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Full Length Research Paper

In-office dental bleaching efficacy assessment in function of the light exposure regime by digital colorimetric reflectance spectroscopy

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In-office dental bleaching has been subject of several studies. Generally those studies quantify through visual analysis, the shade reduction of the teeth submitted to different bleaching protocols (light sources, bleaching agent concentrations and irradiation time). The objective of this work is the determination of the influence of four irradiation protocols on the obtainment of better aesthetic results using a colorimetric spectrophotometer that quantifies color changes in each situation imposed. Forty bovine incisors were selected in function of similar anatomic characteristics; a concentrated coffee solution was used to stain the teeth. A commercial spectrophotometer was used to measure the color changes during evolution of the experiment (stain and bleaching phases) and the obtained data was analyzed by the ANOVA test. The obtained data showed the evolution of teeth color during the staining period, as well as, the color reduction that each bleaching protocol achieved. Based on our findings it is possible to conclude that bleaching protocols with larger irradiation periods did not showed significant differences when compared with shorter irradiation protocols, in that way the use of protocols with 30 min or more of consecutive irradiation are not clinically justified and also can cause several side effects.

Key words: Dental bleaching, light emitting diodes (LEDs), spectrophotometer, objective measurements.

INTRODUCTION

Dental bleaching is a procedure used in dentistry since the beginning of the 19th century (De Mattos et al., 2003; Haywood, 1992). Since then the safety of the process, the aesthetic outcome, the indications, and the use of catalytical methods to improve the chemical reaction are extensively discussed.

The major concern observed in the literature, is related to the safety of the process, once that the different bleaching agents have caustic action when prolonged periods of contact with teeth (Atkinson, 1893). Also with the side effects that can appear when this chemical reaction is improved by any available catalytical methods. More recently, and because still can be observed in the literature, a lack of agreement about the use of light sources to accelerate the dental bleaching procedure, it can be perceived two major lines of thought.

The first line investigates the use of hydrogen peroxide in several commercial presentations, concentrations and associations with other chemical products. Those experiments were based on the natural oxidative characteristics of the hydrogen peroxide that can, in a spontaneous way bleach the teeth (Haywood and Heymann 1991; Leonard et al., 2000).

The studies of the second line of thought, investigates the use of light sources to accelerate the bleaching process, in order to diminish the exposure of the patients to the bleaching agents, to obtain better aesthetic results and at the same time the improvement of the procedure safety, once that this procedure has to be done entirely under professional supervision (Buchalla et al., 2007; Kashima-Tanaka et al., 2003; Luk et al., 2004). Among all

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the possibilities that can be used to improve the dental bleaching outcome, three are of great interest, the use of heat, the use of other chemical agents mixed with the hydrogen peroxide, and nowadays the use of Lasers and LEDs.

Recently several studies are comparing the efficacy of both techniques, home bleaching and in-office bleaching, and some studies point out that there are no significant differences between those techniques (Hein et al., 2003; Papathanassiou et al., 2002). Buchalla et al. (2007) in a systematic review of the literature emphasizes that, light sources used to accelerate the dental bleaching chemical reaction, such as Lasers and LEDS, are considered by the majority of the professionals as the state of the art in terms of quality, safety and aggregation of value in the dental office, but the author also highlights that nothing can be concluded related with the vantages of using light to enhance the aesthetic outcome.

The evaluation of the different dental bleaching techniques available in modern dentistry, is performed in their majority, by visual comparison of the perceived teeth shade during the evolution of the procedure with comercial color pallets, but some studies like the one performed by Klemetti et al. (2006) indicates that, in function of the reproducibility's result (33-43%) obtained among professional observers, the visual comparison analysis is a very subjective method. Other studies report that this method is also highly influenced by the environment illumination, and recommends that every visual analysis that should be performed on different days should be done on the same hour to prevent possible errors (Li and Wang, 2007).

Nowadays there are new approaches available to analyze teeth shades, these methods are based on objective measurements of the color through the acquisition of digital images and by the use of digital spectrophotometers. Studies performed by Jarad et al. (2005), Lath et al. (2006), Li and Wang (2007), describe that those new technologies are reliable tools to support the dentist in evaluate the bleaching levels achieved in each technique available.

