EVALUATION OF SURFACE ROUGHNESS AND COLOR CHANGE OF BOVINE ENAMEL AFTER BLEACHING AND IMMERSION IN DYE SOLUTION

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ABSTRACT

Aim: The aim of this in vitro study was to evaluate the influence of dye solution on enamel color change after bleaching protocols and the effectiveness in maintaining the color of these agents.

Material and Methods: The buccal surfaces of sixty-five bovine incisors were cleaned and polished, and the enamel specimens were divided into thirteen groups: G1 to G6: treated with 6% hydrogen peroxide using different surface agents; G7 to G12: treated with 15% hydrogen peroxide using different surface agents; G13: control. After 24 hours, the groups treated were immersed in black tea solution; the control group was stored in artificial saliva. The color was evaluated prior to bleaching, 24 hours later and after immersion in the dye solution; the roughness was measured immediately after bleaching, 24 hours later and 7 days after immersion in the dye solution. The data was analyzed using the Kruskal-Wallis test, followed by the Miller test for roughness analysis, and the Duncan test for color change analysis. It was used 5% significant level with $p<0.05$.

Results: The data found in the evaluation of surface roughness after bleaching indicated a reduction of roughness in all the groups. The surface agent Bifluoride, when applied, showed an increase in roughness after its application and it decreases after immersion in dye solution; the surface agent Desensibilize and the XP Bond adhesive showed greater color alteration after immersion in dye solution.

Conclusions: All the groups studied, under different whitening technique, were effective in promoting whitening.

KEYWORDS: tooth bleaching, hydrogen peroxide, dental enamel
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INTRODUCTION

The hydrogen peroxide, the main active component of bleaching agents, when in contact with the tooth decomposes (for being highly unstable) in two by-products: water (H2O) and nascent oxygen (O-). The oxygen derived from this reaction is responsible for the bleaching itself.[1] Due to its low molecular

weigh, it has high power of penetration in the porosities of tooth enamel and dentin, making them wider and degrading the pigment molecules which are composed of large amounts of carbon molecules.[2] These molecules are broken and converted into intermediates (smaller chains) that are lighter. This chemical reaction changes the type, number and relative position of the atoms that compose these molecules. Thus, during the bleaching, the carbon chains are converted into CO_2 and H_2O, and it is gradually released with the nascent oxygen, making the molecules become smaller, less pigmented, and even colorless.[1]

One of the most important steps in the evaluation of whitening treatment is the verification of immediate color change and over time. It is usually performed with the use of classical color scales such as VITA and Vitapan 3D-Master,[3] which are subjective methods of evaluation. On the other hand, the objective scales measure the color change quantitatively by the spectrophotometer, calorimeter and digital image analysis.[3,4]

One method to quantify the color data obtained by the spectrophotometer is the CIELab system.[4,5,6] Under normal conditions, it is expected that after the whitening treatment, there is decrease of yellow (reduction in the value of b), decrease of red (reduction in the value of a), and increased brightness (increase in the value of L).[4,6]

In addition to concerns about the effectiveness and maintenance of color, studies since the early 90s report possible morphological changes in the enamel surface that may result from bleaching techniques.[7,8,9]

The study of different bleaching techniques (in-home and in-office), its effectiveness, and the aspects related to the changes in the enamel surface, as well the maintenance of color through clinical and laboratory studies it is important to provide security to the student and dentist in choosing the best whitening treatment plan.

This study aimed to evaluate the influence of dye solution on enamel color change after bleaching protocols and the effectiveness in maintaining the color of these agents.

MATERIAL AND METHODS

In order to perform this study, it was used two hydrogen peroxide bleaching agents at concentrations of 6% (Home Peroxide II, DMC Equipment Ltda) for in-home whitening, and 15% (Lase Peroxide Lite, DMC Equipment Ltda) for in-office whitening. The commercial brands, manufacturers and compositions are shown in table 1.

Five different enamel surface protection agents were used: Bifluoride (Voco®, Cuxhaven - Germany), Dessensibilize (DMC Equipment Ltda, São Carlos/SP-Brazil), Keep White (DMC Equipment Ltda, São Carlos/SP- Brazil), Adhesive XP Bond™ (Dentsply Indústria e Comércio Ltda., Rio de Janeiro/RJ-Brazil) and Lasting Touch (Dentsply International, Mildford DE - USA), which are presented in table 2.

