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LETTER

Effects of LED–laser hybrid light on bleaching effectiveness and tooth sensitivity: a randomized clinical study

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Abstract

The study evaluated the effectiveness and the sensitivity of in-office tooth bleaching with the use of a hybrid photo-activation system composed by LEDs and lasers. 40 patients, both genders, aged 18 through 25 years, were randomly distributed into two treatment groups: group I, 35% hydrogen peroxide, with a total bleaching time of 135 min divided into three sessions, and group II, 35% hydrogen peroxide and photo-thermal catalysis by an LED–laser system (300 mW cm^{-2}), for a total bleaching time of 72 min divided into three sessions. The treatment efficiency was measured by reflectance spectroscopy and sensitivity by a visual analog scale (VAS). The final luminosity value (ΔL), color variation (ΔE) and sensitivity (S) resulting from the treatments were analyzed by the generalized estimating equations method (GEEs), and Bonferroni post hoc multiple comparisons at 5% significance. The two groups presented similar colors (ΔE) and luminosities (ΔL) after treatment. Group I presented a greater sensitivity index ($37.6 \pm 5.9\%$) compared to group II ($11.1 \pm 3.3\%$), statistically significant at $p < 0.05$. The use of LED–laser hybrid light, as a catalyst of the bleaching agents, showed a significant decrease of provoked tooth sensitivity and a treatment time reduced by 53%, with the same aesthetic results as without a light source.

(Some figures may appear in colour only in the online journal)

1. Introduction

The efficiency of a bleaching agent is directly proportional to the resultant chemical reaction rate. That is, its efficiency is limited by the bleaching agent concentration, time of contact, reactivity and penetration in the dental structure, associated with the number of complex molecules in the tooth [1, 2].

The use of methods increasing the chemical reaction rate can allow the development of faster, more efficient and clinically more comfortable techniques [3–6].

In recent years, many methods have been considered to speed up the chemical reaction of the dental bleaching process, such as chemical catalysis for Fenton reactions [7], thermo-catalysis with heat units [6, 8], high intensity light bulbs such as plasma arc type, xenon and halogen [9], and photo-thermal conversion using a light source of low intensity with a light emitting diode (LED) and light amplification by stimulated emission of radiation (laser) hybrid system [6, 8–10].

Table 1. Irradiation parameters and producer time.

Group	Bleaching agent	Light source (mW cm^{-2})	Time
I	H_2O_2 35% Lase Peroxide Sensy, DMC, São Carlos, Brazil	—	3 × 15 min Three sessions Total: 135 min
II	H_2O_2 35% Lase Peroxide Sensy, DMC, São Carlos, Brazil	Six LEDs (425–480 nm) 1.8 W Three lasers (810 nm) 0.6 W Spot size = 8 cm^2 Irradiance 300 mW cm^{-2} Whitening Lase II, DMC, São Carlos, Brazil	3 × 8 min[a] Three sessions Total: 72 min

[a] Light application intercalated 1 min superior arches, 1 min inferior arches until the total of 8 min.

The use of an LED–laser hybrid system is a technology based on the conversion of the luminous energy into thermal energy in the applied bleaching gel on the dental surface. This process increases the molecular vibrations, promoting a higher rate of reactive radical formation, speeding up the bleaching process without the risks of a temperature rise in the dental structure [8].

Notwithstanding the foregoing, the use of these methods remains controversial. Some authors claim that bleaching agents are more efficient when they are photo-catalyzed [6, 8], while other authors deny the effects of electromagnetic energy over bleaching effectiveness [6, 11] or insist that the use of light sources is inefficient, not essential and potentially harmful to the dental structure, even determining greater sensitivity and discomfort to the patients [12–15].

The action of low intensity laser–LED phototherapy on the biological tissue is related to the possibility of inhibiting the occurrence of chemotactic factors in the early stages of the inflammatory process, and also interfering with the effects of chemical mediators induced by the inflammation and inhibiting prostaglandin synthesis [16].

