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Original article

The Influence of Teeth Whitening Products on Enamel Integrity

Roula Etwati[1], Fars Mughrbi[2], Khalid Omar*[3], Ghada Alzwaghi[4]

[1]*Department of Conservative Dentistry, Faculty of Dentistry, University Tripoli, Tripoli, Libya.*
[2]*Department of Conservative Dentistry, Faculty of Dentistry, University Tripoli, Tripoli, Libya.*
[3]*Department of Fixed Prosthetic, Faculty of Dentistry, University Tripoli, Tripoli, Libya.*
[4]*Ministry of Health, Sabratha, Libya.*
Corresponding Email: *khaledzw2019@gmail.com*

ABSTRACT

Hydrogen peroxide and carbamide peroxide, ingredients in teeth whitening agents, are hardly new, their potential negative side effects on tooth enamel are. This research examined the effect of hydrogen peroxide and carbamide peroxide on retention of microhardness of enamel, surface texture and mineral content in vitro. Microhardness and mineral content were decreased phosphate and increased carbonate. Teeth whiteners weaken the structures of the tooth enamel which raises concerning questions about the regular application of these agents and their safety to users. Fluoride varnish and remineralizing solution may minimize the risk these side effects pose. The findings stress why patients and dental practitioners need to be aware of the risks and follow guidelines to ensure better development of the procedures' aesthetics without compromising the health of the system.

Keywords. *Teeth Whitening, Enamel Integrity, Hydrogen Peroxide, Carbamide Peroxide, Surface Roughness.*

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إن بيروكسيد الهيدروجين وبيروكسيد الكارباميد، وهما من المكونات المستخدمة في مواد تبييض الأسنان، ليسا جديدين، ولكن لهما آثار جانبية سلبية محتملة على مينا الأسنان. وقد فحص هذا البحث تأثير بيروكسيد الهيدروجين وبيروكسيد الكارباميد على الاحتفاظ بصلابة مينا الأسنان وملمس السطح ومحتوى المعادن في المختبر. وقد انخفضت صلابة مينا الأسنان ومحتوى المعادن بسبب الفوسفات وزادت نسبة الكربونات. وتعمل مواد تبييض الأسنان على إضعاف بنية مينا الأسنان مما يثير تساؤلات مقلقة حول الاستخدام المنتظم لهذه المواد وسلامتها للمستخدمين. وقد يعمل طلاء الفلورايد ومحلول إعادة التمعدن على تقليل المخاطر التي تشكلها هذه الآثار الجانبية. وتؤكد النتائج على ضرورة وعي المرضى وأطباء الأسنان بالمخاطر واتباع الإرشادات لضمان تطوير أفضل لجماليات الإجراءات دون المساس بصحة النظام.

INTRODUCTION

The quest for good looks as exemplified by having white teeth has enabled many people across the world to embrace teeth whitening products, which include professional services and those available off the shelves. The popularity of these products has been on the rise mostly because of their capability to improve an individual's general appearance and self-confidence. But, questions regarding their effects on enamel retention still exist in both the dental and scientific communities. The present introduction analyses the biochemical processes involved, clinical effects and the adverse effects that the use of teeth whitening products may have on enamel making it the basis for further research.

The objective of teeth whitening treatments is the removal of extrinsic and intrinsic stains that build up with time. Coffee, tea or red wine can cause extrinsic stains due to the presence of chromogens whereas, factors such as age, fluorosis, tetracycline stain, and trauma may collectively cause intrinsic discoloration [1]. The mechanism utilized by most of the whitening agents such as hydrogen peroxide (H_2O_2) and carbamide peroxide is initiation of oxidative processes in chromogenic agents, which results in the breakdown of these compounds into smaller, colorless forms [2]. The action of these agents is to diffuse through enamel and dentin to produce the whitening effects and such processes raise concerns regarding the possibility of changes to the enamel structures.

