

CASE REPORT

Comparative clinical and psychosocial benefits of tooth bleaching: different light activation of a 38% peroxide gel in a preliminary case–control study

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Introduction

Tooth bleaching has become one of the most popular cosmetic procedures offered in dental practice. Patients seek increasingly to have an attractive smile, as it is considered synonymous with health, good appearance, professional and social benefit. Although tooth color is only one of the aspects involved in facial harmony, it represents the most important isolated factor because it is immediately noticed. Smile- and teeth-related physical appearance plays a key role in human social interaction. At the individual level, dental health and esthetics have been demonstrated to be visibly related both to patient self-esteem [1] and increased comfort in social interactions [2] while, at the societal level, physically attractive people are systematically considered as possessing higher social competence, intellectual ability, psychological adjustment, and relationship satisfaction than their less-attractive counterparts [3–5]. Several methods have been described in the literature for bleaching vital teeth, such as the use of different chemical agents, concentrations, time of application, and product format [6–8].

Key Clinical Message

Tooth bleaching is a widespread dental treatment with important psychosocial antecedents and outcomes involved. In the activation of in-office bleaching agents, a selective light radiation, that is, a diode laser seems to be a positive choice to decrease the time of bleaching without surface modification and with no residual tooth sensitivity for maximum effect and minimal clinical and psychological side effects.

Keywords

Abrasion, applied social psychology, dentin sensitivity, professional practice.

Hydrogen peroxide is the main active ingredient of bleaching products. The dissociation of hydrogen peroxide into free radicals and the ability to penetrate through enamel and dentin produce the oxidation of polymeric organic pigments that cause tooth discoloration. Carbamide peroxide decomposes into urea and hydrogen peroxide and the active process of bleaching does the same [9].

Bleaching agents are provided for in-office and at-home treatments. At-home bleaching presents a number of advantages such as ease of application, no need for light activation, less peroxide concentration, and lower costs. However, it also presents some disadvantages, such as longer time of treatment, comparatively lower patient's collaboration, and lacking of professional control. In-office bleaching was proposed with the aim of reducing agent bleaching exposure through total control of the procedure performed by a dentist or a dental hygienist also when the patient does not collaborate. Even if in-office bleaching involves the application of higher concentration of bleaching agents, and often also requires light activation of the whitening product, longer sessions are

necessary to guarantee the effectiveness of the treatment, although this leads to an obvious increase in the costs of treatment [10]. Further, before bleaching, it is always recommended to examine the surface characteristics of dental enamel carefully, in order to avoid unwanted side effects such as, for instance, enamel structural changes or the progression of white-spot lesions [11–13].

In recent years, an increasing number of bleaching products have appeared in the market for professional use only. Manufacturers have introduced different concentrations of hydrogen peroxide for in-office bleaching, ranging from 10% to 38%, which can be activated by light sources or heat. The main side effect often associated with high concentration of hydrogen peroxide is tooth sensitivity due to pulp irritation. Tooth sensitivity may cause both physical and psychological discomfort to the patient, but in most cases, it represents a reversible effect as most sensitivity occurs within the first 2 weeks after treatment [14]. Probably this kind of dental sensitivity is due to some vehicle used to carry the active ingredient, which causes reversible pulpitis, or is the consequence of increased temperature of the pulp when light activation is performed. Light activation accelerates and enhances the power of the bleaching agent. Different sources of light can be used, such as halogen, plasma arc, light emitting diode (LED), ultraviolet lamp, laser, and hybrid light. Available studies do not allow for an ultimate judgment about whether or not tooth bleaching can be either (safely) increased or accelerated by whatever additional light activation [15, 16].

Despite the advantages offered by the bleaching treatment, the effect of bleaching agents on dental hard tissues is still controversial. A number of studies have evaluated the influence of bleaching agents on the properties of enamel and dentin [17, 18]. Some chemical products have a lower than ideal pH which can cause changes in the mineral content of the enamel, this in turn promotes or increases enamel erosion or abrasion. However, studies have shown that the addition of fluoride or calcium to the composition of the bleaching agent can minimize mineral loss in hard tooth tissues [19].

The main purpose of this study was to evaluate the *in vivo* efficacy of a 38% hydrogen peroxide gel with calcium and strontium ions used for in-office bleaching, both with LED and laser activation, in order to test the extent to which different light activation does or does not affect tooth color change. A further aim was to compare the two light-activation techniques with respect to the possible onset of adverse clinical and psychological side effects to determine which of the two light-activation techniques would lead to better outcomes both from an objective (plaque index) and subjective perspective (perceived tooth sensitivity and surface smoothness).

