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Can an LED-laser hybrid light help to decrease hydrogen peroxide concentration while maintaining effectiveness in teeth bleaching?

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Abstract

The aim of this study was to compare the bleaching efficacy of 35% hydrogen peroxide and 15% hydrogen peroxide with nitrogen-doped titanium dioxide catalysed by an LED-laser hybrid light. We studied 70 patients randomized to two groups. Tooth shade and pulpal sensitivity were registered. Group 1: 15% hydrogen peroxide with nitrogen-doped titanium dioxide. Group 2: 35% hydrogen peroxide. Both groups were activated by an LED-laser light. No significant differences were seen in shade change immediately, one week or one month after treatment ($p > 0.05$). Differences were seen in pulpal sensitivity ($p < 0.05$). The use of an LED-laser hybrid light to activate 15% hydrogen peroxide gel with N-TiO₂ permits decreasing the peroxide concentration with similar aesthetic results and less pulpal sensitivity than using 35% hydrogen peroxide for bleaching teeth.

Keywords: LED-laser light, nitrogen-doped titanium dioxide, teeth bleaching, pulpal sensitivity

1. Introduction

In recent years, the focus in dentistry has shifted from a ‘functional demand’ (where the routine treatment was the repair of destructive effects of dental caries) to an ‘aesthetic dentistry’ where patients are concerned with having better-looking teeth [1, 2]. Aesthetics of the teeth, including tooth color, has become an increasingly important issue in clinical dentistry. As a result, bleaching procedures have become popular for both dentists and patients [3]. Vital tooth bleaching is one of the safest, most effective conservative aesthetic procedures available to patients [4].

The application of a peroxide, such as hydrogen peroxide or carbamide peroxide over the tooth surface is at the root of vital tooth bleaching. Whatever the peroxide used, the active ingredient that produces bleaching is hydrogen peroxide (H₂O₂)

capable of oxidising a wide variety of organic and inorganic compounds [5, 6]. H₂O₂ can form a number of different reactive oxygen species (ROS) depending on the reaction conditions [3, 6]. These ROS, especially the hydroxyl radical (HO), remove stains due to decomposition of organic substances [6, 7].

The factors that determine the overall whitening efficacy are mainly the H₂O₂ concentration, the ability to reach the chromophore molecules, and the duration and number of times the agent is in contact with them [6, 8]. When comparing the effectiveness of different peroxide concentrations, it was found that a higher concentration requires a lower time of application to produce uniform bleaching [9–11]. On the effect of application duration, the efficacy rendered by the lower concentrated solution approached that of the higher concentrations when the treatment time was extended [9–11]. Arai concluded that while highly concentrated H₂O₂ has been used to bleach vital

Table 1. VITA shade guide value ordered and corresponding scores.

| Vita Designation | 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 |

discolored teeth during office whitening, low concentration agents might have insufficient whitening capacity [12].

One of the main adverse effects of dental bleaching is the occurrence of postoperative pulpal sensitivity [13–15]. Low concentration bleaching agents cause lower pulpal sensitivity than those with higher concentrations [16, 17]. Potential harm from bleaching agents at the oral cavity are a constant concern for clinicians, manufacturers and investigators, who have searched for more secure and efficient formulations and procedures [18, 19].

A low concentration bleaching agent group (3.5% and 15% H₂O₂) was introduced, where the peroxide action is catalysed and potentiated by an agent such as titanium dioxide (TiO₂), which produces vital oxygen and other compounds by exposure to light [20–23]. According to Maetani *et al* [7] and Suemori [24] this new generation of bleaching agents would be safer (due to the formation of O₂⁻ but no HO⁻) and more efficient than traditionally used formulations, concluding that the irradiation with a 405 nm diode laser promotes a significant bleaching effect [24]. Many researchers aim to activate the TiO₂ photocatalyst using visible light [25]. Nitrogen-doped titanium dioxide (N-TiO₂) is a photocatalyst that exhibits high reactivity under visible light [25]. A low concentration peroxide bleaching agent with a visible light titanium photocatalyst may be useful to decolorize stained teeth [12]. Also, there are reports suggesting that the laser irradiation might contribute to reducing pulpal sensitivity [26].