Taking into consideration the lack of agreement about the use of the light to accelerate the bleaching procedure, the protocols of irradiation that recommend large periods of irradiation in order to achieve more bleaching levels, and the use of more trustworthy tool to measure teeth color, the aim of this work is to evaluate the use of prolonged and consecutive irradiation periods on the obtainment of better aesthetic results on bovine teeth.

MATERIALS AND METHODS

The objective color analysis system was composed by a handheld digital colorimetric spectrophotometer (Pocket Spec® - PocketSpec Technologies Inc – Denver, CO - USA), a notebook (Gateway MSX 6421, USA), a specific color analysis software (ColorQA Pro III®, PocketSpec Technologies Inc – Denver, CO - USA), and a standard black background. This spectrophotometer basically works through the emission of a white light pulse that is emitted by a single high intensity LED (light emitting diode). Once that this light interacts with each one of the samples the backscattered light is collected by a sensor located inside of the device, and then, the data is transmitted to the computer for further processing.

The software ColorQA Pro III (PocketSpec Technologies Inc – Denver, CO - USA) calculates the total color difference (delta E - E) between each one of the color measurements and a gold pattern previously calibrated. This pattern is named as white international standard, has chromaticity coordinates in the RGB color space of 255/255/255, and it was used as base line for all samples.

All experimental data were expressed by the software as numeric values, and those values represent how different from the white pattern were each color measurement during the experiment's evolution. Studies such as realized by Douglas (1997), Hill (1987), Luk et al. (2004), McLaren (1987), Ragain and Jonhston (2000), Rosenstiel et al. (1991) and Wetter et al. (2004) had also expressed their results using the total color difference (delta E).

The color measurements of each one of the samples, was realized after the prophylaxis procedure that was described previously, and in seven different phases, as follows: Phase 1 - (INITIAL; n =10) initial color condition; Phase 2 - (S1W; n =10) one week of staining; Phase 3 - (S2W; n=10) two weeks of staining; Phase 4 - (S3W; n=10) three weeks of staining; Phase 5 - (B1W; n=10) first bleaching session; Phase 6 - (B2W; n=10) second bleaching session, and Phase 7 - (B3W; n=10) third bleaching session. In each experimental phase, ten color measurements were realized for each one of the samples with the handheld spectrophotometer (Pocket Spec® - PocketSpec Technologies Inc – Denver, CO - USA). This device was positioned in parallel orientation and in direct contact with the buccal face of each tooth measured, as indicated by the device manufacturer.

To promote the irradiation of the samples, it was used the Bright Maxx bleaching system (MMO, São Carlos, Brazil). This is LED based equipment, with 3W/cm^2 and emitting visible blue light in 470 ±15 nm. This system was designed with an acrylic optical lens to improve the delivery of the emitted light over the teeth surfaces and also to allow the simultaneously irradiation of the both upper and lower dental arches of a patient.

In order to study only the positive influence of light in 470 ± 15 nm with different irradiation protocols in the obtainment of better bleaching levels, and also avoid other catalytic mechanisms (thermal effects) that derive from the high light absorption presented by the commercial bleaching agents, we have decided to use a transparent bleaching gel. This was a carbopol gel manipulated with 35% hydrogen peroxide (Farmacia Botica – São Carlos, SP – Brazil).

Forty bovine incisors were visually selected in function of their anatomical similarities as size, shape and color. Following all teeth were submitted, individually, to prophylaxis using a paste of pumice powder and distilled water that was applied on tooth's surface with a rubber cup in the low-speed handpiece. After that, each one of the teeth had its root removed of the crown with carburundum discs (Discos de Carborundum 7/8 × 0.23 mm - Dentorium Produtos Odontológicos - São Paulo, Brazil) in the slow-speed handpiece to promote direct access to the pulp chamber via root canal.