Materials and Methods

Ten systemically healthy patients, aged 21–54 years, were recruited from new referrals to Department of Oral Hygiene of Dental Clinic of University Vita-Salute San Raffaele of Milan. Inclusion criteria were: (1) good health; (2) all anterior teeth (superior and inferior) without restorations or caries; and (3) willing to provide informed consent and to ensure compliance throughout the study. Exclusion criteria were: (1) pregnancy or lactation; (2) adverse effects to peroxides; (3) systemic diseases possibly interfering with the research; (4) clinical diagnosis of generalized chronic periodontitis; (5) enamel dysplasia; (6) tetracycline-stained teeth; (7) tooth sensitivity of <1 on the VAS questionnaire scale; (8) use of any bleaching agents within the last year; and (9) physical or mental handicap.

All patients gave informed consent. The study design was approved by the local Ethical Committee and was found to conform with the requirements of the Declaration of Helsinki.

In this study, we used a bleaching agent which was a gel of 38% hydrogen peroxide with calcium and strontium ions (Trilly white DMT – Dental Medical Technologies – Lissone, Italy).

For the light activation, we used a light emitting diode – LED-lamp (430–490 nm, 4 W/Mentadent Professional Xtra White Lamp MC Italia srl – Lainate, Italy) and a diode laser (980 nm, 7 W/Diode Laser DMT srl – Lissone, Italy).

The oral cavity of each patient was randomly divided into two equivalent parts (split-mouth design) – right versus left half upper dental arch + half lower dental arch.

Each patient was previously subjected to a single SRP session. Personalized oral hygiene instructions were verbally provided.

Clinical recordings and subjective ratings

At time 0 (T_0 – baseline), that is, right before the bleaching treatment, the half-dental arches of the patients were assigned to either the test or the control treatment group according to a randomization list. PI (Plaque Index) and BOP (Bleeding On Probing) were recorded. PI was measured according to Silness and Loe [20] criteria; BOP was recorded by means of a standard periodontal probe (PCPUNC15 Hu-Friedy, Chicago, IL) with a manual pressure of approximately 25 g and was considered positive if bleeding occurred within 30 sec after probing. An examiner blind to conditions assessed the color of the teeth according to a classical Vita shade guide (Vita Zahnfabrik) by means of a digital

spectrophotometer (SpectroShade™ Micro – MHT Medical High Technologies, Verona, Italy). Measurements were taken from the same area (middle of the tooth) of each tooth (first upper incisors) two times consecutively. When these two values equaled, they were registered. When the values were not equal, additional measurements were taken until equal measurements were obtained, and only one measurement for each tooth was recorded. Initial digital photos of teeth were taken. In order to calculate the variation between specimens according to the Vita Classical scale, the recorded values were ordered in scores from 1 to 16 in a luminosity sequence, with 1 representing the lightest specimens and 16 representing the darkest. Tooth Sensitivity was registered by a numeric VAS questionnaire scale. Patients were instructed to indicate any tooth or oral sensitivity by marking the corresponding level of perceived sensitivity on the horizontal line, ranging from 0 to 10, with 10 representing the highest sensitivity score. Also Surface Roughness was registered via a numeric VAS questionnaire scale. Patients were instructed to indicate perceived dental surface roughness by reporting (i.e., marking) their feeling on the horizontal line (0 = no sensed roughness to 10 = maximum sensed roughness).

After clinical and subjective recordings, bleaching treatment was performed according to the manufacturer's instructions. Supra-gingival prophylaxis using pumice stone with a brush and the application of a gingival barrier (Acrylic curing dam – DMT srl – Lissone, Italy) was carried out before bleaching. In the test side, the bleaching agent was activated by LED for 10 min, in both arcs simultaneously. This step was performed two times consecutively, while the control site was protected with a gauze. Afterward, in the control side, the application of the bleaching agent was activated by laser diode (1 W – 20" for tooth in pulse mode). This step was performed two times as well.

At the end of the bleaching treatment, the peroxide gel was wiped with cotton, and the gingival barrier was removed.

All patients received instructions to avoid any substance that could stain teeth and any food and beverages with acidic pH levels in the first 48 h following the treatment. No fluorine or anti-inflammatory product was prescribed.

At time 1 (i.e., immediately after the bleaching session), the color of teeth was assessed in the same manner as at time 0 (T_0 = before treatment). Digital photos of teeth were taken. At time 2 (i.e., 2 weeks after the bleaching treatment), clinical recordings of PI, BOP, and tooth color, along with subjective ratings of tooth sensitivity and surface roughness, were collected. Final digital photos of the teeth were taken.

