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Illuminating smiles: Advances in tooth bleaching techniques and aesthetics

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Abstract
Tooth bleaching has seen notable advancements in dentistry, enhancing both aesthetics and patient experience. This review outlines the progression of bleaching techniques, from early chemical treatments like hydrogen peroxide to modern innovations in vital and non-vital tooth whitening. It discusses various options available, including professional in-office procedures, at-home kits, and over-the-counter products, along with newer methods such as cold atmospheric plasma. The review also delves into the causes of tooth discoloration, covering intrinsic and extrinsic stains, while explaining the chemical reactions involved in bleaching. Additionally, it assesses the impact of whitening agents on dental structures like enamel and dentin, addressing common issues such as tooth sensitivity and the risk of external cervical root resorption. The paper concludes by exploring emerging whitening technologies, with a focus on ensuring safety and optimizing patient results.

Keywords: Bleaching, Causes for tooth discoloration, carbamide peroxide, hydrogen peroxide, hypersensitivity, external root resorption

Introduction

In the realm of dentistry, the quest for brighter, more aesthetically pleasing smiles has led to significant advancements in tooth-bleaching techniques. Advancements in dental science have made vital tooth bleaching accessible and effective, allowing patients to achieve brighter smiles from the comfort of their homes.

A variety of over-the-counter products containing low levels of hydrogen peroxide has been marketed for teeth bleaching. Whitening strips, mouthwashes, paint-on brushes, and toothpaste are some of the goods easily available for consumers. Even though these products contain less than 3% hydrogen peroxide, their use result in teeth whitening [1]. Given the large variety of whitening products available, it can be challenging for clinicians and patients to choose the most adequate technique. Among various aspects to be considered, the long-term effect of bleaching is an important factor that might be decisive for treatment choice [2].

History

Back in 1848, dentists experimented with chloride of lime for non-vital tooth bleaching. However, this method had limitations and wasn't highly effective. The process involved utilizing chlorine from a solution of calcium hydrochloride and acetic acid. The breakthrough occurred in 1884 when the tooth-bleaching effect of hydrogen peroxide (H_2O_2) was discovered [3]. Since then, hydrogen peroxide has become a popular choice for bleaching non-vital teeth. In the late 1800s, dentists experimented with various substances to achieve tooth bleaching for non-vital teeth. These agents played a crucial role in enhancing the aesthetics of discolored teeth. Kingsbury introduced the use of cyanide of potassium for tooth bleaching. This substance acted directly on the organic portion of the tooth. In 1872, Bogue explored the use of oxalic acid for non-vital tooth bleaching. Oxalic acid also functioned as a direct oxidizer. Kirk investigated the potential of sulfurous acid in bleaching non-vital teeth. Interestingly, sulfurous acid acted as a reducing agent, unlike other oxidizers. The breakthrough occurred in 1884 when the tooth-bleaching effect of hydrogen peroxide (H_2O_2) was discovered. Hydrogen peroxide remains a popular choice for bleaching non-vital teeth. Dentists also experimented with Aluminum Chloride (1891), Sodium Hypophosphate (1891), Pyrozone, Superoxol, Sodium Dioxide [4].

Among these, the most effective direct oxidizers were Pyrozone, Superoxol, and sodium dioxide, while the indirect oxidizer of choice was a chlorine derivative [5]. Superoxol gained popularity among dentists due to its high safety profile. It became the chemical substance of choice for many dental professionals. During the late 1950s and early 1960s, Pyrozone continued to be effectively used for bleaching non-vital teeth. Dentists found it to be a reliable option. Sodium perborate also played a role in tooth bleaching during this period. Its effectiveness contributed to its usage. In the late 1970s, Nutting made a safety-oriented decision. Superoxol replaced Pyrozone as a bleaching agent. Later, a combination of Superoxol and sodium perborate was used synergistically [6]. Advancements in dental science have led to safer and more effective non-vital tooth bleaching techniques over time.

the historical developments in vital tooth bleaching, include various techniques and products used over time. In the late 1960s, orthodontist Dr. Bill Klusmier introduced a successful home-bleaching technique. Patients used an "over-the-counter" oral antiseptic called Gly-Oxide, which contained 10% carbamide peroxide delivered via custom-fitting mouth trays at night. Not only did this treatment improve gingival health, but it also whitened teeth. Proxigel, a mixture of 10% carbamide peroxide, water, glycerin, and carbopol, replaced Gly-Oxide for orthodontic patients. Its slow release of carbamide peroxide contributed to its effectiveness. In 1989 [7], Haywood and Heymann described a home-bleaching technique known as "Nightguard vital

bleaching." An at-home bleaching product called "White and Brite™" was introduced by Omni International. In the 1990s [8], OTC bleaching agents containing lower concentrations of hydrogen peroxide or carbamide peroxide became available directly to consumers for home use [9].

