

Color Regression and Maintenance Effect of Intracoronal Whitening on the Quality of Life: RCT—A One-year Follow-up Study

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Clinical Relevance

The color of teeth whitened internally remains stable at one year of follow-up; tooth whitening also has a positive effect in terms of psychosocial impact.

SUMMARY

Objective: This randomized clinical study evaluated two parameters: 1) the clinical color rebound of whitening patients' tooth discoloration using the walking bleaching technique and 2) the impact on psychological and aesthetic self-perception at the one-year follow-up of patients who underwent bleaching of nonvital teeth.

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Methods and Materials: Fifty study participants with nonvital tooth discoloration were recruited. Teeth were assigned randomly into one of two groups: 1) 35% hydrogen peroxide (n=25) and 2) 37% carbamide peroxide (n=25). Intracoronal bleaching was carried out over the course of four sessions using the walking bleach technique. Tooth color was evaluated after each session in order to measure the total color variation (ΔE). The guide was arranged from highest (B1) to lowest values (C4) for evaluating color, and color changes using Vita Classical Shade ($\Delta SGUs$) units were calculated. Subjective and objective assessments were compared with the counterpart of the tooth. Aesthetic perception and psychosocial factors were evaluated before and after treatment by the Oral Health Impact Profile (OHIP) and Psychological Impact of Dental Impact Questionnaire (PIDAQ) surveys.

Results: Color changes (ΔE) were 15.48 ± 5.17 and 14.02 ± 4.85 for carbamide and hydrogen peroxide groups, respectively. There were no significant differences ($p > 0.05$) between these two groups at the one-year follow-up. There was a decrease in the PIDAQ scores after treatment compared to baseline values

($p < 0.05$). The majority of OHIP values regressed to baseline values.

Conclusion: The technique of walking bleaching was highly effective and showed minimal color rebound in nonvital teeth and had a positive effect on patients' psychological impact at the one-year follow-up.

INTRODUCTION

In some cultures of the world, tooth color is one of the most important factors in the achievement of a smile that is aesthetically pleasing.¹ It also has a substantial impact on a person's aesthetic and psychosocial perceptions.² Thus, when a single tooth doesn't match the other teeth, the negative effects can be more pronounced because a situation more visible to social scrutiny exists.³ However, there is no information on the incidence of intracoronal color effects and maintenance on a patient's self-perception or on the psychosocial impact to the patient.⁴ Some authors⁵ have shown that alterations in aesthetic dentistry can cause psychosocial consequences that could have more impact on the person who has problems caused by dental caries lesions. Intracoronal whitening is a widely used, minimally invasive alternative treatment/technique to solve discoloration (dark teeth) of nonvital teeth. Although there are several reports in the literature about external combined with internal bleaching, the main effects are seen within the pulp chamber of a tooth that has been endodontically treated and well sealed.⁶

Possible etiologies of tooth discoloration include 1) history of dental trauma with intrapulpal hemorrhage and posterior pulpal tissue necrosis and 2) transfer of metal ions into the dentin substrate of a previous or combined restoration.⁷ The first condition occurs when hemolysis of red blood cells releases iron ions, subsequently forming ferric sulfate, which produces a dark color. The second clinical situation occurs when metal ions penetrate the dentin substrate, causing discoloration of the tooth stump preparation. The first condition has a more favorable prognosis for bleaching, whereas the second does not; thus, consideration of the patient's medical history is very relevant before internal bleaching is undertaken. The recurrence of internal bleaching is much more frequent and damaging and has rarely been studied.⁸

Prospective studies that objectively measure color stability and rebound after intracoronal bleaching and maintenance of the effect on the quality of a patient's life are not available in the literature.

The main objective of this study was to evaluate the following two parameters: 1) color rebound in patients who have undergone bleaching of nonvital teeth with 35% hydrogen peroxide or 37% carbamide peroxide gels using the walking bleaching technique and 2) the impact on aesthetic self-perception and psychosocial impact in this cohort of patients.

The null hypothesis of this article was that there are no differences in the rebound between nonvital bleached teeth treated with either 35% hydrogen peroxide or 37% carbamide peroxide. The second null hypothesis was that there is no impact on aesthetic self-perception and psychosocial impact at the one-year follow-up in patients who have undergone intracoronal bleaching.

