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REVIEW

Erosion and abrasion on dental structures undergoing at-home bleaching

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Abstract: This review investigates erosion and abrasion in dental structures undergoing at-home bleaching. Dental erosion is a multifactorial condition that may be idiopathic or caused by a known acid source. Some bleaching agents have a pH lower than the critical level, which can cause changes in the enamel mineral content. Investigations have shown that at-home tooth bleaching with low concentrations of hydrogen or carbamide peroxide have no significant damaging effects on enamel and dentin surface properties. Most studies where erosion was observed were in vitro. Even though the treatment may cause side effects like sensitivity and gingival irritation, these usually disappear at the end of treatment. Considering the literature reviewed, we conclude that tooth bleaching agents based on hydrogen or carbamide peroxide have no clinically significant influence on enamel/dentin mineral loss caused by erosion or abrasion. Furthermore, the treatment is tolerable and safe, and any adverse effects can be easily reversed and controlled.

Keywords: peroxide, tooth bleaching, enamel, dentin, erosion, abrasion

Introduction

Dental appearance is gaining more importance in modern society. Today, a large number of patients are searching for personal satisfaction and increasing the demand for an attractive smile. Tooth bleaching has become one of the most popular cosmetic procedures offered in dental practice.[1] Several products and techniques are available for vital tooth bleaching, and vary in concentration and type of end products released.[2,3] The whitening procedures can be performed in the office by the dentist or at home by the patient without dentist supervision.

Overall, when applied over an enamel surface, the peroxide-containing agents break down into water and oxygen, which diffuse through the enamel, causing oxidation and reduction of organic pigments that are mainly located within dentin, resulting in a reduction or elimination of the discoloration.[4]

At-home vital tooth bleaching with custom trays is the most common modality used.[5,6] The advantages of this treatment are its application, reduced chair time, safety and low incidence of tooth sensitivity.[5–7] Supervised at-home tooth bleaching involves the use of custom trays loaded with low concentrations of carbamide (10%–22%) or hydrogen peroxide gels (3.4%–7.5%) that are used by the patient for a few hours per day.[2,5] The side effects frequently associated with tray bleaching systems are gingival irritation and tooth sensitivity, which can either be related to shape of the tray or to concentration of the bleaching agent.[8,9]

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In recent years, an increasing number of over-the-counter bleaching products have appeared in the market, which can be used by the patient at home without dentist supervision. These products have increased in popularity and represent a large percentage of the over-the-counter products sold for oral hygiene. Even though such products have low concentrations of peroxide agents, they may produce side effects, including an erosive effect on dental structure, because patients tend to ignore the manufacturers' recommendations and use them for a long period of time.[10] Although the manufacturers have introduced different concentrations of bleaching agents onto the market, 10% carbamide peroxide gel is the only one that has a seal of acceptance from the American Dental Association assuring its safety and efficacy for at-home tooth bleaching.[11]

In an attempt to provide an evidence base for dental practitioners, the aim of this review was to evaluate the erosive potential of at-home bleaching agents, which could increase susceptibility to tooth abrasion. A literature search of the electronic database, MedLine, was performed up to February 28, 2011. The following search format was performed using Mesh terms: ("Tooth Bleaching"[Mesh]) AND ("Tooth Erosion"[Mesh] OR "Tooth Abrasion"[Mesh]).

Erosion and abrasion related to tooth bleaching

Tooth wear can be defined as a progressive loss of hard dental tissues due to the processes of abrasion and erosion.[12] Dental erosion is an irreversible loss of tooth substance due to a chemical process without the presence of bacteria,[13] while abrasion is caused by oral habits and the use of abrasive substances, such as abrasive toothpastes.[14] Even though these processes can occur individually or together, the effect of erosion is often dominant.[14–16] It has been suggested that for enamel demineralization to take place, the pH on the enamel surface must fall below 5.5.[17]

Dental erosion is a multifactorial condition that may be idiopathic or caused by a known acid source.[18,19] Several acids, including some of those regularly found in the human diet, such as acidic food and soft drinks; or those originating in the stomach, like gastric acid from regurgitation or reflux, and some drugs, are related to the pathogenesis of dental erosion.[13,14,18]

Some bleaching agents have a lower than ideal pH, which can cause changes in the mineral content of the enamel, contributing to the formation of shallow depressions, increasing enamel porosity and promoting slight erosion.[20] These changes can be higher when the contact time between bleaching agent and tooth surface is increased.[21,22] However, studies have shown that the addition of calcium or fluoride to the composition of a bleaching agent can minimize mineral loss in the enamel.[23,24]

Brushing is a hygiene procedure for maintaining oral health, usually done with abrasive dentifrices, and plays an important role in prevention of formation or removal of extrinsic stains.[25,26] Nevertheless, the use of more abrasive toothpastes can increase wear on the tooth surface.[27–29] Few in vitro studies have evaluated changes in the bleached enamel and dentin after methods of acid exposure or toothbrushing.[30–33] The majority of studies have reported that the abrasive or erosive actions of combinations containing 10% carbamide peroxide[30,32] or 35% hydrogen peroxide[33] have no deleterious effects on enamel or dentin.

