

# Natural vs. Chemical Teeth Whitening Agents: A Comparative Review of Efficacy and Enamel Safety

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**Abstract:** This review aims to explore how daily routines can maintain and enhance the cosmetic appearance of tooth shade without compromising oral health, and to compare natural and chemical whitening agents across different application methods. Emerging concerns in literature persist with the biological consequences of intrinsic (internal) and extrinsic (external) whitening treatments, and both high-concentration peroxide agents and abrasive whitening toothpastes. The reported biological concerns include transient or sustained reductions in the surface microhardness of the tooth enamel, increased surface coarseness of the tooth enamel, increased susceptibility to enamel erosion, and dentine hypersensitivity. This review of scientific literature synthesised qualitative and quantitative evidence from human clinical trials, in vitro studies, systematic reviews, and professional guidelines to evaluate how tooth shade can be effectively maintained or enhanced while preserving enamel integrity and minimising teeth sensitivity.

The evidence suggests that bleaching products used to remove intrinsic tooth stains, such as peroxide-based whitening agents, consistently produce the most substantial improvements in tooth colour, with  $\Delta E$  values and shade-guide changes exceeding clinically perceptible thresholds. In contrast, natural whitening agents exhibit superior enamel safety profiles, albeit with a minimal whitening effect on the teeth. Additionally, prolonged use of whitening toothpastes (which can be formulated with charcoal or highly abrasive particles to remove extrinsic stains, thereby causing surface discolouration) is associated with increased surface roughness of the tooth's enamel, leading to a loss of enamel microhardness at the surface. However, agents that remineralise the teeth enamel, like fluoride, CCP-ACP (Casein phosphopeptides-amorphous calcium phosphate), protect the enamel from peroxide-based agents and allow the enamel to recover from the oxidative damage caused by peroxides. Thus, the use of whitening agents that include peroxides with formulations that also remineralise the enamel, using mild whitening toothpastes to minimise staining of the teeth, may allow the desired whitening effect with minimal biological risk to their enamel for individuals. Therefore, this technique may achieve the maximum degree of whitening with minimal risk to the biological safety of the teeth, providing a scientific basis for understanding how whitening may be safely performed.

**Keywords:** abrasive whitening, whitening agents, tooth enamel, Intrinsic stain, Extrinsic stain, Sensitivity, Microhardness, CCP-ACP (Casein phosphopeptides-amorphous calcium phosphate)

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## I. INTRODUCTION

This study aims to compare and review different application methods using natural and chemical whitening agents for the maintenance and enhancement of white teeth to minimise enamel wear and sensitivity without compromising oral health. Tooth whitening has become an increasingly popular cosmetic treatment due to the desire for a youthful appearance, enhanced self-confidence, and the influence of societal expectations (Carey, 2014). There are several ways of applying natural and laboratory-made substances, which are tested through varied techniques to see what works best under real conditions. With a vast number of options, there are also a vast number of risks associated with the action taken. Though less concentrated, at-home treatments slowly lighten teeth using 10% to 16% carbamide peroxide applied nightly through fitted trays (Joiner, 2006). These methods often lead to similar outcomes as highly concentrated in-office procedures, but with fewer side effects. Whereas in dental clinics, doses of 25% to 40% hydrogen peroxide are used during brief visits to alter tooth shade rapidly (Kwon & Wertz, 2015). The active ingredient, whether H<sub>2</sub>O<sub>2</sub> or CP, breaks down pigments deep within the tooth by releasing oxygen radicals. As a result, hydrogen peroxide targets discolouration at its source, diffusing into the enamel and dentine layers (Joiner, 2006). Evidence from laboratory tests and patient trials supports this chemical process as reliable and significant research. There have been quite a few well-documented findings that the method of application produces colour changes noticeable to patients, backed by comprehensive analyses (Safe, 2025). Although effective, bleaching compounds may temporarily weaken tooth surface strength, especially when used in stronger concentration forms, due to shifts in protein levels and crystal arrangement within the

enamel (Carey, 2014; Kwon & Wertz, 2015; Lussi, 2006). Recovery often happens on its own over time, though using fluoride products can speed up the process. Discomfort and sensitivity during treatment occur frequently, more so with procedures done in dental clinics than at home.

## II. LITERATURE REVIEW

### 2.1 Mechanisms of Tooth Discolouration

Tooth discolouration stems from the interplay of intrinsic and extrinsic factors, with each contributing differently to the overall appearance. These are:

#### 2.1.1 Intrinsic Discolouration

Intrinsic discolouration originates from inside the tooth structure and often begins during developmental disturbances or is associated with illness, injury, or aging due to contact with pigmented substances (Carey, 2014; Hao, 2025; Joiner, 2006; Navodita Jamwal et al., 2023). These stains are embedded within the enamel, causing them to be resistant to surface mechanical removal methods. Instead, internal discolouration responds when confronted with oxidative treatments that alter their chemical nature over time to achieve and maintain improvement in shade colour.

#### 2.1.2 Extrinsic Discolouration

In contrast, extrinsic discolouration results from the accumulation of chromogenic compounds on the surface of the tooth (Carey, 2014; Hao, 2025; Joiner, 2006; Joiner, 2010; Navodita Jamwal et al., 2023). These are usually derived from dietary sources like coffee, tea, red wine, and highly pigmented foods, as well as the use of tobacco and inadequate plaque control, as displayed in Figure 1. These stains adhere to the pellicle; they can often be removed through mechanical or chemical cleaning of the surface.

