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Effect of bleaching on surface roughness and microhardness of dental enamel. A comprehensive review.

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ABSTRACT

Multiple studies have examined the impact of bleaching on dental tissues. Evaluation of the effect of bleaching is essential for assessing changes in enamel microhardness that may impact dental health in terms of resistance to masticatory forces. The purpose of this review was to ascertain scientific evidence regarding the effects of bleaching on the roughness and microhardness of human dental enamel. Using search criteria, a systematic electronic literature search was conducted in PubMed, Scopus and Web of Science databases. In addition to establishing inclusion and exclusion criteria for article selection, only English-language studies were selected. Studies that satisfied all inclusion and exclusion criteria were chosen for the review. All bleaching treatments promoted a significant reduction in the microhardness values. Several studies also showed that, despite enamel microhardness changes caused by the effects of bleaching, this demineralization can be reversed by the remineralization potential of the saliva that replaces the lost calcium and phosphate ions.

Keywords: Bleaching, enamel,carbamide peroxide, hydrogen peroxide, tooth whitening, hardness, roughness.

INTRODUCTION

Although the efficacy of bleaching agents on vital and nonvital teeth is well documented, the widespread use of bleaching techniques generates some concern about the effects promoted by these agents on the bleached substrates.Risks to soft tissues, such as burning, a possible co-carcinogenic effect, and lesions, are correlated to the use of hydrogen and/or carbamide peroxide in high concentrations.(1)Some alterations in the enamel and dentin, such as an increase in roughness, porosity, and diminished microhardness, have also been observed.(2,3)

The increasing demand for tooth whitening is reflected in the variety of available whitening options. Current tooth whitening products range from professionally administered in-office whitening (OW) and professionally supervised home whitening (HW) to unsupervised over the counter (OTC) and do-it-yourself (DIY) regimens (Table 1). Several studies have examined the effect of various whitening regimens on the effectiveness of tooth whitening. The availability of over-the-counter products and numerous do-it-yourself whitening regimens has increased the public's access to teeth whitening. Concerns have been voiced by the ADA Council on Scientific Affairs regarding the long-term safety of unsupervised whitening procedures due to the possibility of undiagnosed or underlying oral health issues. The objective of this review is to evaluate the effect of different whitening modalities, including in-office whitening, dentist-dispensed home whitening, over-the-counter products, and do-it-yourself whitening, on surface roughness and microhardness of enamel, as measured by microhardness testers, profilometers, and scanning electron microscopy, according to International Standards Organization (ISO) 28399 guidelines. (4)

Several oxidizing agents such as aluminum chloride, oxalic acid, pyrozone (either peroxide or perhydrol), hydrogen dioxide (hydrogen peroxide or perhydrol), sodium peroxide, sodium hypophosphate, chloride of lime, and potassium cyanide were used directly or indirectly to act on the organic portion of the tooth in the past.(5,6) In the 1960s, home bleaching was popularized. At home, carbamide peroxide bleaching agents are typically used for 6 to 8 hours during the night. However, the application of bleaching agents such as carbamide peroxide or hydrogen peroxide (H_2O_2) to the enamel surface has raised significant concerns regarding the enamel's structure. Previous investigations regarding the effects of bleaching compounds on the surface of tooth enamel are controversial. Some of them suggest that the surface texture of the enamel does not change or changes very little after bleaching, while others indicate that bleaching alters the morphology of the enamel. (6,7) Despite this, the vast majority of morphological studies have been conducted in vitro, frequently yielding divergent results based on the testing conditions, morphological aspects, and mechanical properties tested. The major differences between these studies are the study design (in vitro or in vivo), sample size, type of tissue (human or bovine enamel), preparation of the tissue (polished or sound enamel), type of analysis performed (mechanical test or morphological analysis), bleaching agent used (hydrogen peroxide or carbamide peroxide), bleaching agent concentration and formulation (gel or solution), bleaching agent exposure duration, and other evaluation criteria. (8,9)

Table 1: Bleaching agents used in various studies.