The objective of this study was to evaluate the effect of the LED–laser hybrid system irradiation on the efficiency and tooth sensitivity of in-office dental bleaching. The null hypothesis was that there were no significant differences in the efficacy of the bleaching system or in tooth sensitivity with or without an LED–laser source.

2. Material and method

This study was approved by the Ethics Committee of Araraquara Dental School, UNESP, Brazil, protocol number 51/08.

40 patients, aged 18 through 25 years, were selected for the study under the following inclusion criteria: anterior healthy teeth without restorations, patients without bleaching experience, noncarious cervical lesions or dental pain, and properly aligned teeth. Exclusion criteria were pregnancy or breastfeeding, tetracycline or fluorosis stains, malpositioned teeth, orthodontic treatment, periodontal disease or anti-inflammatory intake.

2.1. Experimental protocol

Patients were encoded and randomly distributed into two groups ($n = 20$). In group I, 35% hydrogen peroxide (Lase Peroxide Sensy, DMC, São Carlos, SP, Brazil) was kept in contact with the dental structure for 15 min in each application with three changes per session, totalizing 135 min in three sessions with an interval of 7 days between them.

In group II, the same bleaching agent was subjected to catalysis by the photo-thermal conversion process, using LED–laser hybrid light with irradiance of 300 mW cm^{-2} (Whitening Lase II, DMC, São Carlos, SP, Brazil). The gel was radiated four times, with alternating application of 1 min in each arch, totalizing 8 min of application, 24 min per dental appointment, totalizing 72 min of bleacher contact with the dental structure at the end of the treatment.

All volunteer patients received nine bleaching agent applications, with three applications in each dental appointment, totalizing three appointments with an interval of 7 days between them (table 1).

An examiner blinded to bleaching treatment registered the treatments' efficiency with a reflectance spectrophotometer (Vita EasyShade®, Vident, Brea, CA, USA) at baseline, before the bleaching (T_0), and at the end of each dental appointment (T_1, T_2 and T_3).

Sensitivity (S) or discomfort caused by the bleaching treatment was scored using a visual analog scale (VAS). The patient quantifies his pain response by making a mark in a 100 mm length line anchored by word descriptors at each end: 'no pain' at the left-hand end and 'very severe pain' at the right-hand end [17, 18].

The VAS was codified and grouped into four score levels (0–2.5, low; 2.6–5.0, average; 5.1–7.5, high; 7.6–10, very high). VAS analysis was carried out four times, before bleaching (T_0) and at the end of each dental appointment (T_1, T_2 and T_3).

2.2. Data analysis

The efficiency of the treatments was evaluated over tooth labial surfaces, from the variation data of luminosity values (ΔL) and total alteration of color (ΔE).

Table 2. Factor effects considered by GEEs, for variable ΔL.

Source	χ^2	g_1	P
Tooth	9.360	5	0.096
Session	14.475	2	0.001[a]
Group	0.557	1	0.456
Tooth × session	12.395	10	0.260
Tooth × group	7.684	5	0.175
Session × group	8.668	2	0.013[a]
Tooth × session × group	15.264	10	0.123

[a] Significant ($P < 0.05$).

For each variable, the analysis was achieved using the method of generalized estimating equations (GEEs) with a function of type identity linking. The GEEs were compared using a multifactor ANOVA test for not having independence between the measures collected for the same participant teeth. Moreover, a correlation matrix of interchangeable analysis was assumed. The 'groups' were considered as independent variation, while 'dental appointment' and 'teeth' worked as annealing endowed factors.

All cases were complementarily statistically analyzed with multiple comparisons by a Bonferroni test. By means of this test, the differences between pairs of each factor were observed, as well as the interactions pointed by the GEEs. In the situations where participants had dropped out, data were imputed using the principle of the last observation carried forward, that is, the last collected value was returned in the subsequent sessions. This retention of the data was carried through to prevent the loss of collected data for parts of the sessions, and is based on the argument that those dropping out are expected to keep the coloration of their teeth steady, even after leaving the research.

