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Clinical Research

Effects of Light Activation, Agent Concentration, and Tooth Thickness on Dental Sensitivity After Bleaching

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Clinical Relevance

Increases in the concentration of bleaching agents directly affect tooth sensitivity, and LED/laser activation and tooth thickness are not correlated with tooth sensitivity after dental bleaching.

SUMMARY

Examining three bleaching systems, this *in vivo* clinical trial evaluated the relationship among tooth sensitivity, light activation, and agent concentration, and it correlated dental sensitivity with tooth thickness.

Materials and Methods: Eighty-seven volunteer patients were included. Inclusion criteria were the presence of anterior teeth without restorations as well as the absence of a previous bleaching experience and absence of non-carious cervical lesions or dental pain. Exclusion criteria included pregnancy or breastfeeding, a maximum of TF3 hypoplasia, tetracycline-fluorosis stains, malpositioned teeth, orthodontic treatment, periodontal disease, and/or analgesic/anti-inflammatory intake. Patients were randomly assigned to

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three bleaching groups: Group A (n=25) was treated with 15% H_2O_2 and nitrogenous-titanium-dioxide and was light activated (Lase Peroxide Lite, DMC, SaoCarlos, Sao Paulo, Brazil); Group B (n=27) was treated with 35% H_2O_2 and was light activated (Lase Peroxide Sensy, DMC); and Group C (n=35) was treated with 35% H_2O_2 (White Gold Office, Dentsply, 38West Clark Ave., Milford, USA) without light activation. Tooth sensitivity (TS) was self-reported by the patients using the visual analog scale (VAS) at baseline (TS0), immediately after treatment (TSI), and at seven days after treatment (TS7). In 46 patients, tooth thickness was determined by computed tomography. TS0, TSI, and TS7 were compared between the A and B groups to determine the effect of concentration and between the B and C groups to determine the effect of light using analysis of covariance. The correlation between tooth thickness and TSI was determined by Spearman Rho test (SPSS 15).

Results: Eighty-seven patients were evaluated at baseline, and 61 were evaluated at seven days. Separated by groups, tooth sensitivity, expressed as VAS value at the time points TS0, TSI, and TS7, respectively, were as follows: Group A: 13.76 ± 13.53, 24.40 ± 25.24, and 5.94 ± 5.5; Group B: 15.07 ± 18.14, 42.4 ± 31.78, and 8.68 ± 17.99; and Group C: 10.80 ± 14.83, 31.51 ± 29.34, and 7.24 ± 9.2. Group A showed significantly lower tooth sensitivity than group B at TSI (p=0.032). No differences were observed in the tooth sensitivities between groups B and C. No correlation was encountered between tooth thickness and tooth sensitivity immediately after treatment (Rho=–0.088, p=0.563). The median tooth thickness was 2.78 ± 0.21 mm.

Conclusions: Increases in the concentration of bleaching agents directly affect tooth sensitivity, and LED/laser activation and tooth thickness are not correlated with tooth sensitivity after dental bleaching.

INTRODUCTION

Tooth appearance is an important factor in beauty and attractiveness, and patients often demand esthetic dental treatments. Tooth bleaching is one of the most conservative dental treatments that can improve or enhance the smile and has thus gained popularity in regular oral care.[1-3] Currently, tooth bleaching has been recognized as an efficacious and safe method with which to treat discolored teeth.[4]

Power bleaching reduces the total in-office time by energizing the bleaching agent using light sources, such as lasers or plasma arc light. The theoretical benefit lies in the light's ability to heat the hydrogen peroxide, increasing the rate of decomposition of oxygen to form oxygen-free radicals and enhancing the release of stain-containing compounds.[5] However, it has been observed that while light energy increases bleaching efficacy, it also increases the intrapulpal temperature.[6,7] Expert clinicians know the potential risk associated with tooth heating, and they need to consider the issue of pulp health before rendering this treatment on vital teeth.[8]

Tooth sensitivity is one of the most common side effects of bleaching treatment; this phenomenon directly depends on the bleaching agent concentration and the application time. Therefore, high-concentration agents used in in-office procedures usually generate discomfort.[9-13] Tooth sensitivity normally persists for up to four days after the conclusion of bleaching treatment,[14,15] but longer periods of sensitivity have been reported.[16,17]

In in-office dental bleaching, tooth sensitivity is directly associated with the bleaching agent's ability to reach the pulp chamber by penetrating through dental tissues and establishing contact directly with the pulp.[18,19] The amount of peroxide that can penetrate the pulp chamber may be affected by the thickness of the teeth.[20] A greater thickness would offer the pulp better protection from the bleaching agent.[21] Additionally, pulp penetration would be affected by the concentration of the bleaching agent, as low concentrations of peroxide would extend less deeply into the pulp chamber.[9,13]

The objective of this randomized controlled trial was to determine the relationship among tooth sensitivity, light activation, and agent concentration and to correlate dental sensitivity with tooth thickness in the application of three different bleaching systems.