All the materials used were maintained under appropriate conditions to avoid its alteration, and it were followed the instructions of their respective manufacturers.

Sixty-five lower central incisors of oxen were selected, and all the teeth were taken immediately after animal sacrifice and stored in 0.1% thymol solution contained in a 500mL glass bottle, which were completely submerged. The teeth were cleaned and returned immediately to the thymol solution.

The specimens were fixed in sticky wax Kota (Kota Ind. e Com. Ltda., São Paulo, SP - Brazil) in the center of a suitable metal matrix to adaptation to the cutting machine (Isomet 1000/Buehler). Using the assistance of a diamond disc, the teeth were sectioned at the level of the cementoenamel junction, excluding the root portion.

After cutting, the coronary buccal surface was cleaned and polished, and the pulp chamber was adequately cleaned with endodontic file Kerr, stainless still nº15 (Maillefer-Dentsply International, Mildford DE - USA). After the cleaning, the entry of the pulp chamber was filled and sealed with autopolimerized transparent acrylic JET (Classic - Ind. Brasileira) to prevent the penetration of dye solution through the pulp chamber.

The specimens were fixed in sticky wax Kota (Kota Ind. e Com. Ltda., São Paulo, SP - Brazil) in the center of an acrylic disc (30 mm in diameter and 8 mm thick) with the palatal surface facing the disc, in order to perform the polishing of the bovine enamel.

After the leveled surface, it was polished with a felt disc (Extec Corp.) moistened with 1µm diamond suspension (Buehler) for 2 minutes, observing the same standards of weight, but at high speed.

To prevent that the grains of the first sandpaper would interfere in the quality of polishing of the next, between each polishing step, the set (specimen/disc) was taken to an ultrasound device T7 Thornton (Unique Ind. e Com. de ProdutosEletrônicos Ltda., São Paulo, SP - Brazil), with frequency of 40 KHz for 5 minutes with deionized distilled water.

Previously to the bleaching treatment, the initial color was registered with the spectrometer Vita Easyshade (VITA) and the values (L*, a*, b*) of each

specimen. The color changes were calculated (ΔE) and compared with the values ΔL*, Δa*, Δb* of each specimen. L values define the black and white color, from 0 (pure black) to 100 (white); Δa * (+) red and (-) green; Δb * (+) yellow and (-) blue. To determine the ΔE was used the following formula:
$(\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2})$.

Table 1. Presentation of the commercial brand, manufacturer, and composition of bleaching gels.

Commercial brand	Manufacturer	Composition
Home Peroxide II	DMC Equipment Ltda, São Carlos, SP, Brazil	6% Hydrogen Peroxide
Lase Peroxide Lite	DMC Equipment Ltda, São Carlos, SP, Brazil	15% Hydrogen Peroxide

Table 2. Presentation of the surface protection agents and the commercial brands.

Commercial brand	Manufacturers	Composition
Biofluoride	Voco® (Cuxhaven – Germany)	Sodium fluoride and calcium
Dessensibilize	DMC Equipment Ltda. (São Carlos, SP – Brazil)	2% Sodium fluoride and 5% Potassium nitrate
Keep White Paste	DMC Equipment Ltda. (São Carlos, SP – Brazil)	Water, Sorbitol, Propylene Glycol, Sodium Sulfate Lauril, PVP, Mint Aroma, and Carboxyl Methyl Formula
XP Bond™	Dentsply Indústria e Comércio Ltda., (Rio de Janeiro, RJ - Brazil)	TCB Resin, Penta, DimethacrylateUretane, stabilizers, etil-ethyl-dimethyl-aminobenzoate, camphorquinone, t-butanol
Lasting Touch	Dentsply International, (Mildford, DE - USA),	Nanoparticles, acetone, butanol, photo initiator, additives, resin methacrylate

The whitening process affects the accuracy of the color measurement with spectrophotometer immediately after bleaching, so the time of 24 hours is determined for evaluation of color and the L*, a*, b* values after bleaching. At the end of the study the color of each specimen was evaluated in three stages: prior to bleaching (initial), 24 hours after bleaching (middle) and after immersion in the dye solution (final).

