International Journal of Research and Review
Volume 11; Issue: 4; April 2024
Website: www.ijrrjournal.com
Review Article
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Bright Smiles, Hidden Dangers: A Literature Review on the Potential Side Effects of Peroxide Based Over-The-Counter Teeth Whitening Treatments

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DOI: https://doi.org/10.52403/ijrr.20240425

ABSTRACT

Background: Adults' dissatisfaction with their smile and tooth color has led to an increased demand for teeth whitening products, particularly over-the-counter (OTC) systems, which utilize peroxides like hydrogen peroxide and carbamide peroxide. While generally safe, these products can temporarily increase tooth sensitivity due to enamel surface damage.
Method: An analytical review was conducted using databases like PubMed, Web of Science, and ScienceDirect, focusing on publications from the past 10 years. Initial findings totaled 35, which were narrowed down to 12 after applying selection criteria, with 5 manuscripts ultimately included. Each paper independently assessed by the authors covered the risks and side effects of hydrogen peroxide and carbamide peroxide in whitening products.
Discussion: Studies highlighted the oxidizing mechanisms of hydrogen peroxide and carbamide peroxide, resulting in a lighter tooth appearance. Additionally, they revealed risks associated with prolonged use, including enamel microhardness and ultrastructural changes, and increased tooth sensitivity due to peroxide penetration and release of inflammatory mediators.
Conclusion: While peroxide-based whitening products effectively enhance tooth color, their use necessitates caution due to potential adverse effects on enamel integrity and tooth sensitivity. As demand for at-home whitening rises, balancing efficacy with safety is crucial. Future research should refine whitening protocols, optimize safety parameters, and comprehensively evaluate adverse effects to advance dental whitening practices.

Keywords: Hydrogen peroxide, carbamide peroxide, teeth whitener, teeth bleaching, side effects, Over-the-counter products

INTRODUCTION

Human social interactions have traditionally acknowledged the significant role of physical appearance, with the face typically being the most prominently exposed part. Among facial features, the eyes and mouth, in particular, are closely associated with facial attractiveness. Smiling, as a form of facial expression, serves as a vital means of communication[1,2]. Nonetheless, the absence of an aesthetically pleasing smile can impact an individual's self-esteem, with tooth color being a critical component of smile attractiveness. Dental aesthetics often prioritize tooth color and shape, considering them pivotal factors in evaluating smile appeal[2]. Those who exhibit a positive attitude toward the appearance of their teeth, including color and shape, tend to exude confidence and extroversion. Conversely, individuals with discolored, missing, or damaged teeth may experience social withdrawal due to concerns about their dental appearance[3].

Tooth discoloration is categorized into intrinsic and extrinsic types. Intrinsic discoloration results from various factors including aging (which leads to dentin yellowing due to wear), genetic predispositions, abnormalities in post-traumatic formation, fluorosis, antibiotics, and systemic illnesses like hepatitis. The intrinsic color of a tooth is influenced by how light interacts with and is absorbed by its surface and internal structures. Enamel doesn't entirely mask the color of the underlying dentin, thus dentin plays a significant role in determining tooth color. Additionally, enamel possesses some porosity, making it susceptible to penetration by particles capable of altering the color of both enamel and dentin. On the other hand, extrinsic discoloration arises from external influences such as smoking and food and drink pigments, such as tea, coffee, and red wine[4,5].

Reports indicate that dissatisfaction with smile and tooth color is a prevalent concern among adults. Across various adult populations, studies have revealed that between 20.4% and 50% express dissatisfaction with their tooth appearance, while dissatisfaction with tooth color ranges from 19.6% to 65.9%[2,6]. Generally, this dissatisfaction with tooth appearance and color correlates with an increased inclination towards treatments aimed at enhancing dental aesthetics, such as tooth whitening or bleaching[2]. Moreover, research suggests that higher levels of satisfaction with one's appearance, along with an improved quality of life and psychological well-being, are associated with adequate dental aesthetics and treatments geared towards enhancing them.

Dental bleaching is a minimally invasive procedure involving the use of chemical agents that penetrate the tooth surface, releasing free radicals that oxidize organic pigments within the tooth structure, resulting in whitening. The demand for over-the-counter (OTC) whitening systems has surged in recent years due to the increasing popularity of convenient home-based aesthetic treatments. These systems typically utilize peroxide compounds, such as hydrogen peroxide and carbamide peroxide, which can be applied either directly to the tooth surface or within custom dental trays. Carbamide peroxide is commonly used in varying concentrations for both professional in-office treatments and at-home bleaching. It exhibits a slower degradation rate compared to hydrogen peroxide (H_2O_2) and remains in contact with the tooth surface for an extended duration when applied via dental trays. Peroxides release highly reactive free radicals that oxidize organic chromophores, which are the small molecules responsible for tooth discoloration from substances like coffee, red wine, or tea. As a result of this oxidation process, these molecules are broken down into smaller compounds that absorb fewer wavelengths of visible light, leading to a lighter appearance of the teeth[7,8].