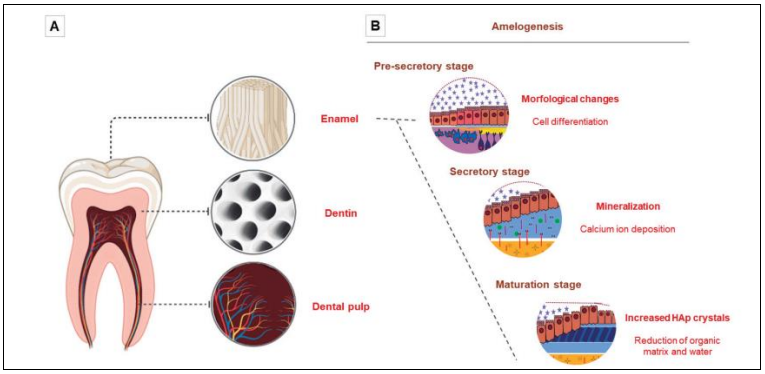

Fig 1: A. Schematic illustration of the tooth structure composed of enamel with its configuration of longitudinally arranged prisms, dentin with the presence of dentinal tubules, and the dental pulp com-posed of cells, blood vessels, and nerve endings. **B.** Stages of enamel formation. HAp: hydroxyapatite

Aetiology of tooth discoloration

Tooth discoloration can occur due to various factors, affecting both the appearance and psychological well-being of individuals [10].

Table 1: Intrinsic stains

Metabolic Disorders	Conditions like alkaptonuria and congenital erythropoietic porphyria may lead to intrinsic tooth discoloration.
Inherited Factors:	Genetic variations can influence natural tooth color, brightness, and translucency.
Iatrogenic Causes	Dental treatments or procedures can sometimes result in tooth staining.
Trauma:	Falls, car accidents, or sports injuries may cause trauma leading to discoloration.
Aging:	As we age, tooth enamel thins, revealing more yellowish dentin underneath
Certain Diseases:	Specific medical conditions can contribute to tooth discoloration.
Medications:	Some drugs, such as tetracycline antibiotics, can stain teeth.
Cancer Treatments:	Chemotherapy and radiation therapy may impact tooth color.

Table 2: Extrinsic Stains

Direct Staining:	Compounds from the diet or substances habitually placed in the mouth can incorporate into the pellicle layer, causing direct staining.
Indirect Staining	Chemical interactions at the tooth surface, often associated with cationic antiseptics and metal salts, lead to indirect staining.
Classification by Origin: Metallic Extrinsic Stains: Non-Metallic Extrinsic Stains:	Result from external metallic compounds. Arise from other substances on the tooth surface.

Types of dental bleaching procedures

Vital bleaching technique

There are three fundamental approaches for bleaching vital teeth: in-office or power bleaching, at-home or dentist-supervised night-guard bleaching, and bleaching with over-the-counter (OTC) products.

1. **In-office or power bleaching**: This method is performed by a dental professional at their office. The dentist applies a high-concentration bleaching agent (usually containing hydrogen peroxide or carbamide peroxide) directly to the teeth. A special light or laser may be used to activate the bleaching process. The entire procedure typically takes about an hour. The main advantage is Patients often notice a significant improvement in tooth color after just one session. Dentists closely monitor the process to ensure safety and efficacy. Complications in In-Office Bleaching is that Some patients may experience temporary tooth sensitivity. In-office bleaching tends to be more expensive than other methods [11].

2. **At-home or dentist-supervised night-guard bleaching:** Dentists create custom-fitted trays (night guards) based on impressions of the patient's teeth. Patients apply a lower-concentration bleaching gel to the trays. The trays are worn overnight or for a specified duration during the day (usually a few hours). Treatment duration varies but typically lasts several weeks. The advantage is that Patients achieve a natural-looking result over time. The fit ensures even distribution of the bleaching gel. The drawback is that Consistent use of the trays is essential for effective results. It may take several weeks to achieve the desired level of whiteness [12].

3. **Bleaching with over-the-counter (OTC) products:** Whitening toothpaste, strips, gels, and pens are available without a prescription. These products contain lower concentrations of bleaching agents compared to professional treatments. The advantage is Users can apply OTC products at home. OTC options are generally more affordable. Results may be less dramatic than professional methods. OTC products may work differently for each person [13].

The use of hydrogen peroxide products with lower concentrations produced color changes that were comparable to those of products with higher concentrations and less risk and intensity of bleaching sensitivity, according to a systematic review and meta-analysis [14].

While some research has indicated damage with a notable reduction in enamel hardness, the use of trays and peroxide bleaching is safe for enamel surfaces. According to a recent review, new whitening solutions and technologies, such as carrier systems and nano-additives, may optimize the bleaching process and reduce structural enamel damage [15].

Nevertheless, dental bleaching may also contribute to the demineralization of remineralized carious lesions because, although improving the color of the arrested lesion, it also increases the risk of demineralization, particularly in cases where adhesive restorations were present.