For sensitivity, the GEE method was used in a similar way to the other variable, changing only the variation factors (groups and time).

The analysis was carried out with a significance level of 5%, corrected by a Bonferroni test, according to the number of pairs compared in each series of analyses. For the inferential tests the PASW Statistics program was used (version 18; SPSS, Chicago, IL, USA).

3. Results

From the total of 40 patients, 32 completed the treatment (80%), five patients dropped out from group I and three from group II.

3.1. Luminosity (ΔL)

In the case of variable ΔL there was a significant variation according to the experimental sessions, whereas the other factors (teeth and groups) did not reach significance. From the interactions considered by the GEE method, only one was significant: 'session × group' (table 2).

As the only factor for which the equality hypothesis was rejected was associated with a significant interaction, the post hoc test was based on the last one (figure 1).

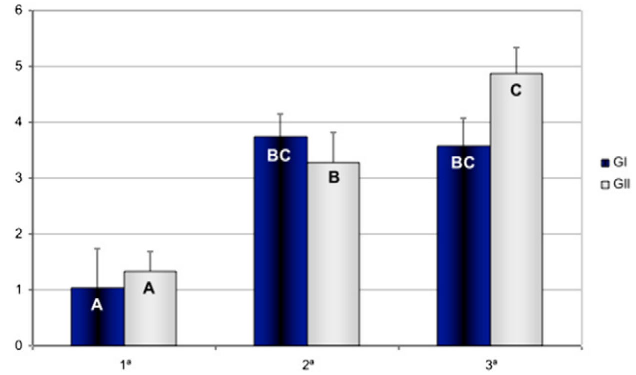

Figure 1. Average value (± standard error) for ΔL by the GEEs, as the interaction between sessions and groups. Identical letters symbolize similarity between the averages.

Table 3. Factor effects considered by GEEs, for variable ΔE.

Source	χ^2	g_1	P
Tooth	14.885	5	0.011[a]
Session	14.977	2	0.001[a]
Group	0.853	1	0.356
Tooth × session	16.764	10	0.080
Tooth × group	4.297	5	0.507

[a] Significant ($P < 0, 05$).

We observed that the first session was responsible for a partial alteration in the tooth luminosity, with the same result for the two groups. Both groups presented significant increases of ΔL in the subsequent sessions. For group I a stabilization of the bleaching from the second session was noticed, while for group II the bleaching continued progressing, reaching higher value in the third session. It is graphically evident that group II presented greater efficiency than group I.

3.2. Color alteration (ΔE)

In both groups, session and tooth variables showed influence over dental color changes, although the factor 'group' does not show a significant effect when considered in isolated form. The GEEs showed a significant interaction between the sessions and the groups, similar to what was observed in ΔL (table 3).

From figure 2, it is possible to notice that the color alteration was a minimum in the first session, with group I tending to present a greater average. This standard is completely modified in the other sessions. In the second session, group I starts to have slightly inferior values, but without significant differences. In the third appointment, group I does not present a significant increase in ΔE, in contrast to group II, whose average in this session is superior and statistically different from the one shown in the second session.

3.3. Sensitivity (S)

In GEEs for the resultant sensitivity level of the bleaching teeth, it is possible to observe that, among the considered fac-

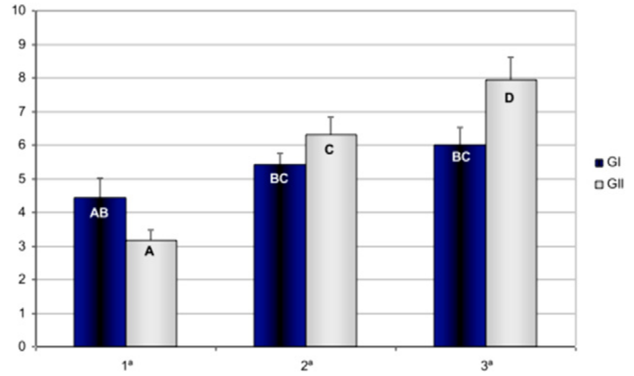

Figure 2. Average value (± standard error) for ΔE by the GEEs, as the interaction between sessions and groups. Identical letters symbolize similarity between the averages.