Data analysis

Data from clinical parameters and subjective ratings were analyzed using statistical software (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL). Data were expressed as the median (Mdn) and interquartile range (IR). As both intra- and intertreatment differences were assessed using a split-mouth design based on a *within-participants* analytical strategy [21–23], all pairwise comparisons were performed using the Wilcoxon nonparametric signed-rank test for related observations. The decision criterion for statistical significance was set at $\alpha = 0.05$ (i.e., $P < 0.05$ for hypothesis testing).

Results

Descriptive statistics for Tooth Color are summarized in Table 1. Baseline tooth color median values (Mdn) were equivalent both in the control and in the test group ($P = 0.655 > 0.05$). Tooth color significantly changed between baseline and 2 weeks after treatment both in the control and in the test group ($P_s = 0.005$ and 0.007 , respectively). No significant difference was observed between control and test group 2 weeks after treatment ($P = 0.180 > 0.05$).

Descriptive statistics for Tooth Sensitivity are summarized in Table 2. Baseline tooth sensitivity median values (Mdn) were identical both in the control and in the test group ($P = 1.000 > 0.05$). Further, tooth sensitivity did not differ between baseline and measurements at 2 weeks after treatment in the control group ($P = 1.000 > 0.05$), while it showed a significant increase in the test group ($P = 0.042$). Two weeks after treatment, tooth sensitivity was significantly higher in the test group than in the control group ($P = 0.042$).

There were no differences in Surface Roughness, neither between test versus control groups nor between baseline versus later measurements. In each cell of the study design, reported tooth roughness turned out to be absent.

Table 1. Tooth color as assessed in 10 selected teeth in test and control group.

	Control group tooth color		Test group tooth color		P-value*
	Mdn	IR	Mdn	IR	
T_0 baseline	9.00	5.75–10.50	9.00	5.75–12.00	0.655
T_2 2 weeks	5.00	2.00–5.00	5.00	2.00–6.75	0.180
P-value**	0.005		0.007		

IR, interquartile range; Mdn, median.

*P-value for pairwise intergroup comparisons (Wilcoxon signed-rank test for related samples).

**P-value for pairwise intragroup comparisons (Wilcoxon signed-rank test for related samples).

Table 2. Tooth sensitivity as assessed in 10 selected teeth in test and control group.

	Control group tooth sensitivity		Test group tooth sensitivity		P-value*
	Mdn	IR	Mdn	IR	
T ₀ baseline	1.00	1.00–1.00	1.00	1.00–1.00	1.000
T ₂ 2 weeks	1.00	1.00–1.00	2.50	1.00–7.75	0.042
P-value**	1.000		0.042		

IR, interquartile range; Mdn, median.

*P-value for pairwise intergroup comparisons (Wilcoxon signed-rank test for related samples).

**P-value for pairwise intragroup comparisons (Wilcoxon signed-rank test for related samples).

Descriptive statistics for PI are summarized in Table 3. The plaque index median value (Mdn) was significantly higher in the control than in the test group ($P = 0.021$) at baseline (T_0), while PI median values were comparable 2 weeks later ($P = 0.721 > 0.05$). Both within the control group and the test group, no significant differences were observed in comparing measurements made at baseline and 2 weeks later ($P_s = 0.106$ and $0.091 > 0.05$, respectively).

Descriptive statistics for BOP are summarized in Table 4. The bleeding on probing median value (Mdn) was slightly but significantly higher in the control than in the test group ($P = 0.047$) at baseline (T_0), while treatment and control BOP median values were comparable 2 weeks later ($P = 1.000 > 0.05$). Within the control group, a significant difference was observed in comparing measurements taken at baseline versus 2 weeks later ($P = 0.007$), while no such difference emerged within the test group ($P = 0.105 > 0.05$).

Discussion

The present clinical study evaluated the effectiveness of a 38% hydrogen peroxide gel with calcium and strontium

Table 3. Plaque index as assessed in 10 selected teeth in test and control group.

	Control group PI		Test group PI		P-value*
	Mdn	IR	Mdn	IR	
T ₀ baseline	0.165	0.11–0.39	0.140	0.08–0.34	0.021
T ₂ 2 weeks	0.175	0.10–0.19	0.150	0.08–0.23	0.721
P-value**	0.106		0.091		

IR, interquartile range; Mdn, median; PI, plaque index.

*P-value for pairwise intergroup comparisons (Wilcoxon signed-rank test for related samples).

**P-value for pairwise intragroup comparisons (Wilcoxon signed-rank test for related samples).

Table 4. Bleeding on probing as assessed in 10 selected teeth in test and control group.