Tooth whitening using peroxide-based agents is commonly regarded as a safe and efficient procedure. However, it is acknowledged to potentially cause temporary tooth sensitivity by inducing microscopic surface damage to the enamel. This damage allows oxygen radicals to reach the dental nerve, resulting in temporary inflammation. Yet, there remains uncertainty regarding whether bleaching procedures with peroxides cause actual enamel damage. Additionally, studies have indicated that tooth whitening with peroxides can induce changes in the enamel surface [7,8,9]. Generally, there is limited evidence regarding the effectiveness and safety of over-the-counter (OTC) teeth-whitening agents, raising concerns as these products are widely used by individuals seeking to improve tooth color without being fully aware of potential risks. This literature review aims to assess the risks of side effects associated with teeth whitening or bleaching products containing hydrogen peroxide or carbamide peroxide.

METHODS

For this literature review, an analytical approach was adopted, gathering comparative data from various databases including PubMed, Web of Science, and ScienceDirect. The search was restricted to publications within the past decade, starting from January 1, 2014. The search terms encompassed Hydrogen peroxide, carbamide peroxide, teeth whitener, teeth bleaching, side effects, and Over-the-counter (OTC) products. Thorough examination of abstracts, studies, and citations was conducted. Moreover, relevant studies were sought by examining the reference sections of chosen journals. Initially, 35 findings were identified, which were then refined to 12 publications after applying specific criteria: publications in English, from international journals, and based on experimental studies. Further screenings led to the selection of a subset of 5 manuscripts. Each reviewed paper was independently evaluated by the reviewer, all of which contained insights into the risks and side effects associated with Hydrogen peroxide and carbamide peroxide in whitening products.

RESULTS AND DISCUSSION

Hydrogen Peroxide and Carbamide Peroxide Mechanism in Whitening Products

Tooth whitening is based on the principle that hydrogen peroxide permeates both enamel and dentin, interacting with organic chromophores. Dental hard tissues, known for their high fluid permeability, exhibit significant fluid flow primarily in the interprismatic spaces of enamel and dentinal tubules in dentin. Consequently, enamel and dentin are presumed to function as semipermeable membranes, facilitating the movement of hydrogen peroxide in accordance with Fick's second law of diffusion. This law posits that the diffusion of a molecule correlates with surface area, diffusion coefficient, and concentration, while inversely proportional to the diffusion distance. The proposed mechanism for dental bleaching involves an oxidoreduction reaction, leading to the release of free radicals. These radicals exhibit high instability upon contact with target tissues, causing oxidation and reduction of pigment chains bound to them. As a result, these pigments undergo cleavage into progressively smaller molecular chains, ultimately dispersing from the tooth structure or indirectly enhancing light absorption due to reduced chain size, thereby creating the appearance of whiter teeth[8,10].

Hydrogen peroxide (H2O2) is a clear liquid with a slightly denser consistency than water and a molecular weight of 34.01 g/mol. Its low molecular weight facilitates effective penetration into dentin, where it liberates oxygen and decomposes organic and inorganic compounds within dentinal tubules. In dentistry, hydrogen peroxide is widely utilized across concentrations ranging from 5% to 35%, functioning as a potent oxidizing agent that generates reactive oxygen molecules and peroxide anions. Importantly, the body naturally produces, regulates, and eliminates hydrogen peroxide as part of its normal physiological processes, employing diverse defense mechanisms to mitigate oxidative stress[10,11].

In contrast to hydrogen peroxide, carbamide peroxide (CH6N2O3) exists as a white crystalline solid that releases oxygen upon contact with water. Typically employed in concentrations ranging from 10% to 35% for bleaching purposes, a 10% carbamide peroxide solution decomposes into 3.35% hydrogen peroxide and 6.65% urea. This combination, along with urea by-products, may attenuate the degradation of carbamide peroxide, rendering it effective in whitening dental structures. Furthermore, carbamide peroxide exhibits proteolytic properties that can enhance tooth whitening efficiency. Products containing carbamide peroxide often incorporate a carbopol or glycerin base, with carbopol-based formulations providing sustained effectiveness by retarding hydrogen peroxide release. Both hydrogen peroxide and carbamide peroxide play pivotal roles in dental bleaching procedures, offering distinct advantages based on their chemical compositions and mechanisms of action[10,11].