METHODS AND MATERIALS

This randomized trial was approved by the ethics committee of the faculty of dentistry of the local university (2016/04) and was carried out according to the standards of consolidated reporting trials⁹ and the Declaration of Helsinki (2002) (1975, revised in 2000).

Study Design

This trial was a randomized, double-blind (patient and evaluator) study. The study groups were selected randomly using Excel 2013 software (Microsoft, Seattle, WA, USA). Patients were recruited through fliers within the local faculty of dentistry and social networks such as Facebook and Twitter.

Sample Size

The sample size was determined using GPower 3.1 software with a significance level of 5%, statistical power of 90%, and a decrease of 25% based on previous studies.¹⁰⁻¹² This study corresponded to a type of therapeutic equivalence, in which a color variation in color tone changes (ΔE) in the range of ≥ 7 to 10, based on effectiveness measurements and necessity of matching the homologous tooth color according to a previous pilot study, was considered significant. This indicated a sample size of 20, and to compensate for the rate of study withdrawal reported in previous studies, a sample size of 25 per group was used.

Entry Criteria

A total of 74 patients were examined in order to assess whether they met the criteria for study inclusion (Figure 1). Inclusion criteria consisted of several parameters: 1) patients >18 years; 2) patients having one or more discolored nonvital

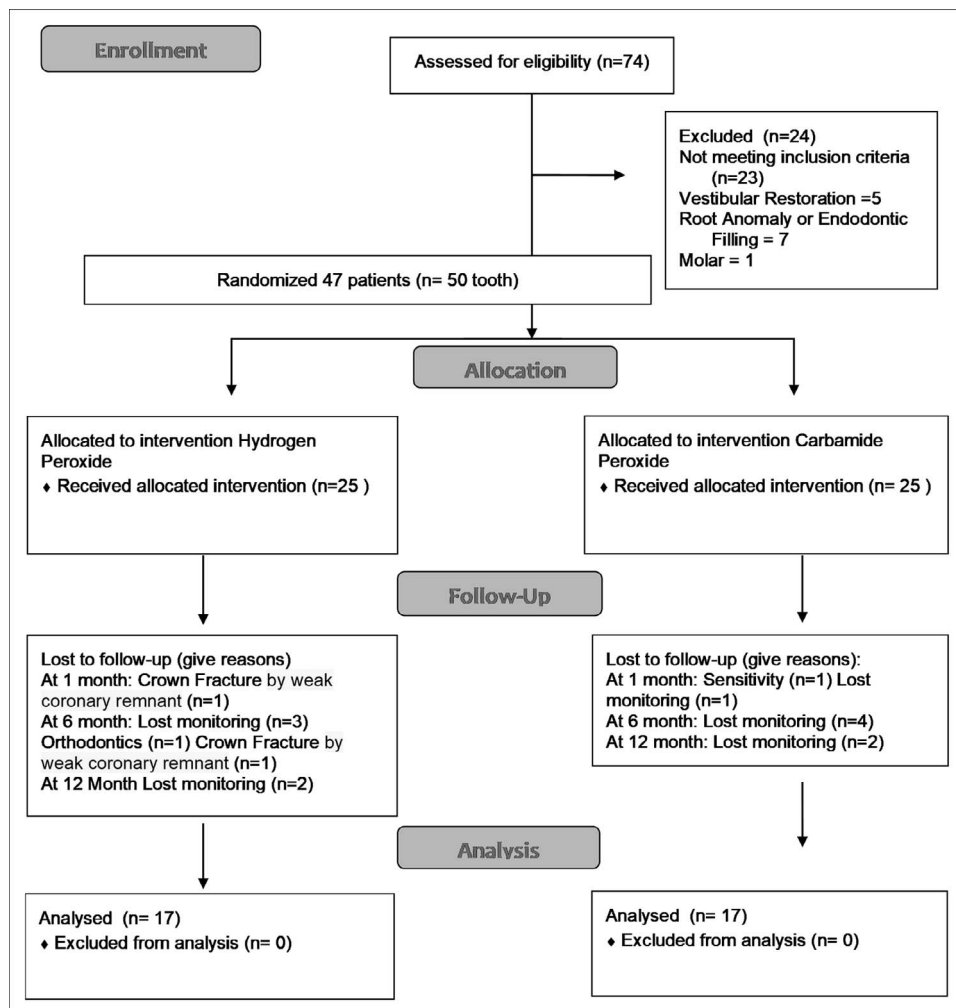


Figure 1. Flow chart of the clinical trial, including detailed information on included and excluded participants.

