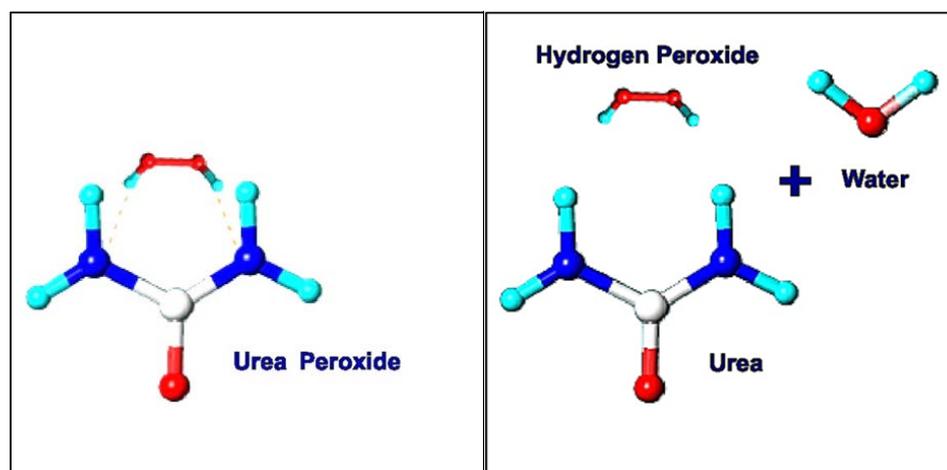
Despite the large number of techniques described in the literature concerning the external bleaching of vital teeth, all are based on the direct use of hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) or its precursor, carbamide peroxide (CH<sub>6</sub> N<sub>2</sub>O<sub>3</sub>) [27].

Whitening occurs through the process of chemical degradation of chromogens. Therefore, the success of the teeth whitening technique is directly related to the ability of peroxides to penetrate or diffuse into the enamel and dentin.

Most bleaching systems use either hydrogen peroxide or carbamide peroxide (or, more recently, both in combination). The chemistry is similar since carbamide peroxide, or urea peroxide degrades into urea and hydrogen peroxide in the presence of water. By weight, carbamide peroxide contains 33 % hydrogen peroxide, so a bleaching gel with 10 % carbamide peroxide contains a similar activity level as one with 3.3 % hydrogen peroxide (Fig. 3) [28, 29].

**Table 1**  
Tooth-whitening methods, indications for use and adverse effects

Type of product or method	Active agents	Indications for use	Potential adverse effects
Internal bleaching – in-office or walking	35 per cent hydrogen peroxide	Endodontically treated teeth	Root resorption
External bleaching – in-office one to three visits	30 per cent to 38 per cent hydrogen peroxide, alone or with heat or light	Single or multiple discoloured teeth	Transient tooth sensitivity and gingival irritation
Custom bleaching trays are worn by the patient daily for two to six weeks	10 per cent carbamide peroxide	Multiple teeth and entire arches, most effective for yellow or brown discoloration; may be effective for tetracycline staining with longer use.	Sensitivity of teeth during bleaching
Brushing with whitening toothpaste	Abrasives	Surface staining	None
Microabrasion followed by neutral sodium fluoride applications	Abrasives and acid	Isolated brown or white discolourations of the shallow depth in enamel	None
Microabrasion followed by custom tray bleaching	Abrasives and acid; 10 per cent carbamide peroxide	White discoloration on yellowish teeth	Sensitivity of teeth during bleaching



**Fig. 3.** Structure of bleaching agents

Tooth-whitening methods include using peroxide bleaching agents to remove internal discolourations and abrasive products to remove external stains. Both methods are safe and effective when supervised by the dentist. Micro-abrasion is indicated for removing isolated discolourations that are often associated with fluorosis. Whitening toothpaste removes surface stains only through the polishing effect of the abrasives they contain (Fig. 4) [30].