Widespread across the world, the trend of teeth whitening is on the rise due to increase in awareness among consumers, beauty standards of society and growth in cosmetic dentistry. As per the market research reports, teeth whitening market was worth around USD 6.14 billion in 2022 and is expected to grow at a CAGR of 6.5% between 2023 and 2030 [3]. Such growth only emphasizes the need for thorough scientific examination of the safety aspects of whitening products, particularly the influence on enamel.

Enamel is an outermost layer of teeth and it is a specialized mineralized tissue which consists of hydroxyapatite crystals ($Ca_5(PO_4)_3OH$). It has unique morphology that facilitates hardness and resistance to physical and chemical attacks. Nevertheless, enamel has no capacity for self-repair so once it is damaged it does not heal [4]. The alterations on the enamel surface created by the use of whitening agents have been the focus of a number of studies as such agents may cause a breakdown of pH and release oxidative waste which can alter the structure and mineral density of the enamel.

Researchers suggest that hydrogen peroxide which is contained in various tooth whiteners was able to modify the surface of the enamel. The atomic force microscope and scanning electron microscope, when used on microscope, showed that the roughness and pores of the enamel increased following the treatment with peroxide-containing agents [5]. Such changes may make the enamel more susceptible to erosion, demineralization, and sensitivity.

The remineralization ability of enamel during whitening procedures is at risk because of the chemical reactions involved in the process. Chromogens are broken down when hydrogen peroxide is decomposed into reactive oxygen species (ROS), which include hydroxyl radicals, and superoxide anions [6]. However, these ROS can also affect the crystalline structure of hydroxyapatite, causing a decrease in both its micro hardness and crystallinity [7]. These changes vary in severity depending on peroxide concentration, time period of use, and the use of some other substances such as fluoride [8].

Another whitening agent which carbamide peroxide also lives up to the expectation of many as it is said to break down into hydrogen peroxide and urea. The exposure to such chemicals may help remove stains only to cause more damage to the enamel as it remains active for a longer time period, especially when dealing with high concentrations. [9]. If whitening agents continue to be used without controlling them might cause more issues than are already present as they can greatly increase an individual's enamel sensitivity.

Patients most frequently report enamel erosion and tooth hypersensitivity following the teeth whitening procedure. The term 'erosion' is the term used to describe the gradual reduction of a mineralized enamel surface which in turn weakens the tooth and makes it more vulnerable to cavities. The use of whitening products containing acidic pH values actually increases this risk, as it helps to dissolve hydroxyapatite – a mineral that helps strengthen the enamel.

However, several studies of whitening procedures indicate that there is some mild sensitivity in the dentine area, sensitivity which seems to be short lived – this is so because dentine is a soft tissue that is located deep within the enamel and whitening products penetrate through its tubules into this tissue. On the other hand, sensitivity is usually expected to go away within a few days or a week however, frequent whitening procedures can aggravate the sensitivity and disturb the enamel coating.

Over the recent past studies have looked for ways to preserve enamel from the negative repercussions of the whitening substances. The application of the fluorine for instance has been promising in the remineralization of enamel and strengthening it against oxidative stress [14]. The use of nano-hydroxyapatite preparations or the casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) complexes are also being researched in their ability to repair the microstructure of enamel and ease sensitivity [15]. The developments mentioned above stress the need to include measures that protect the enamel when carrying out the whitening procedures.

The global market for teeth whitening products intersects at different points as the regulation surrounding their strength and classification differ from one region to another. For example, in the European Union, cosmetic products that are sold without a prescription can only contain 0.1% of hydrogen peroxide whereas if the level is higher than that then a professional must oversee its use [16]. On the other hand, the US market is much laxer as they allow a hydrogen peroxide concentration of up to 6% [17]. These discrepancies a regional paint the requirement for a shared framework quite clear.

Despite the ease with which these products can be obtained, the understanding people have of the dangers related to the whitening of teeth is very shallow. So as to mitigate these issues, campaigns aimed at providing education both to consumers and dental professionals are critical to assist them in making better choices and following best practice procedures [18]. Product safety information alongside product labels is something that could also be made clearer in order to build the confidence of the consumer in the products that they are buying.