One study has evaluated the effect on enamel and dentin of the interaction between 10% carbamide peroxide bleaching, erosion with 1% citric acid, and abrasion using low and high abrasive dentifrices. The authors concluded that bleaching did not increase the susceptibility of enamel to erosive and abrasive wear, but that dentin wear was affected by the interaction of bleaching, erosion, and dentifrices.[30] Another study that evaluated the roughness of human enamel exposed to 10% carbamide peroxide showed that use of this concentration of bleaching agent alone did not alter enamel surface roughness, but when the bleaching treatment was associated with brushing using fluoridated or nonfluoridated abrasive dentifrices, there was a significant impact on enamel surface roughness.[31]

Can bleaching alter properties of tooth structure?

A number of studies have evaluated the influence of at-home bleaching agents on the properties of enamel and dentin.[21,24,30–32,34–51] Most of them have used the 10% carbamide peroxide and different methodologies to investigate the softening effect produced by bleaching agents on mineralized dental tissues, including surface microhardness, surface morphology, surface roughness, and calcium loss.

While some studies have found no significant alteration in enamel surface caused by 7.5%–22% carbamide peroxide or 6% hydrogen peroxide,[21,31,32,34–39] others showed that 10%–22% carbamide peroxide solutions can cause morphological changes and erosive lesions, decreasing microhardness and increasing enamel surface roughness.[24,40–49] Therefore, the question arises as to whether these morphological changes in the enamel surface are transient, permanent, and/or clinically significant?

In general, findings of damage to the enamel surface after bleaching treatment come from studies carried out in vitro, with the methodological limitations inherent in this type of study. Such findings may not be representative of the in vivo condition, in which the oral cavity is continually bathed with saliva containing various minerals, including fluoride, calcium, and phosphate, lipids, carbohydrates, proteins, and other substances.[44] Evaluation of specimens was usually performed soon after the bleaching protocols, without any period of storage in artificial saliva and consequently with no remineralizing effect.[44,46–48] Storage in artificial saliva was performed only between clinical sessions or from the first to the last session.[24,40–49] The relevant studies identified in the MedLine database are summarized in Table 1, with information regarding the type of study, measurement used, tissue evaluated, product concentration, pH values, changes observed, and possible reversibility after remineralization.

Surface evaluations were performed by scanning electron microscopy[24,42,43] or enamel microhardness[41] after exposure to 10%–22% carbamide peroxide for 14,[24,41] 84,[42] and 90[43] days. Erosive lesions were observed for periods up to 84 days after conclusion of bleaching[42] and decreased microhardness even after 14 days.[41] Basting et al[41] showed that an increase in enamel microhardness occurred after the end of bleaching treatment, but without reaching baseline microhardness values. This can be explained by the absence in artificial saliva of proteins present in human saliva, which prevents the formation of the acquired pellicle, a protective barrier of dental tissue formed in vivo. Even though 10% carbamide peroxide caused alterations in the surface morphology of enamel in one study, these alterations were reversed within 3 months following treatment.[43] Additionally, it was observed that enamel microhardness decreased after bleaching treatments containing 10% carbamide peroxide with or without fluoride, but hardness values gradually recovered after cessation of bleaching.[24] These discrepant results may be attributed to wide variation in methodology, which may limit any comparisons between studies.

Using scanning electron microscopy to compare in vitro and in situ methodologies to detect effects of 10% carbamide peroxide on enamel topography, calcium loss, and microhardness, Justino et al[52] observed that test conditions played an important role in deleterious effects. While rougher surface, higher mineral loss, and lower microhardness were observed for bleaching treatment performed in vitro, such alterations were not detected in situ, which is very similar to the in vivo condition. In Figure 1 the effects of 10% carbamide peroxide treatment on the enamel surface can be seen, and the different patterns of erosion caused by 10% carbamide peroxide using in vitro and in situ methodologies are compared with unbleached enamel.

