ORIGINAL ARTICLE

Correlation between pH and surface structural changes on human enamel submitted to different tooth whitening agents

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Abstract

The intense valuation of an esthetic pleasant smile guided the dentistry to bleached tooth due the popularity of whitening treatments. The consequence of it is an increasing interest in searching the effect of peroxides in hard dental tissues. The aim of this work was to analyze qualitatively *in vitro* the human enamel after three different bleaching treatments: Opalescence PF 10%, White Class 7.5% and Opalescence Xtra Boost 38%, correlating the structural changes in the surface of the enamel with its respective pH. A total of 40 sound human pre-molars were randomly divided into four groups of 10 elements, which had been immersed in artificial saliva during all the experiment. Bleaching protocols followed the recommendations of the respective manufacturers. Each bleached sample and control group were submitted to a scanning electronic microscopy analysis and compared with one another. Bleaching agents used in this experiment had modified the morphologic aspect of the surface of the dental enamel; however, it did not have correlation between the degrees of severity of the alterations and pH. There is a correlation between hydrogen peroxide concentration and changes in the enamel, where G4 showed more severe alterations, followed for G3 and G2.

Introduction

Having a harmonious smile means good presentation, beauty, well-being, self-esteem, even longed-for success. This phenomenon caused a technological improvement in so-called cosmetic dentistry, as well as the development of conservative methods intended to promote a beautiful smile, such as tooth whitening procedures.[1,2] This treatment aims to render a natural aspect to teeth with or without their vital pulp that present a change of color for some reason, constituting a negative factor for smile esthetics.

Following an established diagnosis, several tooth whitening treatments may apply. Conventional or in-office procedures are those practiced in a dental office using 30-38% hydrogen peroxide as the bleaching agent.[3-5] In at-home tooth whitening, performed under dentist's supervision, whitening agents may be carbamide peroxide, with a concentration varying from 10 to 22%,[6,7] being 10% carbamide most widely used, besides the use of hydrogen peroxide in concentrations under 10%.

The use of tooth whitening procedures will eventually determine, in major or minor degree, changes on enamel

surface. Those changes are closely related to the type of bleaching agent used in the process,[8-10] its composition,[11] and pH,[4] in addition to exposure time to the bleaching gel on enamel surface.[2,4,6,7,10]

Thus, questions arise concerning the influence of whitening agents on the characteristics of human enamel, inducing to structural changes that will be assessed in our experiment.

Materials and Methods

A sample of 40 hygid premolar teeth (upper and lower jaws) was selected from the Teeth Bank at Faculty of Dentistry "Prof. Albino Coimbra Filho", Universidade Federal de Mato Grosso do Sul – UFMS (CEP Protocol 1198). The first step was removing the teeth debris with periodontal curettes; then, the teeth underwent prophylaxis with pumice paste in a rotating rubber cup at low speed. After that, they were washed in running water and stored into physiological saline until the experiment begins.

The teeth had their radicular portion inserted in pink acrylic resin that filled in the pieces of 1-inch diameter PVC matrix uniformly cut into 2 cm high pieces. After attached, the matrices containing the samples were randomly divided into four groups of 10 elements each, which were laterally put together making a circumference.

Groups 2 and 3, submitted to at-home whitening, were molded with alginate to make cast models, so that the individual trays could be a vacuum made. These trays were made of 0.3 mm semi-rigid acetate. (Bio Art – São Carlos – SP – Brazil). Prior to the confection of the individual matrices, a thin layer of LC Block-Out Resin – Ultradent™ was put on the teeth from the cast models and spread with a brush, characterizing the relief required to make the trays.

Group 4 technical protocol recommended that the teeth must be covered with a 2 mm layer of whitening gel, under absolute operating field isolation. After this previous preparation, the samples were immersed in artificial saliva for 7 days, in properly labeled recipients. At this point, the samples were ready for exposure to bleaching agents. The gels used in this process are listed in Table 1.