teeth; 3) patients whose restorations did not include vestibular surfaces; 4) patients with root canal treatment in good condition with no apical lesions; 5) patients with no previous tooth whitening; and 6) patients with a tooth tone of $\geq A2$ according to the Classic Vita Scale. Exclusion criteria consisted of several parameters: 1) pregnant or breastfeeding patients; 2) patients with enamel hypoplasia; 3) patients with teeth stained by tetracycline; 4) patients with fluorosis or previous metallic restorations related to tooth discoloration; 5) patients receiving fixed orthodontic devices; 6) patients with cancer; and 7) patients with periodontal pathologies. Patients with clinical or radiographic caries, peri-apical lesions, resorption of internal or external tooth structure, or those with periodontal disease were excluded. These patients were referred to specialized treatment clinics.

Patients meeting the inclusion criteria were randomized into two groups of 25 each according to

Table 1: *Participants' Baseline Characteristics*

Baseline Features	Groups	
	1 = Hydrogen Peroxide	2 = Carbamide Peroxide
Age, y; mean \pm SD	30.47 \pm 11.71	30.82 \pm 12.14
Minimum age, y	19	20
Maximum age, y	65	65
Male, %	29.4	29.4
Trauma, %	52.9	47.1
Caries, %	41.67	60.87
SGU baseline median (min;max) Vita Classic	15 (7;16)	12 (7;16)
L*, mean \pm SD	71.88 \pm 9.00	76.65 \pm 6.78
a*, mean \pm SD	4.74 \pm 3.44	4.45 \pm 3.70
b*, mean \pm SD	29.78 \pm 3.63	31.85 \pm 7.04

Abbreviation: SD, standard deviation.

Table 2: Values of ΔE Expressed as Mean and Standard Deviation

Evaluation Times	Color Change by ΔE		Mann-Whitney
	G1 = Hydrogen Peroxide	G2 = Carbamide Peroxide	
Baseline vs immediate subsequent bleaching	Peroxide	13.03 ± 3.90	0.020
Baseline vs 1 wk after bleaching (before restoration)	16.64 ± 6.85	14.26 ± 4.49	0.344
Baseline vs 1 wk after bleaching (after restoration)	16.77 ± 6.30	13.76 ± 4.63	0.163
Baseline vs 1 mo after bleaching	15.64 ± 4.76	13.83 ± 4.75	0.459
Baseline vs 6 mo after bleaching	14.93 ± 5.56	12.51 ± 4.83	0.395
Baseline vs 12 mo after bleaching	15.11 ± 5.59	13.17 ± 5.13	0.399

Abbreviation: ΔE, total color variation.

bleaching agent: Group 1 (G1) - teeth bleached with 35% hydrogen peroxide (Opalescence Endo, Ultradent, United States) and Group (G2) - teeth bleached with 37% carbamide peroxide (Whiteness Superendo, FGM, Joinville, SC, Brazil). Bleaching agents were applied according to the manufacturers' instructions in four weekly sessions using an ambulatory technique (walking bleach).

Preparation Session—The canal was prepared under absolute isolation, removing 3 mm of the endodontic filling from the cemento-enamel junction in the apical direction. To protect the endodontic treatment, a 2 mm seal made with a resin-reinforced glass ionomer (Riva light cure, SDI, Australia) was applied and cured for 60 seconds at a distance of approximately 1 cm (1200-mW/cm², Cal Raddi, SDI, AU). Due to the distribution of dentin tubules in the cervical area of the tooth, the coronal limit of the seal was 1 mm below the cemento-enamel junction to guarantee whitening. To confirm the proper sealing of the endodontic treatment, a radiographic control was made.

