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RESEARCH ARTICLE

Analysis of the Pulp Chamber Temperature of Teeth Submitted to Light Activation with and without Bleaching Gel

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ABSTRACT

Purpose: This study evaluated the temperature of the pulpal chamber (PC) of teeth submitted to the light activation with and without bleaching gel, using different types of light sources.

Materials and methods: A digital thermometer, thermocouple K type, was located in the PC of human upper central incisors and the specimens received light activation from the following sources: G1—Laser, G2—Halogen light, G3—progressive intensity halogen lamp, G4—LED/Laser. The light was applied for 3 minutes, with and without the use of bleaching gel. The data were collected after every 30 seconds and analyzed by three-way ANOVA and Tukey's test.

Results: The mean values were: Use of the gel—with gel: 3.09a, without gel: 2.79b; Type of light source—G1: 0.60a, G2: 2.38b, G3: 4.16c, G4: 4.63d; Time of activation 30 seconds: 1.15a, 1 minutes: 2.20b, 1 minutes 30 seconds: 2.97c, 2 minutes: 3.44d, 2 minutes 30 seconds: 3.81e, 3 minutes: 4.09e.

Conclusions: The use of bleaching gel associated with light activation resulted in higher heating of the PC. LED/LASER light and progressive intensity halogen lamp showed highest levels of heating. The increase of irradiation time significantly increased the temperature.

Keywords: Temperature, Dental pulp, Dental bleaching.

INTRODUCTION

The in-office tooth bleaching technique is based on the application of high concentration hydrogen peroxide gel, about 35%, which is applied on the teeth during a period of 30 to 60 minutes, and the application of this gel can be combined to the activation by different light sources in order to accelerate the bleaching process.[1,2] This acceleration occurs because the pigments present in the gel are capable to absorb the light generated by different devices, increasing the temperature of bleaching gel and consequently accelerating the bleaching process.[3] However, this temperature increase also occurs inside the pulp chamber, which could cause pulpal injuries, making this technique impracticable.

Some light devices are commonly used by professionals for the activation of the bleaching gel, however, these units are safe for use as a resin curing light,[4] considering that the light is applied directly on the tooth just over seconds. The risk of heating results in pulpal damage but is not so expressive as in bleaching treatment, when the light is applied over a layer of gel that improves light absorption and promote the conversion of light energy into heat, resulting in critical high temperatures values, unsafe for the pulpal vitality maintenance.[5,6]

Based on these facts, the objective of this study was to evaluate the temperature of the pulp chamber of teeth submitted to light activation with and without bleaching gel, using different types of light sources. The null hypothesis assessed is that the use of gel does not promote significant differences in temperature increase and that the different light sources do not promote significant heating. It was also evaluated in the hypothesis that temperature does not show variations over the light activation period.

MATERIALS AND METHODS

To perform this study, 80 upper central incisors were used. Conventional endodontic accesses were made through the lingual face of each tooth, using high speed spherical diamond burs, and the pulpal tissue was removed with endodontic files. The buccal face thickness was standardized to simulate the dentin thickness of young adults, using low speed spherical diamond burs.[4] The pulp chamber was filled with zinc oxide thermal paste (Implastec, Votorantim, SP, Brazil) in order to simulate the heat dissipation that would occur through the pulp tissue.[4] A type K thermocouple sensor was immersed in thermal paste, touching internal part of buccal face, to measure intrapulpal temperature. This sensor was connected to a digital thermometer (MT-507, Minipa Ltda, São Paulo, Brazil) and temperature measurements were recorded for every 30 seconds over 3 minutes while the light source was used. All tests were performed at room temperature of 37ºC.