Some authors have reported that the erosive effect associated with bleaching treatment may be related to the low pH of the whitening solutions.[24,43,45] However, when enamel erosion was detected after bleaching with 10%–22% carbamide peroxide, the products used generally had pH values ranging from 6 to 7.8, ie, neutral or very close to neutral.[24,40,41,43,47,48] One study used an agent with an acidic pH (4.7),[44] but the others did not evaluate the pH of the solutions tested.[42,46] Such findings demonstrate that morphological changes induced by bleaching procedures could not be exclusively related to pH.[40]

An investigation was conducted to evaluate the time period required to re-establish enamel surface microhardness after bleaching with fluoridated or nonfluoridated 10% carbamide peroxide gels with neutral or acidic pH that used a daily demineralization and remineralization protocol. After seven days of whitening treatment, a statistically significant loss of hardness ranging from 7%–15% was observed in all groups. Nevertheless, fluoridated gels provided some protective effect, with less loss of hardness than with the nonfluoridated gels. The pH of acidic gels does not seem to contribute significantly to demineralization of enamel.[49]

No significant changes in surface roughness of the enamel have been observed after bleaching with 10%[31] or 16%[21] carbamide peroxide, but susceptibility to abrasion was increased when brushing was performed with abrasive toothpaste.[21,31] However, these studies were carried out in vitro, so would have had more pronounced effects than in conditions in vivo. Another study[39] evaluated enamel microhardness after bleaching with 10% carbamide peroxide, and the authors were unable to find a significant difference before and after bleaching, but their study did show decreased resistance to abrasion. Additionally, the authors observed that bleached enamel showed a greater loss of tooth structure when abraded against both a harshly and mildly abrasive substrate than the unbleached enamel did.[39]

The potentially higher susceptibility of bleached enamel to erosion and demineralization was also evaluated in a study of human incisors. The study was designed to determine if enamel bleached using different carbamide peroxide gel concentrations of 10%, 16%, 22%, or 10% and containing xylitol, fluoride, and potassium, had an increased risk of either acid erosion or demineralization as compared with unbleached enamel. The authors observed that erosion was detected in all samples, and that there was no statistically significant

Table 1 Summary of studies relating to the effects of at-home peroxide treatments on enamel and dentine

Reference	Kind of study	Measurement	Evaluated tissue	Products concentration and (pH)	Changes observed	Reversibility after remineralizing period
Seghi and Denry[39]	In vitro	Microhardness	Human enamel	10% CP (NE)	No reduction on the surface microhardness, but enamel showed lower resistance to abrasion	NE
Josey et al[42]	In vitro	SEM	Human enamel	10% CP (NE)	Enamel partially etched with many shallow depressions and an increased surface porosity	No adverse effect reversal by artificial saliva was observed
Zalkind et al[40]	In vitro	SEM	Human enamel and dentine	10% CP (6.0–6.5)	Moderate erosion on dentin and none on enamel	NE
Attin et al[46]	In vitro	Microhardness	Bovine enamel	10% CP (NE)	Hardness decreased significantly	Hardness was partially recovered by fluoride application
Lopes et al[37]	In vitro	Microhardness and SEM	Human enamel	10% CP (6.0), 3% HP (6.4) and 7% urea (7.5)	Only 3% HP presented a significant reduction in surface microhardness	NE
Türkün et al[43]	In vitro	SEM	Human enamel	10% CP (5,5 and 6,8)	Significant surface alterations of enamel resembling erosion	Reversed after 3 months of immersion in saliva
Basting et al[41]	In vitro	Microhardness	Human enamel	10 (6.2–7.5), 15 (6.2), 16 (7.5), 20 (6.7) and 22% (7,8) CP	All concentrations decreased the surface microhardness of human enamel	Mineral content was recovered, but hardness values did not return to baseline
de Freitas et al[45]	In vitro	Microhardness	Human dentin	10, 20 and 22% CP (NE)	10% and 22% CP decreased dentin microhardness	Microhardness was recovered in the post-treatment period
Justino et al[52]	In vitro and in situ	Microhardness, Calcium loss and SEM	Human enamel	10% CP (7.82)	In vitro, 10% CP increased surface roughness and lead to mineral loss, decreasing microhardness.	Changes were not observed on in situ condition
Efeoglu et al[47]	In vitro	MCT	Human enamel	10% CP (6.8)	10% CP caused mineral loss on enamel	NE
Pretty et al[32]	In vitro	QLF and TMR	Human enamel	10% CP (6.5), 16% CP (6.5), 22% CP (6.5) and 10% CP with xylitol, fluoride and potassium (7.0)	None increase on the risk of erosion	NE
Worschech et al[31]	In vitro	SR	Human enamel	10% CP (NE)	10% CP did not alter the enamel SR, but brushing with abrasive dentifrices after bleaching resulted in a significant increase of enamel SR	After 28 days post-bleaching SR values have not returned to baseline for groups that used brushing with abrasive dentifrices
Attin et al[49]	In vitro	Microhardness	Bovine enamel	10% CP (5.5–7.0)	10% CP led to statistically significant hardness loss	Recovered after fluoride application
Markovic et al[48]	In vitro	Microroughness and CLSM	Human enamel	10 (6.4), 16% (6.4) CP	Both concentrations led to significantly higher roughness	NE
Metz et al[35]	In vivo	Microhardness	Human enamel	15% CP and 15% CP with potassium nitrate and fluoride (6,5–7,5)	No reduction on the surface microhardness	–
Tezel et al[36]	In vitro	Calcium loss	Human enamel	10% CP (8.0)	There was no increase in the mineral loss	NE