Four Tooth Whitening Sessions—Application of the whitening agent was conducted according to the manufacturers' instructions. The correct amount of whitening gel was placed in the cavity pulp chamber in the presence of mild moisture (walking bleach technique). The cavity closure was made with

temporary cement (Fermin, Detax, Germany) until the next session, which occurred seven days later. This procedure was repeated in each of the sessions for up to four weeks. The same amount of gel was used at each session.

Final Session—After washing the cavity access with abundant water, a temporary restoration was inserted for seven days and then the final restoration with composite resin was done. Patients were warned not to eat or drink any foods, including coffee, tea, or wine, that might stain their teeth during the study period. Patients were given instructions in writing and provided with contact information if they had any questions or experienced any adverse events.

Evaluation of Color

Objective Assessments—Two calibrated evaluators (Kappa=0.87) measured the tooth color at baseline and at one week, one month, six months, and 12 months after the bleaching. Evaluation of the color was obtained from a 6-mm area in the middle third of the labial surface of the left and right central incisors. To standardize this evaluation, an impression of the maxillary arch was taken to make a guide with silicone putty (Zetaplus Zhermack, Badia Polesine, Rovigo, Italy). A well-formed window was created on the labial surface in the middle third of

Table 3: Comparison of ΔSGU Values at Different Timepoints Using the Vita Classic Scale [Median (Minimum:Maximum)]

Assessment Points	Color Change by ΔSGU		Mann-Whitney Test
	G1 = Hydrogen Peroxide	G2 = Carbamide Peroxide	
Baseline vs immediate subsequent bleaching	10 (1;15)	7 (3;14)	0.064
Baseline vs 1 wk before bleaching (before restoration)	10 (-1;14)	7 (2;13)	0.115
Baseline vs 1 wk after bleaching (after restoration)	9 (1;14)	7 (2;13)	0.072
Baseline vs 1 mo after bleaching	9 (1;13)	7 (1;13)	0.151
Baseline vs 6 mo after bleaching	9 (1;13)	7 (1;13)	0.151
Baseline vs 12 mo after bleaching	8 (1;13)	7 (1;13)	0.205

Abbreviation: ΔSGU, Vita Classical Shade unit.

Table 4: Comparison of ΔSGU Values at Different Timepoints Using the Vita Bleach Guide [Median (Minimum:Maximum)]

Assessment Points	Color Change by ΔSGU		
	G1 = Hydrogen Peroxide	G2 = Carbamide Peroxide	Mann-Whitney Test
Baseline vs immediate subsequent bleaching	6 (1;9)	4 (3;8)	0.053
Baseline vs 1 wk before bleaching (before restoration)	6 (1;10)	4 (3;7)	0.005
Baseline vs 1 wk after bleaching (after restoration)	6 (1;10)	4 (3;7)	0.005
Baseline vs 1 mo after bleaching	5 (1;9)	4 (2;7)	0.038
Baseline vs 6 mo after bleaching	5 (0;8)	5 (0;7)	0.833
Baseline vs 12 mo after bleaching	5 (0;7)	4 (0;7)	0.736

Abbreviation: ΔSGU, Vita Classical Shade unit.

the central incisor with a radius of 3 mm, which corresponded to the space for the spectrophotometer’s reflectance nozzle (Vita EasyShade Compact, VITA Zahnfabrik, Bad Säckingen, Germany); this device showed high reliability. The color assessed was determined using the obtained parameters L*, a*, and b*. Color alterations after each session were indicated by the differences (ΔE) between the session and baseline values. ΔE was calculated using the following formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

Subjective Evaluation—For the subjective evaluation, 16 (Classic Vita, Vita Zahnfabrik) guide sheets were available—ranging from the highest (B1) to a lowest value (C4)—and a Bleachedguide 3D-MAS-TER Vita Zahnfabrik guide was used; these items were used to evaluate the color. Two calibrated

raters (Kappa=0.85) recorded the upper left and right central incisor shadows at baseline and throughout the study at different assessment points. The researchers checked the color in the middle third of the labial surface of the anterior central incisor following the guidelines of the American Dental Association. Color changes from the beginning of the active phase through different study timepoints were calculated using the change in the number of shade units (ΔSGUs).