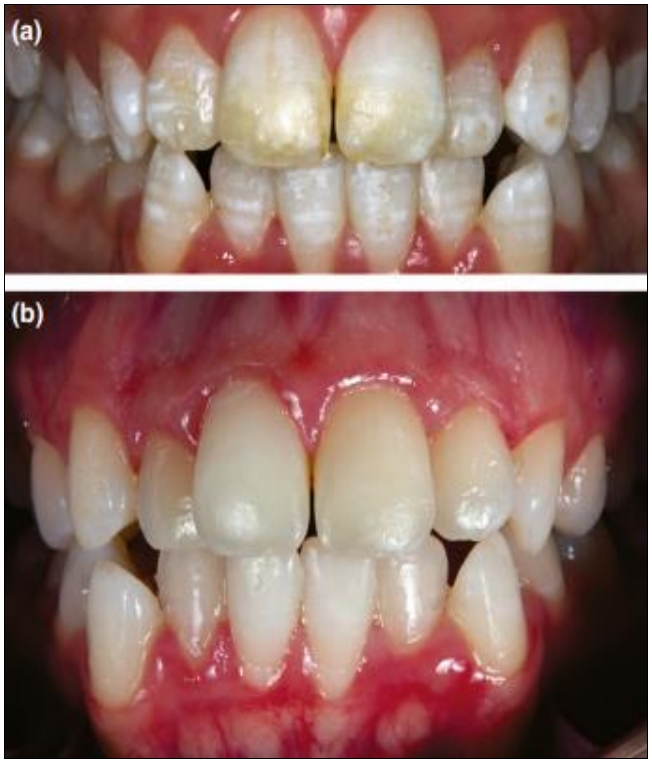

Fig 2: (a) A photograph of an 18-year-old girl with moderate fluorosis. **(b)** A post-treatment photograph.

The teeth received a single visit in-office bleaching with Philips ZOOM (Philips Oral Healthcare) Light Activator using Zoom White Speed gel (25% Hydrogen peroxide). Superficial stains and plaque were first removed using a prophy paste in a rubber cup. The lips were protected with sunblock cream, prior to placement of lip retractors. Isolation of the gingiva was achieved by cotton rolls placed in the vestibule and light-cured resin barrier. The teeth received a total of 30 min application of bleach illuminated with ZOOM lamp on High intensity (190 mW/cm2) for 15 min, followed by medium intensity (120 mW/cm2) for 15 min. One week later, resin infiltration treatment was accomplished using ICON system for three etching cycles, followed by two resin infiltration cycles [60].

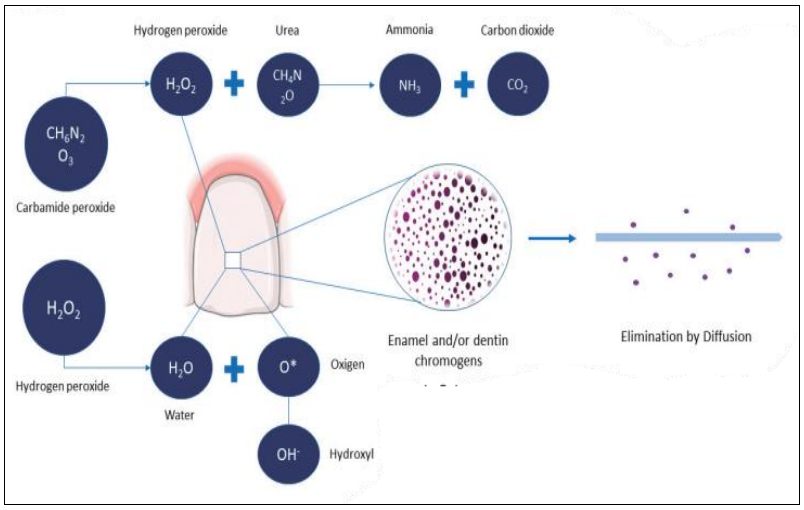

Fig 3: Schematic illustration of the decomposition process of carbamide peroxide (CH6N2O3) into hydrogen peroxide (H2O2) and urea (CH4N2O). This in turn decomposes into ammonia (NH3) and carbon dioxide (CO2). Hydrogen peroxide decomposes into water and reactive oxygen species such as hydroxyl anion (OH-) and reactive oxygen (O*). These molecules promote the oxidation of the chromogens present in enamel and dentin and are then eliminated by diffusion.

Non-vital bleaching technique

1. **Walking bleach technique (Internal Bleaching):** The walking bleach technique is commonly used for non-vital teeth (teeth that have undergone root canal treatment) with intrinsic discoloration. It aims to improve the aesthetics of discolored teeth from within. Sodium perborate (SP) combined with 30% hydrogen peroxide (HP) is used. The SP-HP mixture is placed inside the pulp chamber of the discolored tooth. The tooth is temporarily sealed. Over time, the bleaching agent diffuses into the dentin, lightening the tooth. Patients often experience improved tooth color and aesthetics. The walking bleach technique is particularly effective for tetracycline-stained teeth [16].

2. **Thermocatalytic technique**: It is Intracoronal bleaching using heat. Heat accelerates the bleaching process, enhancing the effectiveness of the bleaching agent. it gives Faster results compared to conventional methods. It helps in Improved penetration of the bleaching agent. The important consideration is the Requirement of precise temperature to avoid damaging the tooth structure [17].

3. **Inside-outside technique (Combined Technique):** Combines internal and external bleaching approaches. A bleaching agent applied both inside the tooth (as in walking bleach) and externally (conventional tooth whitening) shows Comparable aesthetic outcomes to walking bleach. It emphasizes biocompatibility over speed.it is often preferred due to safety and effectiveness [18].

