



Clinical analysis of color change and tooth sensitivity to violet LED during bleaching treatment: A case series with split-mouth design

Marjorie de Oliveira Gallinari, Luciano Tavares Angelo Cintra, Morganna Borges de Almeida Souza, Ana Carolina Souza Barboza, Lara Maria Bueno Esteves, Ticiane Cestari Fagundes, André Luiz Fraga Briso*

Department of Restorative Dentistry, Araçatuba Dental School, UNESP—Univ Estadual Paulista, Araçatuba, São Paulo, Brazil

ARTICLE INFO

Keywords:
Dentin sensitivity
Tooth bleaching
Irradiation

ABSTRACT

Background: The aim of this study was to analyze bleaching treatment performed with different products, with or without the use of Violet LED.

Methods: The color and dental sensitivity of six patients were evaluated as follows: (1) at-home bleaching with 10% Carbamide Peroxide (CP); (2) in-office bleaching with 17.5% Hydrogen Peroxide (HP), and (3) treatment with a placebo gel. All patients, including patients receiving at-home bleaching, received irradiation with violet LED in the office. The right hemiarch was protected with silicone. The color was evaluated using Vita Easyshade digital spectrophotometer and the Vita scale on teeth 13–23. Visual analog scale sensitivity analysis was performed per hemiarch, while the thermal sensation threshold was performed on teeth 11, 13, 21 and 23.

Results: Regarding the color change (ΔE) it can be observed that treatment 1, in which 10%CP was used, presented the highest values, followed by treatment 2, in which 17.5%HP was used. Regarding sensitivity, only patients who received 17.5%HP showed moderate sensitivity, and there was no difference between the arches. The analysis of dental thermal sensation threshold showed that there was more dental sensitization between 7 and 14 days and that the use of violet LED made the teeth more sensitive.

Conclusions: It was concluded that violet LED enhanced the bleaching effect when used with 10%CP gels, and a discreet effect was seen when used either in conjunction with 17.5%HP or alone. Violet LED had no effect on pain sensation, but increased the detection threshold of thermal changes in the teeth that were irradiated.

1. Introduction

Teeth whitening is one of the most sought-after treatments in dentistry and can yield favorable esthetic benefits at a relatively low cost using simple techniques. The speed of chromatic alteration is related to the dose of bleaching agent used in the different protocols adopted by dental professionals. It is, therefore, considered to be a dose-dependent treatment, although primarily in its initial phases [1].

Although low peroxide concentrations are extremely effective, it has been reported that in-office treatments, where highly concentrated peroxides are used, can result in more intense color changes in the initial phases of treatment, making it a more preferable technique among many dental professionals [1–3]. However, this treatment option is associated with a high occurrence of dental [4,5] and irreversible

damage to pulp in the lower incisors, when performed in vivo [6]. Animal studies have reported the increase in hydrogen peroxide (HP) concentration and the prolonged activation of CD5-positive cells [7] and a significant increase in the levels of pain-related neuropeptides (e.g. substance P and calcitonin gene-related peptide) [8] which has raised questions in the scientific community about its biological effects on pulp tissue, as well as its potential to negatively impact patient satisfaction at the end of treatment.

For this reason, the possibility of bleaching teeth using reduced peroxide concentrations, or even without them, would obviate the above-mentioned side effects, thus resulting in a revolutionary paradigm shift in esthetic dentistry.

In this context, some researchers have proposed the use of violet light-emitting diode (LED), either in isolation or in conjunction with

* Corresponding author at: Department of Restorative Dentistry, Araçatuba Dental School, UNESP—Univ Estadual Paulista, 1193 José Bonifácio St, Araçatuba, SP, 16015-050, Brazil.

E-mail addresses: marjo_oliveira@hotmail.com (M.d.O. Gallinari), lucianocintra@hotmail.com (L.T.A. Cintra), morh_borges@hotmail.com (M.B.d.A. Souza), anacarolina_souzabarboza@hotmail.com (A.C.S. Barboza), lm-esteves@hotmail.com (L.M.B. Esteves), ticiane.fagundes@unesp.br (T.C. Fagundes), andre.briso@unesp.br (A.L.F. Briso).

<https://doi.org/10.1016/j.pdpdt.2019.05.016>

Received 14 December 2018; Received in revised form 13 May 2019; Accepted 17 May 2019

Available online 20 May 2019

1572-1000/© 2019 Elsevier B.V. All rights reserved.

bleaching gels. This portable light source is similar to equipment usually used in dental offices and emits light at a wavelength of 405–410 nm, coinciding with the absorption peak of chromophore molecules. This leads to instability and breakdown of these molecules, resulting in whitening by means of a physical process [9,10]. However, due to the novelty of the technique, studies are still required to ascertain the impact of violet LED in bleaching treatments, especially considering that the equipment has already been commercialized [11].

In 2018, Gallinari et al [12] conducted an *in vitro* analysis of chromatic alteration imparted by violet LED used in isolation or in conjunction with bleaching gels of different concentrations. The results obtained practically rejects the possibility of substituting traditional peroxide-based treatment with the isolated use of violet LED. However, under specific experimental conditions, it was found that the use of violet LED could be advantageous, especially when used in conjunction with peroxides at concentrations < 17.5%. Although it is yet to be confirmed, this could be the beginning of an evolution in bleaching therapy, if significant esthetic results can be achieved with a lower oxidative stress.

To our knowledge, there is only a single clinical report in the literature addressing this topic [13]. We hypothesized that a case series, performed in each hemiarch and using different concentrations of peroxides, could fill the current knowledge gap and significantly contribute to further advances in this novel chromatic alteration technology and mitigate postoperative sensitivity.

