Original Article

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Effect of photochemical activation of hydrogen peroxide bleaching gel with and without TiO_2 and different wavelengths

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Abstract

Aim: To evaluate the effect of photochemical activation of hydrogen peroxide (H_2O_2) bleaching gel with different wavelengths. **Methods:** In the study, 80 bovine incisors were used, which were stained in 25% soluble coffee and divided in 4 groups. The initial color was measured with the Easy Shade spectrophotometer by CIE Lab. An experimental 35% H_2O_2 bleaching gel was used, either with or without the presence of titanium dioxide (TiO_2) pigment, associated with two light sources: G1 - Transparent Gel (TG) and no activation; G2 - Gel with TiO_2 and activation with blue LED (l=470nm)\laser (Easy Bleach) appliance; G3 - Gel with TiO_2 and activation with ultraviolet (l=345nm - UV); G4 - TG and activation with UV. Three applications of the gels were made for 10 min, and in each, 3 activations of 3 min, with interval of 30 s between them. The coloration was evaluated again and the variation in color perception (DE) was calculated. The data were submitted to one-way ANOVA and Tukey's test at 5% significance level. **Results:** There were significant differences between G1 and G4. The greatest "E value was observed in G4 (13.37). There was no statistically significant difference (p>0.05) between the groups 2, 3 and 4. **Conclusions:** The presence of TiO_2 particules in the bleaching gel did not interfere at the bleaching results.

Keywords: tooth bleaching, hydrogen peroxide, color.

Introduction

Dental bleaching was introduced in dentistry in 1877. However, due to modern standards of beauty, this treatment modality has been in great demand and has been the subject of various scientific researches. Therefore, this procedure has undergone many changes. Nevertheless, the action mechanism remains the same, consisting of an oxide reduction reaction with release of active oxygen, free radicals in a solvent (especially water) in which the substance to be bleached donates electrons to the bleaching agent, normally hydrogen peroxide[1] .

Due to its low molecular weight, the bleaching agent penetrates through the porosities of the enamel prisms, reaches the dentin, comes into contact with a

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large quantity of pigmented organic molecules and breaks them up into shorter and lighter chains that allow the absorption of light in shorter wavelengths[2]. To accelerate this process of oxidation, various sources of energy can be used, such as heat and light[3-6].

The use of heat consists of contact of a hot instrument with the bleaching agent, resulting in an excessive rise in temperature of the dental structure. This may cause crack formation in the enamel and pulp damage, in addition to the risk of contact with the soft tissues and burns. That is why this technique is no longer used[7]. Heating can also be produced by electromagnetic radiation in the infrared region. This mechanism may also exceed the limits tolerated by dental tissues, contributing to an increase in postoperative sensitivity and pulp irritation[8] .

With the aim of increasing the efficacy and safety of bleaching treatment, other energy sources have been tested, such as, halogen lamps. Although there are filters capable of minimizing the thermal waves reaching the tooth, heating will always occur[9]. As light is applied for long periods in bleaching procedures, and colorants are used to intensify light absorption, there is a greater risk for the occurrence of pulp damage.

The most recent technology developed involves equipment provided with LED (Light Emitted Diode) and laser based energy sources, a highly concentrated and selective form of energy, whose radiation is emitted at a specific wavelength (peak of emission of 470nm)[10]. As this light per se is not capable of substantially heating a transparent hydrogen peroxide (H_2O_2) gel, colorants or pigments are incorporated into the gels, capable of promoting maximum absorption of this light and converting it into heat[3].

Titanium dioxide (TiO_2) is a white pigment of inorganic constitution, chemically inert and thermally stable, and has high power of reflectance and opacity. When present in the composition of the bleaching agent it seems to have the same function as the colorants because when it is irradiated with blue light, its electrical charge undergoes alteration resulting in destabilization of hydrogen peroxide[10].

Another property that TiO_2 seems to present is its greater absorption of light by the gel. This phenomenon consists of the capacity of the pigment to scatter light in the adjacent areas due to refraction and diffraction. However, nothing has yet been proved. Moreover, TiO_2 is a photocatalyzer under ultraviolet rays[11-13].