	Control group BOP		Test group BOP		P-value*
	Mdn	IR	Mdn	IR	
T ₀ baseline	0.040	0.02–0.06	0.030	0.00–0.04	0.047
T ₂ 2 weeks	0.025	0.00–0.03	0.005	0.00–0.05	1.000
P-value**	0.007		0.105		

IR, interquartile range; Mdn, median; BOP, bleeding on probing.

*P-value for pairwise intergroup comparisons (Wilcoxon signed-rank test for related samples).

**P-value for pairwise intragroup comparisons (Wilcoxon signed-rank test for related samples).

ions, used for in-office bleaching, activated either with LED or laser light. Clinical parameters and subjective ratings assessed at the baseline observation were reevaluated after 2 weeks. The main aim of the study was to provide additional data on the effects of different light activations with respect to the whitening power of the light-activated gel. Further aims were to investigate the onset of both objective clinical adverse effects, such as possibly augmented dental plaque, and subjective side effects, such as perceived dental sensitivity and surface roughness.

The real contribution of light sources to dental bleaching effectiveness has been one of the most debated and controversial subjects in recent years. Previous studies have established that tooth bleaching associated with an energy source provides a faster and more effective treatment than the treatment provided without this device, because the presence of light and heat increases the reactivity of hydrogen peroxide. Light, which matches the wavelength of photo initiators in the bleaching gel, increases the formation of hydroxyl radicals from peroxide, and this release is accelerated by a rise in temperature [6, 7, 9].

Strong controversy surrounds the success of light sources. Some researchers believe that they are effective in the bleaching process, while others believe that only certain lights are effective, and still others reported no effect of differential light activations at all [15, 24, 25].

The in-office bleaching gel tested, caused a tooth shade change, independently from the light-activation technique used in this study. Both protocols employed were effective in promoting teeth bleaching with no significant differences in color change between test and control group. This outcome is in agreement with most literature findings which suggest that tooth shade change does not depend on the source of light activation [26–29]. In our study, we observed a significant tooth shade change from a median value of 9.00 to a median value of 5.00 in both

conditions, with only very slight and negligible differences observed in interquartile range (IR) values.

In light-activated tooth bleaching procedures, there is a great concern about heat generated by the light sources which may cause pulp irritation or severe damage like necrosis. When the bleaching agent is activated under the influence of light, some amount of light is absorbed and the resulting energy converted into heat. This can be observed as a possible side effect during this type of tooth bleaching [30, 31].

Zach and Cohen [32] reported pulp irreversibility in 15% of the teeth of rhesus monkeys with a temperature elevation of 5.6°C, 60% for an elevation of 11°C, and 100% for a temperature elevation of 16.6°C, showing a potential histopathological alteration in the pulp tissue when the temperature exceeds 5.6°C. However, some other authors reported different results. Eriksson *et al.* [33] found that 42°C might be a critical temperature to the pulp when sustained for 1 min; Baldissara *et al.* [34] reported that an intrapulpal temperature rise of 8.9–14.7°C in humans does not induce pulpal pathology. As there is no agreement about which is the lowest value of pulp chamber temperature rise that would cause pulp damage, it is rational to use a light source that minimizes possible iatrogenic problems during clinical treatments [35].

Different light sources, such as halogen, Plasma arc, light emitting diode (LED), ultraviolet lamp, laser and hybrid light, can be used for bleaching treatment [36]. Three dental laser wavelengths have been cleared by the FDA (Food and Drugs Administration) for tooth whitening: argon, CO₂, and 980 nm GaAlAs diode, but also other laser radiation systems have been tested for this purpose [37].

Conflicting results have been reported in the literature regarding the behavior of the different light sources. White *et al.* [38] found that lasers and high intensity lamps produce higher temperatures than conventional lights.

Eldeniz *et al.* [31] reported that light activation of bleaching materials with diode laser caused higher temperature changes as compared to other curing units and the temperature rise detected was viewed as critical for pulpal health. Carrasco *et al.* found that during light-activated tooth bleaching, halogen light promoted higher pulp chamber temperature rise than LED unit and LED-laser system, but the increase in the pulp chamber temperature was compatible with pulpal health [39]. Some other authors consider light-activated tooth bleaching as a procedure safe for pulpal health regardless from pulp temperature increase [40]. Probably, treatment time and not only the type of light source, is critical for the final outcome.

As a result, the treatment time should be regulated to receive greater surface temperature increases than the pulp temperature increases [37]. However, Buchalla and Attin, in a systematic view, stressed that the application of activated bleaching procedures should be always critically assessed considering the physical, physiological, and pathophysiological implications [16]. Also He *et al.* [41] in a more recent systematic review, came to similar conclusions.