Evaluation of Quality of Life

Oral Health Impact Profile Questionnaire—Quality of life was measured using the Oral Health Impact Profile (OHIP)—an aesthetics questionnaire that was validated by the Spanish oral health impact profile.¹³ The questionnaire was administered by a researcher at the beginning of the study and then at

Table 5: Comparison of SGU Values at Different Timepoints Using the Vita Classic Scale [Median (Minimum;Maximum)]

Assessment Times	Color Change by SGU	
	G1 = Hydrogen Peroxide	G2 = Carbamide Peroxide
Homologous teeth	5 (1;9)	3 (2;10)
Baseline	15 (7;16) ^a	12 (7;16) ^a
Immediate subsequent bleaching	4 (1;12) ^b	5 (1;12) ^b
1 wk after bleaching (after restoration)	5 (1;13) ^b	3 (1;14) ^b
1 wk after bleaching (before restoration)	5 (1;12) ^b	4 (1;14) ^b
Baseline vs 1 mo after bleaching	5 (1;12) ^b	4 (1;14) ^b
Baseline vs 6 mo after bleaching	5 (1;12) ^b	4 (1;14) ^b
Baseline vs 12 mo after bleaching	5 (1;13) ^b	5 (1;14) ^b

Abbreviation: SGU, Vita Classical Shade.
^a Statistically significant difference intragroup (Wilcoxon test, p<0.05) vs homologous teeth.
^b Statistically significant difference intragroup (Wilcoxon test, p<0.05) vs baseline.

Table 6: Comparison of SGU Values at Different Timepoints Using the Vita Bleach Guide [Median (Minimum:Maximum)]

Assessment Times	Color Change by SGU	
	G1 = Hydrogen Peroxide	G2 = Carbamide Peroxide
Homologous teeth	7 (3;11)	7 (5;9)
Baseline	12 (7;15) ^a	11 (9;15) ^a
Immediate subsequent bleaching	5 (2;12) ^b	7 (4;11) ^b
1 wk after bleaching (after restoration)	5 (3;9) ^b	7 (5;10) ^b
1 wk after bleaching (before restoration)	6 (1;10) ^b	7 (5;10) ^b
1 mo after bleaching	7 (3;12) ^b	7 (5;10) ^b
6 mo after bleaching	7 (1;11) ^b	6 (4;11) ^b
12 mo after bleaching	8 (3;12) ^b	7 (5;11) ^b

Abbreviation: SGU, Vita Classical Shade.
^a Statistically significant difference intragroup (Mann-Whitney test, p<0.05) vs homologous teeth.
^b Statistically significant difference intragroup (Wilcoxon test, p<0.05) vs baseline.

Table 7: PIDAQ. Values of Factors Expressed as Median (Minimum/Maximum) at Different Timepoints[†]

Dimension	G1	Baseline G2	Mann-Whitney	G1	Postbleaching G2	Mann-Whitney	G1	1 mo After Bleaching G2	Mann-Whitney
Dental self-confidence	17 (6:26)	15 (12:26)	0.773	21 (11:30) a	22.5 (12:30) a	0.793	22 (10:30) a	21.5 (6:29) a	0.948
Social impact	24 (8:40)	23 (8:34)	0.845	17 (8:31) a	16 (8:26) a	0.547	12 (8:31) a	17 (8:32) a	0.415
Psychological impact	18 (8:26)	17 (6:24)	0.295	13 (6:24) a	14.5 (6:21)	0.714	12 (6:24) a	14 (6:24)	0.734
Aesthetic concern	9 (3:14)	9 (3:14)	0.607	6 (3:12) a	4.5 (3:12) a	0.099	4 (3:12) ab	6 (3:12) ab	0.227

Abbreviation: PIDAQ, Psychological Impact of Dental Impact Questionnaire.
[†] a = Statistically Significant Difference (Wilcoxon Test, p<0.05) vs Baseline; b = Statistically Significant Difference (Wilcoxon Test, p<0.05) vs One Week After Bleaching (ext.)

one week, one month, six months, and one year after whitening.