Four groups (n = 20) were analyzed, for each one a different light device was used, as shown in Table 1. Each group was

divided into two subgroups (n = 10), according the use or not of bleaching gel associated to light activation. For the groups with gel association, 2 mm layer of 35% hydrogen peroxide bleaching gel (Total Bleach, Clean Line, Taubaté, São Paulo, Brazil) was applied on buccal surfaces according to the manufacturer's specifications. The red light emitting device (Bright Max, Clean Line, Taubaté, São Paulo, Brazil) was used in association with green color gel. For blue light emitting devices, the orange color gel was used.[7] The light-emitting tip was positioned to 1 cm from the tooth surface. The variation of pulpal temperature was calculated and the data were analyzed by three-way ANOVA and Tukey's test ($\alpha = 5\%$).

RESULTS

ANOVA showed p-values = 0.001 for all factors analyzed that were: presence of bleaching gel (1), type of light source (2) and light activation period (3) and also for interaction between factors 1 and 2 and factors 1 and 3. For the interaction between factors 2 and 3, the p-value = 0.17 and for interaction among the three factors p-value = 0.99.

Tables 2, 3 and 4 show the results of the Tukey's test for the factors evaluated. The use of gel increased intrapulpal temperature (Table 2). Table 3 shows that the LED/Laser (Easy Bleach) and progressive intensity halogen lamp (Jet Lite) were responsible for the higher values of pulpal chamber greater heating. In Table 4, it is possible to see that as longer is the light activation period, higher is the pulpal chamber temperature. Graph 1 shows the increase of temperature over time of irradiation. Higher results of intrapulpal heating was obtained for the group that associated bleaching gel and blue LED/Laser light (Easy Bleach). For all tested groups, the intrapulpal temperature increased proportionally to the time of irradiation.

DISCUSSION

The chemical decomposition of hydrogen peroxide releases free radicals of oxygen that has high oxidative capacity. Due to this characteristic, these radicals promote the breakdown of pigments present in tooth structure and results in bleaching.[8] Previous study[9] showed that for high temperatures, the chemical decomposition of peroxide is also increased, according to the rule described by Van't Hoff, that relates changes in temperature according to the variation of constant equilibrium of the hydrogen peroxide decomposition reaction. Important studies[5,10] explained that with each 10°C increase in temperature, the chemical decomposition of hydrogen peroxide increased by 2.2 to 2.5 times. In 1979, it was stated that

Table 1: Different groups and light devices evaluated

Device	*Light type*	*Manufacturer*
Easy Bleach	2 LEDs of 500 mW emitting blue light (λ = 470 nm) and 1 diode laser of 120 mW emitting infrared (λ = 784 nm)	Clean line, Taubaté, SP, Brazil
Bright Max	3 Laser of 50 mW emitting red light (λ = 660 nm)	Clean line, Taubaté, SP, Brazil
Curing Light XL 3000	Halogen lamp 550 mW emitting blue light (λ = 450 nm)	3M ESPE, Grafenau, Germany
Jet Light 4000 Plus	Halogen lamp with progressive increase in power density 100-1400 mW emitting blue light (λ = 500 nm)	J Morita, Osaka, Japan

Table 2: Mean and SD values of the temperature rise in the pulp chamber for samples irradiated with and without the gel

Use of gel	*Means (± SD)*	*Homogeneous groups**
With gel	3.09 (± 2.03)	A
Without gel	2.79 (± 2.26)	B

*The means followed by different letters (homogeneous groups) present significant statistical differences for the test of Tukey ($p < 0.05$)

Table 3: Mean and SD values of the temperature rise in the pulp chamber for samples irradiated with different devices