This access was necessary to facilitate the removal of any remnant of organic tissue that could influence the color measurements, and also to preserve the anatomic natural characteristics of the crowns. Initially these organic remnants were removed with manual endodontic instruments (Hedströen File #80, 25 mm length - kerr, Romulus, USA), and when needed, it was used to complement the pulp chamber cleaning, a system of air/water in high pressure that. This system was able to create an intense positive pressure inside the pulp chambers and efficiently removed all organic particles.

After that, each one of the specimens was individually positioned inside of black plastic containers with a coffee solution, with concentration of 150g of coffee powder to 600 ml of fresh water, in

Table 1. Experimental groups.

Group	35% H_2O_2	λ (470 nm)	Sample	Irradiation time (Min)
1	+	+	n=10	9
2	+	+	n=10	15
3	+	+	n=10	30
4	-	+	n=10	30

Table 2. Statistical differences intra-groups and, inter-groups for each experimental situation ($p \leq 0.05$).

A) Delta log stain 2W - Stain 1W					**B) Delta log stain 3W - Stain 2W**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Group 1		0.278571	0.032841	0.239393		0.856045	0.000008	0.000012
Group 2	0.278571		0.000045	0.001440	0.856045		0.000008	0.000214
Group 3	0.032841	0.000045		0.831039	0.000008	0.000008		0.138992
Group 4	0.239393	0.001440	0.831039		0.000012	0.000214	0.138992	
C) Delta log Bleaching 1W - Stain 3W					**D) Delta log bleaching 2W - bleaching 1W**			
Group 1		0.007056	0.000008	0.000008		0.960471	0.000008	0.000010
Group 2	0.007056		0.000152	0.047600	0.960471		0.000008	0.000008
Group 3	0.000008	0.000152		0.362847	0.000008	0.000008		0.000454
Group 4	0.000008	0.047600	0.362847		0.000010	0.000008	0.000454	
E) Delta log bleaching 3W - bleaching 2W					**F) Delta log bleaching S3W - bleaching 3W**			
Group 1		0.975455	0.000008	0.044300		0.000008	0.000008	0.000008
Group 2	0.975455		0.000008	0.012982	0.000008		0.644189	0.000011
Group 3	0.000008	0.000008		0.000008	0.000008	0.644189		0.000008
Group 4	0.044300	0.012982	0.000008		0.000008	0.000011	0.000008	

order to promote its pigmentation. At every period of twenty four hours, each one of the plastic containers with the specimen and the pigmentation solution was manually shaken during thirty seconds. The total staining period was of twenty one consecutive days. After the conclusion of the staining process, the samples were rinsed in running water for thirty seconds and, were positioned inside of black plastic containers with distilled water during the following bleaching phases of the experiment (twenty one days). The specimens were randomly distributed within each experimental Group as shown in Table 1.

The specimens of each one of the described Groups were, at the same time, positioned over a semi plasticized utility wax plaque, after that, the bleaching agent was put in contact with the buccal surfaces of the teeth, following, the irradiation procedure took place with the Bright Maxx bleaching system and was realized as described in Table 1. The irradiation system was located 1,5 cm far from the buccal surfaces of the specimens. The bleaching was realized in three different sessions, with seven days of interval between each session.

The data distribution was tested using the Shapiro-Wilk test. As the data showed absence of normality, it was performed the transformation to logarithm (log). After the data normalization, the parametric test ANOVA Two ways for repeated measures with the post hoc Tukey was used to evaluate the intra-Groups differences. To evaluate the inter-Groups differences it was used the ANOVA One Way with post hoc Tukey. The statistic analysis was performed with the software Statistica for Windows Release 7 (Statsoft Inc., Tulsa, Ok, USA) with significance level of 5% ($p< 0.05$).

RESULTS

The statistical analysis was realized within each Group by comparing each experimental phase (S1W, S2W, S3W, B1W, B2W and B3W) with the initial color condition (INITIAL). After that, it was calculated the Delta (expressed in log) of each experimental phase, which is the difference between one phase and the previous one (i.e. Delta log S2W = S2W - S1W), in order to evaluate the real contribution of light in the improvement of the aesthetic outcome. The values are shown in the Table 2.