MATERIALS AND METHODS

This study was approved by the Ethics Committee and Research Office of the Dental School, Chile University (protocol PRI-ODO-012-1).

Experimental Protocol

This prospective clinical study included 87 volunteer patients (64 female and 23 male), aged 18 through 37 years, attending the Operative Dentistry Clinic at

the Dental School, Chile University. The inclusion criteria were the following: 1) anterior healthy vital teeth without restorations; 2) patients without bleaching experience; 3) lack of noncarious cervical lesions; and 4) lack of dental pain. The exclusion criteria were the following: 1) pregnancy or breast-feeding, 2) greater than TF3 hypoplasia (Thylstrup-Fejerskov), 3) tetracycline/fluorosis stains, 4) malpositioned teeth, 5) orthodontic treatment, 6) periodontal disease, and 7) analgesic/anti-inflammatory intake. After informed consent was obtained, patients were coded and randomly assigned to one of the three bleaching groups (EF-OO), performed by power analysis and a sample size system with PASS software, version 2004 (Keysville, UT, USA) (clinicians K.E., D.S., and M.C.).

Group A (n=25) contained patients that were treated with 15% H_2O_2 and nitrogenous-titanium-dioxide (prepared according to the manufacturer's instructions) and were light activated (light activation involved six LEDs composed of 470 nm and 1800 mW as well as three infrared laser diodes of 830 nm and 450 mW/cm^2; Whitening Lase II equipment, DMC, Rua Sebastiao Moraes 831, Sao Carlos, Sao Paulo, Brazil). Three 15-minute applications of the bleaching agent were performed via alternating cycles of one minute and 30 seconds, completing five cycles of light activation per arch, reaching a total treatment time of 45 minutes.

Group B (n=27) contained patients treated with 35% H_2O_2 and then light activated (Lase Peroxide Sensy, DMC), according to the manufacturer's instructions. They were treated with three 10-minute applications of bleaching agent. Each application included 60% irradiation time, with a total treatment time of 30 minutes.

Group C (n=35) contained patients treated with 35% H_2O_2 (White Gold Office, Dentsply, 38West Clarke Ave., Milford, USA) for 45 minutes without light activation. The bleaching agent was prepared according to the manufacturer's instructions.

All teeth were cleansed with soft brushes at low speed using fine pumice powder and water. Teeth and gum tissues were dried with air (triple syringe, 25 psi). The gingiva was protected with a gum barrier (Lase Protect, DMC) and was photo-polymerized for 30 seconds with Whitening Lase II equipment (DMC).

Tooth Sensitivity (TS) Determination

TS or discomfort caused by the bleaching treatment was self-assessed with the use of the Visual Analog Scale (VAS), in which the patient quantified his painful response by making a mark in a 100-mm–long line that was anchored by word descriptors at each end: "no pain" at the left end and "very severe pain" at the right end. The patient marked the point on the line that he felt represented his perception of the pain. Patients were questioned: "How severe is your pain today? Place a vertical mark on the line below to indicate how bad you feel your pain is today."The VAS score was determined by measuring in millimeters from the left-hand end of the line to the point that the patient marked.[22,23]

TS was measured only for the central upper incisors and was acquired by one clinician (J.M.) at three time points: at baseline (TS0), immediately after treatment (TSI), and seven days after treatment (TS7).

Tooth Thickness Determination

In 46 patients, tooth thickness was determined by cone beam computed tomography (CBCT) (MyRay Dental Imaging, Via Bicocca 14/c 40026, Imola, Italy), with the following specifications: FOV 4 inches, 15.7 seconds, 90 kVp, 10 mA (max), 50.8 uSv per exam, high resolution, in volume slices of 0.5-mm thickness. The scanner was requested for other clinical reasons (orthodontics, implants, third molar surgery, or temporomandibular joint). The tooth thickness was determined directly on the screen with the use of a bidimensional tool measurement in the Skyview software (MyRay Viewer 3D). One radiologist (J.E.) acquired three measurements made at the center of the labial dental surface in the buccal-palatal axis using a reformatted image of each tooth (Figures 1–3). To reduce bias, the clinician who evaluated tooth thickness was not aware of which group the patients belonged to in the study.