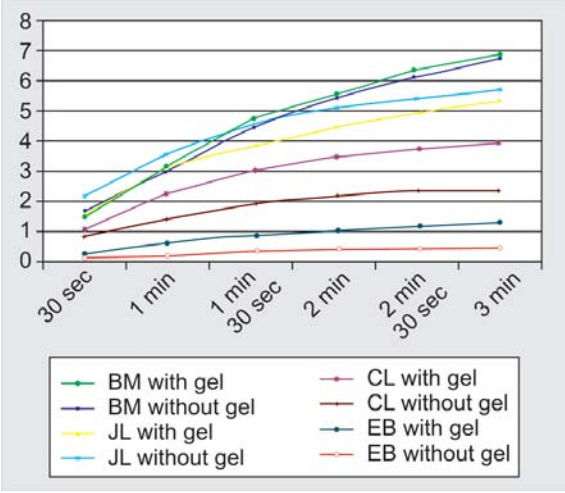
Type of device	*Means (± SD)*	*Homogeneous groups**
Brite Max	0.60 (± 0.43)	A
Curing Light XL 3000	2.38 (± 1.31)	B
Jet Lite 4000 Plus	4.16 (± 1.60)	C
Easy Bleach	4.63 (± 1.67)	D

*The means followed by different letters (homogeneous groups) present significant statistical differences for the test of Tukey ($p < 0.05$)

Table 4: Mean and SD values of the temperature rise in the pulp chamber at different times

Time of light activation	*Means (± SD)*	*Homogeneous groups**
30 seconds	1.15 (± 0.76)	A
1 minute	2.20 (± 1.33)	B
1 minute 30 seconds	2.97 (± 1.77)	C
2 minutes	3.44 (± 2.07)	D
2 minutes 30 seconds	3.81 (± 2.33)	E
3 minutes	4.09 (± 2.57)	E

*The means followed by different letters (homogeneous groups) present significant statistical differences for the test of Tukey ($p < 0.05$)



Graph 1: Temperature rise in the pulp chamber over time. BM: Bright Max; JL: Jet Light 4000 Plus; CL: Curing Light XL3000; EB: Easy Bleach

bleaching is improved by the use of heat[11] and the better efficient temperature of bleaching agent for use in vital teeth ranges between 46 to 60°C.[12] As temperature is increased the diffusion of hydrogen peroxide on enamel and dentin is also increased.[13]

However, the use of light activation may result in excessive elevation of temperature and it may cause pulpal damage. Zach and Cohen[14] observed in a study *in vivo* performed in monkeys, that increase of 5.5°C resulted in 15% of teeth with irreversible pulp damages, and for increases around 11.1°C this risk is 60%. Baik et al[15] observed that the use of light activation with halogen lamp or appliance of plasma arc light resulted in pulpal heating from 5 to 8°C, which was over the limit established by Zach and Cohen[14] and could cause irreversible pulpal damages.

There are three theories that attempt to explain the action of light in accelerating the decomposition of hydrogen peroxide. The first relates to a controlled heating of the bleaching gel, the second refers to an electronic excitation of molecules of hydrogen peroxide, while the third suppose a photochemical action of the pigment.

According to the first theory, when the light is absorbed by the bleaching gel, the radiant energy is converted into thermal energy (heat).[5] This transformation is called photothermal effect.[4] Previous study[9] showed that this is the most important effect of photocatalytic bleaching procedures. Some authors stated that the heating of hydrogen peroxide is able to accelerate its decomposition reaction and formation of radical oxidants.[10,12,16] Furthermore, the increase in temperature promotes a bigger diffusion of hydrogen peroxide through enamel and dentin,[17,18] thus faster penetration may be associated to the use of light devices.[5]

The second theory states that the action of light for bleaching agents activations may produce nonthermal effects on the chemical, known as photochemical effects, photolysis or photodissociation. According to Crim,[19] photons can produce an electronic excitement and/or vibration in the molecules, causing the disruption in certain chemical bonds intramolecular and intermolecular. The change of vibrational state of molecules requires the deposition of a relatively large amount of energy, which can be provided by high-energy photons. This can promote the decomposition of hydrogen peroxide.[20]

Finally, third theory of action of light on the bleaching gels states about the physicochemical interactions with the pigment, that interfere to the hydrogen peroxide stability. There are reports in the literature that substances as carotene, annatto, SiO_2 and TiO_2, present in the composition of bleaching gels, when irradiated with light, can be dissociated or suffer alterations, changing their electrical charges and resulting in destabilization of the hydrogen peroxide or disbalance the pH of the whitening gel. Chen et al[21] found that rapid changes in pH cause a destabilization in the molecule of hydrogen peroxide and results in the release of free radicals.