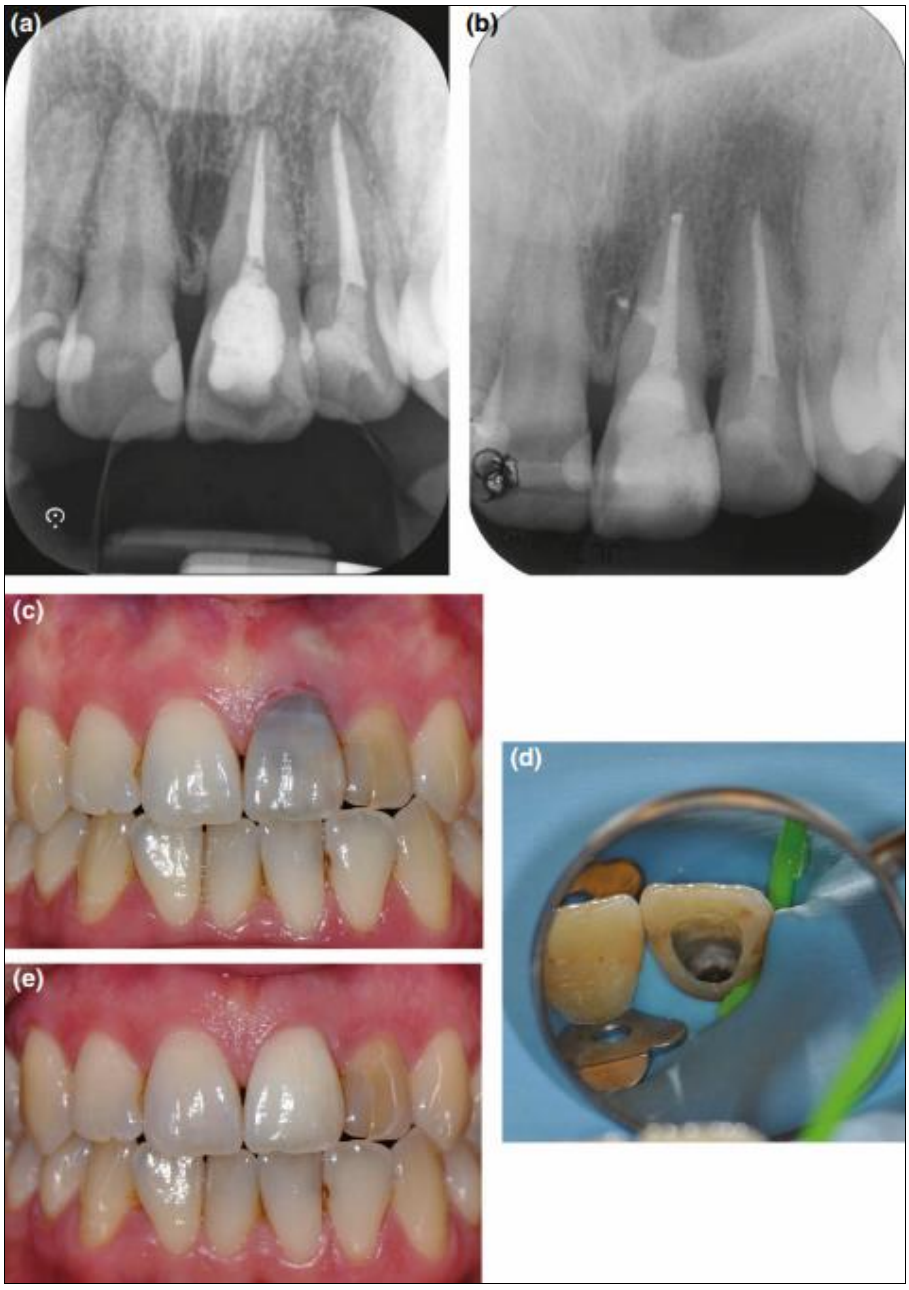

Fig 4: (a) A preoperative radiograph of a root filled left maxillary central incisor with pathos. **(b)** The tooth was successfully retreated. **(c)** A photograph showing the extent of discolouration. **(d)** A photograph of the open assess cavity. Bleaching utilized the walking bleach technique with sodium perborate (Endoprep bleach; PDS) mixed with water. **(e)** A post-treatment photograph immediately post-bleaching showing the bleached tooth having a lighter colour than the adjacent teeth [60]

Novel technique-laser

Laser teeth whitening, also known as laser teeth bleaching, is a procedure performed in a dentist's office to brighten teeth. The dentist applies a bleaching gel to the teeth. Protective eyewear is placed gum barriers are added and then A laser (a Nd: YAG laser irradiation) is directed onto your teeth, heating the gel. This process activates the gel's whitening properties and alters stain molecules on the teeth. The gum barrier is removed, and the bleaching gel is rinsed out. The goal of laser teeth whitening is to reduce discoloration and make your teeth look whiter. Anecdotal evidence suggests that laser teeth whitening is generally painless, but your teeth may be more sensitive than usual for about 24 hours afterward. To protect your teeth, avoid excessive whitening, as it may damage tooth enamel or pulp [19].

Novel technique- cold atmospheric plasma

Cold atmospheric plasma (CAP) has emerged as an intriguing technology in dentistry, particularly for tooth bleaching. Hydrogen peroxide (H2O2) is commonly used for tooth bleaching, but its high concentration can be corrosive to teeth. CAP offers a novel approach to tooth bleaching by combining it with H2O2.When CAP is applied alongside H2O2 gel, it enhances the bleaching effect. CAP's unique properties contribute to improved efficacy while minimizing side effects. Researchers evaluated tooth bleaching using CAP and H2O2 gel *in vitro*. Treatment times ranged from 5 to 20 minutes. THE KEY FINDINGS WAS THAT 5–10 minutes yielded the optimal bleaching effect with minimal impact on tooth enamel and pulp tissue. Longer treatments (>20 minutes) led to reduced microhardness and increased roughness. It minimizes unwanted side effects, such as thermal damage to pulp tissue [20].CAP can potentially remove stains caused by coffee or wine when combined with H2O2.While it may not replace existing methods, CAP could enhance established tooth-whitening procedures [21].