Data Analysis

After verifying the normality of the data distribution and the homogeneity of variances (Levine test), the tooth sensitivity was compared in each group three times using a one-way analysis of variance and *post hoc* Tukey tests. To determine the effect of the bleaching agents' concentration on tooth sensitivity, groups A and B were compared; to determine the effect of light on tooth sensitivity, groups B and C were compared, both using the analysis of covariance (ANCOVA) test. Tooth thickness was correlated with tooth sensitivity, immediately and after seven days of treatment, with the Spearman Rho test. In all tests, the level of significance was set at $\alpha = 0.05$, and calculations were performed using the SPSS 15.0 software package (SPSS Inc, Chicago, IL, USA). (VB-GM Statistics)

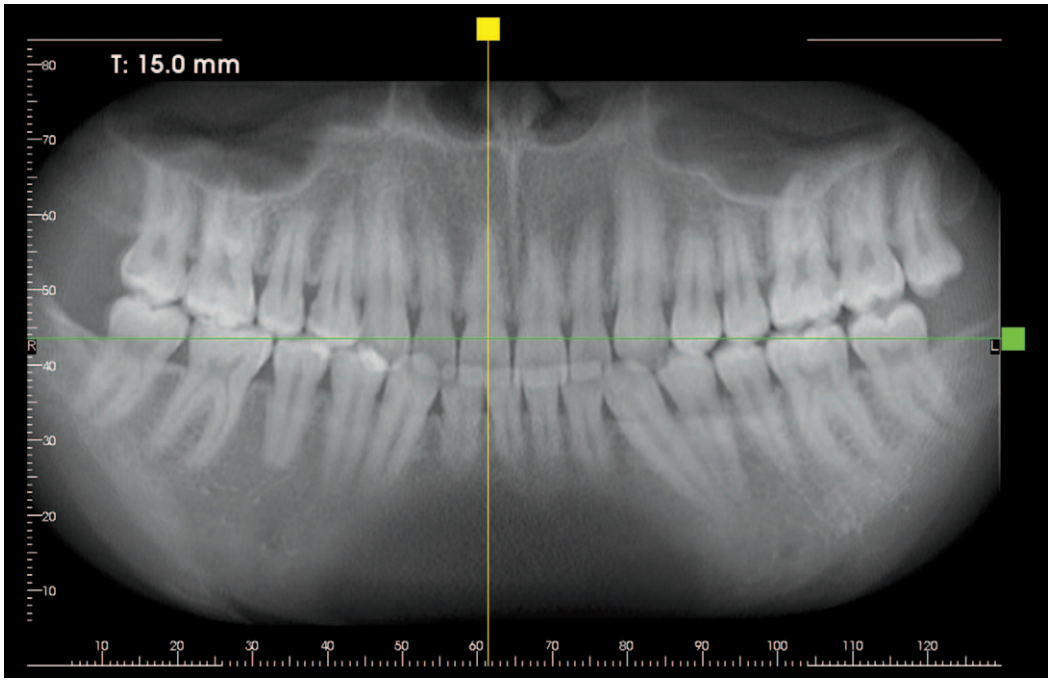

Figure 1. *Reformatted panoramic image of 15-mm depth. The vertical line is the reference used for sagittal slices related to the major axis of the dental crown. This line was located in the center of the crown and determined the location of the measurement made in the sagittal plane.*

RESULTS

Eighty-seven patients (median age, 23.15 ± 3.68 years) were evaluated at baseline and immediately after bleaching, and 61 patients (median age, 23.25 ± 3.54 years) were evaluated seven days after treatment. Most of the patients were female and fell in the range of 18-27 years of age (Tables 1 and 2). Gender did not affect tooth sensitivity initially

