Published online: 2019-09-25

Spectrophotometric and computerized evaluation of tooth bleaching employing 10 different home-bleaching procedures: *In-vitro* study

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ABSTRACT

Objective: The aim of this *in-vitro* study was to evaluate the efficacy of bleaching products, determine the applicability and validation of the measurement methods. **Materials and Methods:** Freshly extracted 110 human incisor teeth were stained with whole blood and hemolysate solution prior to the application of 10 different home-bleaching products. Spectrophotometric measurements of the tooth shades were performed for each specimen before and after bleaching at the 1st, 3rd, 7th, and 14 days. Differences in lightness (Δl), chroma (Δc), hue (Δh) values and shade changes were measured to evaluate process. Computerized digital imaging analyses to determine the color changes were performed with Photoshop CS4 software (Adobe, San Jose, CA, USA). Statistical analyses were performed with analysis of variance, Scheffe and Tukey tests. **Results:** In all of the test groups regardless of the material used, a significant increase in lightness and hue, and decrease of chroma were observed, as compared to the control group. After recommended bleaching applications, Δl and Δh values respectively increased in group Zaris White and Brite (ZWB) and group Pola Night and Δc values showed significant decrease in groups ZWB and Rembrandt REM3 ($P < 0.05$). At the end of the procedure both spectrophotometric and digital imaging analysis showed ZWB was the most effective product among the others while Yotuel and Happy Smile were the least ($P < 0.05$). **Conclusions:** Home-bleaching systems showed slower but almost permanent bleaching effect likewise office-based methods. Both software and spectrophotometric analyses have advantages such as evaluating the results objectively and numerically, also treatment outcomes could be preserved.

Key words: Digital imaging analysis, home-bleaching, spectrophotometer

INTRODUCTION

Tooth bleaching is one of the most noninvasive dental treatments to improve people's appearance.[1,2] Bleaching is a decolorization or whitening process that can occur in solution or on a surface.[3] The color producing materials in solution or on a surface are typically organic compounds that effect the teeth color.[4] Intrinsic tooth color is usually associated with the light scattering and adsorption properties of the enamel and dentine, while extrinsic stains tend to form in areas of the teeth that are less accessible to tooth brushing and is often promoted by smoking, dietary intake, the use of certain cationic agents such as chlorhexidine or metal salts.[5,6]

Tooth color can be improved by a number of methods and approaches including internal bleaching of nonvital teeth, external bleaching of vital teeth, whitening toothpastes, micro-abrasion of enamel with abrasives.[7] Although the benefits and side effects are still controversial for some of them, increased

How to cite this article: Peskersoy C, Tetik A, Ozturk VO, Gokay N. Spectrophotometric and computerized evaluation of tooth bleaching employing 10 different home-bleaching procedures: In-vitro study. Eur J Dent 2014;8:538-45.

DOI: 10.4103/1305-7456.143639

expectancy for aesthetics stops neither the dentists nor the patients to perform such procedures. There are a number of studies and trials in the literature investigates the methods and procedures, two of the most applied approaches in the tooth bleaching treatment are home (night-guard) bleaching and in-office bleaching technique.[8] Lower concentrations of both carbamide peroxide (CP) and hydrogen peroxide (HP) are used for home-bleaching, while higher concentrations are necessary for in-office treatments.[9-11]

In-office bleaching application of light-sensitive, high-concentration bleaching agents associated with a power-unit usually performed in a single appointment, reduces the time required to achieve the expected results and decreases the failure possibility. The home-bleaching technique, with a custom tray, offers a conservative, cost effective method for bleaching teeth.[12,13] In addition using CP formerly used for topical disinfection as an alternative bleaching agent to HP, provided a slower release of active, oxidizing ions which caused more effective and long lasting bleaching impact.[14] Despite the favorable results achieved with both bleaching techniques, some reports in the literature have related adverse side effects of CP as a consequence of the treatment. Sensitivity following the treatment has been related to the possible removal of mineral content from enamel and dentin.[13,15] Therefore some of the authors advised that bleaching materials could adversely affect dental hard tissues and should be used with caution. An *in-vitro* study by Efeoglu *et al*. showed that different concentrations of CP can remove mineral structures from enamel, causing morphological alterations with different forms and intensity and can reach to the subsurface.[14] Nevertheless, it has been proposed that the loss of mineral content and increased porosity could explain transitory dental sensitivity during bleaching treatment.[16] Since little information exists in the literature regarding the clinical response to bleaching treatment, there is a need for studies that simulate clinical conditions in order to evaluate the real effects of such treatment. The hypothesis to be tested is that in a clinical oral simulate condition (*in situ*), the effects of bleaching agents are less evident than when seen in *in-vitro* conditions.