This interaction between UV light and TiO_2 has been extensively studied for the treatment of polluted water. However, there are no reports in the literature about this interaction for dental bleaching. Therefore, the aim of the present study was to evaluate the effect of photochemical activation by different wavelengths in bleaching gels with TiO_2, with the purpose of accelerating the process of pigmented component oxidation.

Material and methods

Eighty bovine incisors were used, divided into 4 groups containing 20 teeth each (n=20). The teeth were cleaned with the aid of a carborundum disk (SSW, Rio de Janeiro, RJ, Brazil), driven by a micromotor at low speed (Dabi Atlante, Ribeirão Preto, SP, Brazil). The teeth were sectioned transversally at the crown 11 mm from the cementoenamel junction (CEJ) and at the root 3 mm from the CEJ, as well as longitudinally to expose dentin, with the lingual half being removed and discarded, and the vestibular half used for the study.

The buccal surfaces of the specimens were submitted to prophylaxis with sodium bicarbonate (Gnatus, Ribeirão Preto, SP, Brazil), while the lingual surfaces were etched with 37% phosphoric acid (DFL, Rio de Janeiro, RJ, Brazil) for 15 s, followed by washing with a jet of water/air for 30 s to expose the dentinal tubules. Afterwards the specimens were immersed in an ultrasound bath (Odontobrás, Ribeirão Preto, SP, Brazil) for 20 min. In order to have better visualization and obtain quantification of the bleaching, the teeth were submitted to a staining process. This procedure was sufficient for the teeth to attain a color close to shade C4, according to the Vita Classical Scale (Vita Zahnfabrick, Bad Säckingen, Germany). The teeth were immersed in 400 ml of a recently prepared solution of instant coffee (Pilão, Barueri, SP, Brazil), at a concentration of 25%, and kept in an oven at 37ºC for 14 days.

After this, dentin exposed by the sections was made impermeable, in order to prevent distilled water from penetrating into the dentinal tubules during the long storage period to which they were submitted, and interfere in the color. They were made impermeable by the application of two coats of transparent nail varnish (Impala, São Paulo, SP, Brazil). Next, the enamel surfaces were polished with diamond paste (FGM, Joinville, SC, Brazil) for polishing associated with felt disks (Figure 1). Then the specimens were stored individually in test tubes, with a cap containing strands of cotton imbibed with distilled water, thus providing an environment with high relative humidity, and were kept in an oven at 37°C.

After staining, the color of the teeth was measured, using a *Vita Easyshade* spectrophotometer (Vita Zahnfabrik, Germany). For this purpose, the color of each specimen was evaluated in three regions of the buccal faces of the teeth, these being the gingival, middle and occlusal thirds, on an imaginary occlusal-cervical line that passes through the center of the tooth crown. Para each specimen, means of the values of L*, a* and b* were found of the three regions analyzed, so that these means represent the color for this specimen, as described below:

$$L^*_{mean} = (L^*_{cervical} + L^*_{middle} + L^*_{occlusal})/3$$
$$a^*_{mean} = (a^*_{cervical} + a^*_{middle} + a^*_{occlusal})/3$$
$$b^*_{mean} = (b^*_{cervical} + b^*_{middle} + b^*_{occlusal})/3$$

After this, each of the groups containing 20 teeth received the following treatments (Figure 2):

G1- 35% H_2O_2 Transparent Gel (Total Bleach – Clean Line, Taubaté, SP, Brazil) without TiO_2 and no activation; **G2**- 35% H_2O_2 Gel (Total Bleach – Clean Line, Taubaté, SP, Brazil) with TiO_2 (Vetec Quimica Fina LTDA; Duque de Caxias, RJ, Brazil) and activation by the appliance with blue LEDs (l=470 nm)\laser (Easy Bleach; Clean Line, Taubaté, SP, Brazil); **G3**- 35% H_2O_2 Gel (Total Bleach;Clean Line)

