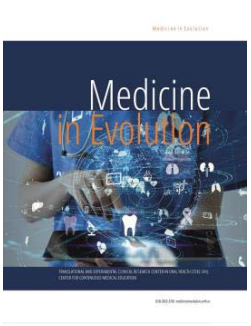
Whitening Efficacy and Enamel Mineralization Effects of Hydrogen Peroxide-Based and Peroxide-Free Whitening Products



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Abstract

1.Background/Objectives: Tooth discoloration can negatively impact self-esteem and social interactions, driving the demand for effective and safe whitening treatments. Whitening agents vary in composition, with hydrogen peroxide-based products being widely used for their strong bleaching effect, while peroxide-free alternatives incorporating remineralizing agents aim to balance whitening efficacy with enamel preservation. 2.Methods: This study evaluated the whitening performance and impact on enamel mineralization of Crest 3D White Professional Effects, a hydrogen peroxide-based product, and My White Secret, a peroxide-free alternative containing hydroxyapatite. Sixty extracted human teeth were divided into two equal groups and subjected to whitening treatments according to the manufacturers' protocols. Color and enamel mineralization were assessed using the VITA Classical Shade Guide and the DIAGNOdent Pen before and after each whitening session. 3. Results: My White Secret demonstrated a rapid initial whitening effect while maintaining enamel mineralization, whereas Crest 3D White exhibited a delayed but more pronounced whitening outcome, raising concerns regarding potential demineralization. Whitening response variability suggests that factors such as enamel structure and baseline mineralization influence treatment outcomes. 4.Conclusion: These findings emphasize the significance of formulation differences in whitening treatments, as hydrogen peroxide may impact enamel integrity, while hydroxyapatite-based alternatives provide a more balanced approach by by combining whitening efficacy with remineralization benefits. Selecting a whitening treatment should consider both aesthetic outcomes and enamel health.

Keywords: tooth whitening, enamel mineralization, hydrogen peroxide, remineralization, aesthetic dentistry

INTRODUCTION

The World Health Organization defines health as a state of complete physical, mental, and social well-being [1]. A bright, healthy smile is often seen as a reflection of overall psychosomatic well-being. In everyday culture, smiling is associated with happiness and serves as a key tool for communication and social connection, impacting not only aesthetic perceptions but also deeper aspects like self-esteem. Physical appearance can influence or enhance personal qualities and behaviours [2,3]. Beyond their primary function in chewing, teeth play a vital role in speech and social interactions. Poor oral health, which prevents a person from smiling confidently, can significantly hinder social relationships and overall quality of life [4, 5].

The importance of aesthetic dentistry and the way individuals perceive their smiles has grown significantly among the population. The visual appeal of a smile has become a key psychological and social factor, with dental appearance and conditions often influencing self-confidence and self-image [6–8]. Many people seek to improve aspects of their smile, especially tooth colour, as discoloration can lead to discomfort, embarrassment, and anxiety in social situations [5, 9].

Due to the increasing demand for aesthetic treatments in the 21st century, dentistry has advanced to meet public expectations. The growing interest in smile enhancement has led clinicians and researchers to develop minimally invasive procedures, such as teeth whitening, as a safer alternative to veneers or crowns, which can be more invasive and potentially damaging when used solely for cosmetic purposes [10].

In the late 1980s, both professional and over-the-counter whitening products were introduced to the U.S. market in response to the growing demand for achieving bright, white teeth. The effects of carbamide peroxide (CP) on dental structures were initially identified during World War I when it was used as an antiseptic for treating acute necrotizing ulcerative gingivitis (ANUG). In 1962, Klusmier proposed the application of a CP-containing gel to manage periodontal inflammation following orthodontic treatments. This led to the unexpected discovery of peroxide's ability to lighten enamel, paving the way for its use in teeth whitening. However, Kusmier's communication to the Arkansas Dental Society regarding this finding remained unnoticed until 1989 when Haywood and Heymann formally described the technique [11].

An imbalance in the shape and colour of the teeth can directly impact the aesthetics of a smile, potentially affecting an individual's personal relationships, psychological well-being, and professional demeanor. These factors may lead to considerable negative consequences for overall health and quality of life [12, 13].