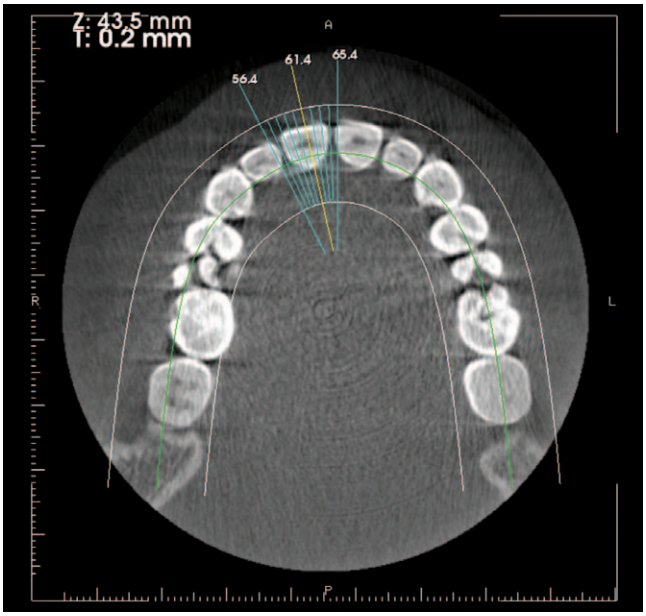

Figure 2. *Axial reformatted image. The yellow line crosses the center in the sagittal plane, perpendicular to the major axis of the tooth crown. This was used to build a sagittal reformatted image, and the curve of the dental arch (green line) was used as a reference.*

Figure 3. *Sagittal reformatted slice of 0.5-mm depth, made in the center of the crown (right central incisor). Lines A, B, and C show the measures of the tooth thickness on the labial face of each tooth.*

Table 1: *Distribution by Age and Gender at Baseline and Immediately After Treatment*

		Male		Female		18-27 Years		28-37 Years	
	N	N	%	N	%	N	%	N	%
Group A	25	6	24.00	19	76.00	23	92.00	2	8.00
Group B	27	7	25.93	20	74.07	24	88.89	3	11.11
Group C	35	10	28.57	25	71.43	31	88.57	4	11.43
Total	87	23	26.43	64	73.56	78	89.65	9	10.34

(p=0.67), either immediately after treatment (p=0.126) or seven days after treatment (p=0.313). At baseline the tooth sensitivities of the groups were compared and did not show statistical differences (p=0.449 between groups A and B; p=0.726 between groups B and C, by ANCOVA test).

All tested bleaching systems generated tooth sensitivity immediately after treatment and returned to baseline levels seven days after treatment. This increase was statistically significant for groups B and C ($p<0.05$) but not for group A (p=0.247) (Tables 3 and 4).

Bleaching with 15% hydrogen peroxide and TiO_2 with LED/laser activation resulted in significantly lower tooth sensitivity relative to bleaching with 35% hydrogen peroxide and LED/laser activation immediately after treatment (p=0.032). Differences in the bleaching concentration did not result in tooth sensitivity differences after seven days (p=0.644) (Table 3).

In groups B and C, a significant increase in tooth sensitivity was observed immediately after treatment (p=0.001 and p=0.002, respectively). After seven days, both groups returned to baseline tooth sensitivity. No differences were observed to be associated with the use of light activation, as both groups failed to exhibit a statistically significant discrepancy in tooth sensitivity immediately after treatment (p=0.191) or seven days after treatment (p=0.921) (Table 4).

The CT analyses were performed on 46 patients (92 teeth), and they revealed a median labial tooth thickness of 2.78 ± 0.21 mm (Figures 1 through 3). No correlation was observed between tooth thickness and tooth sensitivity immediately after treatment (Rho=–0.138, p=0.36) or after seven days (Rho=–0.202, p=0.25).

The 46 patients examined by cone beam CT were distributed by groups as follows: group A: n = 10; group B: n = 10; and group C: n = 26. Correlation between tooth sensitivity and tooth thickness, separated by groups, was not statistically significant in Group A or B, and showed low correlation in Group C (Spearman test) (Table 5).