2. Case Series

Six volunteers of both genders, between 20 and 28 years of age, were recruited. These patients all desired to whiten their teeth and had healthy, vital, upper anterior teeth, with no evidence of spontaneous sensitivity, no history of bleaching treatment, no carious or non-carious lesions, no systemic conditions, no history of continuous anti-inflammatory or analgesic medications, and had healthy oral soft tissues. The volunteers were informed about the intent to create a photographic registry of cases and to publish the results in scientific journals. All patients underwent dental prophylaxis, followed by clinical and radiographic evaluation using periapical radiography and visual inspection.

2.1. Clinical procedures

After the patients recruitment, an impression of the upper arch was taken using alginate (Jeltrate-Dentsply, Konstanz, Germany), and stone gypsum models were cast. Following this, whitening trays were fabricated, using acetate plates (1 mm thick), cut 1 mm short of the gingival margin. The trays used to standardize the location of color reading and tooth sensitivity were fabricated made in a similar manner, however, the trays were extended beyond the gingival margin to provide stability to the equipment.

In all treatments exposure to violet LED light, (wavelength 405–410 nm) was performed three times per week with a 48 h interval between sessions, for 3 weeks, thus totaling 9 irradiation sessions. To perform the irradiation, cotton rollers were placed in the fornix fundus of the maxillary and mandibular vestibules and the photoactivated gingival barrier was applied to any gingival tissue that would be exposed to violet light irradiation. In each session, the light was irradiated for 20 min without interruption, at a distance of 8 mm from the dental structure. It is important to note that in all cases, only the left hemiarch received such irradiation. To prevent the right hemiarch from being exposed to this irradiation, a silicone matrix (Express XT Pasta Densa Soft, 3 M ESPE, Sumaré, SP, Brazil), which blocked the passage of light, was also fabricated (Fig. 1).

The patients were divided into 3 groups (n = 2 per group), according to the whitening gel used:

Treatment 1: Two patients whose incisors and canines were



Fig. 1. Protection of the soft tissues and the protection of the right hemi-arch to not receive the irradiation with the violet LED.



Fig. 2. Treatment with 10% CP and violet light (a) Initial clinical appearance, showing the coloration of the upper incisors and canines. (b) Final clinical appearance (14 days after completion of bleaching), showing significant chromatic alteration, with teeth 13, 12 and 11 presenting shade OM3 and teeth 21, 22 and 23 showing shade B1.

initially of A2 shade received home bleaching in the upper arch with 10% carbamide peroxide gel (Whiteness Perfect, FGM Produtos Odontológicos, Joinville, SC, Brazil) 4 h daily, for 21 days (Fig. 2). During this period (21 days), the patients returned to the clinic 3 times per week, to have their left hemiarch irradiated with violet LED for 20 min, without the application of the whitening gel at the same time.

Treatment 2: Two patients with a similar shade of teeth described above received bleaching treatment of the entire upper arch with 17.5% HP gel obtained by dilution of the Whiteness HP product (FGM Produtos Odontológicos, Joinville, SC, Brazil) and placed in contact with the dental structure for 45 min. This dilution consisted of 3 drops of HP, 3 drops of water and 2 drops of thickener [12]. In this case, the bleaching treatment was performed separately in each hemiarch. The irradiation with violet light in the left hemiarch and application of the bleaching gel were performed simultaneously while protecting the right

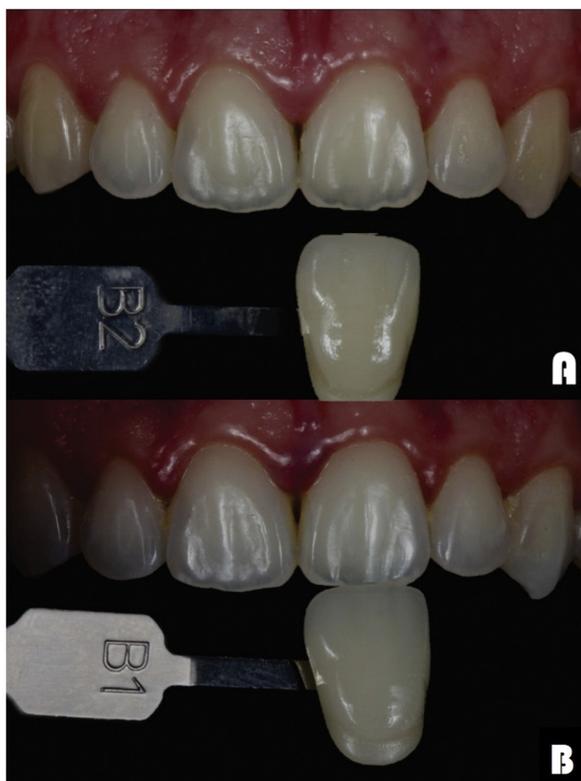


Fig. 3. In-office treatment with 17.5% HP (a) Initial clinical appearance in which the incisors showed shade B2 and the canines showed shade A2 as determined by the Vita scale. (b) Final clinical appearance (14 days after the end of bleaching), showing a considerable chromatic alteration, with the incisors showing shade B1 and the canines showing shade A1 as determined by the Vita scale.

hemiarch with the silicon matrix. After completion, the procedure was repeated in the right hemiarch, with the exception of violet light exposure (Fig. 3). The irradiation protocol was the same as previously mentioned, however in this case the gel was applied simultaneously to light exposure. The patients received 9 sessions of irradiation with the violet LED, as previously described, and the LED exposure and gel application were done simultaneously.