Figure 1 shows the mean results for each situation studied in Groups 1 to 4, in this graph it is possible to observe the similar behavior of the curves along the experimental phases. In order to evaluate which Group was able to promote better aesthetic results, it was plotted in the graphic of Figure 1, shown through the analysis of the color difference (Delta E, in arbitrary unities - u.a.) between the last staining phase (S3W) and the last bleaching session for the Groups 1 to 4.

DISCUSSION

In-office photoactivated dental bleaching is a well

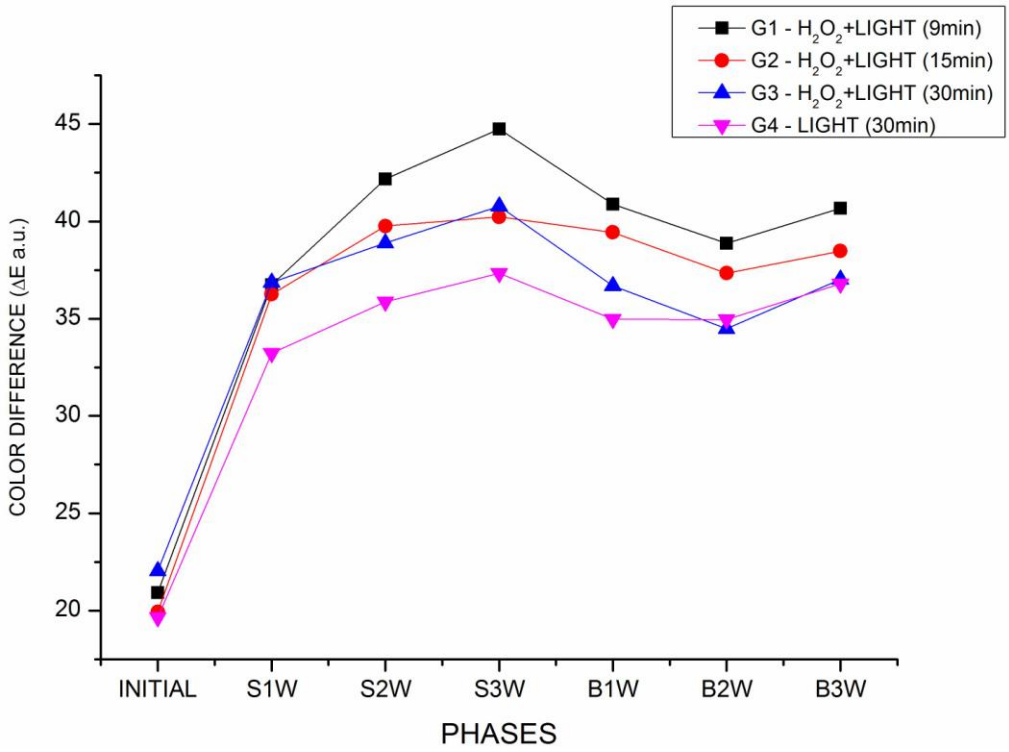

Figure 1. Experimental results for the Groups 1-4 expressed by the mean values in each experimental phase.

established, widely used and nowadays, is recognized as one of the most important and effective techniques available in dentistry to treat a significant part of discolorations in vital and non vital teeth as showed by Sulieman (2000) and Joiner (2006).

In function of its versatility and applicability the search for this treatment is increasing considerably as pointed out by Dahl et al. (2003). Despite this, there are still a lot of questions related with this bleaching technique. Jones (1999), Christensen (2000), Hein (2003) and Papathanasiou et al. (2002) reports that, it would be impossible to distinguish the treatment of dental bleaching using blue light form the treatment performed with no light, independently of the light source used, what in theory should indicate the light activation of the process can be dispensable. In contrast to those authors there are several studies that report the obtainment of better aesthetic results when dental bleaching is performed under light irradiation (Florez et al., 2006; Goldestein et al., 1989; Nash, 1999; Schumb et al., 1955; Van der Burgt et al., 1990).