Chen et al[24]	In vitro	Microhardness and SEM	Bovine enamel	10% CP (6.0–6.8)	10% CP decreased significantly enamel microhardness and significant alteration on surface with erosion appearance	Recovered partially after fluoride application
Faraoni-Romano et al[50]	In situ	Surface wear	Bovine enamel and root dentine	10% CP (6.1)	Significantly higher wear depth was observed just for bleached root dentine	NE
Mondelli et al[21]	In vitro	SR	Bovine enamel	16% CP (6.0)	No increased risk of erosion but after abrasion showed a significant increase in SR	NE
Ren et al[34]	In vitro	Microhardness	Human enamel	6% HP (5.5)	No reduced surface microhardness	NE
Sasaki et al[38]	In vitro	Microhardness and SEM	Human enamel	10% CP (NE) and 7.5% HP (NE)	No reduced surface microhardness	Increased microhardness after 14 days from the end of treatment
Ushigome et al[44]	In vitro	Nanohardness, SR and SEM	Bovine enamel	10% CP (4.6); 10% HP (4.7)	10% HP cause erosion	NE
Engle et al[30]	In vitro	Surface wear	Human enamel and root dentine	10% CP (NE)	Significant wear occurred in dentin, depending on the erosive/abrasive challenge	NE

Abbreviations: QLF, quantitative light-induced fluorescence; TMR, transverse micro-radiography; SR, surface roughness; SEM, scanning electron microscopy; MCT, microcomputerised tomography; CLSM, confocal laser scanning microscopy; CP, carbamide peroxide; HP, hydrogenperoxide; NE, not evaluated.

Figure 1 Scanning electron microscopic analysis of unbleached human enamel and bleached enamel under in vitro or in situ conditions. (**A** and **B**) lower and higher magnification of unbleached enamel, with no signs of eroded structure. (**C** and **D**) lower and higher magnification of 10% carbamide peroxide-treated enamel, using in vitro methodology. The enamel has altered surface topography, showing loss of mineral structure and an eroded surface. (**E** and **F**) lower and higher magnification of 10% CP treated enamel under in situ condition. The enamel has some altered surface, with localized mineral loss, which is lower than the mineral loss observed for bleached enamel in vitro.
Pictures courtesy of Dr Lidia M Justino, Univali, Brazil.

difference between the bleached and nonbleached areas, regardless of the bleaching agent used. When submitted to cariogenic challenges, all samples showed caries-like lesions, in bleached and unbleached specimens. They concluded that tooth bleaching with carbamide peroxide does not increase the susceptibility of enamel to acid erosion or demineralization as occurs during caries formation.[32]

Only one in vivo study evaluated the influence of at-home bleaching agents on enamel microhardness. This clinical trial compared the effects of a neutral fluoridated and a nonfluoridated whitening product, both containing 15% carbamide peroxide, on enamel microhardness after tooth extraction.[35] The authors concluded that 15% carbamide peroxide with or without fluoride in the composition does not seem to alter enamel microhardness. This is in accordance with other in vitro studies using artificial saliva as the storage solution, in which investigators reported that 7.5% or 10% carbamide peroxide did not cause any significant alteration in enamel surface topography[37] or microhardness.[37,38] Additionally, another in vitro study that assessed the amount of calcium loss in enamel previously

bleached using 10% carbamide peroxide, did not detect an increase in enamel solubility.[36] Furthermore, a study comparing the erosive effect of 6% hydrogen peroxide indicated for at-home tooth bleaching and that of orange juice concluded that the erosive effects of 6% hydrogen peroxide on enamel surface were not statistically significant compared with orange juice.[34] The authors also reported that daily intake of acidic soft drinks was potentially more harmful to hard dental tissues than periodic application of hydrogen peroxide-based tooth bleaching products.[34]