Bleaching agents	Manufacturer	Composition
Carbamide peroxide	Prepared in the laboratory: 10%	10% carbamide peroxide
Ipana 3D Whitening	Procter & Gamble GmbH	0.32% sodium floride, aqua, sorbitol, hydrated silica (abrasive), tetrasodium pyrophosphate, sodium lauryl sulfate, aroma, cellulose gum, Cl 77891, sodium saccharin, carbomer, trisodium phosphate, limonene, Cl 74160.
Clinomyn Smokers	CCS, Clean Chemical Sweden AB (Borlänge, Sweden)	0.76% sodium monoflorofosfat, aqua, sorbitol, hydrated silica (abrasive), calcium carbonate (abrasive), aluminyum silicate (abrasive), aroma, cellulose gum, glycerine, cocamidopropyl betaine, sodium saccharin, sodium lauryl sulfate, sodium chloride, trisodium phosphate, limonene, Cl 77891, methylparaben, propylparaben
Moos Dent	Moos Cosmetics (Istanbul, Turkey)	0.15% sodium floride, calcium carbonate (abrasive), tricalcium phosphate, sodium lauryl sulfate, peppermint aroma, sodium benzoate, menthol, and sodium saccharin
Signal Whitening System	Unilever Mashreq, Foods and HPC Division (Alexandria, Egypt)	Flouride (1450 ppm), perlite, calcium carbonate (abrasive), hydrated silica (abrasive), aqua, sorbitol, sodium lauryl sulfate, sodium monoflorofosfat, aroma, trisodium phosphate, cellulose gum, sodium saccharin, methylparaben, propylparaben, glycerine, Cl 77891, Cl 74160.
Colgate 2in1 Whitening	Colgate Palmolive (Liege, Belgium)	Sodium floride 1100 ppmF, aqua, sorbitol, hydrated silica (abrasive), sodium lauryl sulfate, glycerine,

		pentasodium triphosphate, tetrasodium pyrophosphate, aroma, PVM/MA copolymer, sodium saccharin, cocamidopropyl betaine, cellulose gum, sodium hydroxide, carrageenan, limonene, Cl 77891
Listerine Healty White (Whitening Mouth Rinse) (WMR)	Johnson & Johnson Consumer Inc., New Jersey, USA	Water, 8 % alcohol, 2% Hydrogen Peroxide, sodium phosphate, poloxamer 407, sodium lauryl sulfate, sodium citrate, mint aroma, menthol, eucalyptol, Sodium saccharin, sucralose
Cavex Bite&White (Whitening Pen) (WP)/olovka za izbjeljivanje Cavex, Haarlem, Holland	Cavex, Haarlem, Holland	6 % Hydrogen Peroxide, polyethylene glycol, PVP peroxide, glycerin, Peppermint oil
Opalescence (Whitening Toothpaste) (WT)/zubna pasta za izbjeljivanje	Ultradent Products, South Jordan UT, USA	Sodium fluoride, glycerin, water (aqua), silica, sorbitol, xylitol, flavor, poloxamer, sodium lauryl sulfate, carbomer, FD&C Blue # 1 (Cl 42090), FD&C Yellow # 5 (Cl 19140), sodium benzoate, sodium hydroxide, Sparkle (CI 77019, CI 77891), sucralose, xanthan gum.
Opalescence Go (Prefilled Tray) (PT)/Unaprijed pripremljena udlaga	Ultradent Products, South Jordan UT, USA	6 % Hydrogen Peroxide, sodium hydroxide, potassium nitrate, sodium fluoride
Opalescence PF 10 % (Dentist-supervised home whitening (OP)/Izbjeljivanje kod kuće koje kontrolira doktor	Ultradent Products, South Jordan UT, USA	10 % Carbamide Peroxide, Polyacrylic acid, 0.3 % Sodium fluoride, 3 % Sodium hydroxide

MATERIALS AND METHOD

This systematic literature review adhered to the Cochrane Handbook for Systematic Reviews of Interventions guidelines. An electronic literature search of the Pubmed, Scopus and Web of Science databases was conducted. The search was restricted to English-language articles only. The articles were chosen based on the inclusion criteria as well as their titles and abstracts. Inclusion criteria included in vitro and in situ studies, human tooth studies, home bleaching, in office bleaching and Vickers and Knoop microhardness tests.