Table 4. Factor effects considered by GEEs, for sensitivity.

Source	χ^2	g_1	P
Moment	3.378	4	0.497
Groups	4.440	1	0.035[a]
VP[b]	0.093	1	0.760
Moment × group	5.764	4	0.218
Moment × VP	3.317	4	0.506
Groups × VP	0.321	1	0.571
Moment × group × VP	4.985	4	0.289

[a] Significant ($P < 0, 05$).
[b] VP: value pretreatment, inserted as a co-variable.

tors, only the variable groups showed statistical significance as observed in table 4.

The frequency analysis of the sensitivity level showed significant differences. In group I, the sensitivities classified as 'high' and 'very high' occur in 34.7% of patients, while in group II these sensitivity levels were not observed.

At the end of the three clinical sessions the estimated general averages, expressed as the VAS value for each group and the respective standard deviation, were 37.6 ± 5.9% for group I and 11.1 ± 3.3% for group II, showing a significant difference between groups ($p = 0.035$).

4. Discussion

The real contribution of light sources to dental bleaching effectiveness has been one of the most debated and controversial subjects in recent years [9, 14, 15].

Previous studies have established that tooth bleaching associated with an energy source provides a faster and more effective treatment than that without this device, because the presence of light and heat increases the reactivity of hydrogen peroxide [19–21].

Luk *et al* [6] and Tavares *et al* [18] have demonstrated that there are selective bleaching agents that are more effective when radiated with light sources, while others do not present an efficiency profit.

In the cases where the bleaching products are not dependent on an energy source to have their process started, the photo-activation can be used to speed up the bleaching procedure. In these cases, the final aesthetic result will be the same as obtained without the use of light, but the time required to reach it will be shorter in the groups subjected to the irradiation.

In the literature there are studies of light source effect evaluations in which insufficient doses of irradiation had been used [22], comparisons in which the contact time of the agent with the dental structure does not allow the evaluation of the acceleration process effect [14], and use of wavelengths not corresponding to the bleaching agent absorbance capacity [6]. In all cases the authors contradict the physical-chemistry principles and argue that the use of the light sources does not bring any benefit for the tooth bleaching process.

Evidently, scarce knowledge of the distinct forms of the bleaching agents performance leads to interpretation mistakes and imperfections of scientific delineation, and is, probably, the main reason for the controversy about the benefits of the use of light sources in dental bleaching.

In order to be really able to test the irradiation efficiency, in contrast to other literature articles [10–14] that compare light source efficiency to the same time without the light sources, we decided to reduce the contact time of the photo-activated group group II (72 min) in relation to group I (135 min), to evidence if there really was a catalytic process speeding up the bleaching procedure. Our results showed that the experimental group displayed the same effectiveness in whitening in less time than the control group. These results prove the high performance of bleaching when subjected to an active light source.

To establish the evolution curve and the bleaching potential of each technique, the majority of the participants were subjected to nine bleaching agent applications, divided into three clinical sessions with an interval of one week between them. Five participants from group I (25%) and three from group II (15%) abandoned the research because of the sensitivity provoked by the treatments.

In figures 1 (ΔL) and 2 (ΔE), it can be evidenced that the use of photo-thermal catalysis with conjugated LED–laser light conditioned more effective bleaching than the traditional treatment, in spite of the reduction of the gel contact time with the dental structure.

A gradual efficiency according to the clinical sessions' repetitions was also evident. Even though a current trend of reducing the number of treatments exists, we agree with Tavares *et al* and Hang *et al* when they affirm that better aesthetic results can be obtained in relation to the application frequency [8, 23].