The objective of this blind and randomized clinical study is to compare the bleaching efficacy of 35% H₂O₂ and 15% H₂O₂ with the N-TiO₂ agent catalysed by an LED-laser hybrid light.

The null hypothesis to be tested is that the light-activated 15% H₂O₂ N-TiO₂ bleaching agent has no difference in bleaching efficacy to 35% H₂O₂ for in-office treatment.

2. Materials and methods

This study was conducted in 140 upper central incisors of 70 volunteer patients, 18 years of age or older, who attended the Operative Dentistry Clinic at Dental School, Universidad de Chile asking for dental bleaching. Sample size was determined using G*Power 3.1.2 software, considering an α error of $p = 0.05$ and a power value of 0.8 [27]. The Research Office and the Ethic Board of the Dental School at Universidad de Chile approved this study (PRI-ODO 12-01). All patients were recruited by printed advertising located at the Dental School 30 days before the start of the study.

Inclusion criteria included no previous bleaching experience; all anterior teeth without caries, restoration or cervical lesions and no dental pain symptomatology. Candidates were excluded if they were pregnant or breastfeeding patients,

had tetracycline stains classified as 3–4 according to Jordan and Boksman [28] or fluorosis stains categorized as three or higher according to the Thylstrup–Fejerskov Index [29], dental malocclusion or in orthodontic treatment and/or were patients with periodontal disease.

Patients were informed of the study benefits and possible adverse effects and signed an informed consent form. Each patient was assigned by randomization to one of two treatments groups, using NCSS PASS 2008 v08.0.15 software. Prior to color measurement, all teeth were cleaned with pumice and water to remove extrinsic stains. Tooth shade of both upper central incisors was registered according to the Vita shade guide, using a digital spectrophotometer SpectroShade Micro (MHT S P A Medical High Technologies, Italy). All anterior teeth were bleached (upper and lower) by a blind operator.

Group 1: patients treated with a light-activated (Whitening Lase Light Plus, DMC®, Sao Carlos, Brazil) 15% H₂O₂ with N-TiO₂ (Lase Peroxide Lite, DMC®), according to manufacturer's indications. Three applications, 15 minutes each, were completed in one clinical appointment, completing 45 minutes of treatment.

Group 2: patients treated with 35% H₂O₂ (Lase Peroxide Sensy, DMC®), activated by an LED-laser light (Whitening Lase Light Plus, DMC®) according to manufacturer's indications. Three applications, 12 minutes each, were completed in one clinical appointment, completing 36 minutes of treatment.

Both bleaching agents were irradiated with the same light source which has an infrared laser of 808 nm (100 mW) and blue LED light source of 450 nm (400 mW).

Before and immediately after treatment, pulpal sensitivity was assessed with the use of the Visual Analogue Scale (VAS). Upper central incisors were stimulated by activating an air syringe for 2 s at a distance of 1 cm from the tooth surface. Patients wrote on a 100 mm line anchored with the descriptors 'no pain' at the left end and 'very severe pain' at the right end as to how painful the response was. The VAS score was determined by measuring in millimeters from the left end of the line to the point that the patient marked [30, 31].

Tooth shade registry was repeated immediately, one week and one month after treatment and shade change between baseline and post-treatment checkpoints calculated, using the Vita Classical shade guide, arranged from highest (B1) to lowest (C4) value, according to the manufacturer (table 1). The number of shade guide units (SGUs) change was determined.

In addition, one week after completion of treatment, patient satisfaction was registered, asking them to qualify how much they felt the procedure whitened their teeth (none, slight, moderate or a lot) [32].

Tooth shade change was assessed as the number of SGUs changed at each evaluation time with respect to the baseline. The tooth shade of both groups was compared at each evaluation period by the Mann–Whitney test and bleaching agent