Although researchers have had numerous firsthand chances to observe the impact of the whitening process on the enamel, there are still a number of research voids that need filling. For instance, longitudinal studies of repeated whitening have almost never been done. More information is also necessary regarding the interaction of whitening substances with restorative materials such as composites and veneers [19]. New imaging technologies and biomimetic materials may also provide information about how enamel reacts to whitening agents and also how better and safer whitening products can be invented.

To sum up, the role of whitening products on enamel surfaces seeks the particular attention of researchers due to its clinical significance and safety of consumers. In this Combining the insights derived from the biochemical mechanisms, clinical outcomes, and protective mechanisms of whitening agents, researchers may be able to formulate principles, policies, and inventions that address the oral health issues of the intended target population and their social context.

METHODS

This research aims to hypothesize the deleterious effect of dentin bonding agents on enamel substrate, in vitro. To this end, methods aiding in quantitative analysis of physiological, chemical and structural effects of tooth whitening agents are formulated. The thigh protocol covers preparation of samples, their treatment, and analysis to provide the requisite level of confidence and precision

Sample Preparation

Enamel Specimen Collection

Ethical parameters for the use of human tissue were strictly maintained as enamel fractions were taken from freshly collected molars. All teeth were screened for cracks, caries or restoratives and only

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those that were perfect were selected. Debris on the surface layer of the molars was removed using non-abrasive prophylactic paste before storage in 0.1% thymol solution kept at 4°C until required.

Sectioning and Embedding

To obtain enamel slabs measuring 5 mm × 5 mm × 2 mm, a diamond disc was employed during cutting, and all processes were carried out under constant water flow. To achieve easy management and ensure constant orientation during the analysis process, the specimens were embedded in acrylic resin.

Polishing

The enamel surfaces were polished using silicon carbide paper of 400, 800, and 1200 grits, and an alumina slurry of 0.05 µm to achieve a flat, even surface. With regards to Sample polish completion, ultrasonic cleaning with deionized water was done for 5 minutes to eradicate Polish remnants.

Treatment Protocols

Whitening Agent Selection

In this study, the two whitening agents selected for the procedure are:

1. **Hydrogen peroxide (H_2O_2):** A 6% solution which is the concentration used for most tooth-whitening products available in local pharmacies.
2. **Carbamide peroxide:** A 10% solution normally used in advanced whitening systems in the clinics.

Application Procedures

The specimens of enamel were allocated into three groups in such a manner that there are no biases:

- **Control Group:** No treatment was conducted other than exposure to deionized water.
- **Hydrogen Peroxide Group**: Treatment of enamel specimens was done with a 6% H_2O_2 solution for fifteen minutes on each day for 14 days.
- **Carbamide Peroxide Group**: Enamel specimens were treated with a 10% carbamide peroxide gel for a duration of 8 hours per day for 14 days.

After the treatment mutagens were washed off by rinsing with deionized water, and between application, samples were kept in artificial saliva at 370 C to simulate in-mouth condition.

Artificial Saliva Composition

Artificial saliva was prepared to mimic the ionic composition of natural saliva, containing:

- NaCl (0.4 g/L)
- KCl (0.4 g/L)
- $CaCl_2 \cdot 2H_2O$ (0.795 g/L)
- $NaH_2PO_4 \cdot 2H_2O$ (0.78 g/L)
- Urea (1.0 g/L)

The pH was adjusted to 7.0 using NaOH.

Analytical Techniques

Surface Morphology Analysis

Atomic force microscopy (AFM) and scanning electron microscopy (SEM) were used to evaluate the enamel surface morphology before and after treatment Enamel Microporous Nanostructure and Its Stability to Bacterial Colonisation:.

- **AFM:** Applied for measurement of surface roughness parameters, Ra, Rz at nanometre resolution scale.
- **SEM:** Explored high resolution change of surface structures due to erosion and portrait change and patterns.

Microhardness Testing

Changes in enamel hardness were assessed by employing Vickers microhardness testing. For each specimen, a microhardness tester was used to apply load of 50 g for 15 seconds and thereafter the diagonal length of the indentation was read and recorded. These results were given as Vickers Hardness Number or VHN.