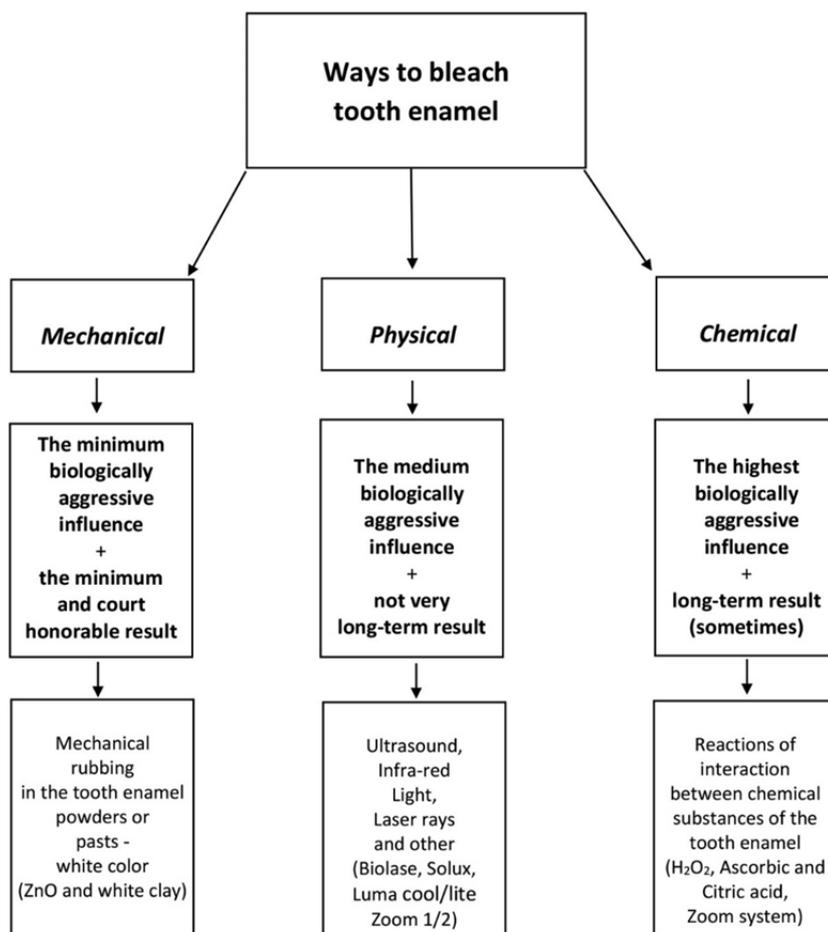


Fig. 4. Varieties of teeth enamel bleaching methods

### 3. 3. Types of stains/discolourations/ comparative diagnosis of stains

Many types of teeth discolourations may affect the appearance of teeth, and the causes of these problems vary, as does the speed with which they may be removed.

Distinguishing between the quality and the cause of stains has more than just academic interest. Knowing the reason for tooth staining allows the dentist to plan the whitening technique better and provide a more accurate prediction of the result. Many factors can cause staining and discolouration of teeth. Traditionally, tooth discolourations are divided into extrinsic and intrinsic (Table 2).

Table 2

Types of tooth discolouration

Reasons	Extrinsic stains	Intrinsic stains	
		Discolourations developed before teeth eruption (follicle development)	Discoloration developed after teeth eruption
	<ul style="list-style-type: none"> <li>- Tobacco</li> <li>- Food and beverages</li> <li>- Medicines</li> </ul>	<ul style="list-style-type: none"> <li>- Amelogenesis imperfecta</li> <li>- Dentinogenesis imperfecta</li> <li>- Endemic fluorosis</li> <li>- Porphyria</li> <li>- Sickle cell anaemia</li> <li>- Staining with tetracycline</li> </ul>	<ul style="list-style-type: none"> <li>- Age</li> <li>- Dental metals</li> <li>- Food, drink and habits such as smoking</li> <li>- Idiopathic pulp recession</li> <li>- Dental material</li> <li>- Traumatic injury</li> </ul>