It was taken the caution to perform the color measurement always in the same place of the specimen through a demarcation done in the first analysis. Thus, the demarcation guides the subsequent reading. In addition, the same environment and the same brightness were used in order to prevent that further measures would be performed with differences in relation to light.

In order to perform the tests of surface roughness was used the Hommel Tester T1000 basic rugosimeter (Hommelwerke GmbH ref. # 240851 – Schwenningem – Germany), which is a highly sensitive device with active diamond tip used to measure surface roughness quantitatively.

Three readings were taken randomly for each specimen segment, and the initial value of surface roughness was obtained using the arithmetic mean

(Ra). The regions where some kind of irregularity was clear were disregarded, and it was sought areas noticeably of greater regularity.

The surface roughness of each specimen was evaluated again 24 hours after of the end of the bleaching, and after 7 days of immersion in the dye solution.

After obtaining the 65 specimens, they were divided randomly into thirteen groups according to table 3.

The bleaching protocol of each group was realized as described below, with exception of Group 13, which was not realized any bleaching protocol or application of the surface agent, and the specimens were stored in artificial saliva for the same treatment time given to the other whitened groups.

In the groups G1 to G6 was applied the whitening gel based on 6% hydrogen peroxide (Home Peroxide II, DMC Equipment Ltda.). Only one application was performed across the buccal surface of the specimen during 40 minutes for 7 days with an interval of 24 hours between the applications, which totalized 240 minutes of application of the whitening gel.

In the groups G7 to G12 was applied the whitening gel based on 15% hydrogen peroxide (Lase Peroxide Lite, DMC Equipment Ltda.). The gel was applied to the buccal surface of the specimen, and waited 30 seconds to a greater penetration of the gel in depth. After that, the activation with a hybrid light of LED/Diode Laser (Whitening Lase II, DMC Equipment Ltda.) was performed for 2 minutes with an interval of 30 seconds to allow a greater release of oxygen and to chill the whitening gel. Following the process, a new activation with light for 2 minutes, and an interval of 30 seconds. A last activation for 2 minutes, and the total was 7 minutes and 30 seconds of application for the same portion of whitening gel. Six applications of the whitening gel were performed in sequence, following the protocol described above. In total, 45 minutes of contact of the whitening gel into the buccal surface of the bovine enamel.

The activation time used for the groups was determined according to the manufacturers' recommendations of the bleaching agent and the light unit.

At the end of the whitening treatment, the specimens previously divided into 13 groups received surface agents as described below.

Groups 1 and 7: no application of any surface agent.

Groups 2 and 8: it was performed an application of a desensitizing agent (Dessensibilize – DMC Equipmentos Ltda.), which is available in the whitening gel kit Lase Peroxide Lite (DMC Equipmentos Ltda.), into the buccal surface for 4 minutes.

Groups 3 and 9: it was performed an application of a thin layer of fluoride varnish (Bifluoride®) in the entire buccal surface, waiting 20 seconds and applying a light jet of air.

Groups 4 and 10: it was performed an application of the whitening maintenance agent Keep White Paste (DMC Equipmentos Ltda.) for 5 minutes. How it is a paste based on PVP, this product was removed with deionized water. After proper drying of the buccal surface, a thin layer of Keep White Rinse (DMC Equipment Ltda.) was applied, and waited 20 seconds applying a light jet of air.

Groups 5 and 11: it was performed an application of a thin layer of the XP BondTM adhesive, waited 20 seconds, and proceeded the photopolymerization with the light unit LED Ultrablue IS (DMC Equipment Ltda.) for 20 seconds.

Groups 6 and 12:it was performed an application of a thin layer of the surface sealant Lasting Touch, and preceded the photopolymerization for 15 seconds with the light unit LED Ultrablue IS (DMC Equipment Ltda.).

Twenty-four hours after the end of the bleaching protocol established to each group, all the specimens were immersed in 5mL of black tea solution, lemon flavor (Nestea – Nestlé S.A.), for 7 days with daily exchanges of the solutions, and stored in an incubator at 37°C. After this period, the buccal surface of the specimens received prophylaxis with pumice/water and rubber cup in order to remove extrinsic stains induced by the storage in black tea solution. In addition, the specimens were washed with deionized water and taken to an ultrasound device T7 Thornton (Unique Ind. e Com. de ProdutosEletrônicos Ltda., São Paulo, SP), with frequency of 40KHz for 5 minutes with deionized water in order to properly remove any remain of the prophylaxis. After the cleaning, the specimens were dried in order to perform the third and final measurement of the surface roughness values and color changes.