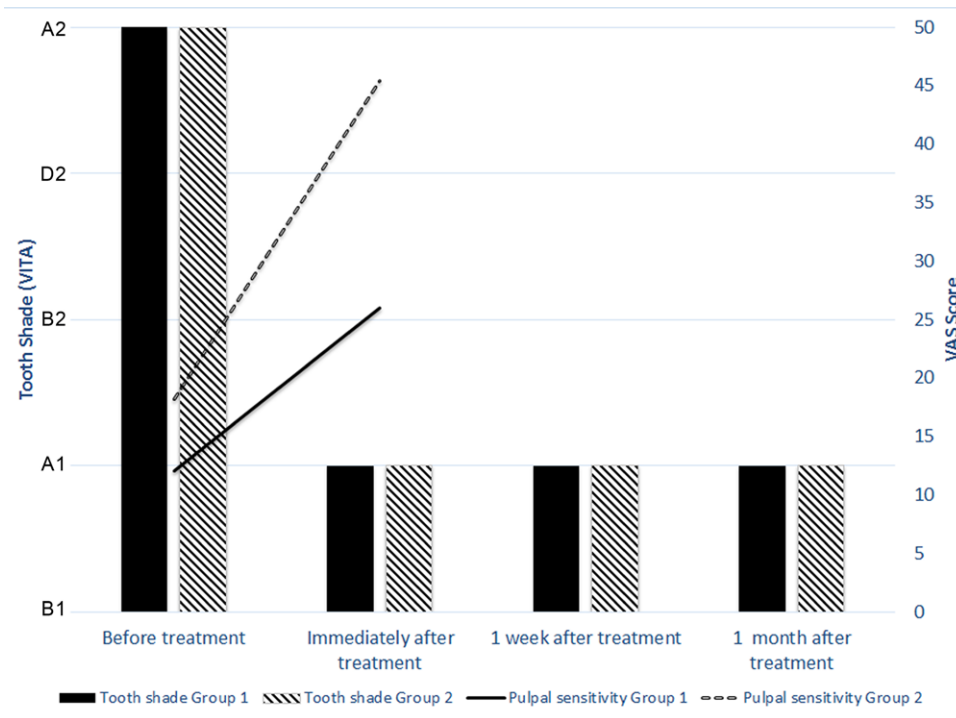


Figure 1. Tooth shade and pulpal sensitivity at each checkpoint.

efficacy over time was evaluated using the Friedman test. SGUs variation between groups was compared by the Mann–Whitney test.

Pulpal sensitivity and satisfaction data between groups were compared using the Mann–Whitney test. For all statistical analysis, a significance level of 95% was considered.

3. Results

The mean age of participants was 23.6 ± 4 years, with all between the ages of 18 and 37 years. All 140 upper central incisors were evaluated immediately after treatment (70 patients), 108 one week after (54 patients) and 50 (25 patients) one month later.

Pulpal sensitivity before treatment was 12 VAS units for group 1 and 18 for group 2, with no differences between them ($p = 0.25$). Immediately after treatment both groups showed a statistically significant increase in pulpal sensitivity ($p < 0.05$) with 26 VAS units for group 1 and 45 for group 2, with differences between groups ($p = 0.03$) (figure 1)

Both groups were approximately the same shade at the beginning of the study with no difference between them (median value of shade score = 5 (A2 Vita); $p = 0.677$). Also, no differences in shade between groups were seen immediately after treatment (median value = 2 (A1 Vita); $p = 0.114$), at one week (median value = 2 (A1 Vita); $p = 0.223$) or one month later (median value = 2 (A1 Vita); $p = 0.186$). (figure 1)

The highest shade change was immediately after treatment, with 3 SGUs for each group and no change was seen seven days or one month after. The Friedman test showed a statistically significant shade difference between baseline and post-treatment checkpoints for both groups ($p = 0.035$ for group 1

and $p = 0.001$ for group 2). When the SGU change between groups at each post-treatment checkpoint was compared, both groups showed the same shade change ($p = 0.339$ immediately, $p = 0.635$ at one week, $p = 0.608$ at one month).

No differences were seen in patient satisfaction with bleaching treatment ($p = 0.239$), with 95% of patients answering that the treatment bleached their teeth ‘moderate’ or ‘a lot’.

4. Discussion

Aesthetics has become an important aspect of dentistry, making tooth bleaching a main demand of patients as tooth color is one of most important aspects of facial attractiveness [2, 6]. In fact, in recent years, tooth bleaching has become one of the most rapidly growing oral care sectors [6].