Dental Aesthetics Psychosocial Impact Questionnaire—The psychosocial aspect of dental aesthetics (PIDAQ)¹⁴ impact questionnaire consisted of 23 items grouped into four components using factor analyses: 1) dental self-esteem, 2) social impact; 3) psychosocial impact; and 4) aesthetic concerns.¹⁵ The PIDAQ was applied in a manner similar to the OHIP-Aesthetics scale.

Statistical Analysis—After checking the normality of the data distribution and the homogeneity of the variance-covariance matrix, we evaluated the treatment efficacy with respect to color alterations (ΔE and ΔSGU) and analyzed the results using the Wilcoxon test for comparisons within the group and the Mann-Whitney for comparisons between groups. Statistical analyses were performed using SPSS (SPSS Inc, Chicago, IL, USA) 23.0, with $\alpha = 0.05$.

The Wilcoxon test was used for comparison of results of the OHIP-Aesthetics and PIDAQ questionnaires.

RESULTS

Participants' characteristics are shown in Table 1. Tooth distribution (G1=12 upper central incisors; four upper lateral incisors, and one lower central incisor; G2=13 upper central incisors and four upper lateral incisors) at one-year follow-up. There were no statistically significant differences between the characteristics of participants in the groups (Mann-Whitney test, $p > 0.05$.) ΔE is shown in Table 2. Efficacy was similar at all times except at immediate subsequent measurement ($p < 0.05$). These two groups showed high efficiency, with an average ΔE of > 13 units. A slight rebound was similar to one-month follow-up values.

Results for ΔSGU differed over time, as shown in Tables 3 and 4. More effective efficiency was noted in

Table 8: OHIP. Values of Factors and Sum Expressed at Median (Minimum/Maximum) at Different Timepoints[†]

Dimension	G1	Baseline G2	Mann-Whitney	G1	Postbleaching G2	Mann-Whitney	G1	1 mo After Bleaching G2	Mann-Whitney
Functional limitation	5 (2:8)	5 (2:8)	0.541	3 (0:6) a	4 (1:6) a	0.497	2 (1:7) a	4 (0:8) a	0.528
Physical pain	3 (0:6)	3 (0:5)	0.290	3 (1:6)	3 (1:6)	0.366	2 (0:6) a	2 (0:8)	0.522
Psychological discomfort	4 (2:6)	5 (0:6)	0.959	4 (0:6)	3 (2:6)	0.616	4 (0:6)	4 (0:8)	0.693
Physical disability	1 (0:6)	2 (0:5)	0.688	1 (0:4)	1 (0:6)	0.989	1 (0:3)	0 (0:6)	0.709
Psychological disability	2 (0:6)	3 (0:6)	0.240	2 (0:6)	2 (0:6) a	0.797	1 (0:5) a	2 (0:6) a	0.474
Social disability	0 (0:5)	1 (0:4)	0.946	0 (0:4) a	0 (0:4)	0.833	0 (0:6)	0 (0:4)	0.701
Handicap	1 (0:6)	1 (0:4)	0.841	0 (0:5) a	0 (0:4)	0.556	0 (0:6) a	0 (0:4)	0.874
Sum	17 (8:38)	19 (5:32)	0.910	13 (4:33) a	15 (4:35) a	0.472	14 (4:31) a	13 (5 :41) a	0.930

Abbreviation: OHIP, Oral Health Impact Profile.
[†] a = Statistically Significant Difference (Wilcoxon tTest, p<0.05) vs Baseline; b = Statistically Significant Difference (Wilcoxon Test, p<0.05) vs One Week After Bleaching (ext.)

Table 7: *Extended*

Dimension	G1	6 mo After Bleaching G2	Mann-Whitney	G1	12 mo After Bleaching G2	Mann-Whitney
Dental self-confidence	19.5 (10:29)	21 (7:25) a	0.480	21 (6:30) ab	19 (11:28) a	0.773
Social impact	15 (8:37)	19 (8:26) a	0.842	15 (8:36) a	16.5 (8:32) a	0.969
Psychological impact	15.5 (6:24)	15 (6:20) a	0.613	13 (6:24) a	14 (6:22) a	0.824
Aesthetic concern	7 (3:15)	8 (3:12) a	0.971	9 (3:15) a	8.5 (3:12) b	0.989

G1. However, values were not significantly different ($p>0.05$). Results of the color comparison of the bleached teeth vs homologous teeth are shown in Tables 5 and 6.