Effects of bleaching procedures

Tooth bleaching can have effects on various dental structures:

1. Enamel and Dentine.
2. Pulp
3. Soft Tissue (Gingiva)
4. Composite Restorations
5. Temporary Effects

Enamel

Numerous studies in the scientific literature have explored the impact of bleaching on enamel morphology and the surface texture of dental enamel. These investigations have delved into various aspects, including increased porosity, demineralization, changes in protein concentration, organic matrix degradation, and alterations in the calcium-to-phosphate ratio. The prevailing hypothesis is that bleaching agents, being chemically active, can induce significant structural changes in human dental enamel. Interestingly, while some studies suggest minimal impact, others highlight morphological alterations in the bleached enamel surface. For instance, Haywood *et al*. (1990) [22] conducted a scanning electron microscopy (SEM) analysis and found no morphological alterations in the enamel surface following the application of 10% carbamide peroxide bleaching. Titley *et al*. (1992) [23] observed a slight increase in surface roughness. Hunsaker *et al*. (1990) [24] and Gurgan *et al*. (1997) reported no modification of surface roughness.

Hegedus *et al*. (1999) [25] employed atomic force microscopy to explore enamel surface changes after 28 hours of bleaching with 10% carbamide peroxide and 30% hydrogen peroxide. Their observations revealed that the sample's surface became more irregular, with deeper surface grooves following bleaching treatment. Moreover, Ernst *et al*. (1996) reported slight, insignificant, or no changes on enamel surfaces under 3000× magnification using 30% solutions of hydrogen peroxide.

Josey *et al*. (1996) [27] investigated the effect of a night-guard vital bleaching procedure on enamel surface morphology and the shear bond strength (SBS) of a composite resin luting cement to enamel. Extracted human teeth were bleached for one week using a vital bleaching product. While bleaching caused changes to the surface and subsurface layers of enamel, the SBS of composite resin luting cement to etched bleached enamel remained clinically acceptable. Azrak *et al*. (2010) [26] conducted an *in vitro* study using enamel specimens from human permanent anterior teeth. These specimens were incubated with different bleaching agents containing active ingredients such as 7.5% or 13.5% hydrogen peroxide or 35% carbamide peroxide. Results indicated that exposure to an acidic bleaching agent (pH = 4.9) led to higher surface roughness compared to treatment with a high peroxide concentration (pH = 6.15).Bleaching agents with a high concentration of peroxide or an acidic pH were found to provoke surface roughness in both sound and eroded enamel. Cadenaro *et al*. (2010) [28] conducted an *in vivo* study using a 38% hydrogen peroxide in-office whitening agent. The enamel surface roughness remained unchanged even after multiple applications. evaluated three carbamide peroxide bleaching agents (Nitewhite, Polanight, and Opalescence) on human enamel. they found no mechanical, morphologic, or chemical changes after bleaching with these agents. Saliva likely played a protective role by diluting, buffering, and supplying Ca and P ions for remineralization. Xu *et al*. (2011) [29] explored the influence of bleaching agent pH values. They treated enamel with 30% hydrogen peroxide solutions at different pH levels (HP3, HP5, HP7, and HP8). SEM and micro-Raman spectroscopy revealed noticeable enamel surface alterations in neutral or alkaline bleaching solutions. Sun *et al*. (2011) [30] compared acidic and neutral 30% hydrogen peroxide effects on enamel. Neutral hydrogen peroxide was as effective for tooth bleaching but caused fewer harmful effects than acidic hydrogen peroxide. Sa *et al*. (2013) [31] demonstrated that in-office bleaching agents with low pH values could alter enamel morphology under *in vitro* conditions. Fortunately, natural human saliva counteracted this effect by preventing demineralization. the intricate dance between bleaching agents and enamel morphology continues to captivate researchers, and ongoing investigations shed light on the multifaceted effects of dental bleaching. The clinical implications of these alterations in enamel composition and surface structure remain an area of active exploration.

Dentine

Basting *et al*. (2003) [32] found that the thickening agent (carbopol and/or glycerin), not just the 10% carbamide peroxide, caused a decrease in dentin microhardness. Tam *et*

al. (2005) [33] reported that direct exposure to 10% carbamide peroxide significantly reduced the flexural strength and flexural modulus of bovine dentin. Tam *et al*. (2007) [34] found that *in vitro* fracture resistance of dentin decreased after prolonged use of bleaching products directly applied to dentin. Faraoni-Romano *et al*. (2008) [35] studied the effects of bleaching agents on bovine enamel and root dentin. While enamel microhardness and surface roughness remained unchanged, root dentin microhardness was affected, depending on the bleaching agent used. Engle *et al*. (2010) [36] investigated the interaction between bleaching, erosion, and dentifrice abrasivity. Bleaching with 10% carbamide peroxide did not increase enamel erosive and abrasive wear, but it might impact dentin wear depending on erosive and abrasive challenges.