The null hypothesis, that the use of gel with light activation does not promote significant differences in temperature, was rejected because there was statistically significant differences for pulpal temperature increase to the groups where the bleaching gel was used in relation to groups where only light activation was performed. According to the literature, the use of light activation for whitening gel generates higher intrapulpal temperature heating,[5,22-25] which is also proved through this study. This suggests that the photothermal effect occurred when light activation was used associated to bleaching gel.

Previous study[24] showed difference between surface temperature and pulpal chamber temperature for teeth submitted to bleaching with and without the use of bleaching gel, and was stated that the gel had an insulating effect on the temperature increase, and the use of the gel would serve as a protective layer minimizing the increase of intrapulpal temperature. It was also shown that the presence of the gel reduced the magnitude of temperature increase, but when using the diode laser device temperature was significantly increased, more than for other types of devices used.[26] Yazici et al[27] demonstrated that the association of source of light energy with the use of whitening gel creates a potential increase in intrapulpal temperature. This factor possibly occurs due to the combination of heat generated by infrared radiation and visible light absorption by the pigments present in the bleaching gel.[28,29]

However, changes in temperature increase are directly dependent on type of light used and light irradiation time that specimens are submitted, and although this study has been performed only for the upper central incisors, it is still possible that the temperature variation may also occur due to anatomical differences of each specimen, and different thicknesses of dentin and enamel in the various specimens used, which is also a factor influencing the increase in intrapulpal temperature.[4] This study was based on the methodology described by Torres et al[4] and Baik et al[15] that standardized the thickness of the buccal face, simulating the thickness of dentin of young adults teeth, to minimize the possible variation in results.

The null hypothesis that different devices do not promote significant heating has been rejected. In this study, the device LED/Laser Easy Bleach with blue LEDs and a diode laser

showed higher results for intrapulpal heating. A surprising result because in these hybrid devices the main source of energy to catalyze the reaction of bleaching comes from LEDs, emitting visible light. These devices have a form of highly concentrated and selective energy and the radiation is emitted at a specific wavelength. Thus, one can choose a predominance of thermal effects, using infrared radiation or a light more cool in the visible spectrum. The emission of light by the LEDs is concentrated in a narrow band of 20 to 80 nm.

The laser diodes present in these devices emit infrared radiation wavelength. Although these waves have the ability to produce some increase in temperature of the gel and help to accelerate the decomposition reaction of hydrogen peroxide, the main goal is to produce nonthermal effects on dental pulp, known as effects of biomodulation, in order to decrease the trans and postoperative sensitivity. For this reason, infrared laser diodes of low intensity, around 100 to 500 mW are used.

However, for the occurrence of a maximum absorption of the light emitted by the LED, pigments are added to the bleaching gels to act as selectors or filters absorbing one or more radiation and reflecting others. Thus, to enhance the absorption of light from LED/Laser Easy Bleach, bleaching gel containing orange pigment was used. Perhaps the combination of these two light sources and the process of luminescence emitting light in a specific wavelength that is wider absorbed by the orange pigment into the bleaching gel can justify the results of this study.[28,29]