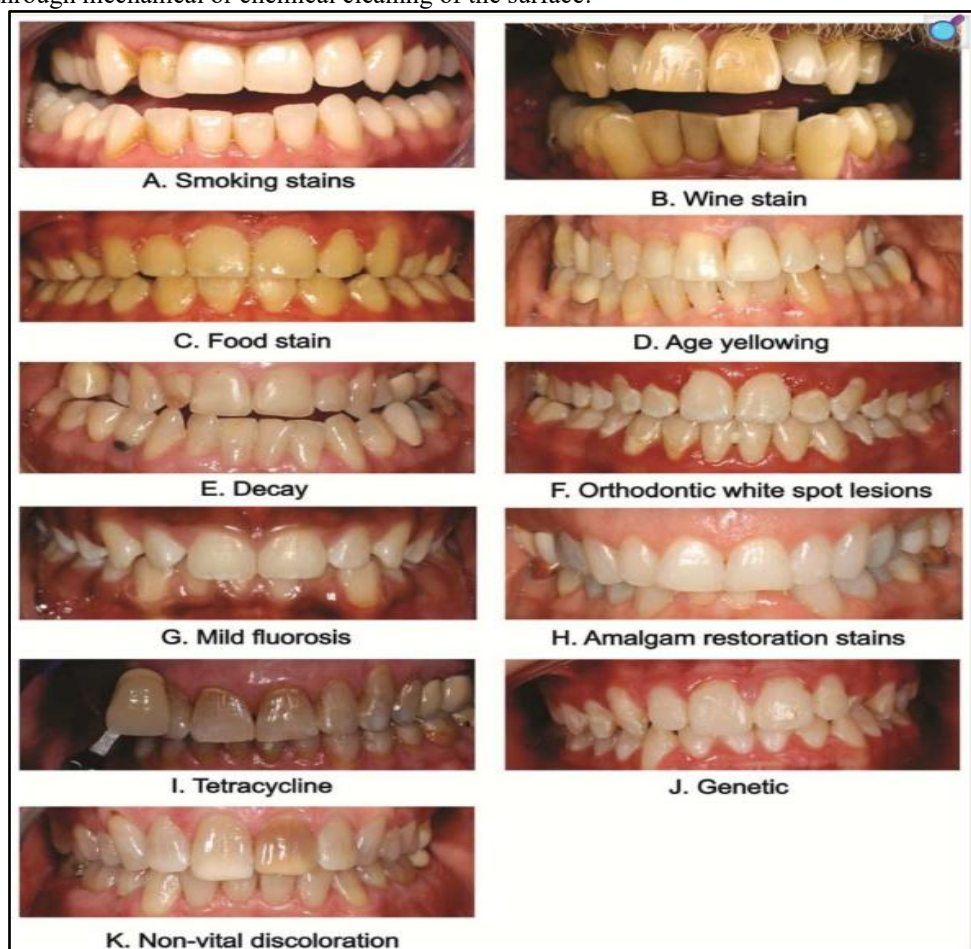


Figure 1: Examples of Tooth Staining

Extrinsic Staining examples: A. Smoking; B. Wine Stain; and C. Food Stain.

Intrinsic Staining Examples: D. Age Yellowing; E. Decay; F. Orthodontic White Spot Lesion; G. Mild Fluorosis; H. Amalgam Restoration; I. Tetracycline Stain; J. Genetic (amelogenesis imperfecta); K. and Non-Vital Colouring.

Source: Carey (2014)

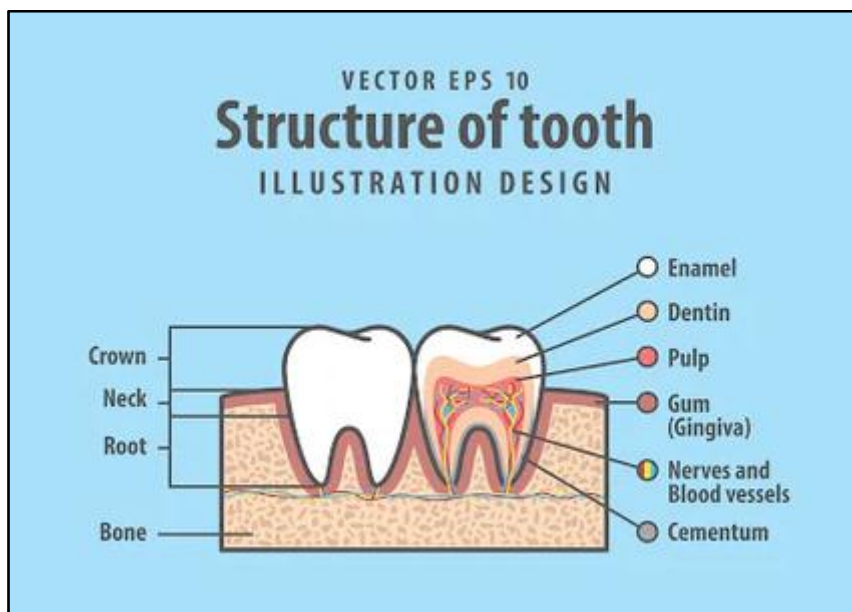


Figure 2: Structure of a Tooth  
Source: Hao (2025)

## 2.2 Mechanisms of Whitening

Whitening agents function through chemical oxidation and mechanical abrasion. The distinction between these mechanisms is clinically significant as it determines both the potential whitening outcome and the biological risks associated.

### 2.2.1 Chemical Oxidation (Peroxide-based Whitening)

Chemical whitening relies on the diffusion of carbamide peroxide into the enamel and dentine (Carey, 2014; Joiner, 2006; Kwon & Wertz, 2015; Mohammadipour et al., 2024; Redha et al., 2021). These compounds release active oxygen that breaks down long-chain chromophores into less pigmented molecules. As a result, it alters the optical properties of the tooth, creating brighter-looking teeth.

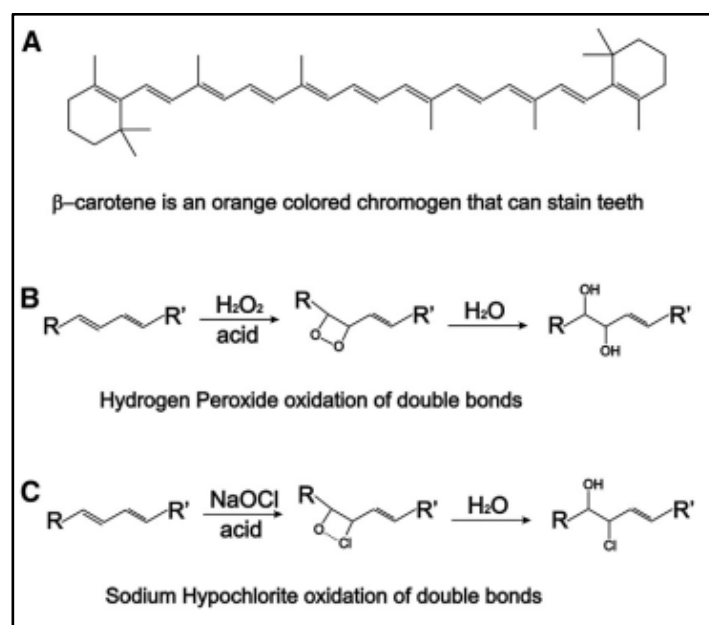


Figure 3: Chemistry of chromogen bleaching. A.  $\beta$ -carotene is an example of an organic chromogen with many conjugated double bonds; B. Chemical reaction of hydrogen peroxide with the achromogen double bond, and C. Chemical reaction of sodium hypochlorite with a chromogen double bond.