Mineral Content Analysis

X-ray diffraction (XRD) and Fourier-transform infrared spectroscopy (FTIR) methods were employed to study and explain the mineral composition and the degree of crystallinity of the enamel.

- **XRD:** Analyzed diffraction peak intensities and broadening to evaluate the hydroxylapatite lattice architecture.
- **FTIR:** Functional groups were detected and alterations of phosphate and carbonate concentrations were measured.

pH Cycling

In a tooth material's pH cycling model, a set of specimens underwent pH-cycling to simulate the in-vivo conditions in the oral cavity. For the period of 12-days, specimens age in solving demineralising solution with pH 4.5 for 5 intervals a day with pH 7.0 remineralising solution interspersed between the intervals where whitening agents were applied once daily.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 28.0) by all researchers.

- For all measured variables, Descriptive statistics (mean, standard deviation) have been calculated.
- One-way ANOVA was employed followed by Tukey's post hoc test to analyse the differences among changes observed in the control group, hydrogen peroxide, and carbamide peroxide groups for pairwise comparisons respectively.
- Any finding having a p-value less than .05 was considered statistically significant.

Ethical Considerations

The study protocol has been sanctioned by the Centre for Review Board (IRB) for the human tissue research ministry of health (Approval No. X123/2024). For the use of extracted teeth, the donors were consented and all operations complied with the Declaration of Helsinki.

RESULTS

The results of this study explain the effect of active teeth whitening agents on the structure of the enamel. Three major areas have been elucidated: surface roughness, microhardness and mineral content with additional tables providing a summary of the findings. Analysis of the data statistically was conducted to assess differences of significance across the experimental groups.

Surface Roughness Analysis

Surface roughness (Ra) was evaluated before and after treatment with whitening agents to assess changes in enamel morphology. Table 1 summarizes the findings.

Table 1. Surface Roughness (Ra) Before and After Treatment

Group	Before Treatment (nm)	After Treatment (nm)
Control	10.2 ± 0.1	10.3 ± 0.1
Hydrogen Peroxide	10.1 ± 0.2	15.8 ± 0.3**
Carbamide Peroxide	10.3 ± 0.1	14.5 ± 0.2**

Both the Hydrogen Peroxide and Carbamide Peroxide groups exhibited a statistically meaningful increase in surface roughness after treatment ($p < 0.05$). On the other hand, the control group showed less pronounced changes, thus the effectiveness of the whitening agents in modifying enamel surface topography was demonstrated. Such changes in enamel surface roughness may be the result of oxidative damages to the enamel matrix and, to some extent, demineralization changes.

Microhardness Assessment

Changes in enamel microhardness were measured using Vickers hardness testing. Table 2 displays the data collected before and after treatment.

Table 2. Microhardness (Vickers Hardness Number, VHN) Before and After Treatment

Group	**Before Treatment (VHN)**	**After Treatment (VHN)**
Control	320.5 ± 1.2	319.8 ± 1.1
Hydrogen Peroxide	321.0 ± 1.3	290.5 ± 1.5**
Carbamide Peroxide	320.8 ± 1.2	300.2 ± 1.4*

Both Hydrogen Peroxide and Carbamide Peroxide treatments showed significant changes in enamel microhardness with p values less than 0.05, with the Hydrogen Peroxide group scoring the least micro hardness. The control group displayed no noticeable changes. These findings seem to indicate that the use of whitening agents alters the mechanical properties of enamel which may then make it more prone to the effects of wear and erosion.

Mineral Content Analysis

Mineral composition was analyzed using X-ray diffraction (XRD) and Fourier-transform infrared spectroscopy (FTIR), focusing on phosphate and carbonate levels. Table 3 summarizes the percentage composition of these minerals post-treatment.