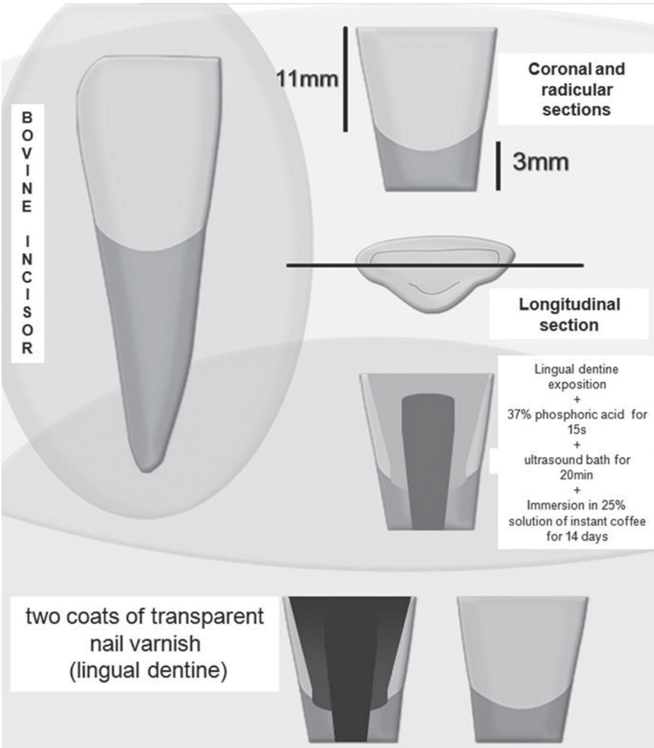

Fig. 1 – Specimen preparation.

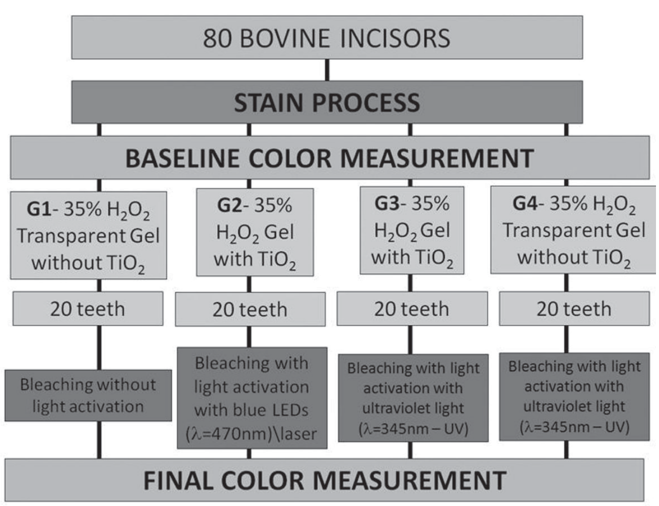

Fig. 2 – Experimental Design.

with TiO_2 (Vetec Quimica Fina LTDA) and activation with ultraviolet light (l=345nm - UV), **G4**- 35% H_2O_2 Transparent Gel (Total Bleach; Clean Line) without TiO_2 and activation by UV; For the irradiation with UV light, it was made a darkroom wood containing the ultraviolet lamp (Revoluz Equi. Ilum., 60W – 4A – 230V). Specimens were then placed inside the box, the lid closed and then the lamp was lit by a switch located outside the box.

The 35% H_2O_2 gel used in this study was the Total Bleach (Clean Line) whose composition is 50% H_2O_2 + thickness agent and activator solution (alkalinization solution), the TiO_2 particle being introduced in the groups 2 and 3 by the manufacturer.

Three applications of the gels were made for 10 min, and in each application, three activations were made for 3 min, with an interval of 30 s between them.