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RESULTS

Eight hundred and twenty-three publications were discovered in Pubmed, Web of Science, and Scopus databases. 128 articles remained after reading the titles and implementing the relevance criteria. The titles and abstracts were read, yielding 47 relevant studies, which were then read in their entirety and subjected to the relevance test. Duplicate entries were also excluded. The possibility of extracting data from the remaining 38 articles was evaluated.

DISCUSSION

Many authors have discovered that bleaching gels can alter dental tissue parameters such as enamel microhardness, superficial roughness, chemical composition, as well as the bond strength of the adhesive system to the enamel after bleaching. The alterations in microhardness can be related to the loss or gain of minerals (demineralization and remineralization) in the dental structure. (10-13) Some studies showed that microhardness tests are adequate to determine small differences in the superficial enamel, which can be caused by the effects of acids, colas, and bleaching gels. Oxygen ions have a short lifespan, are unstable, and react with other free substances or substrates, presenting weak reactions. This is possible because of its high electronegativity, which promotes a powerful reaction characterized by ions seeking molecular stability. This process probably occurs due to the redox mechanism, or a simple reduction promoted by the oxygen ion that reacts with the molecules that stain the teeth, becoming simpler, whiter, or eliminated. Although the exact mechanism of dental bleaching is not totally apparent, it is believed that the permeability of the dental structure to the bleaching agents can reduce the size of the chromogenous molecules. (13,14)

Several studies also showed that, despite enamel microhardness changes caused by the effects of bleaching, this demineralization can be reversed by the remineralization potential of the saliva that replaces the lost calcium and phosphate ions.(15-17)Araujo et al.in , in an in situ study, concluded that changes in microhardness are not significant and can be recovered 14 days after bleaching due to the absorption and precipitation of the calcium and phosphate present in the saliva. Araujo et al. reported that after 15 days, all the specimens bleached with an HP-based gel with a neutral pH were able to re-establish their baseline microhardness. In the present results,

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after 7 days of remineralization, there were no significant differences between all experimental groups and the control group. Lewinstein et al.in 2004 concluded that exposure to low concentrations of fluoride can also restore the surface microhardness after bleaching. However, some studies showed no changes in the enamel surface after bleaching. (18)

Surface hardness measurement is a relatively simple method to determine the mechanical properties of enamel and dentin to resist plastic deformation from a standard source and is closely related to the loss or gain of mineral components. Depending on the indenter used, there are two categories of hardness: Vickers and Knoop. The difference between them resides in the design of their indenters. The Vickers microhardness test leaves a square impression because the indenting diamond has the form of a pyramid with a square base. The Knoop microhardness indenter has the shape of a pyramidal diamond and leaves a lozenge-shaped impression.

Sulieman et al. (10) in 2004 evaluated the effects of high concentrations of HP used in dentistry on the enamel and dentin. The results showed no change in abrasion, hardness, or topography in the enamel or dentin. The authors concluded that, even with the use of high concentrations of HP, no deleterious effects were observed. Finally, they suggested that the deleterious effects may not be caused by the concentration of the peroxide bleaching agent but by the pH level of the gel used. These contradictory studies regarding the microhardness alterations can be explained by the fact that surveys have different methodologies, such as using different bleaching agents (with different concentrations, application times, and methods of application), different forms of hardness evaluation (Knoop, Vickers, weight and length indentation), pH level, and storage method of the specimens. (19) Thus, it becomes difficult to find concrete data to compare the results.

There is always concern regarding the safety of bleaching vital teeth. Consequently, at-home bleaching has been the subject of numerous reports concerning potential enamel surface alterations. The microhardness test can be utilized to assess the mechanical attributes of tooth enamel after bleaching. Several studies found no significant difference in microhardness following at-home decontamination. Nonetheless, some studies revealed less favorable outcomes.