Source: Carey (2014)

### 2.2.2 Mechanical Abrasion (Abrasive Whitening)

Mechanical whitening involves the physical removal of surface discoloration using abrasive particles like silica, calcium carbonate, or baking soda (Jamwal et al., 2022; Joiner, 2006; Joiner, 2010; Kwon & Wertz, 2015; Lin et al., 2025; Lussi, 2006; Navodita Jamwal et al., 2023; Redha et al., 2021). Though effective for extrinsic stains, these abrasive methods have no significant effect in altering the intrinsic discoloration and may increase the enamel wear if excessively used.

### 2.3 Peroxide-based Whitening Agents

Chemical whitening agents, like hydrogen peroxide ( $H_2O_2$ ) and carbamide peroxide (CP), continue to be the most effective and widely studied methods for achieving substantial tooth colour improvement (Carey, 2014; Jamwal et al., 2022; Joiner, 2006; Joiner, 2010; Kwon & Wertz, 2015; Mohammadipour et al., 2024; Safe, 2025). They function as a potent oxidising agent with the capability of penetrating enamel prisms and diffusing into the enamel and dentine, where it decomposes chromogenic molecules responsible for intrinsic staining.

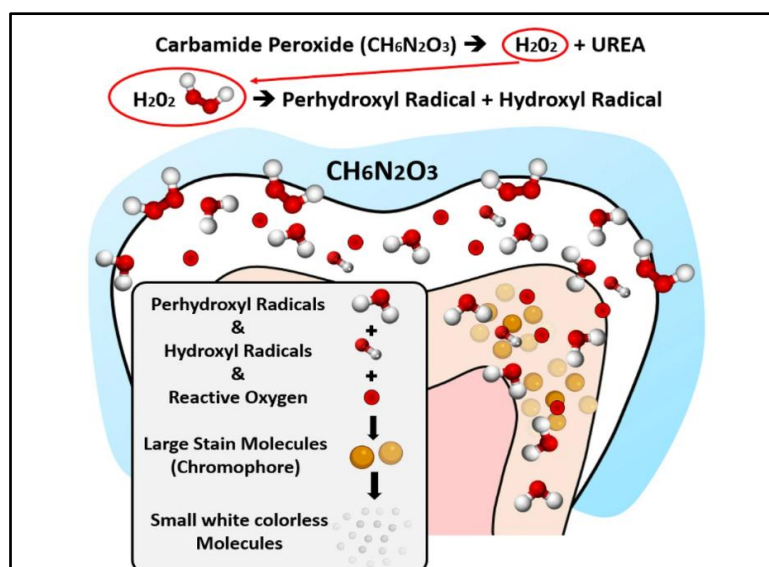


Figure 4: Synopsis of carbamide peroxide teeth whitening chemistry  
Source: Redha et al. (2021)

### 2.3.1 Hydrogen Peroxide ( $H_2O_2$ ) (In Office Whitening)

In-office whitening applies high concentrations of hydrogen peroxide ( $H_2O_2$ ) ranging from 25% to 40% to achieve dramatic and rapid whitening results in a short amount of time (Carey, 2014; Kwon & Wertz, 2015; Lin et al., 2025). Similar high concentration treatments are often used for patients with severe intrinsic discoloration or for seeking immediate aesthetic improvement.

Topic	Key Points
Efficacy	<ul style="list-style-type: none"> <li>Hydrogen peroxide is among the most effective tooth-whitening agents [1,2].</li> <li>Higher concentrations do not always provide superior results; whitening effect depends on protocol and number of applications rather than concentration alone [2,5].</li> <li>Repeated applications at moderate concentrations can yield outcomes comparable to or better than single high-concentration treatments [2].</li> </ul>
Safety	<ul style="list-style-type: none"> <li>High concentrations (e.g., 35%) cause enamel surface irregularities and reduce microhardness (~18.3% reduction reported) [5].</li> <li>Incorporating CaNaTMP into hydrogen peroxide gels reduces mineral loss, surface roughness, and peroxide diffusion [13].</li> <li>Thickener and mineral supplementation of bleaching gels influence enamel demineralization [15].</li> <li>Adjunctive remineralizing agents, including bioactive glass, self-assembling peptides, quercetin, and nano-hydroxyapatite (n-HAp), have shown potential to restore or preserve enamel properties, reduce mineral loss, and improve perceived tooth brightness without compromising whitening efficacy [16,17,18,19].</li> </ul>
Carriers	<ul style="list-style-type: none"> <li>Hydrogen peroxide is commonly formulated as gels for controlled placement and reduced soft tissue irritation [2,5].</li> <li>PVP forms hydrogen bonds with peroxide, stabilizing it against premature decomposition [9,10,20].</li> <li>Carbopol's cross-linked polyacrylic acid network creates a viscous hydrogel that acts as a diffusion barrier, limiting deep penetration of peroxide [21,22].</li> <li>HPMC increases viscosity and modulates release kinetics, enabling gradual oxidative action and reduced sensitivity [11,12].</li> <li>Advanced polymer-based carriers, combined with protective additives (e.g., calcium, fluoride), improve safety and therapeutic efficacy [9,13,14,15,23,24,25].</li> </ul>

Figure 5: Summary of hydrogen peroxide use in tooth whitening: efficacy, safety, and delivery systems  
Source: Lin et al. (2025)

### 2.3.2 Carbamide Peroxide (CP) (At-home Whitening)

At-home whitening uses weaker solutions of carbamide peroxide (CP), usually between 10% to 16%, applied via personalised trays worn daily for several days up to a week (Joiner, 2006; Redha et al., 2021). Although the process to see results is slower, the overall change will match what is done in the office. Yet, this brings less discomfort and a minimal chance of nerve-related issues. Research repeatedly confirms that whether done professionally or at home, peroxide treatments effectively alter the tooth's shade, causing it to be whitened to a satisfactory level (Carey, 2014; Joiner, 2006; Lin et al., 2025; Redha et al., 2021; Safe, 2025).