During the period when the specimens were not being submitted to the described treatments, all of them were stored in white plastic containers with 5mL of artificial saliva, sealed, identified, and placed at a greenhouse at a temperature of 37°C and absolute humidity of 100%.

The artificial saliva solution was specifically formulated for remineralization of dental hard tissues, and it was changed daily.[10] The remineralizing solution is similar to natural saliva in terms of Ca and P according to the proposed by Serra and Cury.[11]

Table 3. Groups, bleaching protocol and surface protective agent.

GROUPS	BLEACHING PROTOCOL	SURFACE AGENT
G1	6% Home Peroxide II - 1 application of 40 minutes for 7 days	Without surface agent (Positive control)
G2	6% Home Peroxide II - 1 application of 40 minutes for 7 days	Dessensibilize (DMC)
G3	6% Home Peroxide II - 1 application of 40 minutes for 7 days	Biofluoride® (Voco)
G4	6% Home Peroxide II - 1 application of 40 minutes for 7 days	Keep White (DMC)
G5	6% Home Peroxide II - 1 application of 40 minutes for 7 days	XP Bond™ (Dentsply)
G6	6% Home Peroxide II - 1 application of 40 minutes for 7 days	Lasting Touch (Dentsply)
G7	15 % Lase Peroxide - 1 session of 6 applications + activation with the Whitening Lase II system	Without surface agent (Positive control)
G8	15 % Lase Peroxide - 1 session of 6 applications + activation with the Whitening Lase II system	Dessensibilize (DMC)
G9	15 % Lase Peroxide - 1 session of 6 applications + activation with the Whitening Lase II system	Biofluoride® (Voco)
G10	15 % Lase Peroxide - 1 session of 6 applications + activation with the Whitening Lase II system	Keep White (DMC)
G11	15 % Lase Peroxide - 1 session of 6 applications + activation with the Whitening Lase II system	XP Bond™ (Dentsply)
G12	15 % Lase Peroxide - 1 session of 6 applications + activation with the Whitening Lase II system	Lasting Touch (Dentsply)
G13	Absence of any whitening treatment	Negative control

The results of the alterations of surface roughness and color (ΔE) were subjected to statistical analysis in order to verify the presence or not of statistical difference significant, It was used the Kruskal-Wallis test. It, the Miller test was used for the data obtained in the roughness analysis, and the Duncan test for individual comparisons between groups in the analysis of color change. In the tests were used 5% significant level with $p<0.05$.

RESULTS

The Kruskal-Wallis test on the change of surface roughness did not show statistically significant differences between the initial roughness of the 13 groups. The test for post-bleaching roughness and after immersion in tea showed statistically significant differences ($F=23.86$ e $F=22.72$; $p<0.05$). Therefore, it was necessary the application of the Miller test for individual comparisons between the groups.

The mean values of the reading recorded by the Hommel Tester T1000 rugosimeter in the time periods are showed in table 4. The values expressed in the these tables are illustrated didactically in graphic 1.

The Kruskal-Willis test on the variation of the initial color change to post-bleaching did not show statistically significant difference between the groups tested ($F=12.12$; $p<0.05$); however, statistically differences were found in the times post-bleaching to the times after immersion.