Different responses of dentin and enamel to bleaching agents

Due to the highest organic content of dentin when compared with enamel, it has been suggested that dentin is more prone to mineral loss resulting from tooth bleaching. Some studies have evaluated the effect of carbamide peroxide on the dentin surface.[30,45,50,51] We found two studies, one in situ[50] and the other in vitro[30], that evaluated enamel and dentin resistance to abrasion after bleaching with 10% carbamide peroxide. Neither study found a significant effect of bleaching on enamel surface wear, but a higher wear depth was detected for bleached dentin, regardless of the abrasiveness of the dentifrice used. Moreover, even with the formation of an acquired pellicle being shown by the in situ study, there was still abrasion on the dentin surface. However, the analysis was done immediately after the bleaching protocol, without any period of recovery for the dental surface.

In summary, most of the studies have shown that at-home tooth bleaching with low concentrations of hydrogen or carbamide peroxide have no significant harmful effects on enamel and dentin surface morphology, microhardness, roughness, or calcium loss. The few studies that showed alterations in enamel or dentin surfaces all had limitations in their in vitro methodology or used highly acidic bleaching agents. In addition, these harmful effects on tooth substrates were generally transitory, and were not significant when remineralization periods were allowed.

Safety and tolerability

At-home tooth bleaching with 10% carbamide peroxide placed in a custom-tray is considered the safest and efficacious method of bleaching, having the additional benefits of a lower incidence of tooth sensitivity and gingival irritation.[5,11,53,54] Although these side effects may occur,[55,56] they usually disappear at the end of treatment.[57,58] Gingival irritation could be attributed either to the design of the tray or to the concentration of the bleaching agent. Interruption of treatment for 1–2 days or adjustment of the tray generally resolves this side effect.[59]

Tooth sensitivity may cause discomfort to the patient, but is a reversible effect that does not last more than 24 hours and rarely leads to cessation of treatment.[60,61] Most sensitivity occurs within the first two weeks of treatment[54] and it may be the result of the glycerine or other vehicle used to carry the active ingredient, which cause tooth dehydration, enabling easier penetration into dental tissues and leading to reversible pulpitis.[62]

The risk of tooth sensitivity increases if there is gingival recession with exposure of cementum and/or dentin.[63] Combination of the bleaching agent with potassium nitrate and fluoride can reduce this undesirable effect.[58] Another method that has been shown to be effective in reducing the intensity of tooth sensitivity is application of fluoride before the bleaching treatment.[64] Additionally, manufacturers have introduced at-home bleaching gels with fluoride in their composition in order to decrease any post-treatment tooth sensitivity.[8,23]

Studies have reported that the histological modifications to the pulp after vital tooth bleaching with 10% carbamide peroxide might cause initial mild, localized pulp reactions. However, the minor histological changes observed did not affect the overall health of the pulp tissue and were reversible within two weeks post-treatment.[65–67]

Thus, at-home bleaching has shown to be a safe and well tolerated method for whitening teeth. The side effects, mainly tooth sensitivity and gingival irritation, are easily controlled when the correct technique is employed, with the use of a well adapted tray, an adequate amount of bleaching gel, and application of fluoride or desensitizing agents before and after treatment.

Conclusion

Based on the present literature review, the following conclusions could be drawn:

- The majority of the studies have shown that at-home tooth bleaching agents based on hydrogen or carbamide peroxide have no harmful effects on enamel and dentin properties.
- In vitro studies have shown that at-home tooth bleaching agents based on hydrogen or carbamide peroxide has no clinically relevant effect on enamel mineral loss caused by erosion or abrasion; additionally, artificial saliva is an efficient media for reversing possible mineral loss associated with bleaching treatment in vitro.
- The bleaching agents used in at-home tooth bleaching have shown satisfactory safety and tolerability, and any

adverse effects can be easily controlled by application of fluoride or desensitizing agents between sessions, using well adapted trays or lower concentrations of bleaching agents.

- More randomized clinical trials are needed to have a better understanding of the effects of bleaching products on the predisposition to erosion and abrasion.

Disclosure

The authors report no conflicts of interest in this work.

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