McCracken and Haywood contrasted the 10% carbamide peroxide decontamination procedure with the consumption of a cola-based beverage for 2.5 minutes and a preventive treatment. The authors discovered that the volume of calcium lost across all three procedures (5–50 lm of surface enamel) was identical. The 10% carbamide peroxide bleached group experienced a minor (25 lm) reduction in enamel microhardness. (20) According to Sunil et al.The degree of acidity of the gel can also influence demineralization. The enamel's calcium and phosphate will be more soluble as the gel's pH decreases. Bleaching gels with a critical pH (between 5.2 and 5.8) can modify the surface of enamel and lead to demineralization. However, the pH of the gel increases as it dissociates in the pharynx. The remineralizing effect of saliva and the degradation of 10% carbamide peroxide in ammonia may increase the pH value and render ineffective the bleaching gel's demineralization potential. (21)

SEM reveals the surface of unbleached enamel and the surface irregularity of enamel treated with 10% carbamide peroxide bleaching buffer. The use of 10% carbamide peroxide results in an increase in surface irregularity, with fissures, dimples, and erosions present. Immediately after bleaching, the pores expand and surface erosion defects appear, which may resolve after three months due to the remineralizing influence of saliva. Araujo et al. emphasized the significance of saliva in the remineralization of bleached enamel following the application of bleaching gel to teeth undergoing a bleaching program. Saliva and fluorinated solutions can prevent the loss of mineral ions naturally. (18) While using artificial saliva as a storage medium, Murchison et al. observed no statistical differences between pre and post-bleaching. The application of 10% carbamide peroxide has minimal effects on the surface morphology of enamel, and these effects do not exacerbate over time. The effect of 10% carbamide peroxide is identical to that of 3.5% hydrogen peroxide. However, 10% carbamide peroxide is more stable and releases oxygen at a slower rate. (22)

Even if the active principle is the same, the formulations and pH values of different commercial brands of the same product vary. However, pH is not a significant factor in microhardness changes. The enamel surface may be subjected to minor abrasions that increase its texture, despite its microhardness remaining unaffected. The following variables may have contributed to this result: low pH, the presence of acidic carbopol substances and prolonged contact between the dental surface and bleaching gel, particularly at night when saliva production decreases, make it difficult to raise the pH.

De Souza et al. evaluated the effect of carbamide peroxide (CP) and hydrogen peroxide (HP) in different concentrations on hardness, roughness, and color parameters (color change, E, lightness, L, and yellow-blue axis, b) of bovine teeth. Bleaching promoted a reduction in hardness; the CP 45% showed the lowest hardness and the CP 20% the highest; the HP 9.5% and HP 38% showed intermediate values of hardness. Bleaching agents did not affect the roughness. CP 20% and HP 38% promoted the highest values of E and a higher reduction of the yellowish tone of the tooth. Lightness increased after bleaching treatment for all groups. All the bleaching agents tested showed effectiveness, but with reduced hardness. (23)

Ozkan et al. evaluated the surface roughness of human enamel bleached with 10% carbamide peroxide or 10% hydrogen peroxide bleaching agents at different times and also subjected to different superficial cleaning treatments. One hundred and forty flat enamel samples were studied. The bleaching with 10% hydrogen peroxide and 10% carbamide peroxide did not alter the enamel surface roughness, but when the bleaching treatment was combined with abrasive dentifrices, a significant increase in roughness values was observed (24).

Basting et al. found that bleaching increased enamel microhardness, and their findings were statistically significant. Other studies found no statistically significant difference in enamel microhardness before and after 21-day bleaching. (25)

CONCLUSION

None of the whitening modalities induce adverse surface morphology changes when observed with SEM and can be considered safe. However, caution should be advised to the general public when using a Do-It-Yourself (DIY) regimen made of strawberry mixture as it may adversely affect enamel microhardness and an OTC product as it has the potential to increase surface roughness. The application of dentist prescribed at home whitening products increased the surface roughness of the enamel.Several studies also showed that, despite enamel microhardness changes caused by the effects of bleaching, this demineralization can be reversed by the remineralization potential of the saliva that replaces the lost calcium and phosphate ions.The

10% carbamide peroxide gel (Opalescence) and the oxygen-free gel (Hi-Lite 11) evaluated in various studies showed no adverse effects on enamel microhardness or surface morphology. The SEM analysis revealed that the tested whitening products cause no deleterious effects on tooth enamel.

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