Treatment 3: The shades of the upper incisors and canines of these patients were similar to those of the other groups. However, in this case, the left hemiarches of these patients were irradiated with violet light, they also received 9 irradiation sessions according to protocol described above, while the right hemiarch received treatment with placebo gel (Fig. 4).

3. Methods of analysis of bleaching efficacy and dental sensitivity

3.1. Bleaching efficacy

All trays and guides were evaluated and adjusted for soft tissue adaptation, extension and compression. The color change and sensitivity analyses were performed according to time point, as shown in Chart 1.

The analysis of bleaching efficacy was performed using 2 methods:

3.1.1. Analysis in portable spectrophotometer

Color analysis was performed using a digital spectrophotometer (Easyshade Advance 4.0, Vident, Brea, CA, USA). This device uses the CIE L* a * b * color space model, established by the International Commission of l'Eclairage - CIE (International Commission on Lighting). The readings were performed on the vestibular surfaces of the upper

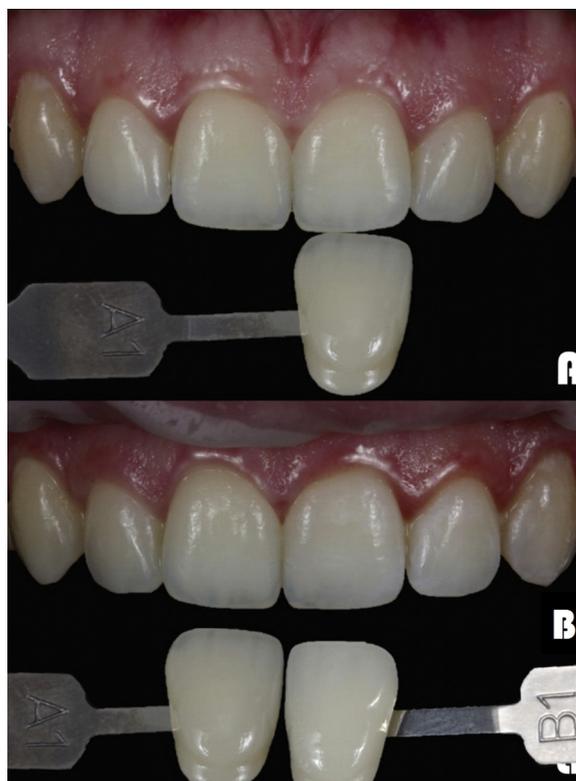


Fig. 4. Treatment with violet light only (a) Initial clinical appearance in which the incisors had shade A1 and the canines had shade A3 determined using the Vita scale. (b) Final clinical appearance (14 days after completion of bleaching) showing B1 shade for tooth 21 and maintenance of initial color on teeth 11 and 13.

Times	
T0	Baseline (before bleaching)
T1	7 days after starting treatment
T2	14 days after starting treatment
T3	21 days after starting treatment
T4	7 days after completion of bleaching treatment
T5	14 days after completion of bleaching treatment

Chart 1. Analysis times.

Table 1
Mean values of ΔE obtained in each hemi-arc in the periods analyzed.

		T1	T2	T3	T4	T5
PC 10% (at home)	No Light	7.17	7.83	11.41	14.45	11.36
	Violet	11.98	14.05	18.23	17.52	16.79
PH 175%	No Light	3.94	6.34	7.54	8.59	8.60
	Violet	5.51	8.03	8.99	10.92	10.95
Gel Placebo	No Light	1.67	1.66	0.68	0.75	0.86
	Violet	2.74	3.34	5.37	4.41	2.88

central and lateral incisors, and upper canines at pre-established times (Table 1) and compared with the initial reading by calculating ΔE using the following equation:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

For this purpose, acetate guides with 8 mm-wide perforations were placed in the central region of the buccal surface of the teeth, aiming to standardize the point of measurement of the color of each tooth being

Bleaching scale					Vita scale														
Scale	OM1	OM2	OM3	B1	A1	B2	D2	A2	C1	C2	D4	A3	D3	B3	A3,5	B4	C3	A4	C4
Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

Chart 2. Scores assigned to the color scale (Vita Zahnfabrik, Bad Säckingen, Germany), ordered by luminosity.

studied [14].

3.1.2. Visual analysis of color change

For this analysis, the upper and canine central incisors were used, and the corresponding tooth color on a Vita scale was chosen at each point of the analysis. Color selection was performed by a research member who was unaware of the treatment administered to each hemiarch. Chart 2 illustrates the data and scores obtained after the various treatments (modified from Machado et al.) [14]. Chromatic variation was calculated at each time of analysis, with the initial color of the tooth the comparator. The final score assigned was an average of the individual scores of the incisors and canines.

3.2. Dental sensitivity

Dental sensitivity was also examined using 2 methods

3.2.1. Spontaneous report analyzed by visual analog scale (VAS)

The visual analog scale (VAS) method of analysis involves of the patient's self-report of sensitivity. Accordingly, a questionnaire was administered to the patients in which they reported the occurrence of sensitivity, along with a visual scale on which they indicated how sensitive they felt after the bleaching session (Fig. 5). This scale ranges from 0 to 10 according to intensity, with 0 corresponding to no sensitivity and 10 corresponding to the greatest discomfort the patient could experience. In addition, the patient was asked where the peak of sensitivity occurred [15,16].