Aspect	Key Points
Efficacy	<ul style="list-style-type: none"> <li>Gradual decomposition into hydrogen peroxide and urea allows controlled whitening [3,29].</li> <li>Lower concentrations (10–16%) effective but slower; higher concentrations (≥37%) act faster but raise sensitivity risk [5,6,8].</li> <li>OTC clinical trials (10% carbamide peroxide) confirm efficacy, compliance is critical [30].</li> </ul>
Safety	<ul style="list-style-type: none"> <li>Safe for restorative dental materials (amalgam, composites, ceramics); no significant ion release [31].</li> <li>Even very low concentrations (0.0001–0.1%) cause morphological changes and reduce pulp cell viability [6].</li> <li>Careful regulation of concentration, application time, and frequency essential to balance efficacy and cytotoxicity [6,31].</li> <li>n-HAp reduces demineralization and enhances stain removal; supported by reviews and in vitro studies [18,19].</li> </ul>
Carriers	<ul style="list-style-type: none"> <li>Gels with polymers (e.g., Carbopol) improve viscosity, tray retention, and reduce soft tissue exposure [3,6,25].</li> <li>Urea by-product increases local pH, reduces demineralization, and alters peroxide kinetics [3,31].</li> <li>CaNaTMP addition mitigates mineral loss and preserves enamel integrity [13].</li> <li>PVP stabilizes peroxide via hydrogen bonding, prolonging activity [10,20].</li> <li>Carbopol cross-linked hydrogel structure acts as diffusion barrier and modulates penetration [21,22].</li> <li>HPMC regulates viscosity, swelling, and release kinetics for gradual oxidation [11,12,32].</li> </ul>

Figure 6: Summary of key findings on carbamide peroxide use in teeth whitening  
Source: Lin et al. (2025)

**2.3.3 Biological Effect of Peroxide**

However, peroxide-based whitening is not without biological consequences. Numerous in vitro studies have documented transient reductions in enamel microhardness followed by exposure to high-concentration peroxide products (Carey, 2014). One clinic has reported significant decreases in Vickers Hardness Number (VHN) of the surface tooth enamel after applying a 35% hydrogen peroxide formula (Kwon & Wertz, 2015). This result also aligns with another clinic displaying consistent patterns when testing various in-office whitening methods (Kwon & Wertz, 2015). These changes are attributed to peroxide-induced alterations in enamel organic content and mineral structure (Carey, 2014; Lin et al., 2025; Safe, 2025). Fortunately, lost firmness and surface hardness often return, either via natural repair processes fuelled by saliva or with the help of fluoride treatments and products that support remineralisation.

**2.3.4 Sensitivity Associated with Peroxide**

One common downside of peroxide-based whitening is heightened tooth sensitivity. Though in-office procedures use stronger doses, they bring discomfort in many cases, often tied to brief pulp swelling or shifts in liquid inside tooth channels. At-home kits tend to have less irritation. Over-the-counter (OTC) strips usually lead to the least noticeable reactions (Carey, 2014; Hao, 2025; Jamwal et al., 2022; Joiner, 2006; Joiner, 2010; Kwon & Wertz, 2015; Lin et al., 2025; Lussi, 2006; Mohammadipour et al., 2024; Navodita Jamwal et al., 2023; Oosterlaken et al., 2021; Redha et al., 2021; Reynolds, 1997; Safe, 2025).

**2.4 Natural Whitening Agents**

Though natural whitening agents have minimal risks and minimal to moderate results, they are less powerful and effective than chemical whitening agents.

**2.4.1 Baking Soda (Sodium Bicarbonate)**

Sodium bicarbonate stands among the best options for natural teeth whitening in the literature. This is attributed to its slight abrasive properties and an alkaline pH to effectively remove extrinsic stains with minimal damage to the tooth enamel surface (Jamwal et al., 2022; Joiner, 2010; Lin et al., 2025; Navodita Jamwal et al., 2023; Safe, 2025). This is supported by research data, which reports that toothpastes containing sodium bicarbonate only cause slight changes in enamel hardness, compared to silica-based products. Another clinic found similar conclusions of appreciable stain removal with minor risk of enamel erosion (Jamwal et al., 2022; Joiner, 2010; Lin et al., 2025; Navodita Jamwal et al., 2023; Safe, 2025).

Aspect	Key Points
Whitening efficacy	<ul style="list-style-type: none"> <li>■ Removes extrinsic stains through mechanical action, not chemical bleaching [1,33,45].</li> <li>■ Achieves perceptible color changes (<math>\Delta E \sim 3.8-4.2</math>), though less than peroxide-based products (<math>\Delta E \sim 5.7</math>) [43,44].</li> <li>■ Outperforms some natural agents (e.g., charcoal, strawberry-based pastes) while preserving enamel surface [44].</li> <li>■ Systematic review and clinical trials confirm superior stain removal with 45–65% sodium bicarbonate dentifrices (up to 62% stain reduction after 6 weeks) [45].</li> </ul>
Safety and biocompatibility	<ul style="list-style-type: none"> <li>■ Generally safe up to ~7%; higher concentrations (<math>\geq 10\%</math>) reduce cell viability in vitro (to 2–3%) [46].</li> <li>■ Clinical studies show high tolerance, no gingival irritation, and improved gingival health with ~67% formulations [47].</li> <li>■ Discrepancy between in vitro cytotoxicity and clinical safety underscores importance of formulation, exposure time, and delivery mode [46,47].</li> </ul>
Formulation considerations	<ul style="list-style-type: none"> <li>■ Incorporation of polymers (e.g., Carbopol, cellulose derivatives) improves viscosity, disperses particles, moderates abrasivity, and enhances cleaning uniformity [1,9,33].</li> <li>■ Specific experimental evidence on polymer benefits in baking soda pastes remains limited and requires further investigation [9,33].</li> </ul>

Figure 7: Summary of sodium bicarbonate in tooth whitening  
Source: Lin et al. (2025)

**2.4.2 Enzymatic Whitening (Papain, Bromelain)**

Enzymatic whitening agents, like papain and bromelain, function by breaking down protein components of the acquired pellicle, facilitating stain removal without mechanical abrasion (Joiner, 2010; Navodita Jamwal et al., 2023).

2.4.3 Hydroxyapatite

Hydroxyapatite is a biomimetic that blends into the enamel, offering beneficial whitening and remineralisation. Research indicates that hydroxyapatite-based pastes strengthen the enamel at a microscopic level and increase the surface smoothness of the enamel to enhance the luminous characteristics of the teeth (Joiner, 2010; Kwon & Wertz, 2015; Mohammadipour et al., 2024).