In our study, the main difference between the two light-activation groups was the onset of perceived tooth sensitivity, which was significantly higher in the LED side than in the diode laser side 2 weeks after treatment – this finding pointing not only to a clinical but also to a social-relational relevant outcome. In fact, dental sensitivity could importantly affect both patients' perception of quality of treatment and their social functioning. However, even if ostensibly causing some discomfort to the patient within the first 2 weeks after the bleaching treatment, this unwanted side effect should attenuate and disappear at later points in time.

According to the data from the literature discussed above, one could assume that this different behavior does not depend so much on the type of light activation used, as the total exposure time to the activation light. In the test side – LED activation – teeth were exposed to a total of 20' of light activation while in the control side – diode laser activation – each tooth received only 40" of light exposure. Our finding on postbleaching dental sensitivity is in agreement with some literature reports in which bleaching with diode laser resulted in less tooth and gingival sensitivity than bleaching with other systems [27, 42]. To date, however, no ultimate judgment can be formulated on this issue.

In the bleaching gel tested in our study, manufacturer developed a particular formulation by combining hydrogen peroxide with calcium and strontium ions. This combination should have resolved the sensitivity problem and the enamel-dentin decalcification by the formation of insoluble salts, in particular, calcium phosphate and oxalate of strontium having affinity with enamel hydroxyapatite and dentinal tubules. This would contrast the decalcification allowing the remineralization of enamel and, clogging dentinal tubules would prevent dentinal sensitivity. This hypothesis has not been confirmed, at least as regards the prevention of the onset of dental sensitivity.

The subjective feeling of surface roughness was invariably absent among participants, who reported a constant feeling of smoothness, and no differences of any sort – neither between groups, nor before and after bleaching.

Most of the studies available in the literature have revealed no significant micromorphological changes associated with the whitening process in subsurface enamel,

DEJ, and dentin areas. These findings mainly resulted from *in vitro* studies on extracted teeth for periodontal or orthodontic reasons. Less common are *in vivo* reports by making replicas of the teeth treated with the whitening technique. In scanning electron microscope observation, typical enamel surface morphology is generally observed after bleaching treatment, leading to the conclusion that any change caused by the whitening agents are minimal or imperceptible [43, 44].

Nevertheless, some other studies revealed that bleaching agents can affect the hard tissues of the teeth leading to a loss of mineral content in the enamel, changing the surface of the enamel with erosions, modifying its physical properties, and increasing the superficial roughness and the susceptibility to caries.

Miranda *et al.* [18] demonstrated that in-office bleaching agents affected human enamel morphology producing porosities, depressions, increased depth of enamel grooves, and partial removal of enamel prisms. Sasaki *et al.* [45] observed that home-bleaching agents may lead to microalterations in the surface micromorphology of enamel with no alterations in microhardness. Ito and Momoi (2011) demonstrated, on SEM images, that the increase in enamel surface roughness, and erosion depth due to 30% hydrogen peroxide were smaller when the bleaching product was in addition with NaHCO₂. This could well be explained by the higher pH level resulted [46]. The reason for the lack of unanimity concerning the effects that bleaching agents have on the enamel may be due to a variety of factors such as the use of nonstandardized protocols in different studies, the origin of the enamel samples employed, the immediate remineralizing effect of saliva, and the pHs of the product employed. Also for the bleaching agent tested in our study, SEM images would be necessary, especially on *in vivo* samples. The lack of changes in sensed surface roughness is not per se a sufficient criterion to exclude any micromodifications of the enamel surface.

In our study, there were no significant differences in the PI and BOP scores between the test and control sides 2 weeks after treatment.

In conclusion, in this study – a preliminary case–control study with small sample size – the type of light activation of the tested bleaching product (a 38% hydrogen peroxide gel with calcium and strontium ions) does not seem to be essential for differential tooth color change. The type of light-activation technique, however, would seem important in determining the extent to which unwanted side effects, such as the onset of dentine sensitivity, can be reduced. Patients treated with the laser-activation technique reported no residual tooth sensitivity already after 2 weeks from treatment. As sensitivity is one of those side effects that, in extreme cases, can lead to physical and

psychological disability [47], the lack of sensitivity after bleaching treatment with laser activation represents a clear advantage for the patient who can return to his or her habitual social functioning in a short period of time.

Our preliminary results are worthy of additional investigations to better elucidate the effectiveness of these two different light-activation techniques and their side effects. Right now no definitive conclusion can be drawn.

Conflict of Interest

This is to state that there is no actual or potential conflict of interest including any financial, personal, or other relationships with other people or organizations that could have inappropriately influenced the results of the study.

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