Dental Aesthetics Psychosocial Impact (PIDAQ)

The PIDAQ score was significantly different at the start of the study in comparison with one year later for all factor scores except aesthetic concern in G2. When comparing groups (Table 7), no statistical differences were observed between them ($p>0.05$).

Oral Health Impact Profile (OHIP-Aesthetics)

There were statistically significant differences in G2 ($p<0.05$) for total score, functional limitations, and psychological disabilities. G1 was not statistically

different when compared with baseline. There were no statistically significant differences between groups at the one-year follow-up (Table 8).

DISCUSSION

This randomized trial showed that the effectiveness of two bleaching agents (35% hydrogen peroxide and 37% carbamide peroxide) can be measured objectively and subjectively, and both agents can be applied for intracoronal nonvital teeth using the walking bleach technique. Both products showed high efficiency with very low rebound at the one-year follow-up period. The results showed that the treatment had a positive influence on a patient’s psychosocial aspects one year after showing improvement in the tooth color in the majority of participants. Therefore, the first null hypothesis was accepted, as the two

Table 8: *Extended*

Dimension	PH	6 mo After Bleaching PC	Mann-Whitney	PH	12 mo After Bleaching PC	Mann-Whitney
Functional limitation	2 (0:6) a	3 (0:6) a	0.543	3 (0:8) a	3 (1:8) a	0.779
Physical pain	2 (0:5) ab	3 (0:5)	0.600	2 (1:8)	3 (0:6)	0.835
Psychological discomfort	4 (0:6) a	4 (1:6) a	0.905	4 (0:6)	3 (0:7)	0.270
Physical disability	0 (0:5)	1 (0:5)	0.121	1 (0:8)	0 (0:5)	0.210
Psychological disability	1 (0:5)	2 (0:5) a	0.303	1 (0:8)	1 (0:7) a	0.948
Social disability	0 (0:5)	0 (0:3) a	0.822	0 (0:8)	0 (0:6)	0.148
Handicap	0 (0:5)	0 (0:4)	0.401	0 (0:8)	1 (0:7)	0.967
Sum	10 (3:36) a	12 (4:27) ab	0.279	15 (3:54)	12 (4 :39) a	0.427

gels are widely effective according to objective and subjective measurements at the one-year follow-up. The second hypothesis was partially accepted, but the psychosocial impact was maintained, and the aesthetic perception showed a partial regression to baseline values.

Our results showed that after four sessions with the walking bleach technique at one-year follow-up after the treatment, there was a ΔE of 15.11 ± 5.59 for G1 and of 13.17 ± 5.13 for G2. In terms of the final results, no differences between agents ($p > 0.05$) were observed, although there was a tendency for the color to recur after one month of treatment. Subjective evaluation of the color changes also indicated that treatment was very effective.

Few clinical studies have evaluated the effectiveness of nonvital whitening, and the most commonly used bleaching agent is sodium perborate.⁸ In an *in vitro* study by Lim and others,¹⁶ it was concluded that both 37% carbamide peroxide and 35% hydrogen peroxide were more effective than was sodium perborate. This study evaluated the color of each tooth using the Vita Lumin guide; after seven days, there was a change of 8 Δ SGU, and the color shifted by two additional units after 14 days.¹⁶ This study, however, is not considered to have provided a high level of evidence. In the present clinical trial, intracoronal whitening rebound was slight at the one-year follow-up period and was comparable to vital extracoronal whitening rebound results from another clinical trial¹² that was recently published. It is important to mention that the measurements were made on the middle sector of the vestibular face of the central incisors; since color recurrence in a nonvital tooth occurs from the cervical portion of the tooth, this finding could have been obviated by this difference in measurement location.¹⁷

The whitening agents that are most commonly used to whiten nonvital teeth are hydrogen peroxide, carbamide peroxide, and sodium perborate. Hydrogen peroxide is the active ingredient in the tooth whitening gels currently used. It can be applied directly or it can be produced by a chemical reaction of carbamide peroxide or sodium perborate.