2.4.4 Activated Charcoal

Activated charcoal is quite harsh on teeth, which may cause enamel erosion and surface roughness. Laboratories found insufficient evidence to confirm any reliable brightening effect from charcoal-based products (Hao, 2025; Jamwal et al., 2022; Lin et al., 2025; Navodita Jamwal et al., 2023; Safe, 2025). Instead, recent studies reported clear declines in enamel strength after exposure to similar pastes (Hao, 2025; Jamwal et al., 2022; Lin et al., 2025; Navodita Jamwal et al., 2023; Safe, 2025).

Aspect	Key Points
Whitening efficacy	<ul style="list-style-type: none"> <li>■ Acts mainly via abrasion and adsorption of pigmented molecules [34,35,37,38].</li> <li>■ Limited or no effect on intrinsic tooth color; generally less effective than peroxide- or silica-based toothpastes [32,34,35].</li> <li>■ Tooth color changes are commonly assessed visually or more precisely with instruments (spectrophotometers, colorimeters) [34,36].</li> </ul>
Safety	<ul style="list-style-type: none"> <li>■ Frequent use linked to increased enamel wear, surface roughness, and microhardness reduction [34,35,37,38].</li> <li>■ Potential consequences include gloss loss, plaque retention, and higher risk of stain accumulation [34,37].</li> <li>■ No conclusive evidence of cytotoxicity on oral soft tissues, but abrasion-related risks remain [34,35,37,38].</li> </ul>
Formulation	<ul style="list-style-type: none"> <li>■ Some charcoal toothpastes contain polymers (e.g., carbomer, cellulose derivatives) to increase viscosity and stabilize particles [34,35].</li> <li>■ No strong evidence that polymers provide protective effects against abrasion in charcoal-based formulations [35].</li> <li>■ Marketing claims such as "natural," "chemical-free," or inherently safer are not substantiated by robust evidence [35].</li> </ul>

Figure 8: Summary of the efficiency, safety, and formulation considerations of charcoal toothpastes in tooth whitening  
Source: Lin et al. (2025)

2.5 Whitening Toothpastes

2.5.1 Abrasive Mechanisms and Relative Dentine Abrasivity (RDA)

Instead of intrinsic stain removal, these pastes often depend on scrubbing bits that mechanically abrade surface stains. A few additional substances, like blue covarine, form a fine surface coating which alters the reflection behaviour of light to yield a whiter teeth appearance. Improvements tend to be slight, even when used regularly (Joiner, 2010; Kwon & Wertz, 2015; Lin et al., 2025). While whitening toothpastes can produce modest improvements in tooth brightness, their long-term impact is minimal on the enamel's integrity. The abrasive property of the toothpaste is quantified using the Relative Dentine Abrasivity (RDA) scale.

RDA-Table	
0 – 70	low abrasive
70 – 100	medium abrasive
100 – 150	highly abrasive
150 – 250	regarded as a harmful limit

Figure 9: RDA Table  
Source: Relative Dentin Abrasivity Toothpaste Chart (2017)

Common toothpastes are measured below 70 RDA, making them gentle and suitable for regular brushing sessions. Treatment products that measure between 70 and 100 RDA are regarded by the dental industry as moderately abrasive. Products scoring above 100 RDA are limited for usage by the industry due to their high abrasive properties, which increase the risk of chipping the tooth's surface over time (*Relative Dentin Abrasivity Toothpaste Chart*, 2017). A few fast-acting cleaning gels may be characterised in this RDA group range, especially ones promising visible shifts in a few days (Joiner, 2010).

### *2.5.2 Evidence of Enamel Wear*

One analysis from a laboratory research group showed that whitening toothpastes tend to make enamel surfaces rougher than standard ones (Joiner, 2010; Lin et al., 2025; Lussi, 2006; Safe, 2025). Following up, their laboratory work discovered that every whitening product examined weakened the surface enamel hardness over time, mimicking three months of brushing (Carey, 2014; Navodita Jamwal et al., 2023). Among them, pastes containing charcoal stood out for causing more pronounced softening. Because of this, regular use might carry hidden downsides, especially if paired with additional whitening methods people often adopt.

## **2.6 Application Methods**

This section discusses how getting teeth whitened affects the efficiency and safety of treatment.

### *2.6.1 In-office Whitening*

In-office whitening procedures use high-concentration peroxides, applied by a professional, allowing for rapid and visible results. These treatments are accompanied by adjunctive technology like LED and laser activation, yet research indicates these mainly speed up the process of the chemical breaking down, not increasing the whitening itself (Carey, 2014; Navodita Jamwal et al., 2023). Despite its efficiency, in-office treatments bring the highest risk of increased sensitivity and transient enamel softening.

### *2.6.2 At-home Whitening*

At-home tray methods, which are gentle and have a gradual pace, rely on lower concentrations of peroxides applied over an extended period (Carey, 2014; Joiner, 2006; Safe, 2025). These systems provide a midground balance between efficiency and safety, reducing sensitivity and risks involved.

Most OTC (over the counter) whitening strips contain 6% to 10% hydrogen peroxide, making them an accessible option for mild discolouration (Carey, 2014; Joiner, 2006; Safe, 2025). Although its whitening effect is less pronounced than the in-office treatment, these products provide less discomfort and little harm to the enamel. However, the lack of professional supervision increases the risk of misuse.

The clinical industry now recognises LED home whitening kits, and research shows that light itself does little to whiten teeth. Instead, results mainly come from the peroxide inside the gel (Carey, 2014; Joiner, 2006; Safe, 2025). Light just speeds up the chemical's breakdown. However, skipping steps or overusing raises risks, but when applied properly, these devices work well.

## **2.7 Remineralisation Strategies**

This section discusses how remineralisation strategies restore minerals, strengthen the tooth surface over time, and help balance damage from whitening procedures.

### *2.7.1 Fluoride*

Fluoride treatment stands out amongst other substances known for rebuilding tooth structure, supported with a conscious amount of research that it strengthens enamel and lessens sensitivity after whitening treatments (Lin et al., 2025). Research reports that the application of fluoride before or after bleaching significantly improves enamel microhardness compared to bleaching alone (Lin et al., 2025). Similarly, more research points out fewer wear risks on enamel once exposed to peroxide if fluoride has been applied.