Effects of Tooth Whitening Products on The Enamel Microhardness and Ultrastructural Damage

Extended use of peroxides can lead to detrimental effects on enamel, including alterations in its chemical structure and eventual enamel loss. In a study conducted by Júnior et al. in 2020, the effects of a 22% carbamide peroxide gel on enamel surface roughness and microhardness were examined over a 28-day bleaching period. The study involved three key observation points: T0, before the initiation of the bleaching protocol (serving as the negative control); T1, at the conclusion of the 14th day of bleaching (serving as the positive control); and T2, at the conclusion of the 28th day of bleaching. Additionally, the experiment was divided into three distinct groups: the excessive tooth bleaching group (G1), the excessive bleaching + erosive challenge group (G2), and the excessive bleaching + erosive challenge + abrasive challenge group (G3)[12].

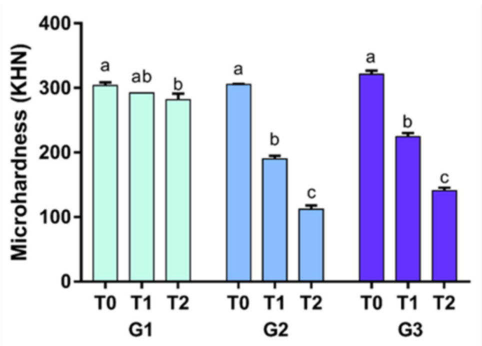

Figure 1. The mean ± standard deviation of the microhardness subjected to two-way analysis of variance for repeated measurements according to the periods for the groups tested. Different lowercase letters indicate an intragroup statistically significant difference[12].

In this experiment, the integrity of enamel prisms was also assessed through scanning electron microscopy (SEM) images representative of the specimens. At T0, the specimens remained untreated, allowing for the observation of intact enamel prisms. By T1, some degree of enamel prism exposure, indicative of aprismatic enamel loss in the horizontal direction, was observed. This effect was more pronounced in groups G2 and G3. The results are presented below.

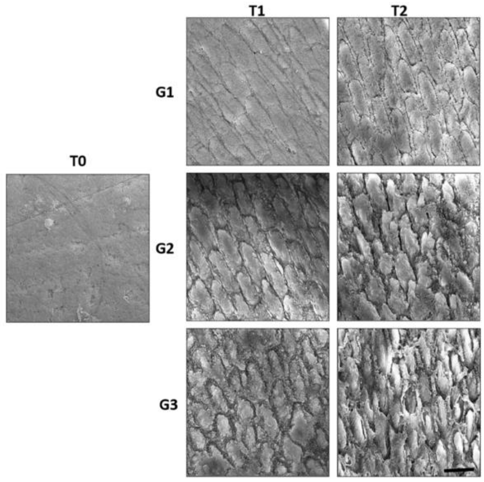

Figure 2. The scanning electron microscopy images representative of the effect of the following treatments with time on dental enamel: T0 without treatment (artificial saliva), G1-T1 CP22 for 14 days, G2-T1 CP22 + Gatorade for 14 days, G3-T1 CP22 + Gatorade + simulated toothbrushing for 14 days. T2 images following the same treatments for 28 days. Scale Bar: 5 µm. CP22, 22% carbamide peroxide[12].

The results from both experiments indicate that while not as pronounced as in groups G2 and G3, group G1 demonstrates some side effects associated with the use of peroxides. This finding is further supported by an in vitro study conducted by Tompkins et al. in 2014, where five different bleaching products were tested for their effects on human enamel erosion. These products included strips containing 6.5% hydrogen peroxide, gels containing 10% and 22% carbamide peroxide, 35% hydrogen peroxide, and a gel system containing sodium hypochlorite. The experiment adhered to manufacturer instructions and assessed enamel surface loss using polarized light microscopy. While the results showed softened enamel surfaces, no erosion was observed[12]. However, a 2019 study by Ribeiro et al., which evaluated changes in dental enamel mass following prolonged use of 10% carbamide peroxide, did not find any loss of mass. This contrasts with the findings of the present study. The difference could be attributed to the higher concentration of bleaching gel used in the present study, potentially leading to more pronounced damage, as evidenced by the SEM images[13].

Effects of Tooth Whitening Products on Dental Sensitivity

In 2018, Chemin et al. conducted a study focusing on tooth sensitivity following the use of an over-the-counter (OTC) product. Participants had their upper and lower arches molded using avagel alginate (Dentsply, Petrópolis, RJ, Brazil). These molds were disinfected and promptly filled with dental stone, creating trays that were ensured to be fully adapted to the participants' dental arches. Any excess material from the labial and lingual surfaces was trimmed to 1 mm from the gingival junction[11].