High concentrations (35%) of hydrogen peroxide are caustic and can burn tissues on contact and cause free radical release. As a result of its low molecular weight, this substance can penetrate the dentin and release oxygen that breaks the double bonds of organic and inorganic compounds within the dentinal tubules. Carbamide peroxide [CO(NH₂)₂H₂O₂] is an organic crystalline white compound

formed by urea and hydrogen peroxide and is used in different concentrations. In a hydrophilic environment, it decomposes into approximately 30% hydrogen peroxide and 70% urea. Currently, the most popular commercial whitening preparations that contain carbamide peroxide also include different concentrations of glycerin because this makes it more chemically stable compared to hydrogen peroxide. Sodium perborate is an oxidizing agent available in powder form. It is stable when dry; however, in the presence of acid, hot air, or water, it decomposes to form sodium metaborate, hydrogen peroxide, and nascent oxygen. Sodium perborate is easier to control and safer than concentrated solutions of hydrogen peroxide.⁸

Visual assessment by colored guides is a complex process that involves individual and general parameters, such as age and experience of the examiner, fatigue of the human eye, external lighting, the color of the wall and the interior, and the angle of perception.¹⁸ The determination of the tooth color by visual means becomes less reliable as a result of the lack of guides of dental colors that are commercially manufactured. The concept of the threshold of perceptibility that varies among individuals is relevant, and despite being able to achieve good agreement rates between evaluators, the error of the subjective assessment is always greater.¹⁹ On the other hand, objective color instruments can measure color tones with greater precision and enable the communication of tone matches.²⁰ The reliability of the device used is important, as it ensures the reliability of these measurements using relatively simple and easy-to-replicate methodologies. Currently, the devices used are highly accurate and provide reliable measurements that correctly guide dentists with respect to the measured color.^{20,21}

The research team was not surprised at the high satisfaction levels of patients who underwent a whitening procedure in this trial and were then followed.²² For various reasons, we have been able to completely match neighboring tooth colors using our nonvital tooth whitening method. Results relative to the aesthetic perception and psychosocial impact were positive and significant with respect to whitening after one month. Whether this effect was maintained over time needs to be confirmed in patients undergoing positive vital tooth whitening² and then correlated with the maintenance of the bleaching procedure effectiveness at one year.

The OHIP-Aesthetic survey also showed positive effects on G2 patients' aesthetic perceptions. This

result is supported by other studies,²³ whose authors evaluated the influence of extracoronal vital bleaching on patients' aesthetic perceptions. Our data confirmed that a patient's quality of life is complex, important, but poorly studied, and there are multiple factors that influence it. However, dental aesthetics appear to be important to a patient's quality of life, although its influence on patients' perceptions and psychological and social factors are unknown. The impact of psychological and social factor perceptions is unknown. No differences in OHIP-Aesthetic scores between the groups was observed, but there were differences in the changes in each group over time. This resulted in an effect that was more pronounced and positive for G2; however, there was a regression of values in G1, likely because the effect was not as durable and because patients were accustomed to the condition after one year. This finding must be further investigated to assess the correlation between perception and aesthetic color changes.

PIDAQ has been shown to decrease the negative impact of cosmetic dentistry for a patient and to decrease the values in social and psychological impact and aesthetic concerns. The psychosocial impact was similar in both groups ($p > 0.05$). We found that a big impact was indicated by the PIDAQ data for all relevant factors, but minimal intervention in a tooth has a major effect in people who undergo intracoronal whitening.

CONCLUSION

Hydrogen peroxide (35%) and carbamide peroxide (37%) were highly effective for the nonvital tooth walking bleach technique and can achieve a high level of color matching with the counterpart teeth and color maintenance at the one-year follow-up, with a slight rebound. Each gel produced a positive impact on patients' psychosocial impact at the one-year follow-up.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of approval of the Ethics Committee of the Faculty of Dentistry of the local University and carried out according to the standards of consolidated reporting trials and the Declaration of Helsinki (2002). The approval code for this study is 2016/04.

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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