After this, coloring was again evaluated. In sequence, the variation in color after the different treatments was calculated. To evaluate the change in color after each treatment the values of the variation in L^*_{mean} were calculated (ΔL^*), of $a^*_{mean.}$ (Δa^*) and of $b^*_{mean.}$ (Δb^*). The values after each bleaching procedure were subtracted from those with the darkened tooth. The variation in the composition of color or total variation in color was also calculated, designated by the sign ΔE^*ab. For this purpose the values obtained after darkening and after each bleaching treatment from those with the darkened tooth were considered. The following equations were used:

$$\Delta E^*ab_{\text{bleached x darkened}} = [(\Delta L^*_{\text{bleached - darkened}})^2 + (\Delta a^*_{\text{bleached - darkened}})^2 + (\Delta b^*_{\text{bleached - darkened}})^2]^{0.5}$$

The data were subjected to one-way ANOVA and Tukey's test at a significance of 5%.

Results

The ANOVA test showed a p value of 0.013, indicating the presence of significant differences among the groups. There was a greater degree of dental bleaching in the group whose transparent H_2O_2 gel without TiO_2 was irradiated with ultraviolet light (G4). However, there was no statistically significant difference ($p>0.05$) between groups 2, 3 and 4, suggesting that the presence of TiO_2 particles in the bleaching gel do not interfere at the bleaching degree, since irradiated. The mean values, standard deviation and the results of the Tukey's test are shown in Table 1.

Table 1. The mean values, standard deviation (SD) and results of the Tukey's test.

Group	Mean	SD	Homogeneous Sets*	
G1	8.28	± 5.73	A	
G2	9.93	± 6.16	A	B
G3	12.83	± 5.72	A	B
G4	13.37	± 4.39		B

* Sets accompanied by the same letters presented no statistically significant difference at 5%.

Discussion

The present study evaluated the effect of photochemical activation by different wavelengths of light on bleaching gels with TiO_2, with the purpose of accelerating the process of pigmented component oxidation. The shade of the teeth was measured using Vita EasyShade spectrophotometer (Vita Zahnfabrik, Germany), which automatically provides the values of L*, a* and b* for each area analyzed. Several studies have successfully evaluated the effectiveness of dental bleaching with the use of spectrophotometers and colorimeters[14]. This method has the advantage of eliminating subjectivity from the analysis and providing more precise results[15]. This system allows the numerical definition of color and the differentiation existent between two colors, by means of the mathematical calculation of ΔE (difference in color). The advantage of the CIE L*a*b* system is that the differences in color are expressed in units that can be related to visual perception and clinical significance[16-17]. In the present study, bleaching gels containing or not the particle of TiO_2 were evaluated. Even the TiO_2 particle has excellent pigmentation property[18], the presence of the particle did not interfere at the calculation of the color variation (ΔE) once the gel was removed from the tooth surface before color measurement and the CIE L*a*b* system expresses the color in units, eliminating subjectivity.

At present, H_2O_2 is the most used bleaching agent is hydrogen peroxide. In spite of its action mechanism not being completely elucidated, the basic process involves an oxide reduction reaction with release of active oxygen and free radicals in a solvent (particularly water) in which the substance to be bleached donates electrons to the bleaching agent, normally H_2O_2[1]. This process can be accelerated by various sources of energy, such as heat and light[3-6]. Torres et al.[10] presented three theories that try to explain the action of light on activating the bleaching gel: controlled heating of the gel, whose radiant energy is converted into thermal energy, causes an increase in temperature; electronic excitation of the hydrogen peroxide molecules by the photons, provides rupture of the intra and inter molecular chemical bonds and the physical-chemical action on the colorant interferes in the H_2O_2 stability.

Ishibashi et al.[19] incorporated the particle of TiO_2 into chemical bleaching agents and provided incidence of different wavelengths of light on the gel, thus obtaining the best results in the groups whose chemical agent was hydrogen peroxide and the wavelength of 385 nm. In the present study, the association of ultraviolet light with the gel containing TiO_2 (G3) produced slightly more bleaching than was produced by the gel without TiO_2 and no activation by UV (G1), though without significant differences.