The assessment involved participants recording the occurrence or absence of dental sensitivity using both the five-point analogue numerical scale (NRS), where 0 indicates no sensitivity and 4 indicates severe sensitivity, and the visual analogue scale (VAS), ranging from 0 (no pain) to 10 (severe pain). The distance in millimeters from the zero point on the VAS was measured using a millimeter ruler. The results revealed that the absolute risk of tooth sensitivity among participants was 65% (95% CI 46 to 93%), with a mean VAS intensity of 2.0 ± 2.3 (95% CI 0.9 to 3.0) and a mean NRS score of 1.2 ± 1.2 (95% CI 0.6 to 1.7)[11].

The absolute risk of dental sensitivity resulting from whitening procedures indicates that 65% of the volunteers experienced sensitivity at some point during the protocol. This finding is corroborated by a study conducted by Martini et al. in 2019, which examined the absolute risk of tooth sensitivity associated with dental whitening products. The study reported that tooth sensitivity affects 60 to 100% of patients who undergo bleaching treatment, particularly when in-office bleaching is the chosen protocol. Among 81 patients, pain was reported before application, with only 1 patient experiencing pain exclusively in this group, indicating a positive correlation[14].

Tooth sensitivity induced by hydrogen peroxide or carbamide peroxide bleaching gels is a common occurrence, with multiple potential causes and not entirely preventable[11].

This incidence occurs because hydrogen peroxide penetrates through enamel and dentin, increasing dental permeability and reaching the pulp, where it triggers the release of inflammatory mediators. This mechanism may lead to tooth sensitivity after bleaching procedures[11].

Limitations

The review compare studies with varying methodologies, posing challenges in comparing results and potentially limiting the generalizability of findings. Moreover, its focus on tooth sensitivity induced by dental whitening products may overlook other adverse effects such as enamel damage or gum irritation. Factors like individual patient characteristics, pre-existing dental conditions, and variations in treatment protocols also could confound study results, potentially affecting the reliability of the given conclusions. These limitations underscore the need for future research to adopt standardized methodologies, conduct subgroup analyses, and include a broader range of adverse effects to provide a more comprehensive understanding of the safety profile of dental whitening procedures.

CONCLUSION

The demand for over-the-counter (OTC) whitening systems has increased in recent years due to the increasing popularity of convenient home-based aesthetic treatments and the amount of adults dissatisfied with their tooth color. These products mostly utilize the peroxide compounds, such as hydrogen peroxide and carbamide peroxide.

Peroxides release highly reactive free radicals that oxidize organic chromophores, which are the small molecules responsible for tooth discoloration from substances like coffee, red wine, or tea. As a result of this oxidation process, these molecules are broken down into smaller compounds that absorb fewer wavelengths of visible light, leading to a lighter appearance of the teeth.

While dental whitening is generally considered safe, it's important to note the associated risks, particularly heightened sensitivity and potential damage to the ultrastructure of the teeth. While studies suggest that the degree of ultrastructural damage may not be significant, its impact on sensitivity is substantial. This underscores the need for careful consideration and monitoring during whitening procedures to ensure both effectiveness and patient comfort. As the demand for at-home whitening solutions continues to grow, further research into optimizing safety and efficacy parameters will be essential in delivering satisfactory outcomes for individuals seeking to enhance their smile aesthetics.

Recommendations

1. Future research should apply standardized methodologies across studies to enhance comparability and facilitate meta-analyses. Consistent protocols for whitening procedures and uniform methods for assessing tooth sensitivity and other adverse effects would improve the reliability and generalizability of findings.
2. To provide a more comprehensive understanding of the safety profile of dental whitening procedures, future reviews should expand their scope to include a broader range of adverse effects beyond tooth sensitivity. This would enable a more balanced evaluation of the risks associated with whitening treatments and contribute to informed decision-making by clinicians and patients.
3. Study designs incorporating appropriate control groups and adjustments for potential confounders are essential to mitigate the impact of individual patient characteristics and treatment variations on study results. By implementing controlled study designs, researchers can more accurately assess the causal relationship between dental whitening procedures and adverse effects while minimizing bias and confounding factors.

Declaration by Authors

Ethical Approval: Not Applicable

Acknowledgement: I would like to express my sincere gratitude to Dean and all of Vice Dean of Dentistry Faculty Universitas Jember for their unwavering support and provision of resources throughout the course of this manuscript.

Source of Funding: None

Conflict of Interest: The author declares no conflict of interest.

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How to cite this article: Dea Permata. Bright smiles, hidden dangers: a literature review on the potential side effects of peroxide based over-the-counter teeth whitening treatments. *International Journal of Research and Review*. 2024; 11(4): 224-230. DOI: *https://doi.org/10.52403/ijrr.20240425*

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