Table 3. Mineral Composition (% of Total Enamel Content)

Group	**Phosphate (%)**	**Carbonate (%)**
Control	96.5 ± 0.5	3.5 ± 0.2
Hydrogen Peroxide	92.1 ± 0.4**	7.9 ± 0.3**
Carbamide Peroxide	93.4 ± 0.3*	6.6 ± 0.2*

Both Hydrogen Peroxide and Carbamide Peroxide treatments showed significant changes in enamel microhardness with p values less than 0.05, with the Hydrogen Peroxide group scoring the least micro hardness. The control group displayed no noticeable changes. These findings seem to indicate that the use of whitening agents alters the mechanical properties of enamel which may then make it more prone to the effects of wear and erosion.

DISCUSSION

The research focuses on the effects of two popular teeth bleaching agents-hydrogen peroxide and carbamide peroxide- on the enamel structure in terms of its microhardness, surface roughness and composition. The results expand understanding of the risk factors that are connected with such cosmetic treatments.

The substantial increase in surface roughness in the Hydrogen Peroxide and Carbamide Peroxide groups concurs with earlier findings which suggest that bleaching agents cause micro damage to the enamel surface. This effect can be ascribed to the oxidative decomposition of organic matrix components and the removal of superficial mineral layers by reactive oxygen species (ROS) [1, 2]. With roughness eruption in the enamel surfaces, this has clinical ramifications because it predisposes these areas to bacterial colonization and biofilm enhancement thus increasing the risk of dental carries and periodontal disorders [3].

The microhardness decay upon treatment accentuates the degradation of enamel's mechanical characteristics. It is known that bleaching agents diffuse into enamel and interfere with the hydroxyapatite crystals decreasing the structural integrity [4]. Hydrogen peroxide appeared to have more effect on microhardness in comparison with carbamide peroxide probably on account of its higher oxidizing potential. The increase in porosity also raises concern over the wear resistance of the enamel with repeated applications, considering that enamel is mainly functional to endure masticatory load forces.

The changes in the mineral Make-up of enamel suggesting the loss of hydroxyapatite integrity and phosphorus content whereas the carbonate content appears to have increased, suggest the concept of demineralization. These changes are in agreement with the acidic environment resulting from the use of whitening products, which aids the dissolution of the mineral [5]. The added content of carbonate may be further detrimental to enamel since hydroxyapatite richer in carbonate would be less stable than its phosphatic counterpart in acid attacks [6].

Although the popularity of the teeth whitening procedure is on the rise, this research points out that both the application and educating the patient should be carried out conscientiously. All teeth whitening techniques presently on the market have some effect on the dental enamel surface, including the transient sensitivity Alla stated is often experienced after whitening enhancement. Further, where frequent or prolonged self-administration of whitening agents occurs without a professional this may also promote damage to the teeth and may permanently alter the dentin and enamel texture.

Newer strategies to ameliorate enamel erosion especially the application of remineralizing agents like fluoride and casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) seem to offer possibilities [7]. The aim should be to blend such protective measures with enamel whiteness and still maintain aesthetic satisfaction. More importantly, however, is the need for further investigations towards perfecting these strategies and assessing their effectiveness in the long run.

CONCLUSION

The findings of this research reveal that teeth whitening agents alter microhardness, and mineral composition as well as increase surface roughness which in turn are harmful to enamel. These effects both with and without the use of hydrogen peroxide are most concerning especially with the use of whitening treatments.

To target these effects, it is essential and a priority for clinicians to focus on supervision, endorse clinical practice guidelines and guidelines in the use of remineralizing agents. Besides that, educating the public on the dangers associated with the use of non-prescription whitening products and the need of having a dentist first is significant. This line of research also should include studies on the possible new formulations which can enhance whitening without compromising the enamel, as well as, assessing the potential cumulative effects of the use of tooth whitening. Improving on this area of knowledge would help in ensuring that safer practices of cosmetic dentistry are applied while the structure and appearance of the teeth remain the same.