The scope of the current study is focused on the evaluation the *in-vitro* bleaching efficiency of different products in similar concentrations used in home and office applications and validate the results with software and hardware methods to assess the sufficiency of the measurement techniques. Our hypothesis was similar CP concentration results in similar bleaching effect and different measurement methods validates each other.

MATERIALS AND METHODS

A total of 110 freshly extracted for aggressive untreatable periodontitis, caries free human incisors were collected from Department for Oral and Maxillo-Facial Surgery, Ege University to obtain similar enamel and dentin thickness, also start-up shades. Ethical approval of the Ege University Committee of Medical Ethics (Reg. No.: 11-10.1/9) was obtained. All of the teeth were examined under a stereomicroscope in order to select those without surface defects. All of the specimens were stored in 1% thymol solution until used. The debris and calculus was removed with periodontal scalers mechanically. The labial surfaces were ground and polished with water-cooled finishing and polishing discs (Sof-Lex, 3M ESPE, St. Paul, MN, USA) removing approximately 100 μm of the outermost enamel layer to obtain flat and smooth enamel surfaces. The teeth were artificially stained with whole blood and hemolysate solution prior embedding in prepared acrylic jaws with acrylic resin (Meliodent, HerausKulzer, Werheim, Germany), to achieve an adequate and uniform staining [Figure 1a].[17] A total of 110 teeth were embed in acrylic jaws according to the random distribution in order to make the templates for bleaching and color measurement procedures.[18] An alginate impression was taken to obtain a plaster model for the bleaching processes. The labial teeth surfaces were covered with 1 mm thick spacer up to 1 mm of the apical

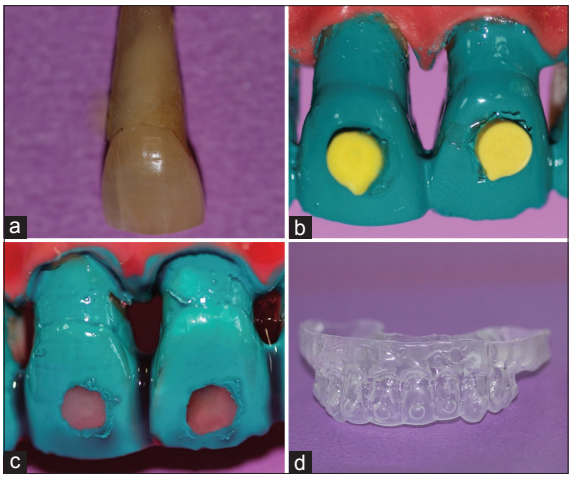

Figure 1: Example of specimen (a) after staining, (b, c) embed in acrylic jaws and covered with nail polish, (d) prepared custom trays for bleaching application

foramen [Figure 1b]. A vacuum forming machine was used to make a 0.8 mm thick custom tray. Teeth were isolated using two layers of nail polish, leaving a 3 mm. Diameter standardized buccal area exposed to the bleaching agent shown as Figure 1c. Bleaching agents placed in the custom trays on all study groups, in a 2 mm thick layer in order to get enough material to produce active bleaching [Figure 1d]. Baseline tooth color was recorded using a spectrophotometer (VITA EasyShade - Vita Zahnfabrik, Germany).[18] From the beginning of the study to the end, all specimens were stored for 48 h at 37°C in artificial saliva that was renewed everyday.[19] All of the specimens randomly assigned to, eleven groups (n = 10) which would be applied a different type home-bleaching procedure which contains approximately 15.5% CP. The distribution of study and control groups is described below:

- Nite White Excel (NWE) (Discus Dental, USA; 16% CP)
- Pola Night (PN) (SDI, Australia; 16% CP)
- Zaris White and Brite (ZWB) (3M ESPE, USA; 16% CP)
- Opalescence (OP) (Ultradent, USA; 15% CP)
- Bite and White (BW) (Cavex, Netherland; 15% CP)
- Whiteness Perfect (WP) (FGM Dental, Brazil: 16% CP)
- Rembrandt REM3 (R3) (Oral-B, USA; 15% CP)
- Illumine (Dentsply, USA; 15% CP)
- Yotuel (YO) (Biocosmetic Laboratories Spain; 16% CP)
- Happy Smile (HS) (HappySmileUK, UK; 16% CP)
- Control (Zoom, Philips, Nederland; office bleaching system: 25% HP).

Every home-bleaching technique was conducted for 14 days. Session arranged in the day time, at 37°C and lasted for 1, 2 and 4 h as recommended by the manufacturer [Table 1]. Subgroups (SGs) arranged by the application time of the products (SG-1: 1 h products, SG-2: 2 h products, SG-3: 4 h products). The bleaching agent was applied on the dried enamel surfaces. Before application teeth were left to dry for 3 min and after bleaching the agent remnants on the teeth were carefully removed with a soft toothbrush under tap water for 3 min. In control group an office bleaching system was conducted to compare the bleaching efficacy of home-bleaching systems with the control and the other study groups.[20] In control group approximately a 1-2 mm thick layer of 25% HP bleaching gel (Zoom!™, Philips, Nederland) was applied to the buccal surfaces of the teeth. Then the light source was positioned according to the manufacturer's instructions using the integral bite appliance guide to set the distance between the teeth and the light source (~6 cm). The teeth were exposed with the light for 15 min three times. After each 15 min session, the bleaching gel was rinsed off and reapplied with cotton pellets.

Data collection

Digital photos of each tooth were carefully taken with a SLR camera (Canon EOS 650D with a macro lens 100 mm, Canon, Tokyo, Japan) prior to the staining, before and after each procedure and transferred to a digital imaging software (Adobe Photoshop CS4, Adobe, San Jose, CA, USA) to evaluate the color changes objectively using the histogram processing ability of the software.[21] Figure 2 displays the assessment of color changes employing the digital photo processing software (CS4). The range of lightness (L) and hue (h) values are different when compared to the Commission Internationale de I'Eclairage (CIE) L^* and h^* values. In Photoshop, the range of the mean L^* c^* h^* values, respectively, is 0-255. The CIE L^* value ranges from 0 to 100, and the CIE c^* and h^* value ranges from −80 to +80. A transformation should be figured using a specific formula.[22]

Table 1: Evaluation of the bleaching products used in this study

SG	Product name	Study code	Active ingredient %	Bleaching method	Time of use
SG-1	Pola night	PN	16 carbamide peroxide	Home-bleaching	14×1 h
	Bite and white	BW	15 carbamide peroxide	Home-bleaching	14×1 h
	Rembrandt REM3	R3	15 carbamide peroxide	Home-bleaching	14×1 h
	Happy smile	HS	16 carbamide peroxide	Home-bleaching	14×1 h
SG-2	Zaris white and brite	ZWB	16 carbamide peroxide	Home-bleaching	14×2 h
	Illumine home	IH	15 carbamide peroxide	Home-bleaching	14×2 h
	Yotuel	YO	16 carbamide peroxide	Home-bleaching	14×2 h
SG-3	Opalescence	OP	15 carbamide peroxide	Home-bleaching	14×4 h
	Whiteness perfect	WP	16 carbamide peroxide	Home-bleaching	14×4 h
	Nite white excel	NWE	16 carbamide peroxide	Home-bleaching	14×4 h
	Control group	ZOOM	25 hydrogen peroxide	Office-bleaching	45 min