Castanho et al[30] evaluated the influence of color gel in the temperature of the bleaching gel and pulp chamber, using activation with the blue light produced by LED devices. The authors observed that the red gels resulted in significantly greater heating than the blue, confirming the relationship between color and energy absorption. Torres et al[4] observed that the temperature of whitening gel layer is elevated when irradiated with light sources, maybe due to absorption of light by certain colors or due to the concentration of some products. Previously,[17] it was reported that the application of blue light from different sources on a gel with pigment, resulted in temperature significantly higher than the absorption that occurs by gel without pigment. For equipment Jet Light 4000 Plus and Curing Light XL 3000 that present bulb as a source of light activation, we observed mean temperature increase of 4.16 and 2.38°C respectively. A problem of these devices is the heating of the teeth due to the characteristics of the light produced. According to Buchalla and Attin,[6] the wavelength emitted by these lamps ranges from the ultraviolet ($\lambda < 380$ nm) across the visible spectrum ($\lambda = 380$-770 nm) and penetrates deeply into the red ($\lambda > 770$ nm). While there are filters that can minimize the arrival of the waves to the tooth, they are not completely eliminated, and a heating will always occur[6] promoting a sum of heating, resulting from the infrared absorption of visible light by colored gels.[17] It can also be observed in this study, that the unit Light Jet 4000 Plus had a mean increase of intrapulpal temperature, statistically significant in relation to the unit Curing Light XL 3000. This result is probably due to a power density of the device Jet Light 4000 Plus, which can reach the value of 1400 mW, while the unit Curing Light XL 3000 has a power density of up to 550 mW. Therefore, most of the energy produced by halogen lamps consists of infrared radiation, also called thermal waves, and higher the power density, higher the energy that can generate an immediate heating of any object which is in contact.

Contradicting the findings of this study, another one[31] evaluated that the temperature increases during the pulp bleaching procedure using light curing units with halogen lamps and hybrid device LED/Laser emitting blue light (Easy Bleach). For activation with halogen Jet Light (J Morita), sending a power density of 1200 mW/cm^2, there was a heating over the critical temperature of 5.5°C after 40 seconds irradiation. After 3 minutes and 20 seconds, the pulp temperature increased about 11°C. On the other hand, for the device equipped with LEDs, the critical temperature was not reached in any period, even after 3 minutes and 20 seconds of irradiation, indicating bigger security for the use of these devices, so the light can be applied for longer times without risk of pulp damage. Similar results were observed by Eldeniz et al,[32] who observed that the LEDs promoted the lower heating pulp in relation to the halogen lamps.

The device Bright Max showed the lowest values of pulp temperature increase among the devices tested. This result may be because the device presents three lasers with a small power density of 50 mW, and although these waves have the ability to produce some increase in temperature of the gel and help to accelerate the decomposition reaction of hydrogen peroxide, the main goal is to produce biomodulation effects.

The null hypothesis that the temperature does not vary with increasing time of irradiation was also rejected. The results of this study showed that higher is period of light irradiation, higher is the increase of intrapulpal temperature because of the longer exposure of gel to light activation, therefore getting longer stimulus and then absorbing more light and generating more heat. This result can be strengthened by the results obtained before[4] where bleaching gel was activated by LED/Laser and halogen light and the temperature was measured after each 40 seconds, and it showed temperature increases proportionally to the time of light exposure, as like as bleaching gel exposed to halogen lamp over 20 seconds, the pulpal temperature rised to 3°C, while for 60 seconds it was incresead up to 4.8°C, what can suggest that the light activation over long periods can enhance the risk of pulpal damages.[33]

Priority, this study focused on intrapulpal temperature changes and not the histological changes, it is also important to consider that this study was conducted *in vitro* and has some limitations that could not exactly simulate the conditions *in vivo*, where there is the intrapulpal blood circulation, which is able to dissipate the heat before intrapulpal cells damage occur and the natural movement of fluid, pulpal fluid through enamel and dentin is capable of preventing transfer of heat to the pulp tissue, which cannot be simulated in the laboratory.

CONCLUSION

It was concluded that the temperature of the pulp chamber of teeth light-activated with bleaching gel showed a significant increase compared to light-activated without the use of whitening gel. The temperature of the pulp in teeth submitted to light activation with LED/Laser showed a significant increase, followed by the devices Jet Light 4000 Plus, Curing Light XL 3000 and Bright Max. It was also observed that the intrapulpal temperature rise is directly proportional to increased exposure time of activation.

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