Traditionally the assessment of dental bleaching procedures occurs through the establishment of a relation between the initial teeth color and after the execution of the technique. This color quantification is performed by visual analysis (subjective methods) through the compa - rison of the teeth color with a commercial color pallet or through digital analysis (objective methods) using colorimeters, spectrophotometers and digital image (Dozić et al., 2007).

Visual analysis is the most frequently used method in the daily clinical routine (O´Brien et al., 1990; Papathanasiou et al., 2002; Van der Burgt et al., 1990), but this method is greatly influenced by factors as metamerism, aging, fatigue and color-blindness. The visual comparison demands the realization of larger number of assessments, criterious calibration of the examiners, as well as a rigid control of the environment light condition in order to increase this method confiability. In addition, commercial color pallets are not systematically organized (O´Brien et al., 1990) and do not include the total color variability observed in the population (Schumb et al., 1955), also the for the same color pallet brand there are significant variations as described by Portero et al. (2007).

The color assessment using digital methods as colorimeters and spectrophotometers, despite the good color reproducibility among measurements both for in vivo and in vitro studies, those systems show some disadvantages described in the literature (Segui et al., 2007; Berns et al., 1988). First, those systems are designed to assess solid colors. Second, it should take into to consideration, the low level of reproducibility between measurements of different devices (O´Brien et al., 1990) and the inconsistency of the analyzed color by those devices, third the great sensibility inherent of each system available that

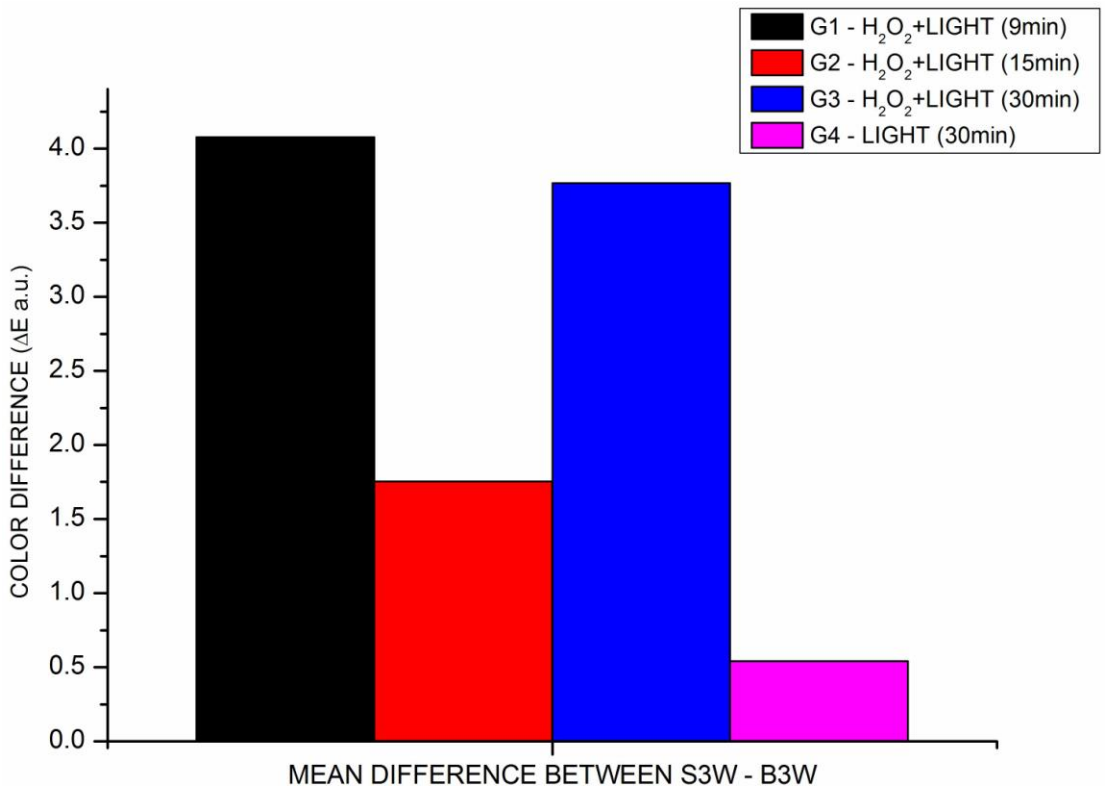

Figure 2. Mean differences between the phase (S3W) and the phase (B3W). Higher differences observed in the Delta E scale (Y axis) mean better bleaching levels for each studied Group

difficult the data acquisition and comparison between studies (Clarke et al., 1999).