3.2.2. Neuro-sensory analysis of the thermal sensation threshold

Quantification of sensitivity was performed using a thermal sensation device (TSA II NeurosensoryAnalyzer, Medoc, Israel) [15,17], to measure the thermal sensation threshold [18–20]. The intra-oral thermometer of this device was positioned in the flattest region of the labial surface of the central incisors and canines (13, 11, 21 and 23), and activated in the "limits" function [15,17,21]. In this configuration, the central unit of the device generates and transmits decreasing thermal signals, starting at 36 °C and gradually reduces the temperature at a rate of 1 °C/s. The patient is asked to stop the stimulus by triggering a handheld device immediately once they sense a change in temperature. The test was performed 3 times in each tooth, at each point of analysis, and an average of the readings was obtained and recorded. The teeth were greased with a thermo-conductive paste made from silver oxide (Implastec Thermal Paste, Implastec Eletroquímica Ltda., Votorantim,

São Paulo, Brazil) before the tests were conducted to optimize thermal conduction. To standardize the sites of analysis, acetate guides with perforations of 8 mm were also used in the region of the central incisors and canines [15].

4. Results of analysis of bleaching efficacy and dental sensitivity

4.1. Bleaching efficacy

4.1.1. Analysis in portable spectrophotometer

The data reported in Table 1 demonstrate that the most pronounced color change (ΔE) occurred in peroxide-based treatments, while the isolated use of violet LED demonstrated highly discreet action, especially in the 14-day control. Nevertheless, that the use of light potentiated chromatic alteration in all treatments, emphasizing its association with carbamide peroxide.

When the other axes of the CIE L* a* b* system were analyzed in detail, it was observed that the use of the violet LED positively influenced higher L* values mainly in the 14- and 21-day periods, reducing its effect on the control performed 14 days after the end of treatment (Table 2). The coordinate a* remained unchanged during and after treatment, demonstrating that both the use of the gels and the violet LED had no influence (Table 2). In the analysis of the b* coordinate, it was noted that the effects of dosages tested were enhanced by the use of violet LED. In other words, the teeth tended to be bluer at the end of the treatment (Table 2).

4.1.2. Visual analysis of color change

The data reported in Table 3 reveals that all peroxide treatments resulted in a more pronounced change on the Vita scale compared with violet LED alone, which had a very little action after the 21 st day of bleaching treatment, remaining in the controls at 7 and 14 days. It was also observed that the use of light potentiated the chromatic alteration in all treatments, emphasizing its association with 10% carbamide peroxide.

4.2. Dental sensitivity

4.2.1. Spontaneous report analyzed by visual analogue scale (VAS)

In the spontaneous report of the sensitivity, it was possible to verify that the 2 patients who received 17.5% HP presented moderate sensitivity in the analyses performed at 14 and 21 days after the initiation of

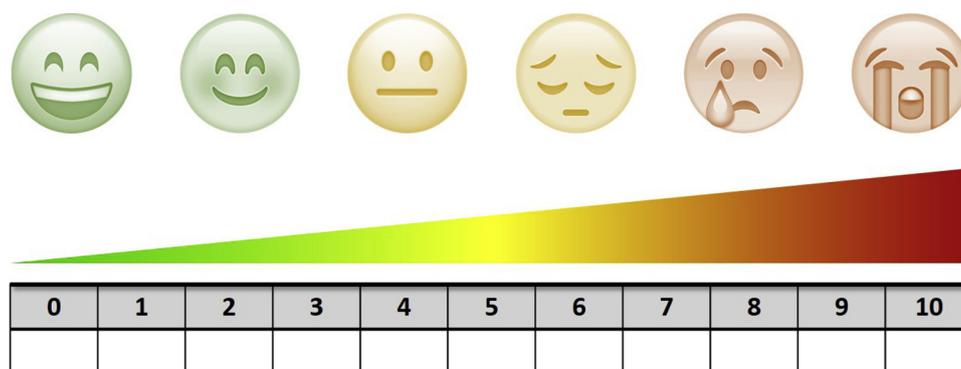


Fig. 5. Average temperatures (°C) of cold detection obtained in the canine teeth in each hemiarch (without light and violet light).

Table 2
Mean values of ΔE obtained in each hemi-arc in the periods analyzed.

			ΔT1	ΔT2	ΔT3	ΔT4	ΔT5
ΔL	CP 10% at-home	No Light	1.27	2.97	4.53	2.21	2.46
		Violet light	1.77	2.23	3.77	2.34	2.53
	HP 175%	No Light	0.87	1.37	-0.50	2.13	1.90
		Violet light	2.97	2.50	1.57	2.60	3.83
	Placebo	No Light	1.4	0.70	0.10	-0.40	-0.50
		Violet light	0.7	1.30	4.20	3.70	1.00
Δa	CP 10% at-home	No Light	-0.87	-0.57	-0.30	-0.34	-0.51
		Violet light	-0.30	0.03	0.07	-0.4	-0.42
	ph 175%	No Light	-0.70	-0.93	-0.77	-0.97	-0.70
		Violet light	-0.70	-0.90	-0.77	-0.73	-0.73
	violet light	No Light	0.10	0.10	0.60	0.40	0.00
		Violet light	0.50	0.70	1.00	0.70	0.10
Δb	CP 10% at-home	No Light	-2.47	-1.13	1.40	-0.50	-0.59
		Violet light	-4.70	-4.23	-3.77	-7.40	-7.61
	HP 175%	No Light	-3.67	-6.10	-7.43	-8.20	-8.10
		Violet light	-4.47	-7.57	-8.80	-10.47	-10.13
	Placebo	No Light	0.90	1.50	0.30	0.50	0.50
		Violet light	2.60	3.00	-3.20	-2.30	-2.30

Table 3
Mean of the differences of the scores of the Vita scale of the central and canine.