In our study, both bleaching agents, 15% and 35% hydrogen peroxide, promote changes in shade immediately after treatment. Matis *et al* [33] showed that after application of different concentrations of bleaching agents (in one clinical appointment), the greatest shade change was achieved immediately after treatment, with a reduction in the following weeks. Similarly, Marson *et al* [32] evaluated two 35% hydrogen peroxide bleaching agents applied with or without light in two clinical appointments, concluding that both groups showed a change between 4–5 SGUs one week and one month after treatment, with the greatest shade change achieved immediately after treatment.

In terms of patient satisfaction, all showed high satisfaction with treatment, no matter the agent used. Satisfaction with tooth appearance is mainly influenced by tooth color and most patients are interested in improving it by bleaching their teeth

[2]. It has been shown that different concentrations of peroxide can be used to achieve bleaching and the results might be similar between them, but this might be possible if both agents are used for an adequate time, i.e. higher concentrations need less time to reach the result [6, 10, 34]. Leonard in a study where he used different concentrations of carbamide peroxide demonstrated that lower concentrations of peroxide take longer to bleach teeth but eventually achieve the same results as higher concentrations [9]. In the same way, Sulieman showed that higher peroxide concentration gels need fewer applications to produce the bleaching effect [11].

Although it is known that after one application of bleaching agent there is an immediate effect, this is not necessarily the end point in terms of bleaching and additional sessions might be necessary [35, 36]. In our study, one application of the agent was used and it has been demonstrated that a 35% hydrogen peroxide might produce uniform results after that time [11]. Also, standardising treatment time simplifies comparison with other studies, while studies where the number of sessions and applications depends on patients might be difficult to compare [32]. The minimal change of shade after treatment seen in our study compared to others might be because we did not include baseline shade as an inclusion or exclusion criteria. Baseline shade values for both treatment groups was approximately A2. Zhou *et al* [37] found that the baseline color significantly determines whitening effectiveness. An increase of 1 unit in yellowness results in approximately 10% more color improvement.

Hydrogen peroxide concentration and application duration are the two key factors that determine the overall tooth whitening efficacy, with best results achieved with higher peroxide concentrations [6, 9–11, 34]. In our study, although bleaching agents had differences in peroxide concentration, both achieved a similar result applied in one clinical appointment, with less pulpal sensitivity in the low concentration hydrogen peroxide group. To achieve the bleaching of teeth, hydroxyl radical generation from hydrogen peroxide can be accelerated by the rise of temperature of the bleaching agent or its activation with light [18]. Another way is by the use of a nanoparticle semiconductor such as titanium dioxide that, when exposed to ultraviolet light catalyses the formation of hydroxyl radicals from hydrogen peroxide [23, 38]. The combination of low concentration hydrogen peroxide with titanium dioxide might be safer than high concentrations of hydrogen peroxide due to the formation of O_2^- but no OH^- radicals, which are a risk factor for bleaching [7] with the inconvenience that the use of ultraviolet radiation might have harmful effects [39, 40]. The use of $N-TiO_2$ permits its activation by visible light [12, 25]. This combination is a clinically effective and safe agent for discolored teeth, causing less augmentation of pulpal sensitivity after the treatment [7, 15, 38, 41–43]. It is known that an infrared laser acts at a wavelength that can promote a high polarisation of the nervous membrane, thus diminishing the generation of action potentials and consequently reducing the occurrence and the intensity of the generated sensitivity. Besides, lowering the concentration of hydrogen peroxide may also contribute to an undesirable effect on the diffusion and cell damage of tooth

pulp [44, 45]. The use of light can augment the effects of tooth bleaching peroxide, reaching the desired color after a shorter time than when no light is used as it can augment the effects of tooth bleaching peroxide and indeed, appears to have a tooth bleaching effect by itself [26, 46, 47]. Our results confirm this, showing that the 15% hydrogen peroxide bleaching gel containing $N-TiO_2$ activated by an LED-laser light showed similar results to the 35% hydrogen peroxide gel, with less pulpal sensitivity.

5. Conclusion

The use of an LED-laser hybrid light to activate 15% hydrogen peroxide gel with $N-TiO_2$ permits decreasing the peroxide concentration with similar aesthetics results and less pulpal sensitivity than using 35% hydrogen peroxide for bleaching teeth, applied in one clinical appointment.

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