The TiO_2 is a solid, has good dielectric properties, high ultraviolet absorption, high stability beyond being a semiconductor that in normal state, presents not continuous levels of energy[18]. However, several authors[20-22] have explained that when the TiO_2particle is irradiated by UV light, a photocatalytic process is started through chemical reactions on the surface of the particle, which produce oxidant radicals (O_2 and OH) that cause the chemical degradation of any compound. Furthermore, Ishibashi et al.[18] affirmed that these reactions generate H_2O_2 in an aqueous solution and thickening agents. Romero and Robles[13] and Rigone[18] explained that when TiO_2 is irradiated an electronic excitement occurs resulting in the electron promotion of the layer of valence to the layer of conduction, leading to formation of pairs electrons/gap. These gaps located in the valence band have sufficiently positive potentials in the band measured from +2,0 to +3.5 against a saturated calomel electrode, depending on the semiconductor and pH. This gap is capable to oxidate water or the OH ion at the surface of the semiconductor, leading to the formation of highly oxidant hydroxyl radicals, capable of causing the chemical degradation of any compound. This means that from the thermodynamic point of view, practically any organic composition can be oxidated when displayed to this potential[13,18]

However, in the present study, the gel without incorporation of the TiO_2 particle irradiated by UV light (G4) presented the highest degree of dental bleaching, demonstrating the UV light has action on hydrogen peroxide, irrespective of the presence of TiO_2.

Another important factor that could explain the better performance of UV light on gel without TiO_2 seen in this study is the size of the particle used. Although the concentration of the particle in the gel was the same as that recommended by Ishibashi et al.[19], the size of the particle used may not have been optimum for the absorption of the light. If there is excess of white pigment in the system, almost all the light that reaches the teeth would be reflected, making light penetration difficult, and consequently, preventing photocatalysis in the bleaching gel. Therefore, pigment excess as well as the size of TiO_2 particle might have prevented the entrance of light in the bleaching gel, thus hindering the photocatalysis.

As regards the result of the gel with the particle of TiO_2 activated by the appliance with blue LEDs (l=470nm)\laser (Easy Bleach) (G2) not having been much efficient for bleaching the specimens in this study, this can be explained by the selectivity of the light source used. As the LED units act by the absorption of the complementary color of the bleaching gel for greater effectiveness, the color orange being complementary to blue light[10], the unsatisfactory result could be explained by the lack of interaction between the light and the white gel, leading to no statistically significant difference from the gel without activation (G1).

As LED/laser sources of radiation are the most recent developed technology and are widely used in clinical dentistry[10], in this study was used this type of radiation. However, studies show that the ultraviolet light is indicated to generate photocatalysis when TiO_2 is used[11-13,18-19,23].

UV radiation can be classified, for the effect to the human health and the environment, in UVA (400 - 320 nm, also called “dark light” or long wave), UVB (320-280 nm, also called average wave) and UVC (280 - 100 nm, also short call of UV or “antimicrobial. The wavelength used in this study was 350 nm (UVA) does not cause damage to the patient’s health if some precautions are taken. The Discus Dental Company already sells a device including UV Whitening (Zoom!). Since the patient is protected from this radiation by the use of suitable protective clothing and eyewear, avoiding contact with skin and gingival tissues, there is no risk to the patient health. Thus, for the application of UV light, certain precautions are essential and necessary.

Moreover, the bleaching effect of H_2O_2 generally depends on the extent to which hydroxyl radicals are generated, which can be increased by ultraviolet light (UV) irradiation. This is because H_2O_2 has a tendency to absorb UV, which then induces the molecular vibration and degradation of H_2O_2, subsequently leading to an increase in temperature[24]. This might explain the result of the present study in which the transparent H_2O_2 gel without TiO_2 particle was irradiated with UV light (G4) increased significantly the degree of dental bleaching compared to the non-irradiated group[24].

It could be concluded that the presence of TiO_2 particules in the bleaching gel did not interfere at the bleaching results and the use of irradiation increased the degree of dental bleaching although with no statistical difference.

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