		T1	T2	T3	T4	T5
PC 10%	No light	0	2	4	4	4
	Violet light	0	4	5.5	5.5	5.5
PH 175%	No light	0	4	4	4.5	5
	Violet	0	4	6	6	6
Gel Placebo	No light	0	0	0	0	0
	Violet	0	0	1	1	1

Table 4
Analysis of the intensity of spontaneous dental sensitivity obtained using Visual Analog Scale (VAS) in the different study periods.

		Occurrence	Intensity				
			T1	T2	T3	T4	T5
PC 10%	No light	No	0	0	0	0	0
	Violet light	No	0	0	0	0	0
PH 175%	No light	Yes	0	4	8	0	0
	Violet	Yes	0	4	8	0	0
Placebo	No light	No	0	0	0	0	0
	Violet	No	0	0	0	0	0

bleaching treatment. The report was generalized, with no influence of light (Table 4).

4.2.2. Neuro-sensory analysis of the thermal sensation threshold

To analyze the effect of light on sensitivity, data from the central incisor and canine of each hemiarch were grouped and averaged at each time of analysis. Thus, in general, it was possible to observe that the bleaching treatment using traditional techniques altered the threshold of dental thermal sensation from 10 °C to 15 °C (in T2), while the association of violet LED altered the threshold of dental thermal sensation of teeth of the left hemiarches from 12 °C to 17 °C. This suggests that during the treatment, the right and left hemiarches may present similar tendencies in the bleaching effect, which may be confirmed by future clinical work.

The control analyses (T4 and T5) showed that the thermal sensation of teeth that received only the bleaching gels were restored, while those that received violet light remained altered with a tendency toward decrease in sensation (Fig. 6).

5. Discussion

In most patients, traditional bleaching treatments provide significant esthetic improvements; however, they may also generate undesirable side effects, especially when using highly concentrated products are used [5,16,22–25].

In this sense, the possibility of altering the color of the teeth without subjecting patients to the typical side effects of therapies based on topical applications would represent an indisputable advance in esthetic dentistry, opening the possibility for safer treatments compared with those currently used [9,10]. The use of violet LED, with or without bleaching gel, has attracted the attention of dental professionals, although there is little evidence supporting its efficacy [10,13,26].

In the present report, 6 clinical cases were presented, in which the effects of violet LED with 3 different concentrations of bleaching gels were analyzed. The protocol consisted of the use of violet LED light as the sole bleaching agent, used in combination with in-office treatment, and in association with at-home treatment, all with violet LED irradiation for 20 min three times per week for 3 weeks. None of the cases, however, provided sufficient supportive evidence enabling definitive conclusions regarding the success of the treatment. Nevertheless, a positive effect was noticed when light was used in conjunction with peroxides. The most pronounced chromatic changes during the bleaching process were mainly due to variations in the b* and L* coordinates, which were potentiated as violet light [27].

The mechanism of action of this new technology is based on the emission of light at a wavelength of 405–410 nm, which coincides with the absorption peak of chromophore molecules, in which instability and breakdown could occur, thus resulting in a photolytic effect [9]. In this context, the molecules would be more receptive to reactions with peroxides from the bleaching gels and would be diffused by the dental tissues [10,12]. Klaric et al. [10] observed the same effect, in which the association of light positively influenced the bleaching effect achieved with different concentrations of gels.

The isolated use of violet LED was previously reported by Lago et al. who indicated, from a single case study in which the shade was altered from A3 to A1 after 3 irradiation sessions without the use of peroxide, that treatment using this type of light can be promising. These data somewhat conflict with those obtained using treatment 3 in the present study, which adopted a significantly more intense protocol with 9 radiation sessions, and achieved slight alteration by changing the shade of tooth 21 from A1 to B1. A visual analysis performed using the Vita scale was confirmed by spectrophotometric analysis, which recorded differences of 4.69 for ΔE between the hemiarches. These data were slightly higher than the value of 3.3, which is considered to be the minimum

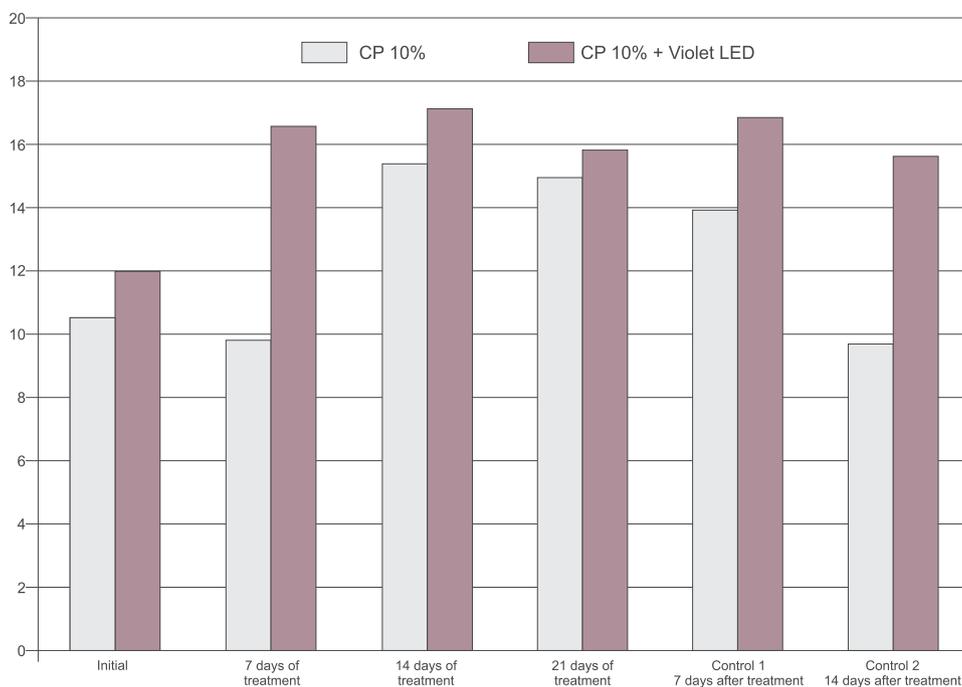


Fig. 6. Visual Analogue Scale used to assess the patient's dental sensitivity.