Teeth whitening has become the primary method for addressing discoloration, offering beneficial results depending on the cause and severity of tooth staining. Various techniques are available, including in-office whitening, which utilizes hydrogen peroxide at concentrations of 35-37%, and at-home treatments under professional supervision, where patients apply carbamide peroxide in concentrations between 10% and 22% [14, 15].

Whitening agents primarily function by oxidizing organic compounds. Due to their high instability, these agents release free radicals, particularly nascent oxygen, upon contact with dental tissue. This oxygen penetrates the dentinal tubules and interacts with highly pigmented carbon ring compounds, breaking them down into lighter, less pigmented substances. For an effective whitening process, several factors must be considered, including the concentration of the bleaching agent, its ability to penetrate the dental structure to reach chromophoric molecules, and the duration and frequency of its exposure to these molecules. A well-balanced combination of these elements ensures optimal whitening results. [13, 16].

The most commonly suggested treatment is at-home whitening; however, some patients may feel uneasy about wearing a whitening tray for extended periods [17]. Besides professionally supervised whitening techniques, there are also over-the-counter whitening products available in pharmacies and supermarkets, which do not require professional oversight. This method has gained popularity, driven by patients' growing desire to achieve brighter, whiter teeth [13].

Aim and objectives

This study aims to evaluate and compare the whitening efficacy and impact on enamel mineralization of Crest 3D White Professional Effects and My White Secret by analyzing shade changes and mineralization levels over multiple days using the VITA Classic Shade Guide and DIAGNOdent Pen, providing insights into their effectiveness and safety in aesthetic dentistry.

MATERIAL AND METHODS

For the analysis, a total of 60 extracted human teeth from the maxillary and mandibular anterior regions were used. These teeth were intact, non-carious, and extracted for orthodontic reasons or due to periodontal disease affecting their supporting bone structure. Prior to inclusion in the study, informed consent was obtained from all patients. The teeth were initially cleaned under a water jet to remove organic residues and then stored in a physiological saline solution.

After selection, the teeth were randomly divided into two equal groups of 30 specimens each to ensure an accurate and detailed comparison. The first group was assigned to whitening with Crest 3D Whitestrips Professional Effects, a hydrogen peroxide-based product, while the second group underwent whitening with My White Secret, a product formulated by UK-based dentists that does not contain hydrogen peroxide.

Before starting the whitening process, the initial mineralization and color of all teeth were recorded using the Vita Classical shade guide. Whitening was then performed following the manufacturers' instructions. In both groups, the whitening strips were applied for 30 minutes per session. After this period, the strips were removed, and each tooth was thoroughly rinsed with water to eliminate any residual whitening agents. Subsequently, the mineralization and color of each tooth were re-evaluated before being stored in saline solution until the next whitening session.

To mimic an in vivo scenario, as recommended by both manufacturers, the whitening procedure was conducted once daily for several consecutive days. Each session followed the same protocol, including mineralization and color assessment after the application of the whitening strips. The second and third whitening sessions were carried out under identical conditions, ensuring consistent monitoring of changes in both enamel integrity and color throughout the whitening process.

Two at-home tooth whitening solutions were utilized, each with distinct active ingredients. Crest 3D White Professional Effects Level 18, manufactured by Procter & Gamble, contains hydrogen peroxide as the primary whitening agent, which acts through an oxidative mechanism to break down stains on the enamel surface [18]. In contrast, My White Secret, produced by Smile Beauty Care, is a peroxide-free alternative that employs phthalimidoperoxycaproic acid (PAP) and hydroxyapatite, components known for their enamel-safe whitening properties and remineralizing effects [19]. The application of both whitening products was carried out strictly in accordance with the manufacturers' guidelines to ensure standardized conditions, optimal efficacy, and safe use throughout the study. (Table 1)

Table 1. Composition and Manufacturer Details of Whitening Products Used in the Study

Materials	Manufacturer	Ingredients
Crest 3D White Professional Effects Level 18	Procter & Gamble Global Privasi Tim	PVP, Water, PEG-8, Acrylates Copolymer, Hydrogen Peroxide, Sodium Hydroxide, Sodium Saccharin
My white secret	Smile beauty care	Glycerin, Water/Aqua, PVP, Ethylcellulose, Alcohol, SodiumPolyacrylate, Phthalimidoperoxycaproic Acid (PAP) Xylitol,Potassium Citrate, Hydroxyapatite, Rebaudioside A, Menthol.Sodium Citrate, Xanthan Gum, PVM/MA Copolymer, C12-15 Pareth-3