Pulp

The dental pulp (located in the pulp chamber) contains blood vessels and nerves. Although bleaching agents do not directly harm the pulp, some patients may experience transient sensitivity during or after treatment. This sensitivity usually resolves on its own. Certainly! The effects of tooth bleaching on dental pulp have been studied, particularly in relation to commonly used bleaching agents. Let's delve into the details:

1. **Carbamide peroxide (CP) and dental pulp stem cells (DPSCs):**

A study investigated the impact of exposure to CP, a bleaching agent commonly found in at-home whitening products, on adult dental pulp stem cells (DPSCs) using an *in vitro* model. DPSCs were cultured and exposed to various CP concentrations (0.1%, 0.5%, and 1%). Results showed that CP-exposed DPSCs had lower cell viability and adherence than non-stimulated cells, likely due to increased cell death. CP-stimulated DPSCs released pro-inflammatory cytokines (IL-6 and IL-8) in a dose-dependent manner. CP did not affect wound healing in this context [61].

2. **Thermal effects**

Activation of bleaching gel can lead to an increase in pulpal temperature. Factors such as energy-applying medium, set parameters, and tooth type influence temperature changes. Heat from bleaching can result in the loss of odontoblasts and damage to pulpal tissue [62].

Composite restoration

Research has yielded varying results regarding the impact of low-concentration carbamide peroxide gels (10–16%) on the surface microhardness of restorative composite materials. Some investigations associated the use of at-home bleaching gels with softening of composite resins. Other studies found no significant changes in hardness or even an increase in surface hardness due to at-home bleaching gels [41]. In-office tooth whiteners containing 35% carbamide peroxide or 35% hydrogen peroxide did not significantly affect the hardness and tensile strength of composite materials. A study by Hannig *et al*. (2007) [42] reported a significant decrease in the surface hardness of bleached composite resins (such as Tetric Flow and Tetric EvoCeram). This reduction was observed not only on superficial surfaces but also in the deeper layers of the filling materials. The decrease in hardness was attributed to oxidation and degradation of the resinous matrix in the composites. In 2013, Alqahtani [43] conducted an *in vitro* study to assess the effect of a 10% carbamide peroxide bleaching agent on the microhardness of four types of direct resin-based restorative materials. The materials tested included Microhybrid resin composite (Z250), nanofilled resin composite (Z350), silorane-based low-shrink resin composite (P90), and hybrid resin composite (Valux Plus). Results showed a general reduction in Vickers hardness values for treated groups compared to the control group. Z250 showed minimal reduction, while Z350, P90, and Valux Plus demonstrated a significant decrease in Vickers hardness after bleaching.

Marginal seal and microleakage: Two studies using the dye penetration test reported that post-operative contact with 35% hydrogen peroxide or 10–16% carbamide peroxide gel could adversely affect the marginal seal at both dentin and enamel margins in extracted teeth restored with composite restorations [44]. However, another study found no increased microleakage rates, at least at enamel margins, when bleaching teeth with Class I composite restorations using 20% carbamide peroxide [45].

Studies have explored the use of 10% sodium ascorbate to reverse the compromised bond strength of enamel previously bleached with 10% carbamide peroxide when bonded to resin composite. Surface treatment with sodium ascorbate can immediately reverse the compromised bond strength of teeth bleached with hydrogen peroxide or treated with sodium hypochlorite [46].

Feiz *et al*. (2011) [47] suggested that applying sodium ascorbate as an antioxidant could significantly increase the bond strength of composite resin to bleached dentin. Dabas *et al*. (2011) [48] studied the effects of different concentrations of sodium ascorbate hydrogel (10% and 20%) on the bond strength of bleached enamel. The application of sodium ascorbate hydrogel increased the resin-enamel bond strength, with duration of application being a factor. Delaying the bonding procedure by one week after bleaching reduced the compromised shear bond strength (SBS) of composite resin and resin-modified glass ionomer. Applying 10% sodium ascorbate hydrogel reversed the compromised SBS, serving as an alternative to delayed bonding. The efficacy of antioxidants as reducing agents can be influenced by the method of application and the chemical composition of adhesives [49].

Studies have compared bonding resin composite after home bleaching with 10% carbamide peroxide using either etch-and-rinse or self-etch adhesives [50]. Etch-and-rinse adhesives generally resulted in better SBS for bleached enamel. The use of dental adhesives containing organic solvents, such as an alcohol-based bonding agent like OptiBond, may enhance composite bond strength when restorative treatment is completed immediately after bleaching [51]. sodium ascorbate shows promise in improving bond strength after bleaching, and its effectiveness depends on factors such as concentration, application method, and adhesive type. Niat *et al*. (2012) [52] reported that the acetone-based adhesive (One Step) had higher bond strength than the alcohol-based adhesive (Single Bond). Catalase or catalase-like substances can reduce residual hydrogen peroxide on bleached teeth, but practical limitations make it less clinically feasible. α-Tocopherol formulated in solution significantly increases the bond strength of bleached enamel. A waiting period of at least 1 week after bleaching treatment is still recommended

before bonding procedures [53]. The use of grape seed extract (OPCs) after bleaching with 38% hydrogen peroxide and before bonding procedures on enamel neutralizes the deleterious effects of bleaching and significantly increases bond strength [54]. Reduction in bond strength after dental bleaching is reversible. The best approach is to postpone the bonding procedure for some time after tooth bleaching, which varies from 24 hours to one week, two weeks, or even up to four weeks.