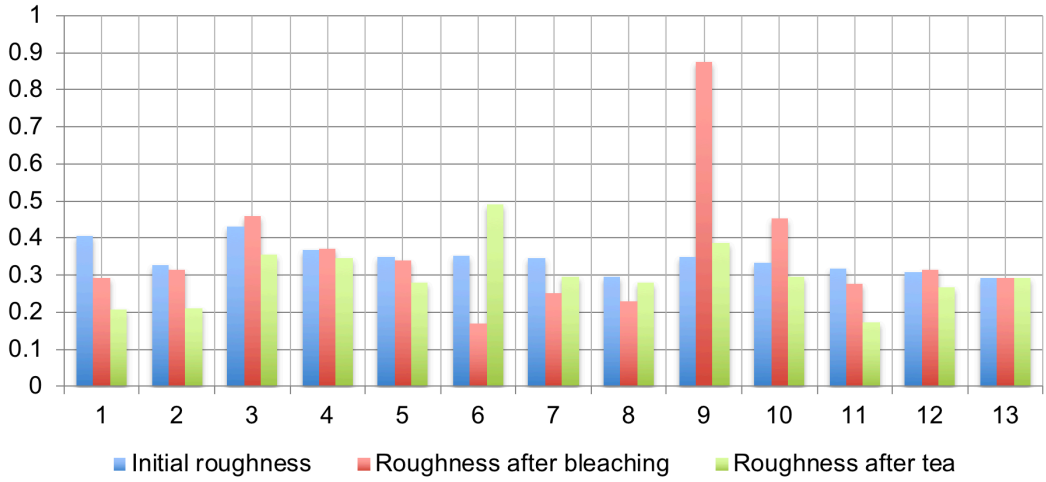
In the table 5 are shown the ΔE values, standard deviation, and statistical analysis obtained in each experimental group. The graphical representation of the results can be seen in graphic 2.

Table 4. Mean of initial roughness de (µm), after bleaching, after immersion in tea, standard deviation (SD) and statistical analysis of the groups.
* Uppercase letters: analysis between lines

Groups	*Initial Roughness ± SD*	*Roughness post-bleaching ± SD*	*Roughness after tea ± SD*
1 *(6% Home Peroxide - Positive control)*	0.405 ± 0.121^{A}	0.294 ± 0.057^{AB}	0.207 ± 0.035^{AB}
2 *(6% Home Peroxide + Dessensibilize)*	0.327 ± 0.088^{A}	0.315 ± 0.076^{AB}	0.210 ± 0.059^{AB}
3 *(6% Home Peroxide + Bifluoride)*	0.431 ± 0.045^{A}	0.458 ± 0.161^{B}	0.354 ± 0.113^{AB}
4 *(6% Home Peroxide + Keep White)*	0.369 ± 0.057^{A}	0.372 ± 0.111^{AB}	0.346 ± 0.142^{AB}
5 *(6% Home Peroxide +* XP Bond)	0.350 ± 0.076^{A}	0.339 ± 0.069^{AB}	0.281 ± 0.064^{AB}
6 *(6% Home Peroxide + Lasting Touch)*	0.353 ± 0.068^{A}	0.171 ± 0.070^{A}	0.491 ± 0.142^{B}
7 *(15% Lase Peroxide Lite - Positive control)*	0.346 ± 0.098^{A}	0.252 ± 0.058^{AB}	0.295 ± 0.101^{AB}
8 *(15% Lase Peroxide Lite + Dessensibilize)*	0.297 ± 0.104^{A}	0.228 ± 0.072^{AB}	0.280 ± 0.126^{AB}
9 *(15% Lase Peroxide Lite + Bifluoride)*	0.348 ± 0.098^{A}	0.877 ± 0.825^{AB}	0.387 ± 0.162^{AB}
10 *(15% Lase Peroxide Lite + Keep White)*	0.333 ± 0.033^{A}	0.454 ± 0.241^{AB}	0.297 ± 0.104^{AB}
11 *(15% Lase Peroxide Lite + XP Bond)*	0.318 ± 0.054^{A}	0.278 ± 0.073^{AB}	0.172 ± 0.054^{A}
12 *(15% Lase Peroxide Lite + Lasting Touch)*	0.307 ± 0.039^{A}	0.315 ± 0.076^{AB}	0.266 ± 0.144^{AB}
13 *(Negative control)*	0.291 ± 0.065^{A}	0.291 ± 0.065^{AB}	0.291 ± 0.065^{AB}

* Uppercase letters: analysis between lines

Graphic 1. Initial roughness mean (µm), after bleaching, and after immersion in tea of the groups studied.



DISCUSSION

The data found in the evaluation of surface roughness of the bovine enamel after bleaching indicated a reduction of roughness in the groups, but statistically significant differences were found between the G3 and G6 groups. These results corroborate the findings of Schmitt et al.,[12] which found median roughness immediately after the application of Last Touch sealant, but after simulated the brushing procedure the roughness values increased and the surface of the sealant became irregular being assessed at MEV.