Intrinsic stains are localised inside the tooth, either in the enamel or the underlying dentin. They can result from systemic causes are 1) drug-related (tetracycline); 2) metabolic: dystrophic calcification, fluorosis; and 3) genetic: congenital erythropoietic porphyria, cystic fibrosis of the pancreas, hyperbilirubinemia, amelogenesis imperfecta, and dentinogenesis imperfecta [31, 32]. Intrinsic staining of teeth happens prior to tooth eruption during tooth development. However, intrinsic staining can also occur after tooth eruption. Mainly pulpal hemorrhagic products following trauma may lead to intrinsic discolouration by blood penetration into the dentin tubuli. Dental procedures like amalgam fillings or endodontic treatments can also cause them. Deeper internal stains or enamel defects usually cause intrinsic stains.

Extrinsic stains usually result from the accumulation of chromogenic substances on the external tooth surface [14, 33]. Colouring compounds – chromophores – are of organic and inorganic origin. Chromophores absorb light in the visible range and reflect mainly a complementary colour, usually yellow or brownish, recognised by the human eye. Organic chromophores are small organic molecules, such as tannins or furfural, found in tea, coffee, red wine or fruits. Chromophores can also be formed by chemical processes (e.g., oxidation) of initially colourless compounds. Coloured tin sulfide, SnS, may result from the chemical reaction of stannous fluoride, SnF<sub>2</sub>, from toothpaste with volatile sulfur compounds produced by oral bacteria [34].

The causes of tooth staining must be carefully evaluated to predict better the rate and extent to which whitening will improve tooth colour, as some stains are more sensitive to the process than others. The indications for appropriate use of tooth-whitening methods and products depend on the correct diagnosis of the discolouration. Several approaches are available for measuring changes in tooth colour. These include visual measurements by trained clinicians and instrumental measurements using spectrophotometry, chromameters and digital image analysis [34, 35].

### 3. 4. In-office treatments

In-office bleaching (“powerful bleaching”) is done with concentrated solutions of H<sub>2</sub>O<sub>2</sub> in water (typically 15 %, 30 %, 35 wt %) for about 20-30 min. However, care must be taken because a concentrated hydrogen peroxide solution is highly oxidising and harmful to soft tissue. Therefore, the gingiva and tongue must be protected by suitable means (e.g. rubber dam). Furthermore, peroxides are antibacterial agents that may lead to an imbalance (dysbiosis) of the oral microbiome [36–40].

Some professional whitening procedures employ light sources. The following types of light are the most frequently used: LED, plasma arc and halogen. From a chemical viewpoint, this irradiation should not change the oxidative effect of hydrogen peroxide, but it may enhance the reaction rate due to local temperature increases [41–46].

Overnight (“nightguard”) bleaching is accomplished by the application of a 10-20 % carbamide peroxide-containing gel (see below) in a patient-specific mouthguard [47, 48]. A 10 % carbamide gel has been approved by the American Dental Association for home bleaching. Due to the lower concentration of hydrogen peroxide, several overnight treatments are necessary to achieve visible effects. The whitening effect of both power bleaching and nightguard bleaching was reported to persist for several years after treatment. Other bleaching options are paint-on gels and whitening strips based on peroxides [49–51].

### 3. 5. Over-the-counter teeth whitening products

#### *Whitening toothpaste*

Whitening toothpaste often (but not always) contain harder abrasives in greater amounts than standard toothpaste. Abrasives with such quality and in such amount are included in toothpaste to achieve sufficient removal of external stains [33, 52–54]. Therefore, abrasives are the most important ingredients in toothpaste formulations for effective stain removal.

To achieve teeth whitening, many different agents are used, e. g., in commercially available toothpaste (**Table 3**).

Common abrasives are hydrated silica, SiO<sub>2</sub>·n H<sub>2</sub>O, calcium carbonate, CaCO<sub>3</sub>, and alumina, Al<sub>2</sub>O<sub>3</sub> (**Table 4**). These abrasives may also differ in particle size, morphology and hardness [33, 54].

Especially the properties of silica abrasives strongly depend on parameters such as water content, cross-linking, particle shape and particle size [55].