Most available research in the current literature has focused on the preoperative influence of bleaching gels on adhesion of composites to enamel. However, few studies have dealt with the influence of bleaching gels on the adhesive bond of previously prepared composite restorations. Barcellos *et al*. (2010) [55] evaluated the impact of bleaching gel containing 10%, 15%, and 20% carbamide peroxide on bond strength. The micro-tensile bond strength (μTBS) between restoration and dental structure was significantly affected by carbamide peroxide bleaching agents. Dudek *et al*. (2012) [56] investigated the durability of adhesive bonds using different adhesives (Gluma Comfort Bond, Clearfil SE Bond, Adper Prompt, and iBond). After 25 eight-hour cycles of bleaching with a 20% carbamide peroxide gel, the shear bond strength (SBS) was tested. The bleaching gel significantly decreased bond strength on both enamel and dentin for the simplified single-step self-etch adhesives ADP and IBO. ADP specimens showed altered fracture patterns at the periphery of their bonded area. Different adhesives exhibited varying levels of sensitivity to the bleaching gel. a RECENT study assessed the influence of different sodium ascorbate (SA) presentations (liquid, gel, and semi-gel) on the composite resin–enamel bond strength after a bleaching protocol. Sound human anterior teeth were collected, cleaned, prepared for a bond strength test, and randomly allocated into groups according to the bonding procedure. Sodium ascorbate (SA) increased the potential bond strength associated with bleached enamel. Different concentrations of SA tested restored the bond strength values to those of the unbleached teeth [57]. Sodium ascorbate (SA) is effective in restoring the reduced bond strength of bleached enamel. Grape seed extract and aloe vera also play a role in increasing bond strength after bleaching. These studies highlight the importance of antioxidants like sodium ascorbate in maintaining bond strength after dental bleaching [58]. The choice of concentration, duration, and application method of sodium ascorbate can significantly impact the results.

Soft tissue

Gingival irritation, a common side effect of vital tooth bleaching, occurs when the bleaching agent comes into contact with the gums during the procedure. To minimize this irritation, clinicians can take the following steps:

1. **Trim customized trays**: For at-home vital bleach techniques, clinicians can trim customized trays to ensure they fit accurately and avoid irritating the gingiva [59].

2. **Use a barrier**: Applying a protective barrier (such as petroleum jelly or a gingival barrier gel) to the gingiva before applying the bleaching agent can prevent direct contact and reduce irritation [59].

Temporary effects: After bleaching, teeth may appear slightly dehydrated, leading to a “chalky” appearance. This effect is temporary and resolves as the teeth rehydrate.

Complications of bleaching

1. External Cervical Root Resorption (ECRR)
2. Hypersensitivity

External cervical root resorption (ECRR)

ECRR is a serious complication associated with bleaching using peroxide compound. IT IS SEEN IN 6%–8% for cases using 35% hydrogen peroxide AND18%–25% if hydrogen peroxide is heat-activated. Predisposing factors ARE Cementum deficiency exposing dentin, Orthodontic Treatment, Prior trauma, The position of the root filling relative to the cementoenamel junction (CEJ) affects the risk. Teeth with the root filling at or above the CEJ have a lower risk of ECR AND Periodontal ligament injury [37].Approximately 10% of teeth have an incomplete CEJ (cementoenamel junction) that exposes underlying dentin. Bleaching agents can penetrate to the cervical area of teeth, especially in areas with CEJ defects. Free oxygen radicals generated during bleaching may contribute to resorption by breaking down collagen and hyaluronic acid. Dentin protein denaturation can occur due to changes in pH and heat [38]. The thermocatalytic technique in bleaching procedures is no longer recommended. Inflammation may play a role in external cervical resorption. Heithersay (2004) suggested that microorganisms might not be the primary cause but could become secondary invaders. Bone resorption markers RANK-L and IL-I ß increased in gingival crevicular fluid after bleaching with hydrogen peroxide agents. These inflammatory mediators persisted for 3 months post-bleaching. Sodium perborate, an alternative to hydrogen peroxide, is less toxic to periodontal ligament (PDL) cells. Carbamide Peroxide Contains both hydrogen peroxide and urea.IT Breaks down more slowly than hydrogen peroxide. IT Releases 50% of its whitening effects during the first 2 hours of application, and the rest over the next 6 hours [38]. Commonly used for in-office or professional tooth whitening procedures. WHEREAS Hydrogen Peroxide IS Highly reactive and breaks down quickly. Releases most of its whitening power within the first 30 to 60 minutes of application and is Popular for at-home teeth whitening kits due to its fast action. Hence some dentist advocate the use of carbamideperoxide however it is used in external bleaching. Studies indicate that concentrations of 2% or less do not harm hard or soft oral tissues. At-home teeth bleaching products typically contain 5% to 10% hydrogen peroxide or 35% carbamide peroxide. In-office treatments use 25% to 40% hydrogen peroxide for shorter durations [39]. Studies have associated external resorption with young patients who have undergone bleaching. Modern bleaching procedures with lower hydrogen peroxide concentrations likely pose a lower risk. The walking bleach technique for root-filled teeth is considered safe with minimal risk of invasive cervical resorption [39].