This is particularly true for group II. While in group I a trend of stabilization is noticed, or a reduction of effectiveness between the second and third sessions, in group II a continuous evolution of the bleaching efficiency can be evidenced, based on the number of clinical sessions undertaken, which is explained by the conjugated use of the LED–laser irradiation potential (figures 1 and 2).

However, even though the results point to a greater efficiency of the photo-thermal-catalyzed treatment (group II), we cannot affirm that this difference will remain with time. As the bleaching process persists for some days after the end of the applications and authors such as Dietschi *et al* [24], Matis *et al* [20] and Polydorou *et al* [25] have demonstrated that the final aesthetic result is similar regardless of whether photo-catalyzation is use or not, we believe that there will be a fast loss in the quality of the bleaching obtained in group II, leveling it to group I after some weeks.

As for the luminosity and color change, the groups did not present significant differences, which proves the action of the light sources. Therefore, in the group with the light source, the procedure was diminished to half. Probably because the gel contact time with the dental structure is longer in group I, the trend to stabilization is bigger, while group II continues bleaching; however, the results were not significant. Apparently, as group II presented a catalyzation and, consequently, greater molecular vibration, the bleaching results showed better performance, without significant differences [8] (figures 1 and 2).

In table 3, in which the teeth present statistical differences between them, we can perceive that the canines have a greater propensity to change color in relation to other teeth. This fact is explained by the number of complex carbonic molecules providing the bleaching agent with greater reactivity [26]. Based on these results of different color variations between teeth, the literature papers with split-mouth analysis can present oblique results, justifying the methodological delineation of this paper.

Another aspect considered in this study was tooth sensitivity (S) provoked by the bleaching treatment; this is the most common side effect of tooth bleaching and represents the aggression level of this aesthetic procedure on dental tissues [13].

In this aspect the literature is also contradictory. It is common to affirm that office bleaching provokes more sensitivity due to the high concentration of peroxide [20], especially if this is catalyzed by light sources or lasers, normally associated with the extreme heating of the dental structure due to the use of high intensity irradiation [15, 18, 24].

It is clinically observed that some patients feel a lot of pain while others do not, even when subjected to the same bleaching technique, regardless of being carried out in-office or at home. The reason for this remains uncertain. It is believed that it is because of structural defects of dental tissues and individual predisposition, even though there are no objective data for this affirmation.

We believe that the biggest contribution of the hybrid LED–laser irradiation used is the reduction of pain sensitivity. Due to the characteristics of the lights used (blue LED and infrared laser), we can have an activation effect for conversion of luminous energy into low intensity thermal energy in the inner bleaching gel [19], as an analgesic and anti-inflammatory action [16]. It is known that an infrared laser acts at a wavelength that is able to promote a high polarization of the nervous membrane, thus diminishing the generation of action potentials and consequently reducing the occurrence and the intensity of the provoked sensitivity [10].

This capacity became very evident in this study. GEE statistics evidenced significant difference only for groups ($p =$ 0.03) when the resultant sensitivity (S) was analyzed. The sensitivity average and respective standard mistakes had been respectively 37.6 ± 5.9% (group I) and 11.1 ± 3.3% (group II).

More important was the frequency of pain classified as high and very high. In group I this occurrence represented 34.7% of the cases, whereas in group II no participant related this level of sensitivity in the first session.

Beyond the effect of the therapeutical infrared laser used [25], another factor that may have contributed to the less frequent sensitivity occurrence in group II is the reduction of the bleaching gel contact time with the dental structure, minimizing the interaction of hydrogen peroxide with the pulp tissue.

In this paper, it was evident that the use of photo-catalyzation with LED–laser hybrid light was an important component for a more secure and effective bleaching technique with reduction of the bleaching agent application time and tooth sensitivity.

5. Conclusion

The use of an LED–laser hybrid device for catalysis of bleaching agents allows a significant decrease in the provoked tooth sensitivity and reduces bleaching treatment time by 53%, with the same aesthetic results as non-photo-thermal activation.

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