Aspect	Key Points
Whitening efficacy	<ul style="list-style-type: none"> <li>Fluoride itself does not bleach teeth but functions as a supportive agent during bleaching, mainly through remineralization and sensitivity reduction [34,36].</li> <li>Clinical trial: 2% NaF added to in-office hydrogen peroxide gels showed similar <math>\Delta E</math> values (~5.5–5.9) compared to control, but significantly reduced tooth sensitivity (1.7 vs. 3.2; <math>p &lt; 0.001</math>) [8].</li> <li>In vitro study demonstrated higher enamel microhardness recovery with fluoride-containing formulations compared to NovaMin (94.3% vs. 86.5%) [39].</li> </ul>
Safety and biocompatibility	<ul style="list-style-type: none"> <li>Fluoride-containing gels enhance enamel microhardness and reduce mineral loss after bleaching [39,40].</li> <li>Trans-amelodentinal assays showed &gt;80% pulp cell viability after exposure to fluoride-containing gels [42].</li> <li>Fluoride + nano-TPM formulations reduced enamel hardness loss (12% vs. 26%) compared to conventional gels [41].</li> </ul>
Clinical considerations	<ul style="list-style-type: none"> <li>Particularly beneficial for patients prone to sensitivity or enamel demineralization during whitening procedures [8,34,36].</li> <li>Enhances treatment comfort and supports enamel preservation, improving patient acceptance [39,40,41,42].</li> </ul>

Figure 10: Role of fluoride components as supportive agents in tooth whitening protocols  
Source: Lin et al., (2025)

### 2.7.2 CPP-ACP (Casein Phosphopeptide–amorphous Calcium Phosphate)

CPP-ACP (casein phosphopeptide–amorphous calcium phosphate) is another effective remineralising agent that stabilises calcium and phosphate ions, facilitating their incorporation into enamel (Mohammadipour et al., 2024). Research exhibits that CPP-ACP can remineralise subsurface enamel lesions, creating a vulnerable adjunct to bleaching treatments (Mohammadipour et al., 2024).

### 2.7.3 Hydroxyapatite as a Remineraliser

According to Jamwal et al. (2022), hydroxyapatite, which is a biomimetic mineral that mirrors the composition of natural enamel, has also shown strong remineralising potential. Reports indicate that hydroxyapatite-based toothpastes can increase enamel microhardness and surface smoothness, contributing to both enamel repair and aesthetic enhancement (Mohammadipour et al., 2024).

## 2.8 Daily Maintenance Behaviours

Daily maintenance behaviours are equally important to maintaining white teeth and discolouration control, which include safe brushing techniques with toothpastes that are low-abrasive and feature whitening agents. Individuals can also regulate their diet and consumption of food or drinks to minimise extrinsic staining of the teeth. Intermittent use of mild whitening boosters, like low-concentration peroxide gel or baking soda toothpastes, also preserves the white appearance of teeth, combined with regular visits to dentists for proper cleaning (Carey, 2014; Hao, 2025; Joiner, 2010; Kwon & Wertz, 2015; Lin et al., 2025; Lussi, 2006; Navodita Jamwal et al., 2023; Safe, 2025).

## III. METHODOLOGY

This study uses a secondary source design combining a systematic synthesis approach to examine how daily routines can maintain oral health that effectively whiten teeth while minimising enamel wear and sensitivity. Whilst comparing natural and chemical agents with different application methods. This study will be based on released dental evidence, data, and research results from dentists and researchers. Throughout the study, blogs and low-credible sources with little information were consistently avoided to maintain high academic reliability throughout this study. But there was an exception for this one blog, for it provided reliable data and information for the subtopics. The academic sources were found using Google Scholar and Bond University Library. This review of scientific literature synthesised qualitative and quantitative evidence from human clinical trials, articles, journals, in vitro studies, systematic reviews, professional guidelines, and literature reviews, to evaluate how tooth shade can be effectively maintained or enhanced while preserving enamel integrity and minimising teeth sensitivity. In using these types of sources, the data and information collected would be reliable and useful to the study. Throughout the study, the data were compared against both similar and different whitening agents, products, procedures, methods, routines, and effects that minimise enamel wear and sensitivity without compromising oral health.

## IV. RESULTS

### IV.1 Whitening Efficiency

Despite differences among products and techniques, professional whitening treatments stood out as most effective. The usage of strong hydrogen peroxide in dental settings between 25% and 40% revealed clear shifts in tooth shade (Carey, 2014; Kwon & Wertz, 2015; Lin et al., 2025). Studies showed colour difference scores jumping by more than five to eight points, far past what people can easily notice. On standard scales, teeth became lighter by three to eight steps, indicating deep pigment alteration. Clinic-based whitening procedures often attract individuals seeking visible results without delay.

### IV.2 Enamel Microhardness

The change in tooth enamel by whitening treatment matters more than it might seem in terms of tooth surface hardness levels. Research studies agree that strong bleach weakens enamel hardness over a period of time, despite different laboratory test methods. A research team showed clear drops in Vickers Hardness (HV) measurement of the tooth surface following the usage of 35% hydrogen peroxide for whitening treatment (Carey, 2014). In contrast, research spotted parallel results with three different office-based whitening methods (Carey, 2014). Beneath these outcomes lies a common cause: peroxides shift both organic components and mineral layout within enamel. Home-based carbamide peroxide (CP) applications led to smaller drops in surface microhardness, due to reduced peroxide levels and a gradual delivery pattern (Carey, 2014; Joiner, 2006; Lin et al., 2025; Redha et al., 2021; Safe, 2025). Whitening strips available over the counter caused slight shifts in microhardness, aligning with their modest peroxide amounts.

One study found that certain whitening toothpastes drastically lowered enamel hardness in a brief period of usage, where these products contained charcoal or strong grinding particles (Hao, 2025; Jamwal et al., 2022; Lin et al., 2025; Navodita Jamwal et al., 2023; Safe, 2025). After a laboratory simulation mimicking three months of brushing, every whitening paste tested showed lower Vickers Hardness (HV) values. Charcoal-based versions stood out by doing the most damage to the enamel in terms of the highest reductions in hardening levels (Hao, 2025; Jamwal et al., 2022; Lin et al., 2025; Navodita Jamwal et al., 2023; Safe, 2025). The damage to enamel appears to build up gradually, where small hardness reductions add to larger effects over the long term. Minimal microhardness loss was associated with the use of natural agents like baking soda, a result of gentle abrasion.