Colour Assessment

A spectrophotometer (Vita Easyshade® V Compact, Vita Zahnfabrik, Bad Säckingen, Germany) was utilized to measure colour [20]. Calibration was carried out using standard tiles from the National Institute of Standards and Technology (NIST). The testing conditions included a spectral range of 360 to 750 nm, a wavelength interval of 10 nm, and a reflectance angle of 45°. Measurements were conducted against a black background, with each specimen undergoing an average of three scans [21]. The recorded tooth colour was noted according to the Vita Classical shade guide. Tooth shades were numerically coded based on an ordered scale, assigning higher values to darker shades and lower values to lighter ones, following the VITA Classic guide.

Assessment of Dental Mineralization

To assess the level of tooth mineralization, the DIAGNOdent Pen 2190 (Kavo) device, based on LASER fluorescence technology, was used. This device measures the fluorescence of dental tissues through a laser beam with a wavelength of 655 nm [22]. Demineralization of dental structures leads to a loss of autofluorescence, which appears as darkened areas. For accurate use, the equipment was individually calibrated for each tooth, considering variations in dental mineralization [23]. According to the DIAGNOdent classification, values were interpreted as follows: 1-13 indicates healthy enamel, 14-20 suggests early enamel caries, 21-29 signals deep enamel caries, and values above 30 indicate dentin caries [24]. To ensure measurement accuracy, each assessment was performed twice, and all measurements were conducted by the same researcher.

Statistical analysis

Statistical analysis was performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including mean values and standard deviations, were calculated for each whitening product at different time points.

Ethical approval

All participants willingly signed a written informed consent form prior to their inclusion in the study. The research adhered to the ethical principles outlined in the Declaration of Helsinki and was officially approved by the Ethics Committee of the University of Medicine and Pharmacy "Victor Babeş," Timişoara, Romania (Approval No. 09/11.03.2024).

RESULTS

The comparative analysis of Crest 3D White Professional Effects Level 18 and My White Secret over three days demonstrated distinct patterns of whitening efficacy. At baseline, My White Secret exhibited a higher mean value (3.26) compared to Crest 3D White (1.6), indicating a stronger initial whitening effect. However, while My White Secret showed a gradual and consistent increase in whitening over time, reaching a final mean of 4.73 on Day 3, Crest 3D White displayed a more rapid and pronounced improvement after Day 2, increasing from 1.6 to 4.2. This suggests that Crest 3D White may have a delayed but more

intense whitening effect, whereas My White Secret provides a more stable but progressively improving outcome.

The standard deviation (SD) values provide additional insights into the variability of the products' effects among participants. My White Secret exhibited greater inter-individual differences, with an SD of 1.66 on Day 3 compared to 1.22 for Crest 3D White. This indicates that while My White Secret maintained a relatively steady progression in whitening, the extent of its effectiveness varied more significantly between individuals. On the other hand, Crest 3D White showed a lower initial mean but a more uniform response among participants, as indicated by its lower SD values in the early days of application (Table 2, Figure 1).

These findings suggest that the choice between these two whitening products may depend on individual preferences and expectations. Users seeking a faster and more dramatic improvement in whitening might benefit more from Crest 3D White, which demonstrated a substantial increase in effectiveness after Day 2. Conversely, individuals preferring a gradual, more consistent whitening effect, despite potential variability in outcomes, may find My White Secret to be a better option. Further studies with larger sample sizes and extended assessment periods could provide deeper insights into the long-term efficacy and stability of these whitening treatments.