SG indicates the subgroups according to their application time (1-2-4 h)

As a second colorimetric measurement method, shades of the teeth were determined in the *L*c*h* (lightness, chroma, and hue) color space using spectrophotometer (EasyShade), which allowed images not affected by a visual determination, such as visual perception, office lighting or time of day.[23,24] Spectrophotometer can express the color in various values (*L* c* h**), can be displayed by the software of the system and compared the data with standard shade guides.[21] Total color differences or distances between two colors (*E*) are calculated automatically by the software according to the following formulas: CIE color space L (0-100) c and h (−80 to +80); $\Delta E^2 = [(\Delta L)^2 + (\Delta c)^2 + (\Delta h)^2]$, $\Delta E = 247.4$ and RGB color space *L-c-h* (0–255); $\Delta E = 441.7$. Tooth color assessments were performed with one evaluator who measured the shades at two different evaluation sessions prior to the staining, before and after bleaching. The final measurement decision was recorded only if it was an exact at both sessions. Custom templates were arranged with holes on labial surfaces suitable for the tip of the spectrophotometer and to obtain a definite measurement process, a standardizing jig was used to ensure the positioning of the device is consistent.[25] After the fully insertion of these templates double check have been performed to control the measurement areas left unpolished and clear prior to the spectrophotometric measurements [Figure 3a and b].

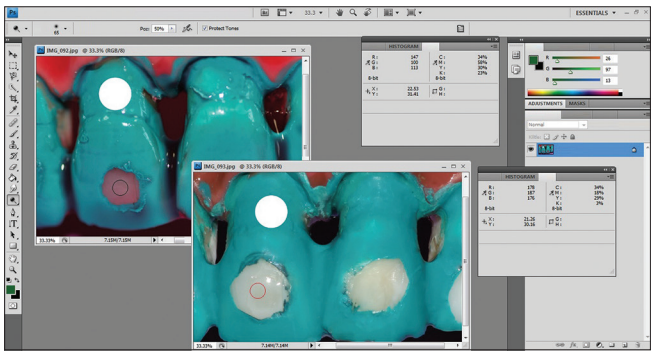

Figure 2: Assessment of color changes employing the digital imaging analysis software

Statistical analyses

The results for both experimental and control groups were submitted to statistical analysis software SPSS 17, (IBM, Endicott, NY, USA). Differences in *L*c*h* values before and after application were tested with a repeated-measures analysis of variance (ANOVA) followed by a multiple-comparison Scheffe test.[17,23] All tests were carried out at a 5% level of significance. Prior to the study, a repeatability test of the photograph shooting and the resulting color measurements was performed with *posthoc* Tukey test.[26]

RESULTS

The degree of repeatability of the photograph shooting was found to be highly reliable, as confirmed by the ANOVA, since no significant difference ($P > 0.05$) was observed among the values of for each specimen in each groups.

*L*c*h** values for each study groups, before and after coloration, as well as after each treatment phase, are presented in Table 2. Table 3 presents the color

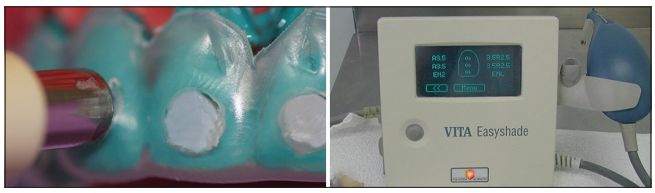

Figure 3: Spectrophotometric measurement of bleaching efficacy

Table 2: Summary of initial, postcoloration, and posttreatment's Δ*L*, Δ*h*, Δ*c*, and Δ*E* values