**Table 3**

Examples of commonly used whitening agents in products for home and professional use (in alphabetical order; the most efficient whitening agents are given in the example) [52, 55]

Whitening Agent	Mode of Action
Abrasives (e. g., hydrated silica, perlite, alumina) → Most important toothpaste ingredient for stain removal	Mechanical removal of extrinsic stains
Antiredeposition agents (e. g., polyphosphates, sodium citrate)	Prevention of the deposition of chromophores and inhibition of calculus formation where external stains could be incorporated
Calcium phosphates (e. g., hydroxyapatite)	Adhesion of white calcium phosphate particles on the tooth surface and prevention of bacterial attachment/plaque formation on the teeth
Colourants (e. g., blue covarine)	Shifting colour absorption and reflection spectra from yellow to blue
Enzymes/proteases (e. g., papain, bromelain)	Support stain removal due to degradation of proteins (hydrolysis of peptide bonds)
Peroxides (e. g., hydrogen peroxide, calcium peroxide)	Oxidation of organic chromophores
Polyaspartate (e. g., sodium polyaspartate)	Inhibition of plaque-formation
Surfactants (e. g., sodium lauryl sulfate)	Removal of hydrophobic compounds from the tooth surface

**Table 4**

Overview of commonly used abrasives in toothpaste [54]

Name (INCI*)	Chemical Formula	Relative Hardness	Expected Stain Removal
Sodium bicarbonate	NaHCO <sub>3</sub>	Soft	Low
Dicalcium phosphate dihydrate (brushite)	CaHPO <sub>4</sub> · 2 H <sub>2</sub> O	Soft	Low
Calcium carbonate	CaCO <sub>3</sub>	Soft	Low
Calcium pyrophosphate	Ca <sub>2</sub> P <sub>2</sub> O <sub>7</sub>	Medium hard	Medium
Hydroxyapatite	Ca <sub>5</sub> (PO <sub>4</sub> ) <sub>3</sub> (OH)	Medium hard	Medium
Hydrated silica	SiO <sub>2</sub> nH <sub>2</sub> O	Medium hard	Medium
Perlite	A mineral silicate	Hard	High
Alumina	Al <sub>2</sub> O <sub>3</sub>	Hard	High

Note: \*INCI: International Nomenclature of Cosmetic Ingredients

Whitening compounds in whitening toothpaste are also based on peroxide. However, due to the chemical instability of hydrogen peroxide, other compounds are used, such as calcium peroxide, sodium percarbonate and magnesium peroxide, surfactants, anti-fouling agents, dyes, enzymes and poly-aspartate [53, 55–57] (Table 5).

**Table 5**

Bleaching agents that are frequently used and contained in-home or in-office whitening products

Bleaching agent	Mechanism of action
Abrasive substances (hydrated silica or silicon dioxide, perlite, alumina)	Mechanical removal of external stains
Abrasive substances (hydrated silica or silicon dioxide, perlite, alumina)	They prevent the deposition of chromophores and inhibit the formation of hard dental deposits
Agents preventing the precipitation of chromophores (polyphosphates, sodium citrate)	
Calcium phosphates (hydroxyapatite)	Adhesion of white calcium phosphate particles on tooth surfaces and prevention of bacterial attachment/biofilm formation
Dyes (covarin blue)	Change in the absorption spectrum and colour reflection from yellow to blue

In addition to whitening toothpaste, whitening mouthwashes, whitening strips, whitening floss, and whitening chewing gums have been reported in the literature. Whitening mouthwashes containing a low concentration of hydrogen peroxide (1.5 %) and sodium hexametaphosphate have been used with moderate success [51, 58, 59].

#### *Whitening mouthwashes*

Whitening oral rinses fight the formation of plaque and tartar. Whitening mouthwashes have a low concentration of HP and sodium hexametaphosphate, potassium pyrophosphate, and sodium citrate. These ingredients work to whiten teeth either by bleaching or removing and controlling stains. Hydrogen peroxide diffuses through the organic matrix of the tooth and produces free radicals that lead to successful whitening. However, the efficacy of whitening mouthwashes may be decreased by the fact that they are in contact with the teeth for a short period compared with bleaching gel for use at home [60, 61].