Table 1: Composition of whitening agent, manufacturer and lot/reference

Whitening agent	Concentration	Lot/reference
Opalescence PF (Ultradent Products Inc., Salt Lake City, UT, USA)	10% CP*	3098W
White class (FGM Odontológica, Joinville, SC, Brazil)	7,5% HP**	4512K
Opalescence xtra boost (Ultradent Products Inc., Salt Lake City, UT, USA)	38% HP**	0976L

CP*: Carbamide peroxide, HP**: Hydrogen peroxide

Right before the whitening treatments begin, a standardized instrument (pHmeter GEHAKA digital, model PG1800) was used to measure the potential of hydrogen (pH) of every gel distributed respectively amongst the groups G_2, G_3 and G_4, with G_1 as the control group. During the pH measurement process, bleaching gels and artificial saliva was at a temperature of 24.3°C. Bleaching treatment protocols followed material manufacturer's norms and recommendations. Experimental groups, pH measurement and application protocol are summarized in Table 2.

Prior to the insertion of whitening products G_2 and G_3 in the individual mold trays, a drop of artificial saliva was deposited to activate the product. Finished the exposure period, the trays were removed and abundantly washed with air/water spray; the teeth were brushed with soft toothbrush and non-abrasive dentifrice, then they were again immersed in artificial saliva until the next whitening gel application.

When the whitening treatment was finished, the samples were sectioned in their cervical limit and longitudinally so that we could obtain only the vestibular surface as the body of proof. After that, the dental portions were impregnated with a carbon film made by carbon fiber vacuum evaporation in temperatures up to 2000°C – Carbon Evaporator Machine SCD 050 BAL-TEC® – for observation in an scanning electron microscope (SEM) – JEOL JXA 840 A in standardized magnifications (500, 1000 and 2000 times).

The criteria for SEM image analysis were based on structural changes on an enamel surface, such as the presence of erosions, depressions and porosity.

Results

Group 1 (Control: Artificial saliva)

Analysis of control samples [Figures 1-3] revealed that the enamel surface morphological pattern sometimes shows alternate undulations of crests and grooves, sometimes shows characteristic undulations of a non-prismatic enamel. It is possible observing plain surfaces and the presence of wide fissures and grooves, probably a consequence of physiological abrasion caused by tooth brushing.

Table 2: Experimental groups, pH measurement and application protocol

Group	Whitening agent	pH	Samples (*n*)	Protocol
1	Control – Artificial saliva	7.00	*n*=10	-
2	Opalescence PF 10% CP*	6.57	*n*=10	1 daily application (4 hrs) for 21 days
3	White class 7,5% HP**	6.15	*n*=10	2 daily applications (1 hr) for 12 days
4	Opalescence xtra boost 38% HP**	7.01	*n*=10	2 applications of 15 min