Table 2. Mean Values and Standard Deviations of Whitening Products

Moment assessment	Crest(Mean)	Crest (SD)	My White secret(Mean)	My White Secret(SD)
Initial	1.6	0.67	3.26	1.43
Day 1	1.6	0.63	3.26	1.43
Day 2	2.86	0.83	3.93	1.49
Day 3	4.2	1.22	4.73	1.66

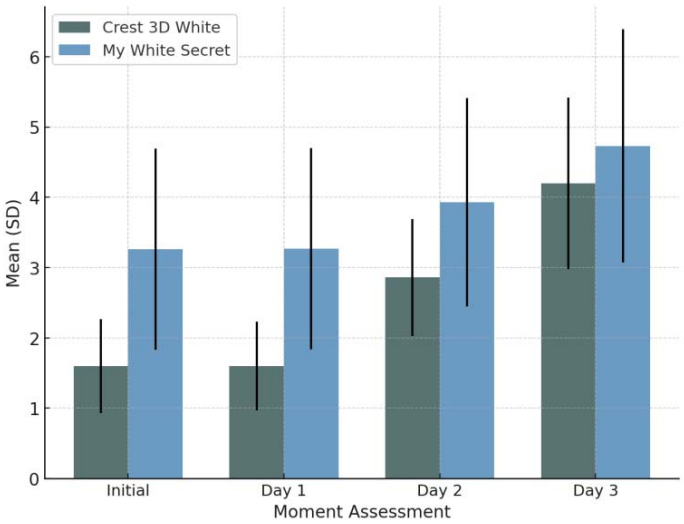

Figure 1. Comparison of Crest 3D White Professional Effects Level 18 and My White Secret

At the initial assessment, both groups exhibited relatively high average colour values, indicating darker shades. By day 1, a significant reduction in shade value was observed for both treatments, with My White Secret demonstrating a steeper decline, suggesting a more rapid whitening effect compared to Crest. As the study progressed to day 2 and day 3, the downward trend continued, although the rate of change slowed. By the final assessment on day 3, My White Secret reached the lowest shade values, indicating a stronger overall

whitening effect, while Crest also showed improvement, but with a more gradual reduction in colour values. These findings suggest that My White Secret may offer a faster whitening outcome, whereas Crest provides a steadier but less pronounced effect over the same period (Figure 2).

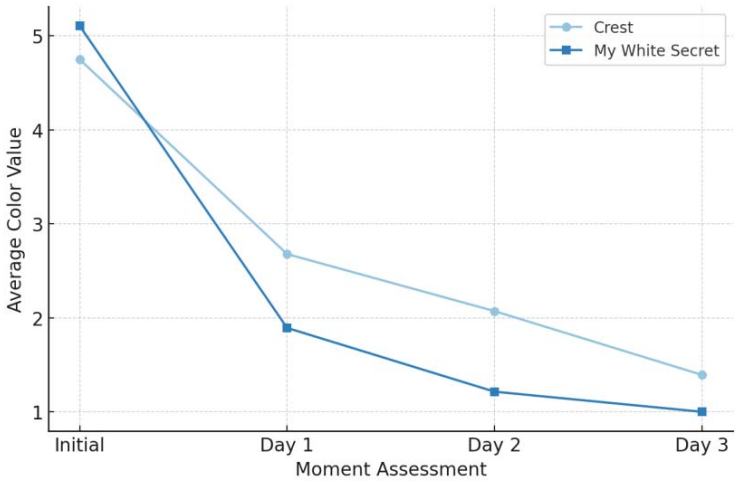

Figure 2. Comparing colour evolution Crest versus My White Secret (Vita Shade Guide)

DISCUSSIONS

The findings of this study demonstrate notable differences in the whitening efficacy and impact on enamel mineralization between hydrogen peroxide-based (Crest 3D White Professional Effects) and peroxide-free (My White Secret) whitening products. My White Secret exhibited a rapid initial whitening effect, while Crest 3D White showed a delayed but more pronounced improvement after the second day. The variability in whitening responses among samples suggests that factors such as enamel composition and baseline mineralization levels may influence treatment outcomes. Additionally, the oxidative mechanism of hydrogen peroxide raises concerns regarding potential enamel demineralization, whereas the inclusion of hydroxyapatite in My White Secret may contribute to a gradual whitening effect while supporting remineralization.

These findings align with previous research indicating that hydrogen peroxide is an effective bleaching agent due to its ability to oxidize chromogenic molecules. However, studies such as that of Li et al. (2024) emphasize its potential adverse effects, including enamel demineralization and increased tooth sensitivity. Our study supports this observation, as Crest 3D White produced a strong whitening effect but also raised concerns about its impact on enamel integrity. On the other hand, My White Secret, which utilizes phthalimidoperoxycaproic acid (PAP) and hydroxyapatite, exhibited a more gradual but controlled whitening effect, potentially reducing the risks associated with peroxide-based formulations. The variability in whitening response observed in our study may also be linked to individual differences in enamel structure and mineral content, a factor highlighted in previous research exploring the penetration depth of bleaching agents and their interaction with dental tissues.