After using such means, the teeth become cleaner and whiter, and plaque accumulates on them more slowly. However, frequent use of oral whitening rinses can lead to irritation of the mucous membrane and increased sensitivity of the teeth [62–64].

#### *Whitening strips*

In addition to whitening toothpaste, whitening strips, dental floss, and chewing gums have been reported in the literature [65, 66].

Peroxide gels are used in tooth strips. They contain urea and hydrogen peroxide. As soon as you remove the protective sticker from the strip, the gel is activated: it produces peroxide ions of oxygen in an active form, which, in turn, have pronounced oxidising properties. Ions penetrate into the deepest layers of tooth tissue and destroy pigments (organic) to ordinary water and carbon dioxide. As a result of these processes, tooth enamel is also brightened [51, 67].

Whitening dental floss has been brought to the market (coated with abrasive silica), but up to 2009, no clinical report was published. Whitening chewing gum containing sodium hexametaphosphate did not perform better than normal chewing gum [30, 51, 68].

### **3. 6. Side Effects, Risks and Hazards**

The most commonly reported side effects are tooth sensitivity and gingival or mucosal irritation [69–73].

Almost always, the sensitivity that occurs during bleaching is short-termed and disappears after the bleaching is stopped. Patients usually experience sensitivity during both home and dental office whitening. There are several simple and complex reasons for tooth sensitivity during whitening:

Possible causes of tooth sensitivity and gingival irritation

- Addition of Carbopol and other thickening agents.
- Age of the patient (patients younger than 40 experience more side effects).
- Anhydrous-based whitening products.
- Chemical byproducts of carbamide peroxide.
- Chemical interaction of the tray.
- The concentration of the whitening solution.
- Dissolving media.
- Exposure time.
- Flavours were added to the whitening solution.
- Frequency of application.
- Inherent patient sensitivity.
- Medical status of the patient.
- The pH of the whitening solution.
- Sex of the patient (women appear to experience more side effects than men).

- Tray material used.
- Tray rigidity.

Two methods to consider for treating sensitivity during whitening treatment are the passive method and the active method.

Passive method:

- Altering the whitening time.
- Changing the frequency.
- Reducing concentration to find a comfortable solution for the patient.
- Allowing the patient to skip a night of whitening.
- Using less whitening gel in the tray.
- Trimming back the whitening tray so it does not impinge on the gingival margins.

Active method:

– In the active method, desensitising materials are applied either directly onto the teeth or inside the whitening tray.

– Products used are fluoride or potassium nitrate applied in the tray as a pretreatment, at the onset of symptoms, or after a course of treatment.

– The use of fluoride and potassium nitrate to treat whitening sensitivity has been clinically researched and works well.

Typically, the gingival or mucosal irritation is related to improperly fitted trays, improper or excess application of the gel, and the use of the gel longer than prescribed. The soft tissue irritation noted is usually mild and transient and is resolved shortly after the treatment has ended.

Peroxides harm the adhesion of composite resins to dental tissues owing to oxygen supersaturation in the recently bleached enamel.

As we know, oxygen is a strong inhibitor of composite material polymerisation. The excess oxygen, however, is depleted in approximately 2 weeks. Therefore, the rule of thumb is to wait 3 weeks after completion of at-home bleaching before placing composite restorations.

#### **4. Conclusions**

Teeth whitening and bleaching are great ways to improve your smile and make you feel more confident.

Teeth whitening/bleaching is a form of dental treatment and should be done as part of a comprehensive treatment plan developed by a dentist after an oral checkup. When used appropriately, tooth-whitening methods are safe and effective.

Patients should be informed of the risks associated with tooth whitening and instructed on identifying adverse occurrences so that they may seek professional help as needed.

#### **Conflict of interests**

The authors declare no conflict of interest.

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