CP*: Carbamide peroxide; HP**: Hydrogen peroxide

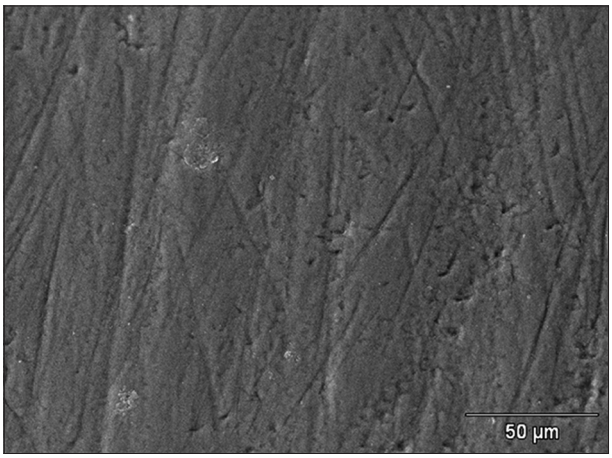

Figure 1: Accelerating voltage: 25.0 Kv/magnification: ×500

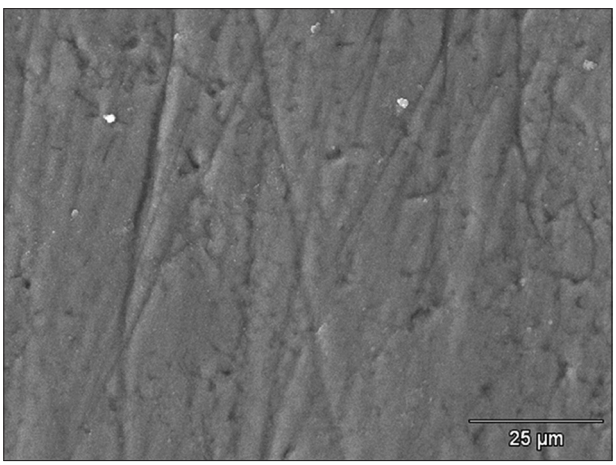

Figure 2: Accelerating voltage: 25.0 Kv/magnification: ×1000

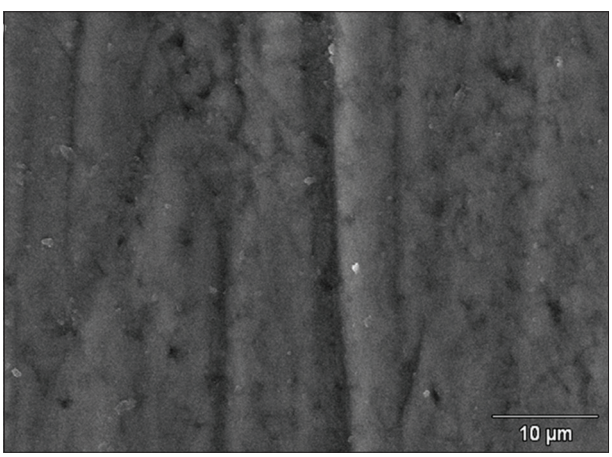

Figure 3: Accelerating voltage: 25.0 Kv/magnification: ×2000

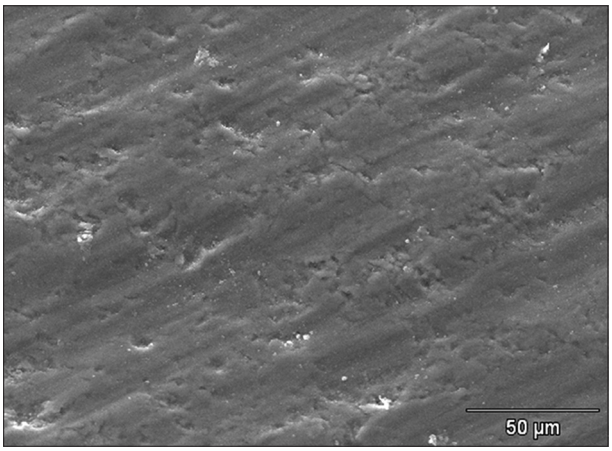

Figure 4: Accelerating voltage: 25.0 Kv/magnification: ×500

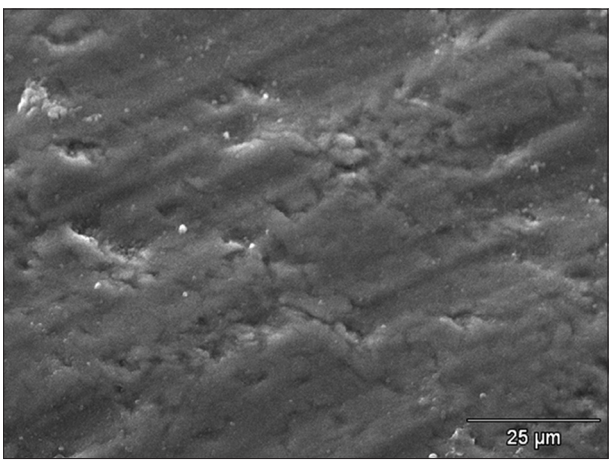

Figure 5: Accelerating voltage: 25.0 Kv/magnification: ×1000

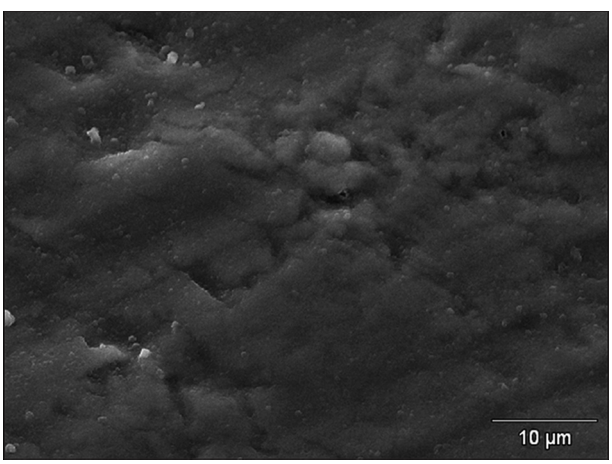

Figure 6: Accelerating voltage: 25.0 Kv/magnification: ×2000

Group 2 (Opalescence PF 10% CP)

Tooth enamel has a frosted-grass aspect (surface presenting an irregular aspect with shallow depressions). It is possible observing discrete morphological aspects, such as small erosion areas [Figures 4-6], conferring it an aspect of flaking due to adamantine projections.

Group 3 (White class 7.5% HP)

It is possible observing non-prismatic enamel with focal cavities and white spot lesions with irregular distribution along the surface [Figures 7-9]. Restricted areas present a porous aspect.