Evaluating the enamel alterations when subjected to the action of bleaching agents, the authors report the effects on dental structures and show that bleaching agents can change the surface roughness,[1,4,13,14] chemical composition,[7,15,16] the bond strength of adhesive systems and dental composites to the newly bleached enamel.[17] Same way, other authors affirm the absence these changes in the surface texture of the enamel when subjected to the treatment with bleaching agents.[9,13,18,19,20]

Even though the selants and/or surface agents used in this study exhibit the function of sealing the irregularities produced by the finishing and polishing procedure, and to improve the marginal sealing of the restorations or even the maintenance of the color after bleaching there is a surface roughness limit for bacterial adhesion to surface protection agents (Ra=0.2 µm). An increase in roughness above this limit would result in the accumulation of bacterial plaque, which may generate periodontal pathologies and carious lesions, which correlate with the results found in the present study.[12]

Although the specimens were kept in artificial saliva, therefore without contamination of microorganisms, a precipitate could have occurred on the surface of the enamel in the group that underwent the application of Bifluoride. This would explain the increase of roughness after bleaching, as well as in the study of Schiavoni[21] where fluoride applied after bleaching was effective in all groups with the formation of a granular mantle on the applied surface. In the group that received the application of XP Bond adhesive the increase of roughness can be explained by the work of Dickinson et al.[22] where the authors stated that the clinical performance of these materials can be affected by some factors, such as: chemical modification of the resin matrix, increase of the adhesion between the charge particle and the polymer, and the improvement of the characteristics of the charge particle. Supposedly, these materials may have been partially removed from the surface of the specimens, thus not fulfilling their function of protecting and promoting smooth surfaces and causing exactly the opposite effect, leaving the surface irregular. In a visual analysis of the specimens after immersion in dye solution, it was noted that the areas where Bifluoride, Lasting Touch and XP Bond agents had been applied were irregular, sometimes without the presence of the layer of the agent that was applied.

Although many studies are concerned with morphological alterations in the enamel structure, the methodologies used are often conflicting due to the wide variety of methods used, as well as the influence of product diversity, concentrations, pH, times of action of the gels, technical orientations, and commercial brands analyzed.

The activation of the gel with sources of light or heat aims to increase the temperature of the hydrogen peroxide accelerating its breakdown and, consequently, the degradation of the peroxide and its reactive components of oxygen free radicals, in order to improve the effectiveness of the technique.[23] To promote this acceleration can be used a

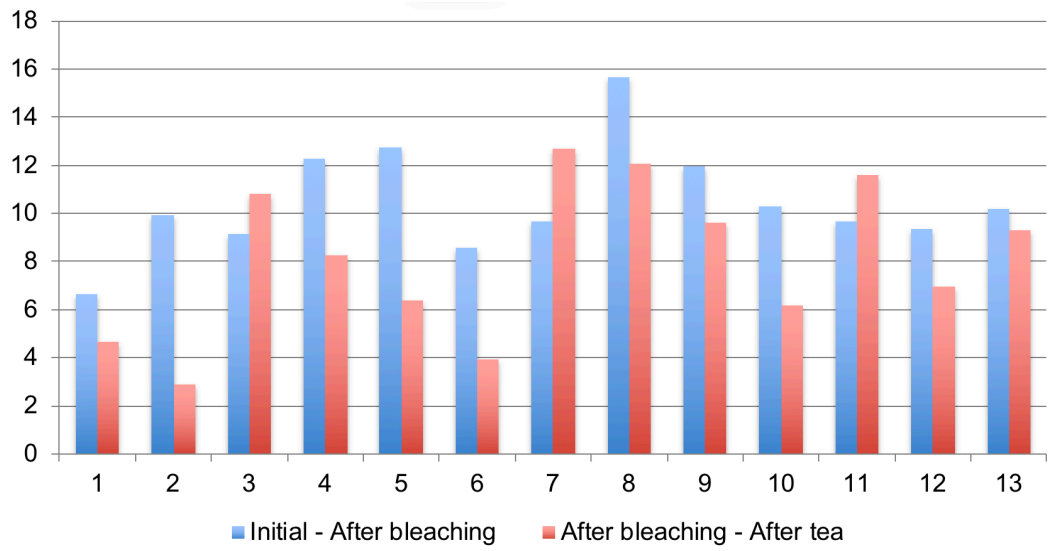
light source and/or heat, such as appliances and equipment based on halogen light, Plasma arc, LED (light emitted by diode), combination of LED / Therapeutic laser or leisure appliances of argon, diode, YAG-neodymiumor CO2.[1,23,24] Each device has its own characteristics such as: wavelength, power density, and temperature of the emitted light, which may interfere with the effectiveness of bleaching.[4,23]

Table 5. Color change (ΔE) initial and after bleaching, post-bleaching and after immersion in tea, standard deviation (SD) and statistical analysis of the groups studied.