value to detect visible difference [27], confirming that the slight difference found in these clinical cases was, in fact, clear. The difference between the results reported by Lago and those obtained in this study is possibly due to the different lighting conditions, the times of analyses and the initial shade of the teeth.

Regarding chromatic alteration, the difference in the values of b^* obtained after the whitening therapies should be addressed. It was observed that when the violet LED was used, the values of b^* tended to decrease (reduction in yellow and increase in blue) when compared with the side that did not receive light irradiation. It is believed that the light source acts directly on the yellowish enamel and dentin pigments, promoting the destabilization and breakage of some of the carbon double bonds present in the chromophores, [9] making the molecules smaller and lighter and / or more reactive when in contact with the peroxide. These data, corroborated with the data obtained in the study by Gallinari et al. [12] which analyzed in vitro the chromatic alteration imparted by the isolated use of the violet LED, as well as when associated with the 17.5% HP gel. In the experimental conditions it was verified that the use of violet LED could be advantageous, especially when associated with the use of peroxides at concentrations < 17.5%.

Regarding sensitivity, it is known that the higher the concentrations of bleaching gel, the greater and more frequent the painful sensations. [15,28] In this context, the spontaneous report of sensitivity showed that the reported discomfort was related to the concentration of peroxides used in the different dosages. Thus, only the in-office treatment using 17.5% HP resulted in spontaneous and generalized reports of discomfort, regardless of the use of light. This response was probably related to reversible pulp changes [25,29]. The products from the redox reaction of these bleaching gels result in reactive oxygen species (ROS) [2,30,31], which come in contact with the pulp tissue, causing oxidative stress which in turn trigger an inflammatory process. The painful process occurs by sensitization to nerve fibers, which may be mediated by the action of inflammation mediators (among others), or by increased intrapulpal pressure due to the inflammatory process [32,33].

As a complementary analysis of dental sensitivity, a Quantitative Sensory Test was also performed. Similar to the report by Rahal et al. it was verified that bleaching treatment with peroxides altered the threshold of dental thermal sensation, with the major changes occurring in the second and third weeks of treatment (T2 and T3). However, in

the controls performed at 7 and 14 days post-treatment, the irradiated hemiarcs remained sensitized, and a slight tendency to decrease dental sensitivity was observed on day 14 in the controls. However, the teeth of patients who underwent conventional treatment, were gradually restored to their normal state. Although Klaric et al. [26] did not observe a significant alteration in the intrapulpal temperature of teeth exposed to this light in their in vitro study, there remains a lack of literature data regarding the effects of this irradiation on dental tissues, which may explain the alterations in dental sensitization, because in general, in light activated tooth bleaching procedures, there is a significant concern regarding the heat generated by the light source, which may cause pulp irritation or severe damage. For acceleration or more effective tooth whitening, different light sources may be used, including violet LED light.

The results of tooth sensitivity obtained on the VAS scale, were different from those observed in the clinical studies of Mondelli et al. (2018a, 2018b) [34,35], who observed that the use of light reduced sensitivity, while in the present analysis the use of LED did not influence spontaneous reports of pain. Moreover, the analysis of the thermal sensation threshold showed that the teeth were sensitive even after 14 days after the end of the bleaching treatment. However, in both studies (Mondelli et al. 2018a, 2018b) [34,35], a hybrid light source was used only during the bleaching procedure, which was once a week, while in the present clinical cases, the maximum protocol recommended by the manufacturer was followed, that is the teeth were irradiated for 3 sessions.

Regarding the efficacy of bleaching, during T2 the results for HP exhibited their greatest variation, especially when violet LED was used. This data can be partially corroborated with that of clinical studies by Mondelli et al. (2018a, 2018b). [34,35] Mondelli et al. observed that the light source provided a more effective bleaching treatment in a shorter time. However, they performed bleaching using highly concentrated gels, which differed from this study that used gels with 17.5% hydrogen peroxide or with 10% carbamide peroxide. Even though different concentrations of gels were used, we agree with Mondelli et al. [34,35] in reducing the number of clinical sessions, since there was chromatic stabilization at the 14th day of bleaching treatment. Thus, reducing the number of clinical sessions during the treatment will enhance the bleaching effect with fewer repercussions on pulpal health.

Finally, notwithstanding the strict criteria for patient selection and the several comparisons made of the hemiarcs, it is known that case-series have inherent limitations related to the individual characteristics of the subjects. Additionally, a small sample size with varying characteristics can generate significant biases in the interpretation of results. Sample standardization was performed in relation to the health condition, age and sex of the patient, because these factors may influence the results of self-reported sensitivity. Previous studies that assessed dental sensitivity through self-reports and questionnaires using the VAS are in agreement with these results [17].