The enamel's strength and hardness increased with the application of hydroxyapatite, along with CPP-ACP, due to mineral restoration effects (Jamwal et al., 2022; Lin et al., 2025; Mohammadipour et al., 2024). Application of fluoride following bleach treatments also restored microhardness levels to the enamel, which aids recovery of the tooth. The efficacy of hardness restoration following fluoride treatment depends on the timing during and after the whitening procedure (Jamwal et al., 2022; Lin et al., 2025; Mohammadipour et al., 2024).

### IV.3 Sensitivity Incidence

Most people report sensitivity or discomfort when using teeth-whitening products. Though it varies by method, dental settings tend to cause discomfort to approximately 30% to 70% of individuals, especially with stronger concentrations of peroxide products for whitening treatment (Carey, 2014; Hao, 2025; Jamwal et al., 2022; Lin et al., 2025; Navodita Jamwal et al., 2023; Redha et al., 2021; Safe, 2025). Home whitening kits cause fewer sensitivity issues to individuals, which is reported approximately 20% to 40%, which can be associated with less concentrated gel treatment over extended periods (Carey, 2014; Hao, 2025; Jamwal et al., 2022; Lin et al., 2025; Navodita Jamwal et al., 2023; Redha et al., 2021; Safe, 2025). Store-bought whitening strips result in milder reactions; only about one-tenth to three-tenths notice any irritation at all.

Most teeth whitening pastes do not appear to cause discomfort to individuals because they rely on the scrubbing action for extrinsic stain removal rather than reactive ingredients. Sensitivity is rare with plant-based options, so people already dealing with exposed dentine may find them gentler.

### IV.4 Abrasivity and Surface Roughness

Most mechanical damage to enamel surfaces arises from whitening toothpastes with increased abrasive properties (Jamwal et al., 2022; Joiner, 2006; Joiner, 2010; Lin et al., 2025; Navodita Jamwal et al., 2023). According to American Dental Association (ADA) standards, any product that scores under 70 on the RDA scale counts as gentle enough for everyday brushing (*Relative Dentin Abrasivity Toothpaste Chart*, 2017). Treatment products scoring past 100 RDA are labelled as highly abrasive and are limited for temporary routines.

Changes to the surface texture of tooth enamel are also implicated with the usage of certain types of whitening toothpastes, according to a group of researchers, where such products led to noticeably rougher enamel surfaces than standard alternatives (Jamwal et al., 2022; Joiner, 2006; Joiner, 2010; Lin et al., 2025; Navodita Jamwal et

al., 2023). In place of mild effects, their work revealed stronger impacts with charcoal-infused variants, which increased the roughness at microscopic levels (Hao, 2025; Jamwal et al., 2022; Lin et al., 2025; Navodita Jamwal et al., 2023; Safe, 2025). Rather than assuming safety through common use, these results prompt closer attention to physical consequences, especially if paired with peroxide-based agents that may compound damage over time.

#### **IV.5 pH Levels and Tooth Erosion Risk**

The use of acidic, low pH whitening gels leads to a reduction of the enamel's extrinsic hardness, with abrasive components further accelerating this softened effect (Carey, 2014; Lin et al., 2025; Lussi, 2006). Neutral pH helps reduce enamel damage, which is why peroxide solutions usually maintain a balanced acidity. Toothpastes designed for whitening may turn problematic once acidity enters the mix (Carey, 2014; Lin et al., 2025; Lussi, 2006). Frequent use of such acidic products tends to speed up mineral loss from the tooth surface.

### **V. DISCUSSION**

#### **V.1 Balancing Whitening Efficiency and Enamel Safety**

Minimal enamel survives untouched when whitening agents are applied using high concentrations of peroxide agents. Dramatic shifts in tooth colour are common following teeth whitening with 25% to 40% hydrogen peroxide content (Kwon & Wertz, 2015). Laboratory tests show drops in microhardness of surface enamel after peroxide exposure, hinting at disruption within the organic framework and mineral structure of enamel (Lin et al., 2025). While fluoride treatments or even saliva-driven repair can reverse some enamel damage over time, moreover, teeth risk wearing down faster under brushing or acid contact, where whitening sessions pile up without adequate time for enamel restoration and recovery (Lin et al., 2025).

Some whitening toothpastes, which feature charcoal-based or highly abrasive particles, increase the risk of enamel damage through mechanical wear on the surface of the tooth (Hao, 2025; Jamwal et al., 2022; Lin et al., 2025; Navodita Jamwal et al., 2023; Safe, 2025). While bleach-based methods temporarily soften the enamel layer, gritty pastes wear it down gradually and lead to potentially permanent damage. Studies combining multiple trials show these products make enamel surfaces rougher and weaker with repeated use (Lin et al., 2025). Charcoal versions tend to be worse, frequently exceeding the recommended levels of RDA. This results in a rougher surface of the tooth enamel with reduced surface hardness, which weakens the protective layer, enabling the entrapment of stains to counteract the goal of lasting teeth brightness.

#### **V.2 Sensitivity**

Most people notice tooth sensitivity when using peroxide-based whiteners. Higher levels of peroxide tend to increase both how often it happens and how intense it feels, especially if the teeth already show dentine. Procedures done at dental settings apply stronger solutions, which often lead to discomfort. Though symptoms usually fade fast by the next day or two, some individuals feel sharp and longer duration in pain due to receding gums or prior sensitivity, which includes open tubules or thin enamel. Home use whitening tray methods tend to cause less tooth sensitivity, mainly because they deliver peroxide at weaker levels and over longer periods. Whitening strips bought without a prescription often lead to the least intense reactions, which helps people who react strongly to treatments feel more comfortable using them (Carey, 2014; Hao, 2025; Jamwal et al., 2022; Joiner, 2006; Joiner, 2010; Kwon & Wertz, 2015; Lin et al., 2025; Lussi, 2006; Mohammadipour et al., 2024; Navodita Jamwal et al., 2023; Oosterlaken et al., 2021; Redha et al., 2021; Reynolds, 1997; Safe, 2025).

Natural teeth whitening options like baking soda, papain, bromelain, or hydroxyapatite tend to cause little irritation to teeth, although their whitening efficacy is less than that of peroxide-based products when notable results for discolouration treatment are sought (Joiner, 2010; Navodita Jamwal et al., 2023). These products are categorised as supportive rather than central to teeth brightening routines.