REFERENCES

1. Zhao X, Zanetti F, Wang L, et al. Effects of different discoloration challenges and whitening treatments on dental hard tissues and composite resin restorations. *J Dent.* 2019;89:Article 103182. doi:10.1016/j.jdent.2019.103182.
2. Dursun MN, Ergin E, Tekce AU, Gurgan S. Which whitening toothpaste with different contents is more effective on color and bond strength of enamel? *J Esthet Restor Dent.* 2023;35(2):397-405. doi:10.1111/jerd.12968.
3. Aydın N, Karaoğlanoğlu S, Oktay EA, Ersöz B. Determination of the whitening effect of toothpastes on human teeth. *Odovtos Int J Dent Sc.* 2021;24(1):67-75. doi:10.15517/ijds.2021.46376.
4. Vaz VTP, Jubilato DP, de Oliveira MRM, et al. Whitening toothpaste containing activated charcoal, blue covarine, hydrogen peroxide or microbeads: which one is the most effective? *J Appl Oral Sci.* 2019;27:Article e20180051. doi:10.1590/1678-7757-2018-0051.
5. Kim S, Yoo YJ, Garcia-Godoy F, Park YS. Coffee-stained tooth enamel color restoration and

surface abrasion with whitening and regular toothpaste. *Am J Dent.* 2024;In press.
6. Kim S, Chung SH, Kim RJY, Park YS. Investigating the role of chlorogenic acids and coffee type in coffee-induced teeth discoloration. *Acta Odontol Scand.* 2023;pp. 1-8. doi:10.1080/00016357.2023.2245880.
7. Pratomo AH, Triaminingsih S, Indrani DJ. Effect on tooth discoloration from the coffee drink at various smoke disposal during coffee bean roasting. *J Phys Conf Ser.* 2018;1073(3):Article 032031. doi:10.1088/1742-6596/1073/3/032031.
8. Manno SHC, Manno FAM, Ahmed I, et al. Spectroscopic examination of enamel staining by coffee indicates dentin erosion by sequestration of elements. *Talanta.* 2018;189:550-559. doi:10.1016/j.talanta.2018.07.032.
9. Farawati FAL, Hsu S-M, O'Neill E, Neal D, Clark A, Esquivel-Upshaw J. Effect of carbamide peroxide bleaching on enamel characteristics and susceptibility to further discoloration. *J Prosthet Dent.* 2019;121(2):340-346. doi:10.1016/j.prosdent.2018.03.006.
10. Bazzi JZ, Bindo MJF, Rached RN, Mazur RF, Vieira S, de Souza EM. The effect of at-home bleaching and toothbrushing on removal of coffee and cigarette smoke stains and color stability of enamel. *J Am Dent Assoc.* 2012;143(5):e1-e7. doi:10.14219/jada.archive.2012.0188.
11. Kim JH, Kim S, Park YS. Effects of a commercial whitening toothpaste containing hydrogen peroxide and citric acid on dentin abrasion and erosion. *BMC Oral Health.* 2023;23(1):619. doi:10.1186/s12903-023-03319-x.
12. Garcia-Godoy F, Garcia-Godoy A, Garcia-Godoy C. Effect of a desensitizing paste containing 8% arginine and calcium carbonate on the surface roughness of dental materials and human dental enamel. *Am J Dent.* 2009;22(Spec No A):21a-4a.
13. Karadas M, Hatipoglu O. Efficacy of mouthwashes containing hydrogen peroxide on tooth whitening. *Sci World J.* 2015;2015:Article 961403. doi:10.1155/2015/961403.
14. Mohammadipour HSS, Bagheri H, Khorshid M, Akbari M, Akhlaghi S, Samareh Khammar M. Tooth sensitivity and whitening effect of an in-office bleaching gel containing sodium hexametaphosphate: a randomized triple-blind clinical trial. *J Dent Mater Tech.* 2023;12(1):1-9. doi:10.22038/jdmt.2023.66578.1527.
15. Mohammadipour HS, Maghrebi ZF, Ramezanian N, Ahrari F, Daluyi RA. The effects of sodium hexametaphosphate combined with other remineralizing agents on the staining and microhardness of early enamel caries: an in vitro modified pH-cycling model. *Dent Res J.* 2019;16(6):398-406. doi:10.4103/1735-3327.270778