In comparison to Agarwal et al. (2024), who evaluated over-the-counter whitening products available in online marketplaces, our findings highlight similar concerns regarding the role of active ingredients in determining whitening efficacy and enamel safety. Their study found that the most effective over-the-counter product achieved results comparable to a dentist-prescribed whitening agent, while lower-quality formulations led to enamel surface

alterations and reduced microhardness. Similarly, our study suggests that the formulation of a whitening product plays a critical role in both effectiveness and enamel protection. The presence of acidic agents in some over-the-counter whitening products has been associated with increased enamel erosion and susceptibility to staining, reinforcing the importance of selecting formulations that incorporate remineralizing agents to counteract potential damage.

Furthermore, our results are consistent with the study by Loguercio et al. (2024), which explored the role of hydroxyapatite-capsaicin (HAp-CAP) composites in reducing hydrogen peroxide diffusion and preventing enamel demineralization. Their findings suggest that bioactive components in whitening formulations can help mitigate the adverse effects of bleaching while maintaining whitening efficacy. This aligns with our observation that hydroxyapatite-containing My White Secret provided a more controlled whitening process while potentially preserving enamel integrity. The inclusion of bioactive compounds in whitening products represents a promising direction for future research, offering a balance between effective bleaching and enamel preservation.

An important aspect to consider is the potential impact of whitening agents on dental sensitivity, a commonly reported side effect in the literature. Previous studies have shown that hydrogen peroxide can induce structural changes in enamel, increasing porosity and microcracks, which may lead to short- and medium-term tooth sensitivity [25]. Although this study did not directly assess dental sensitivity, it is essential to highlight that patients using hydrogen peroxide-based whitening agents may experience temporary discomfort after treatment, especially if the product is applied incorrectly or for longer durations than recommended by the manufacturer. In contrast, peroxide-free formulations, such as My White Secret, may reduce this risk due to the presence of remineralizing components like hydroxyapatite. The findings of this study support the idea that peroxide-free alternatives may represent a safer option for individuals prone to dental sensitivity or those seeking a gentler whitening treatment. Further research is necessary to determine to what extent prolonged use of these products affects enamel strength and the longevity of the whitening effect over time.

Despite the insights provided by this study, several limitations should be acknowledged. The in vitro design does not fully replicate the complex oral environment, where factors such as saliva, diet, and bacterial activity may influence whitening efficacy and enamel mineralization. Additionally, the sample size was limited to 60 extracted teeth, which, although providing controlled conditions, may not fully represent natural variations in enamel composition. The relatively short evaluation period also prevents conclusions about the long-term effects of these whitening treatments on enamel integrity. Finally, this study focused on only two commercially available whitening products, limiting the generalizability of the findings to other formulations. Future research should incorporate in vivo assessments, larger sample sizes, and extended follow-up periods to better understand the long-term safety and effectiveness of different whitening approaches.

This study reinforces the importance of balancing whitening efficacy with enamel health when selecting a bleaching treatment. While hydrogen peroxide-based formulations offer strong and rapid whitening effects, their potential impact on enamel integrity should be carefully considered. Peroxide-free alternatives, particularly those incorporating remineralizing agents, may provide a safer option for long-term use while still achieving effective whitening results.

CONCLUSIONS

This study highlights the distinct whitening efficacy and impact on enamel mineralization of hydrogen peroxide-based and peroxide-free whitening products. My White

Secret provided a rapid initial whitening effect while maintaining enamel mineralization, whereas Crest 3D White exhibited a delayed but more pronounced whitening outcome, raising concerns about potential demineralization. These findings emphasize the critical role of ingredient composition in whitening formulations, as peroxide-based treatments may compromise enamel integrity, while peroxide-free alternatives incorporating remineralizing agents such as hydroxyapatite offer a more balanced approach. The results underscore the need to consider both whitening efficacy and enamel preservation when selecting a whitening treatment, as the long-term impact on dental health is an essential factor in aesthetic dentistry.

Conflicts of Interest

The authors declare no conflict of interest.

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