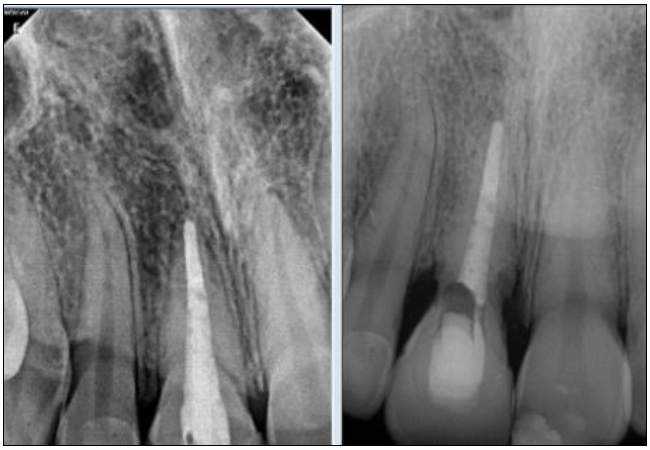

Fig 5

A periapical radiograph revealing external cervical root resorption of the bleached left maxillary central incisor that had been bleached with the walking bleach technique with unknown medicaments.

Treatment of cervical resorption

Affected teeth can be treated with direct restorations. After debriding the resorptive defect, 90% trichloroacetic acid may be used to induce sterile necrosis of remaining resorptive tissue [40].

Hypersensitivity

Dental sensitivity is a common adverse effect associated with tooth bleaching, primarily caused by the penetration of hydrogen peroxide through enamel and dentin, which reaches the pulp chamber within minutes of application. Hydrogen peroxide and its by-products can induce oxidative stress on pulp cells, triggering the release of inflammatory mediators and leading to sensitivity. Studies have shown that using neutral or alkaline pH bleaching gels can significantly reduce this sensitivity by minimizing the amount of peroxide that reaches the pulp. Acidic gels, in contrast, tend to cause more enamel demineralization and porosity, allowing greater passage of peroxide into the pulp chamber and increasing sensitivity. Clinical trials also confirm that patients report less post-bleaching sensitivity when neutral or alkaline gels are used, as opposed to acidic ones. Furthermore, limiting the application time of bleaching gels to around 15-20 minutes can help preserve enamel integrity and reduce the risk of sensitivity. High-concentration gels are particularly stimulating to the pulp and should be avoided in favor of lower-concentration options with neutral or alkaline pH to minimize adverse effects and ensure a more comfortable patient experience.

This aligns with a broader consensus in the field of dentistry, where research suggests that the long-term safety of bleaching treatments depends on the careful selection of gel concentration and pH, along with shorter application durations.

Treating dentine hypersensitivity after tooth bleaching involves both immediate care and long-term strategies to manage discomfort.

1. **Desensitizing toothpaste:** One of the easiest ways to manage sensitivity is by using toothpaste specifically designed for sensitive teeth. These toothpastes contain ingredients like potassium nitrate or stannous fluoride, which help block the pain signals traveling from the tooth surface to the nerve, gradually reducing sensitivity.

2. **Fluoride treatment:** In-office fluoride treatments can effectively strengthen enamel and reduce sensitivity. Dentist may apply a fluoride varnish or gel to create a protective barrier, which can help seal the exposed dentin and decrease sensitivity over time.

3. **Desensitizing Agents:** Dentist may also use desensitizing agents, such as calcium phosphate, oxalates, or other compounds that form crystals on the surface of the tooth to block the small tubules in dentin. These tubules are the pathways through which sensations of pain travel, so blocking them can reduce sensitivity.

4. ****Minimize trigger foods:**** During the sensitive period after bleaching, try to avoid foods and drinks that trigger sensitivity. Hot or cold beverages, acidic foods like citrus, and sugary items can exacerbate the problem. Sticking to neutral, lukewarm foods will help keep discomfort at bay.

5. ****Shorter bleaching sessions next time:**** If you've experienced sensitivity, let your dentist know. They can adjust your treatment plan for future sessions by using lower-concentration bleaching gels, reducing the application time, or recommending neutral or alkaline pH gels. This will help prevent the problem from recurring.

6. ****Hydration and saliva stimulation:**** Drinking plenty of water helps rinse away any residual bleaching agents and keeps your mouth hydrated. Chewing sugar-free gum can also stimulate saliva production, which aids in natural remineralization of the enamel and dentin, offering additional protection against sensitivity.

7. ****Professional guidance:**** If the sensitivity persists or worsens, it’s important to visit your dentist. They can assess the severity and provide more intensive treatments, such as applying dental sealants or even recommending restorative options if enamel wear is contributing to the problem.

By combining these steps, you can manage and alleviate post-bleaching sensitivity while continuing to enjoy the benefits of a brighter smile.

Summary

Managing discolored teeth involves understanding the underlying causes and interdisciplinary management. Trauma, developmental factors, and lifestyle choices often contribute to tooth discoloration. Bleaching endodontically treated teeth can be a safe and effective approach for managing discolored teeth. The risk of external cervical root resorption may be lower when using sodium perborate and avoiding high concentrations of hydrogen peroxide. However, the link between bleaching and resorption remains unclear, although prior trauma may play a role. It’s essential to avoid thermocatalytic methods and use a base/sealer to protect gutta-percha.

Public interest in tooth whitening continues to grow. Dental professionals should educate patients about the risks associated with over-the-counter bleaching products and emphasize professional supervision. Waiting at least 2 weeks after bleaching before bonding procedures can help prevent adverse effects on polymerization.Lastly, clinicians should inform patients about potential changes in dental restorations during bleaching and consider replacing bleached restorations As needed.

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