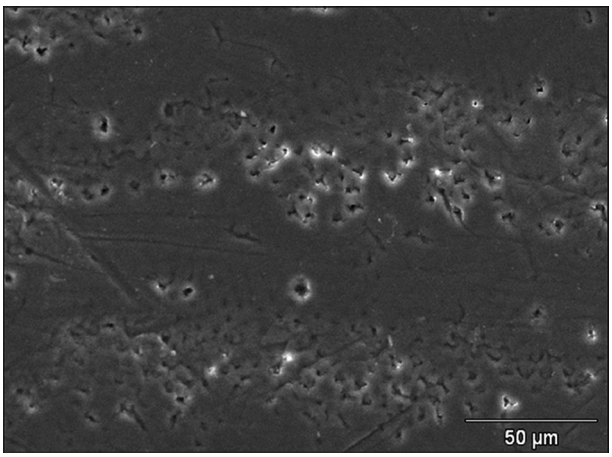

Figure 7: Accelerating voltage: 25.0 Kv/magnification: ×500

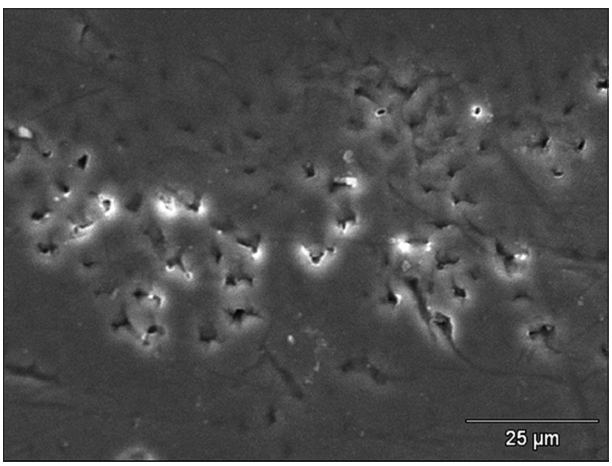

Figure 8: Accelerating voltage: 25.0 Kv/magnification: ×1000

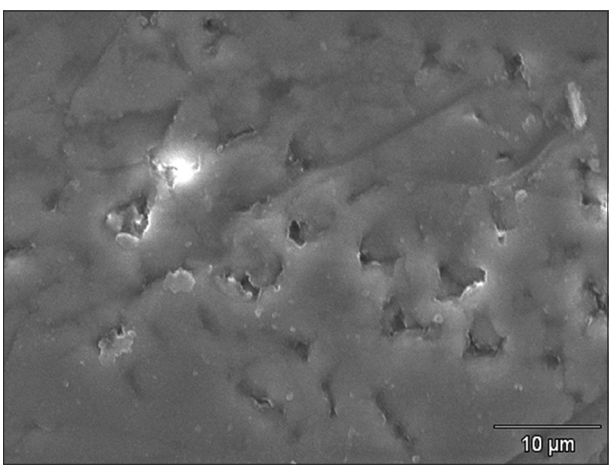

Figure 9: Accelerating voltage: 25.0 Kv/magnification: ×2000

Group 4 (Opalescence Xtra Boost 38% HP)

It is possible observing a remainder of non-prismatic enamel with irregular distribution along the enamel surface and a generalized porous area [Figures 10-12]. The surface is characterized by shallow erosions covered by a granular layer that seems to cover the entire surface, giving the enamel a rough aspect.

Discussion

Whitening agents effects on dental structure have demonstrated that they may cause changes in the chemical structure as well as in the superficial texture of tooth enamel.[9]

As other researches that assessed surface structural changes on enamel exposed to peroxide-based materials, the results of this work showed that all bleaching gels caused superficial changes., These alterations were more severe after whitening with 38% hydrogen peroxide, since this gel has a higher