Although case series can be valuable, caution should be exercised when interpreting the results of individual. Randomized clinical trials, therefore, are essential to arrive the conclusive results. Moreover, laboratory and animal studies are fundamentally important in validating methods and verifying possible side effects. In addition, regarding the reduced time of follow-up, it is believed that this time is sufficient for rehydration of the teeth, and to monitor the actual effectiveness of the violet LED [36]. Nevertheless, considering that this new technology has been commercialized, even with very little information about its efficacy and safety, we believe that our results can contribute to the knowledge of the potential of this modality in bleaching procedures and to establish new protocols and levels of safe irradiation to perform bleaching treatment.

7. Conclusion

Based on data obtained from these clinical cases, there is insufficient evidence to draw a definitive conclusion regarding the success of treatment. However, a positive effect was noted when violet LED light was used in conjunction with peroxides. Furthermore, violet LED light had no influence on self-reported pain sensation; however, its use sensitized the front teeth in low temperature situations.

Conflicts of interest

The authors state no conflicts of interest

References

- A.L.F. Briso, M.S.M. Fonseca, L.C.A.G. de Almeida, S.J. Mauro, P.H. dos Santos, Color alteration in teeth subjected to different bleaching techniques, *Laser Phys.* 20 (11) (2010) 1–4.
- R.S. Gonçalves, C.A. Costa, D.G. Soares, P.H. dos Santos, L.T. Cintra, A.L. Briso, Effect of different light sources and enamel preconditioning on color change, H₂O₂ penetration, and cytotoxicity in bleached teeth, *Oper. Dent.* 41 (1) (2016) 83–92.
- Y.H. Kwon, M.S. Huo, K.H. Kim, S.K. Kim, Y.J. Kim, Effects of hydrogen peroxide on the light reflectance and morphology of bovine enamel, *J. Oral Rehabil.* 29 (5) (2002) 473–477.
- L.C. de Almeida, C.A. Costa, H. Riehl, P.H. dos Santos, R.H. Sundfeld, A.L. Briso, Occurrence of sensitivity during at-home and in-office tooth bleaching therapies with or without use of light sources, *Acta Odontol. Latinoam.* 25 (1) (2012) 3–8.
- Pd.C. Cardoso, A. Reis, A.D. Loguercio, L.C.C. Vieira, L.N. Baratieri, Clinical effectiveness and tooth sensitivity associated with different bleaching times for a 10 percent carbamide peroxide gel, *J. Am. Dent. Assoc.* 141 (10) (2010) 1213–1220.
- C.A. Costa, H. Riehl, J.F. Kina, N.T. Sacono, J. Hebling, Human pulp responses to in-office tooth bleaching, *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.* 109 (4) (2010) e59–64.
- F. Benetti, J.E. Gomes-Filho, L.L. Ferreira, G. Sivieri-Araujo, E. Ervolino, A.L.F. Briso, L.T.A. Cintra, Concentration-dependent effect of bleaching agents on the immunolabelling of interleukin-6, interleukin-17 and CD5-positive cells in the dental pulp, *Int. Endod. J.* 51 (7) (2018) 789–799.
- M.O. Gallinari, L.T.A. Cintra, F. Benetti, V. Rahal, E. Ervolino, A.L.F. Briso, Pulp response of rats submitted to e0210338 and the use of different anti-inflammatory drugs, *PLoS One* 14 (1) (2019) e0210338.
- F. Zanin, Recent advances in dental bleaching with laser and LEDs, *Photomed. Laser Surg.* 34 (4) (2016) 135–136.
- E. Klaric, M. Rakic, M. Marcius, M. Ristic, I. Sever, Z. Tarle, Optical effects of experimental light-activated bleaching procedures, *Photomed. Laser Surg.* 32 (3) (2014) 160–167.
- F. Benetti, C.A.A. Lemos, M. de Oliveira Gallinari, A.M. Terayama, A.L.F. Briso, R. de Castilho Jacinto, G. Sivieri-Araujo, L.T.A. Cintra, Influence of different types of light on the response of the pulp tissue in dental bleaching: a systematic review, *Clin. Oral Investig.* 22 (4) (2018) 1825–1837.
- M.O. Gallinari, T.C. Fagundes, L.M.A.V. da Silva, M.B.A. Souza, A.C.S. Barboza, A.L.F.B. Briso, A New Approach Dental Bleaching Using Violet Light With or Without the Use of Whitening Gel: Study of Bleaching Effectiveness Operative Dentistry, (2018).
- A.D.N. Lago, W.D.R. Ferreira, G.S. Furtado, Dental bleaching with the use of violet light only: Reality or Future? *Photodiagnosis Photodyn. Ther.* 17 (2017) 124–126.
- L.S. Machado, R.B. Anchieta, P.H. dos Santos, A.L. Briso, N. Tovar, M.N. Janal, P.G. Coelho, R.H. Sundfeld, Clinical comparison of At-Home and in-office dental bleaching procedures: a randomized trial of a split-mouth design, *Int. J. Periodontics Restorative Dent.* 36 (2) (2016) 251–260.
- V. Rahal, M.O. Gallinari, J. Perdigo, L.T. Cintra, P.H. Santos, A.L.F. Briso, Quantitative sensory testing of the effect of desensitizing treatment after dental bleaching, *Acta Odontol. Latinoam.* 28 (3) (2015) 263–270.