Table 2: *Distribution of Age and Gender at Seven Days After Treatment*

		Male		Female		18-27 Years		28-37 Years	
	N	N	%	N	%	N	%	N	%
Group A	18	4	22.22	14	77.78	17	94.44	1	5.56
Group B	22	6	27.27	16	72.73	20	90.91	2	9.09
Group C	21	6	28.57	15	71.43	18	85.71	3	14.29
Total	61	16	26.22	45	73.77	55	90.16	6	9.83

Table 3: *Mean tooth Sensitivity of Groups A and B at Baseline, Immediately After Treatment, and Seven Days After Treatment, Compared at Different Stages of Evaluation and Between Groups*

	Initial VAS Value ±SD	Immediate VAS Value ±SD	7-d VAS Value ±SD	*p*-Value Initial/ Immediate	*p*-Value Initial/7 d	*p*-Value Immediate/7 d
Group A	13.76 ± 13.53	24.40 ± 25.23	5.94 ± 5.50	0.247	0.062	0.029
Group B	15.07 ± 18.14	42.40 ± 31.78	8.68 ± 17.99	0.001	0.056	0.000
p-Value between groups	0.449	0.032	0.644	—	—	—

Abbreviations: VAS, visual analog scale; SD, standard deviation.

DISCUSSION

In the present study, all in-office bleaching systems showed an increase in tooth sensitivity immediately after treatment. However, the sensitivity returned to baseline levels seven days after treatment, sometimes reaching a level even lower than baseline. Sensitivity often occurs during the early stages of tooth bleaching, and for most patients, it is tolerable to complete the treatment.[24] Salem and Osman[15] reported that tooth sensitivity was a temporary side effect that disappears after four days of treatment in most patients. The fact that sensitivity reached levels lower than baseline seven days after treatment was also observed by Trowbridge and Silver,[25] who stated that this phenomenon can be explained by a positive emotional predisposition that may activate the central nervous system's pain inhibitor, causing the release of endorphins and decreasing painful sensations.

In our study, a high standard deviation of tooth sensitivity values was observed. Tooth sensitivity is caused by the passage of hydrogen peroxide molecules through the enamel and dentin into the pulp chamber.[26] This results in pulp inflammation, which affects the pulp sensory nerves that can trigger increased response to stimuli, such as cold drinks, until the inflammation subsides.[27] Therefore, tooth sensitivity may vary with the different factors that affect this passage into the pulp, such as presence of dental cracks, dentin exposure, or pulp chamber dimensions. Additionally, the high standard deviation of sensitivity could be due to the subjective nature of the sensitivity threshold and/or because sensitivity is not dependable and is not associated with the use of a particular bleaching system.[28] Based on the high standard deviation of postoperative tooth sensitivity that was observed in this and other studies,[27-31] it is difficult to obtain an accurate measurement of problems in the population,[32] and clinicians have a limited ability to predict the tooth sensitivity that may affect each patient. Additionally, because of this complex etiology, a definitive strategy for sensitivity prevention has not yet been developed.[28]

Clinically, tooth sensitivity is the most common side effect of bleaching; thus, this treatment is not adequate for every patient.[24] A complete clinical history is necessary to recognize any previous abnormal responses to temperature changes or other stimuli.[29] In the current study, no patients present-

Table 4: *Mean tooth Sensitivity of Groups B and C at Baseline, Immediately After Treatment, and Seven Days After Treatment, Compared at Different Stages of Evaluation and Between Groups*

	Initial VAS Value ±SD	Immediate VAS Value ±SD	7-d VAS Value ±SD	*p*-Value Initial/ Immediate	*p*-Value Initial/7 d	*p*-Value Immediate/7 d
Group B	15.07 ± 18.14	42.40 ± 31.78	8.68 ± 17.99	0.001	0.560	0.000
Group C	10.80 ± 14.83	31.51 ± 29.34	7.23 ± 9.20	0.002	0.433	0.001
p-Value between groups	0.726	0.191	0.921	—	—	—

Abbreviations: VAS, visual analog scale; SD, standard deviation.

Table 5: *Correlation Between Tooth Sensitivity and Tooth Thickness, Separated by Groups, (Spearman Test)*

	p	Rho
Group A	0.906	−0.43
Group B	0.067	0.60
Group C	0.040*	−0.405

* Statistically significant (α=0.05).

ed with irreversible tooth sensitivity, and tooth bleaching is a safe treatment when the dental history of the patient is considered. Thus far, there are no reported cases of pulp necrosis caused by tooth bleaching[24] or of long-term adverse pulp sequelae when the proper techniques are employed.[3] However, teeth with caries or exposed dentin, teeth with surfaces in close proximity to pulp horns, or those that are suspected to have cracks are potentially at risk for developing severe sensitivity and thus are not recommended for bleaching.[24] In such cases, the use of an ambulatory bleaching system, which depends on the use of carbamide peroxide, may be considered.[29]

When comparing the tooth sensitivity that was developed in the group treated with 15% hydrogen peroxide with that of the group treated with 35% hydrogen peroxide, when both were light activated, a lesser concentration of bleaching agent resulted in less sensitivity immediately after treatment (p=0.03). This finding is in agreement with the findings of Benetti and others[13] and Gokay and others,[9] who concluded that increasing peroxide concentrations would affect tooth sensitivity. This result indicates that agents with low concentrations will be more favorably accepted by patients; therefore, these agents may be used in every patient, even in those at risk of developing severe sensitivity.