Groups	***Initial – After Bleaching ± SD***	***After Bleaching – After immersion in tea ± SD***
1 *(6% Home Peroxide - Positive control)*	6.65 ± 3.26^{A}	4.64 ± 1.53^{AB}
2 *(6% Home Peroxide + Dessensibilize)*	9.94 ± 2.87^{A}	2.88 ± 1.81^{A}
3 *(6% Home Peroxide + Bifluoride)*	9.156 ± 4.81^{A}	10.79 ± 4.27^{AB}
4 *(6% Home Peroxide + Keep White)*	12.25 ± 3.16^{A}	8.24 ± 3.37^{AB}
5 *(6% Home Peroxide + XP Bond)*	12.73 ± 3.29^{A}	6.37 ± 1.15^{AB}
6 *(6% Home Peroxide + Lasting Touch)*	8.56 ± 3.35^{A}	3.94 ± 1.82^{AB}
7 *(15% Lase Peroxide Lite - Positive control)*	9.68 ± 1.70^{A}	12.70 ± 4.24^{B}
8 *(15% Lase Peroxide Lite + Dessensibilize)*	15.68 ± 6.88^{A}	12.04 ± 8.97^{AB}
9 *(15% Lase Peroxide Lite + Bifluoride)*	11.97 ± 5.17^{A}	9.60 ± 4.15^{AB}
10 *(15% Lase Peroxide Lite + Keep White)*	10.31 ± 2.17^{A}	6.19 ± 4.50^{AB}
11 *(15% Lase Peroxide Lite + XP Bond)*	9.66 ± 3.51^{A}	11.60 ± 3.94^{B}
12 *(15% Lase Peroxide Lite + Lasting Touch)*	9.35 ± 1.58^{A}	6.98 ± 0.97^{AB}
13 *(Negative control)*	10.21 ± 2.11^{A}	9.32 ± 1.51^{AB}

* Uppercase letters: analysis between lines

Graphic 2. ΔE values obtained on the groups.



Some authors report that the light sources do not interfere in the potentiation of the bleaching gel. Hein et al.[25] verified the in-office whitening with and without addition of activating sources. They used three light sources (LumaArch, Optilux 500 and Zoom!) In human teeth (central incisors, laterals and canines), dividing the dental arch of each patient into two groups: it was bleached one hemiarch with addition of light and one hemiarch without additional source. The results showed that adding the lights tested did not increase the degree of whitening. They concluded that the heat produced by the accessory lights was not responsible for the reaction activation of the bleaching gel of the three systems tested and that bleaching using the hydrogen peroxide from 30% to 35% does not require additional sources.

To perform the in-office technique, the groups received bleaching treatment with Lase Peroxide Lite 15% (DMC Equipamentos Ltda.). This gel needs to be irradiated by a hybrid light source (LED/Laser) according to the manufacturer's guidelines. The function of the hybrid light is to sensitize the dye, [23,24,26,27] accelerating the bleaching by increasing the temperature and greater release of the nascent oxygen, which is the ion responsible for the bleaching effect, as it was done in the present study.

The in-home technique was included with the purpose of evaluating and comparing different techniques of whitening. It is still widely used because it presents a lower cost, lower sensitivity, and lower concentration of the bleaching gel and offers greater stability in color.[28] However, it is known that in the clinic some patients do not adapt to the in-home whitening due to the use of a plastic whitening tray and/or the wait of 2 weeks to notice the change in tooth coloration. In this study the gel chosen to perform the in-home technique was Home Peroxide 6%, where the bleaching gel was applied for 40 minutes for 7 days, with a 24 hour interval between each application, totalizing 280 minutes of bleaching gel application. The time factor of application of the bleaching gel may also have been determinant for the statistical difference found in the roughness of the groups G3 and G6 after bleaching, since in the in-home technique the total time of application of the gel on the enamel was 280 minutes against 45 minutes of gel contact in the in-office technique.