- L.C. Almeida, H. Riehl, P.H. Santos, M.L. Sundfeld, A.L. Briso, Clinical evaluation of the effectiveness of different bleaching therapies in vital teeth, *Int. J. Periodontics Restorative Dent.* 32 (3) (2012) 303–309.
- V. Rahal, M.O. Gallinari, J.S. Barboza, L.T. Martins-Junior, P.H. Santos, L.T.A. Cintra, A.L.F.B. Briso, Influence of skin cold sensation threshold in the occurrence of dental sensitivity during dental bleaching: a placebo controlled clinical trial, *J. Appl. Oral Sci.* 26 (0) (2018) 1–11.
- A. Kalantzis, P.P. Robinson, A.R. Loescher, Effects of capsaicin and menthol on oral thermal sensory thresholds, *Arch. Oral Biol.* 52 (2) (2007) 149–153.
- L. Baad-Hansen, T. Arima, L. Arendt-Nielsen, B. Neumann-Jensen, P. Svensson, Quantitative sensory tests before and 1(1/2) years after orthognathic surgery: a cross-sectional study, *J. Oral Rehabil.* 37 (5) (2010) 313–321.
- G.I. Juhl, P. Svensson, S.E. Norholt, T.S. Jensen, Long-lasting mechanical sensitization following third molar surgery, *J. Orofac. Pain* 20 (1) (2006) 59–73.
- A.L.F. Briso, V. Rahal, F.A. Azevedo, M.O. Gallinari, R.S. Gonçalves, S.M.B. Frascino, P.H.D. Santos, L.T.A. Cintra, Neurosensory analysis of tooth sensitivity during at-home dental bleaching: a randomized clinical trial, *J. Appl. Oral Sci.* 26 (2018) e20170284.
- A.L.F. Briso, V. Rahal, R.H. Sundfeld, P.H. Santos, R.S. Alexandre, Effect of sodium ascorbate on dentin bonding after two bleaching techniques, *Oper. Dent.* 39 (2) (2014) 195–203.
- A.L.F. Briso, R.S. Gonçalves, F.A. de Azevedo, M.O. Gallinari, P.H. dos Santos, T.C. Fagundes, Transenamel and transdental penetration of H₂O₂ in restored bovine teeth, *J. Adhes. Dent.* 17 (6) (2015) 529–534.
- A.F. Cartagena, S.O. Parreiras, A.D. Loguercio, A. Reis, N.H. Campanha, In-office bleaching effects on the pulp flow and tooth sensitivity - case series, *Braz. Oral Res.* 29 (2015).
- D.G. Soares, F.G. Basso, D.S. Scheffel, J. Hebling, C.A. de Souza Costa, Responses of human dental pulp cells after application of a low-concentration bleaching gel to enamel, *Arch. Oral Biol.* 60 (9) (2015) 1428–1436.
- E. Klaric, M. Rakic, I. Sever, Z. Tarle, Temperature rise during experimental light-activated bleaching, *Lasers Med. Sci.* 30 (2) (2015) 567–576.
- D. Dietschi, S. Rossier, I. Krejci, In vitro colorimetric evaluation of the efficacy of various bleaching methods and products, *Quintessence international* (Berlin, Germany:1985) 37 (7) (2006) 515–526.
- M. Kashima-Tanaka, Y. Tsujimoto, K. Kawamoto, N. Senda, K. Ito, M. Yamazaki, Generation of free radicals and/or active oxygen by light or laser irradiation of hydrogen peroxide or sodium hypochlorite, *J. Endod.* 29 (2) (2003) 141–143.
- T.T. Wu, L.F. Li, R. Du, L. Jiang, Y.Q. Zhu, Hydrogen peroxide induces apoptosis in human dental pulp cells via caspase-9 dependent pathway, *J. Endod.* 39 (9) (2013) 1151–1155.
- L.C. de Almeida, D.G. Soares, M.O. Gallinari, C.A. de Souza Costa, P.H. Dos Santos, A.L. Briso, Color alteration, Hydrogen peroxide diffusion, and cytotoxicity caused by in-office bleaching protocols, *Clin. Oral Investig.* 19 (3) (2015) 673–680.
- F. Benetti, J.E. Gomes-Filho, L.L. Ferreira, E. Ervolino, A.L.F. Briso, G. Sivieri-Araujo, E. Dezan-Junior, L.T.A. Cintra, Hydrogen peroxide induces cell proliferation and apoptosis in pulp of rats after dental bleaching in vivo: effects of the dental bleaching in pulp, *Arch. Oral Biol.* 81 (2017) 103–109.
- J. Caviedes-Bucheli, H.R. Munoz, M.M. Azuero-Holguin, E. Ulate, Neuropeptides in dental pulp: the silent protagonists, *J. Endod.* 34 (7) (2008) 773–788.
- J. Caviedes-Bucheli, N. Lombana, M.M. Azuero-Holguin, H.R. Munoz, Quantification of neuropeptides (calcitonin gene-related peptide, substance P, neurokinin A, neuropeptide Y and vasoactive intestinal polypeptide) expressed in healthy and inflamed human dental pulp, *Int. Endod. J.* 39 (5) (2006) 394–400.
- R. Mondelli, F. Rizzante, E.R. Rosa, A. Borges, A.Y. Furuse, J. Bombonatti, Effectiveness of LED/Laser irradiation on in-office dental bleaching after three years, *Oper. Dent.* 43 (1) (2018) 31–37.
- R.F.L. Mondelli, C.M. de Almeida, F.A.P. Rizzante, A.F. Sanches Borges, S.K. Ishikiriyama, J.F.S. Bombonatti, The effects of hybrid light activation and enamel acid etching on the effectiveness, stability and sensitivity after a single session in-office bleaching: a 12-month clinical trial, *Photodiagnosis Photodyn. Ther.* 24 (2018) 22–26.
- S. Deliperi, D.N. Bardwell, A. Papathanasiou, Clinical evaluation of a combined in-office and take-home bleaching system, *J. Am. Dent. Assoc.* 135 (5) (2004) 628–634.