Taking into consideration the limitations of the objective systems available for color assessment in dentistry, the method proposed in this studied, evaluated the progression of color changes during the experimental phases with a handheld digital colorimetric spectrophotometer by reflectance (Pocket Spec - PocketSpec Technologies Inc Denver, CO – USA). This system had to be calibrated previously in each experimental phase by the acquisition of the reflectance pattern (color coordinate) of a zirconia plate provided by the manufacturer. This pattern presents color chromaticity coordinates of 255,255,255 in the RGB (RED, GREEN, BLUE) color space, it is the baseline for all performed color analysis and, in that way turned possible the long term comparisons performed in this study.

The staining process proposed in this study is new, and by the graphic comparison intra-Groups shown in the Figure 1, it is possible to observe that this method was able to promote significant color changes for all studied Groups. It is also observable in the Figure 1, for the Groups one to three (G1-G3), that the proposed bleaching protocols, using a transparent 35% hydrogen peroxide bleaching gel (Farmacia Botica – São Carlos, SP – Brazil) and the Bright Maxx (MMO, São Carlos, Brazil) irradiation system, were efficient and promoted significant color reductions.

The bleaching protocol used in the Group four (G4), did not used the transparent 35% hydrogen peroxide bleaching gel, and the results clearly demonstrates that the use of visible light by itself, emitted from a LED based equipment, it is no capable to promote significant color changes, as it can be observed in the Figure 2.

Light is been used to improve dental bleaching procedures for long time, first was the use of the halogen lamps, then the use of curing units. Basically the mechanism involved in this process, is the temperature increase, in order to catalyze the speed of the chemical reaction, so the transformation of light into heat that, consequently, improves the bleaching outcome can be described as photolysis (Florez et al., 2006). So it is believed that increasing the irradiation time must result in better aesthetic outcome.

LEDs based equipment present several advantages and drawbacks when compared to Lasers and other halogen systems. Probably, the emission of cold light can be described as its most advantageous feature, but the professionals around the world and their patients are discontented with the obtained bleaching outcomes when those kinds of equipments are used. In that direction, some professionals and also a few manufacturers are recommending larger periods of consecutive irradiation to achieve satisfactory aesthetic results.

In the other hand, the analysis of the experimental data

of this work clearly suggests that the increase of the exposure time did not promoted significant color differences that justifies the use of protocols with long periods of light irradiation. The analysis of the experimental data of this work clearly suggest that the increase of the exposure time did not promoted a significant color difference among the experimental Groups that justify the use of protocols with long periods of light irradiation.

Also we believe that other factors directly associated with the technique can promote great influence on the results outcome, as for example, the intense degradation of hydrogen peroxide promoted by the higher irradiation periods and time of contact of the oxidant agent with the teeth. Other important factors are related with the hydrogen peroxide permeability in the crystalline structure, and the high surface tension of the gel.

Once that this study was performed in vitro and used bovine incisors, it is not possible to extrapolate our results to a real clinical situation which is a important limitation. The digital spectrophotometer is a good tool, it is reliable, and it must be used to aid the dentist in the registry and the diagnostic of the case, but this equip-ment also shows some limitations related with tooth anatomy, thickness, translucency, opalescence and rela-ted to its positioning during color measurements. Also it is of great importance the realizations of future studies to assess the temperature changes that such intense irra-diation protocols could promote in the pulpar chambers.

Conclusions

1. The increase of the exposure time of the samples to the visible light did not showed a significant increase in the obtainment of the better levels of shade reduction;

2. The visible light by itself it is not capable to promote the breakage of the organic pigments incorporated in crystalline structure of bovine teeth.

3. None of the protocols proposed in this study could give back the initial color to the teeth.

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