When comparing groups treated with 35% hydrogen peroxide with and without light activation, no differences in tooth sensitivity were observed. It has been proposed that lasers may decrease tooth sensitivity,[33,34] but high-intensity LEDs included in the lamp may raise the temperature,[35,36] neutralizing this beneficial effect. Different light sources have been applied in dental whitening. Utilizing light sources in in-office dental bleaching with 35% hydrogen peroxide, on vital teeth, did not prove to be more effective. Light is not important in clinical results; it apparently affects only the treatment time and differences in color stability were not found through six months of evaluation.[37]

Even though there were differences observed in tooth sensitivity between agents with different concentrations, the fact that all patients presented with this side effect cannot be ignored. Evidence indicates that the initial diffusion of peroxide into and through the enamel may reach the dentino-enamel junction and dentin regions. Indeed, *in vitro* experiments by a number of authors[38-42] have demonstrated the penetration of low levels of peroxide into the pulp chamber of extracted teeth after exposure times of 15 to 30 minutes, with intact teeth showing less penetration of peroxide than restored teeth. In our study, the total treatment time per appointment was 45 minutes for groups A and C and 30 minutes for group B. This finding likely indicates that in all patients, the peroxide reached the pulp chamber, explaining the increase in tooth sensitivity observed in all studied groups. The clinically reversible effects of tooth sensitivity have been histologically studied by Fugaro and others[43] in other types of treatment, including bleaching with 10% carbamide peroxide. These authors observed that peroxide might initially cause mild, localized pulp reactions. However, the slight histological changes that were observed did not affect the overall health of the pulp tissue and were reversible within two weeks of the conclusion of treatment.

Finally, no correlation between tooth thickness and tooth sensitivity was found, either immediately after treatment or after seven days. In recent years, CBCT has been demonstrated to be one of the most accurate methods for the study of hard tissue in dentistry. CBCT is used for numerous clinical applications, especially because of its low cost, easy accessibility, and low radiation compared with multi-slice computerized tomography.[44] The measurements obtained by CBCT technology have proven to be accurate and concordant with physical measurements.[45-50] The present observations on the relationship between dental bleaching and dental thickness offer the first available conclusions on this topic. The present study found that labial tooth thickness was not related to tooth sensitivity in bleaching treatments. Labial tooth thickness showed high uniformity and low standard deviation, and these results could be associated with the average age of the participants and the characteristics of the sample, as the sample was comprised of young adults without cavities or restorations who

had esthetically aligned anterior teeth, without a loss of molars or premolars.

The patients in group C studied by CBCT were the only patients who showed a moderate degree of statistically significant correlation between tooth sensitivity and tooth thickness; however, caution must be used in interpreting this result, given the low number of samples by group.

For tooth sensitivity and thickness of the 46 patients examined by CBCT, the 12 younger (18-20 years) and the 12 oldest (25-37 years) were compared and differences in sensitivity between groups immediately (p=0.124) or seven days after treatment (p=0.391) were not found, also differences in tooth thickness (p=0.311) were not found. No correlation was found between age groups and sensitivity immediately (p=0.933) and seven days after treatment (p=0.209).

Although this study did not identify a correlation between tooth thickness and sensitivity, De Souza Costa and others[51] histologically observed the presence of differences in the inflammatory pulpal response to bleaching when comparing upper premolars with lower incisors.

CONCLUSIONS

Increases in the concentration of bleaching agents also increases tooth sensitivity immediately after treatment. After seven days of treatment, tooth sensitivity returned to baseline for both concentrations tested. The light activation of bleaching agents did not affect dental sensitivity. No correlation between tooth thickness and dental sensitivity was found immediately after treatment.

The present study provided additional clinical information related to the risks of tooth pain after bleaching, and the results aid in determining the optimal bleaching agent concentration and light source to enhance these treatments.

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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