#### **V.3 The Role of Natural Agents in a Whitening Regime**

Most natural whiteners fit into a broader routine meant to lighten teeth colour. Though less powerful than peroxide agents, these options tend to be gentler on the tooth surface. Take baking soda, it lifts surface stains well, partly because it does not scrape hard and remains neutral in pH. Instead of scrubbing, enzymes like papain or bromelain work by dissolving sticky film layers on top of the enamel, which suits individuals who adversely react to friction or suffer from a thin layer of tooth enamel (Joiner, 2010; Navodita Jamwal et al., 2023).

Hydroxyapatite boosts resistance to enamel wear while refining texture as it fills microscopic gaps within tooth enamel (which becomes visible under close examination) following bleaching procedures.

CPP-ACP encourages mineral redeposition in early decayed zones rather than just masking damage. Hence, addressing the structural weakness caused by whitening treatments. Regular usage of CPP-ACP also

reduces the surface porosity in the tooth enamel, which increases the resistance to teeth discolouration effectively (Mohammadipour et al., 2024; Reynolds, 1997).

#### **V.4 Influence of Application**

The success of teeth whitening is partly contingent on the method of application of the product and other individual factors. The fastest effects of teeth whitening often appear under dental settings where dental clinicians apply strong peroxide formulas. Still, stronger formulas often increase chances for tooth discomfort and temporary loss of surface hardness to the enamel. Slower and steadier shifts in teeth whitening happen with take-home trays while keeping the risks of tooth damage relatively low. These products often work well because they remain on the teeth longer, even at low peroxide concentrations. Irritation tends to be less common, along with harm to the tooth surface, but results often fall short when compared to in-chair options offered by a dentist. The LED lights used in at-home teeth whitening devices add little real benefit in comparison to the actual bleaching gel that is largely responsible for the teeth whitening effect.

#### **V.5 Importance of Remineralisation Maintenance**

The application of fluoride boosts the repair of tooth enamel after bleaching while lowering the discomfort that often follows such procedures. This mineral helps create fluorapatite, which is a stronger version of natural enamel that better resists acid (Lin et al., 2025). Moving on, CPP-ACP works differently by holding calcium and phosphate in place so they can seep into weakened areas of teeth (Mohammadipour et al., 2024; Reynolds, 1997). This mineral supports healing beneath the surface where damage begins unseen. Finally, hydroxyapatite, which behaves like real enamel, slots smoothly into damaged zones. The application of this mineral increases the hardness at a microscopic level, leaving the outer layer less rough over time (Kwon & Wertz, 2015; Lussi, 2006; Mohammadipour et al., 2024).

Brushing each day gently protects the outer layer of teeth. Instead of harsh scrubbing, softer methods keep the surface intact over time. Skipping the consumption of dark pigmented drinks like coffee or wine limits visible marks on enamel. Routine visits to a dental provider also clear away hardened deposits that dull the appearance of the teeth. Between appointments, occasional touch-ups with gentle products sustain lightness. Products containing diluted peroxide, used now and then, offer subtle renewal. Even baking soda formulas, when applied sparingly, support lasting clarity without damage. Over time, small choices shape long-term outcomes more than intense treatments do (Carey, 2014; Hao, 2025; Joiner, 2010; Kwon & Wertz, 2015; Lin et al., 2025; Lussi, 2006; Navodita Jamwal et al., 2023; Safe, 2025).

#### **V.6 Integrating findings into a Safe Whitening Protocol**

Although results point toward a mixed approach, combining treatment methods wisely reduces downsides to teeth whitening. Instead of relying on one technique, treatments using hydrogen peroxide work best when duration and strength are intensively managed professionally or self-administered. Following teeth whitening, mineral formers like fluoride, CPP-ACP, or hydroxyapatite help rebuild mineral loss in tooth surfaces. Evidence favours the timing of these repair-focused products alongside or right after brightening steps.

Enamel begins to regain strength when given the right conditions and time interval. Through consistent use of remineralising toothpaste, mineral loss slows down. Acidic drinks and harsh brushing habits interfere with healing, pausing the repair. Recovery takes place gradually, provided irritants are set aside. Time becomes a quiet ally in rebuilding the surface resilience of the tooth enamel.

Throughout upkeep, soft brushing matters most, paired with careful attention to food choices that affect colour. Instead of frequent strong treatments, occasional mild brighteners work well enough. Less aggressive routines reduce reliance on intense lightening later. Over time, these habits protect the outer tooth layer without demanding extra steps.

## **VI. CONCLUSION**

This study finds that teeth whitening treatments which follow science procured approaches yield favourable outcomes in brightness and cosmetic gains while ensuring enamel defence and sensitivity management. Following tested protocols means teeth whitening benefits emerge without compromising dental health. Close and correct oversight supports visible improvements in teeth whitening while keeping the potential harm of tooth damage to a minimum. The lasting success of teeth whitening treatment depends on shade shift and, more importantly, the preservation of nerve function and the strength of the tooth enamel.

Most whitening methods are based on scientific evidence, which reduces teeth damage with positive results in colour appearance. Still, fairness counts where brighter teeth should never pose safety risks to gum or teeth damage. Peroxide solutions may lighten teeth effectively, yet careful monitoring helps avoid short-term enamel softening or irritation. Milder alternatives for teeth whitening also exist for individuals experiencing sensitivity or suffering from compromised enamel, for teeth whitening using nonaggressive formulations. Products claiming whitening effects sometimes wear down the outer tooth layer gradually, particularly if they contain gritty or excessive abrasive substances like charcoal.

Recovery using mineral formation products like fluoride, CPP-ACP, or hydroxyapatite is key to support essential remineralisation of the tooth enamel surface following whitening treatment with peroxide agents. Long-term results of teeth whitening rely heavily on routine choices, which include adopting softer brushing motions, limiting stain-causing foods, and regular visits to dental professionals.

Following long-term clinical trials, researchers combine objective enamel evaluations with firsthand participant insights. Comparison becomes key at this stage between hybrid natural-chemical whitening approaches and advanced peroxide delivery systems. These trials, which are grounded firmly in evidence rather than speculation, suggest that teeth whitening guidance and prognosis grow more precise. Working best over time, outcomes of teeth whitening often improve when controlled peroxide agents' usage joins forces with routines that reinforce the surface strength of the tooth enamel. Instead of acting alone, strategies gain effect through small, consistent actions - brushing softly, avoiding frequent staining triggers. Progress builds quietly where attention stays steady. Rather than chasing quick fixes, lasting change to teeth brightness and whiteness follows from a balance between treatment and prevention.

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