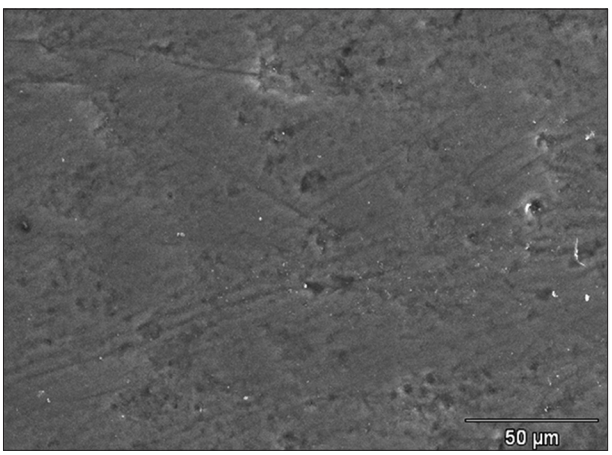

Figure 10: Accelerating voltage: 25.0 Kv/magnification: ×500

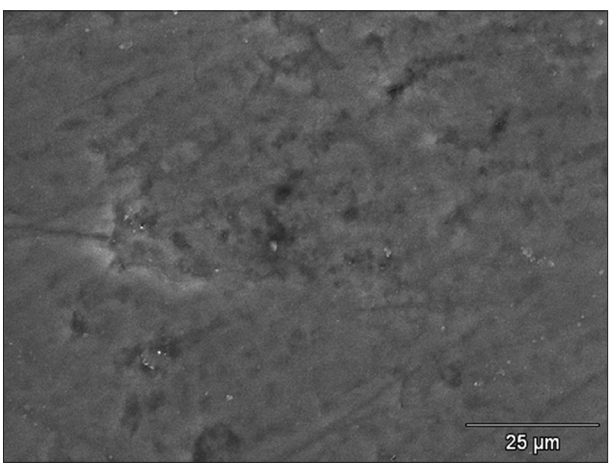

Figure 11: Accelerating voltage: 25.0 Kv/magnification: ×1000

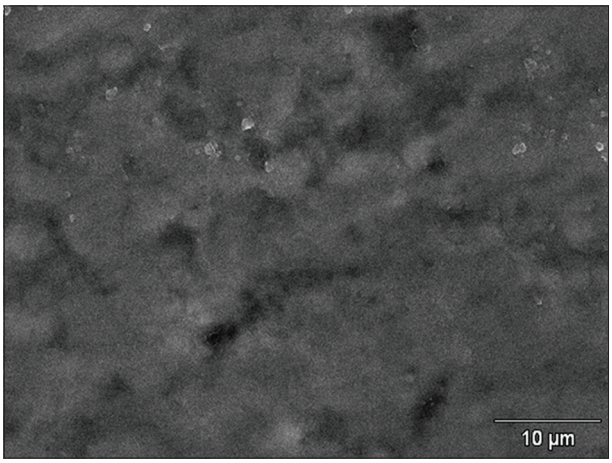

Figure 12: Accelerating voltage: 25.0 Kv/magnification: ×2000

concentration of peroxide, leading to an increased porosity and deposit of precipitations typical of erosion in these assessed samples.

As well as Oltu and Gurgan,[7] Pinto *et al.,*[3] Efeoglu *et al.,*[1] Miranda *et al.,*[12] Faraoni-Romano *et al.,*[10] artificial saliva was used in this study (G_1; pH=7.0) to simulate mouth conditions. However, its potential of remineralization is not equivalent to the natural saliva *in vivo*, and fluoride ions in the oral cavity are essential to the balance of the demineralization process.[12]

SEM images showed the dissolution of enamel organic layer (G_2, G_3 and G_4), however, there was no loss of the non-prismatic layer of enamel surface, in discordance with Markovic *et al.,*[13] who reported a dissolution of the non-prismatic layer and exposure of prisms after long exposure to agents with high percentage of hydrogen peroxide. The most severe effect of 38% hydrogen peroxide observed in this experiment resulted from the keeping of the samples in distilled water;[13] the effects of 38% hydrogen peroxide in our samples were probably mitigated by immersion in artificial saliva. It was also detected a decrease in the number of fractures caused by the oxidation in the enamel matrix evidenced by frosted-grass[8,14] effect on the surface, which showed irregularities such as shallow depressions (G_2). Thus, the natural translucency of the enamel turned more opaque, hiding the underlying dentin.

G_2 samples (10% carbamide peroxide) still showed discrete effects smoothed with flaking due to adamantine projections related to the low concentration of hydrogen peroxide (G_2; pH = 6.57) resulting from the decomposition of carbamide peroxide.[3,8,15] Redox reaction of organic compounds in the dental structure for a period of 4 hrs a day might have been neutralized by the buffering effect of saliva in the remaining 20 hrs, as stated in the applied method.

Restricted porous areas were evidenced in G_3 (7.5% hydrogen peroxide). Focal cavities and white spot lesions resulted from the dissolution and quick fusion of superficial non-prismatic enamel (G_3; pH = 6.15). These white areas are made of a more condensed enamel [Figures 7-9], having an irregular distribution along the surface.

A porous surface was evidenced in G_4 (38% hydrogen peroxide). A high concentration of hydrogen peroxide (G_4; pH = 7.01) caused a generalized dissolution of non-prismatic enamel,[5,14,16,17] however, without exposing enamel prisms [Figures 10-12]. The quick dissolution and slow recrystallization of non-prismatic enamel resulted in a surface showing some erosions.[8,13] Its rough surface resulted from the presence of a granular layer covering the entire surface. This fact is probably attributed to the short exposure time to the bleaching gel (3 applications of 15 min) recommended by the manufacturer and attested by the methodology applied in this experiment, as well as to the neutralizing buffering effect of artificial saliva.[1,3,7,10,12]

Conclusions

- The whitening agents used in this experiment have changed the morphological aspect of tooth enamel, however, there was no correlation between the degree of severity of the changes and their pH;
- There is a correlation between the concentration of hydrogen peroxide and the changes on an enamel surface, where G_4 showed the most severe changes, followed by G_3 and G_2.

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