The process of choosing the color is multifactorial, since it depends on the light source used, the tooth to be evaluated, the experience, standardization of the evaluators and the method, among others.[29] In order to verify the color change of the whitened teeth, visual evaluation can be used by using a color scale, a method widely employed due to the simple and fast handling[30,31] or the objective evaluation that employs spectrophotometer, calorimeters, and image analysis techniques with the help of software. Instrumental perception has been preferred over the visual because it makes the process objective and quantitative.

Guan et al.[30] analyzed three methods of color evaluation, which were captured digital image, spectrophotometer and visual observations, in order to measure and compare the color of the teeth. They concluded that for yellowish, white and non-translucent flat surfaces, the spectrophotometer achieves the necessary accuracy. There was a correlation between the data obtained in

the visual evaluation and in the two instrumental methods. Kim-Pusateri et al.[31] evaluated the reliability and sensitivity of four spectrophotometers (SpectroShade, ShadeVision, VITA Easyshade and ShadeScan) and concluded that they all show high reliability (around 96%), but the sensitivity showed significant differences (67-93%). The VITA EasyShade was the only spectrophotometer with good reliability and sensitivity (over 90%).

The present study used a room and artificial lighting, and the VITA Easyshade spectrophotometer (Vita-Zanhnfabrik, Germany), with the objective of avoiding discrepancy in the choice of the color, standardizing the comparison of the color measurement. This method has been increasingly used in research because it is a portable and lightweight device, with objective measurement, and it allows the reading of teeth in small areas.[4,30] In addition, the VITA Easyshade has high reliability and sensitivity values, over to 90%, when compared to other spectrophotometers.[31]

Changes in ΔE values indicate that there has been a change in color but do not inform the direction of this change. In the present study, it can be considered that the ΔE values of all the groups, that is, the different whitening techniques promoted color changes.

It was verified through the statistical analysis that the techniques of whitening in-office, using the lightening gel activated with the hybrid light, presented results similar to the ones found in the in-home whitening in the initial times after bleaching. Marson et al.[32], in a clinical study, did not find statistically significant differences in relation to the degree of color change, between whitening performed with and without the use of light sources (LED, LED/Laser, and Halogen). However, the authors did not report which protocol and activation time with the various light sources was used. Studies such as Rosa and Mondelli[5] have shown that the auxiliary sources can be used to reduce the time of application of the bleaching gel, since they accelerate the bleaching process.[4,33] Thus, based on the results found, the groups that used an auxiliary light source for thein-office technique required a protocol with a shorter treatment time (45 min) to obtain the same color change result as the groups that were bleached with the in-home technique (280 min).

The immersion in dye solution promoted a statistically significant difference in relation to the color change in the groups G2 (Home Peroxide 6% + Dessensibilize), G7 (Lase Peroxide Lite 15% without treatment) and G11 (Lase Peroxide Lite 15% + XP Bond). It can be concluded that both the untreated group and those receiving a layer of Desensibilize and XP Bond had a greater color change after the 7 days of immersion in dye solution. The fact that the XP Bond adhesive and the Desensibilize agent were not effective in maintaining the color after immersion in tea may be associated with the roughness values and that they were supposed lydetached from the enamel surface.

After the findings, it can be concluded that the dye solution used in this study was able to stain the enamel providing the possibility of evaluating the effectiveness of the whitening techniques as well as the effectiveness in maintaining the whitening of the agents that were applied on the surface of the bovine enamel. Moreover, it demonstrated that the in-office technique associated with the hybrid light source does not significantly alter the surface of the enamel.

CONCLUSIONS

(1) All the groups studied, under the different whitening techniques, were effective in promoting whitening.

(2) Bleaching agents alone showed a decrease in roughness after bleaching and when associated with XP Bond adhesive.

(3) The surface agent Bifluoride, when applied to the enamel surface, showed an increase in the roughness after its application with a tendency to decrease it after immersion in a dye solution.

(4) The surface agents Desensibilize, when associated with the in-home technique, and the XP Bond adhesive, when associated with the in-office technique showed greater color alteration after immersion in a dye solution.

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