Product	Initial			Postcoloration				Recommended applications			
	L	*c*	*h*	ΔL_s	Δc_s	Δh_s	ΔE_s	ΔL_s	Δc_s	Δh_s	ΔE_s
PN	67.8	15.5	91.9	−13.7	2.1	−1.9	14.0	23.8	−2.3	8.1	25.2
BW	69.1	16.8	78.9	−18.2	7.7	−3.7	16.1	17.7	−1.0	4.0	18.2
R3	79.6	17.0	88.2	−14.6	5.0	−2.7	13.7	13.8	−2.9	4.3	14.7
HS	64.1	20.0	80.1	−11.0	1.5	−1.1	11.2	6.9	−0.4	4.9	8.5
ZWB	75.2	21.3	83.4	−17.3	7.0	−1.4	18.7	24.6	−2.9	6.8	25.7
IH	65.3	19.4	83.0	−11.3	8.9	−0.7	12.4	13.7	−0.2	3.6	14.2
YO	65.5	14.6	75.1	−9.8	4.5	−2.1	11.0	12.7	−1.5	5.2	13.8
OP	64.8	15.2	79.3	−13.8	7.0	−1.1	15.5	16.5	−2.2	4.1	17.1
WP	72.6	15.4	83.0	−18.3	5.4	−1.8	15.2	15.8	−0.7	5.8	16.8
NWE	74.8	15.1	78.3	−19.2	3.7	−0.3	14.6	14.2	−0.8	5.6	15.3
Control	70.1	16.5	80.8	−17.1	5.1	−1.6	19.7	25.2	−3.1	9.3	27.1

ΔE values on the postcoloration stage represent the coloration on darker shades compared to the initial stage. Sub-symbol "s" represents the spectrophotometric results

Table 3: ΔE_s values of the experimental and control groups

Product name and time of application	Mean	SD	*P* (baseline-related day)
Pola night			
Baseline	14.0#	4.0	
Day1	15.6	3.6	<0.05
Day 3	16.3	3.7	<0.05*
Day 7	20.3	3.9	<0.05*
Recommended bleaching applications (14 days)	25.2	3.6	<0.05*
Bite and White			
Baseline	16.1#	3.0	
Day1	9.5	2.5	<0.05
Day 3	14.0	3.6	<0.05
Day 7	14.5	3.6	<0.05
Recommended bleaching applications (14 days)	18.2	4.1	<0.05*
Rembrandt REM3			
Baseline	13.7#	3.4	
Day 1	9.1	2.4	<0.05
Day 3	11.2	3.1	<0.05
Day 7	12.5	3.6	<0.05
Recommended bleaching applications (14 days)	14.7	3.2	<0.05*
Happy smile			
Baseline	11.2#	3.5	
Day 1	7.5	2.4	>0.05
Day 3	7.9	2.6	>0.05
Day 7	8.4	2.4	>0.05
Recommended bleaching applications (14 days)	8.5	2.1	>0.05
Zaris white and brite			
Baseline	18.7#	3.6	
Day 1	19.1	2.6	<0.05
Day 3	21.5	3.1	<0.05*
Day 7	23.4	3.7	<0.05*
Recommended bleaching applications (14 days)	25.7	3.7	<0.05*
Illumine Home			
Baseline	12.4#	3.3	
Day 1	12.2	3.2	>0.05
Day 3	13.0	2.8	>0.05
Day 7	13.9	3.0	<0.05*
Recommended bleaching applications (14 days)	14.2	3.0	<0.05*
Yotuel			
Baseline	11.0#	3.0	
Day 1	8.6	2.3	>0.05
Day 3	10.4	3.3	>0.05
Day 7	12.6	3.3	<0.05*
Recommended bleaching applications (14 days)	17.2	3.0	<0.05*
Opalescence			
Baseline	15.5#	3.0	
Day1	10.5	2.9	<0.05
Day 3	13.9	2.9	<0.05
Day 7	14.9	2.6	<0.05
Recommended bleaching applications (14 days)	17.1	3.2	<0.05*
Whiteness perfect			
Baseline	15.2#	3.8	
Day1	9.1	2.7	<0.05
Day 3	11.2	3.0	<0.05
Day 7	14.3	3.1	<0.05
Recommended bleaching applications (14 days)	16.8	3.4	<0.05*
Nite white excel			
Baseline	14.6#	3.4	
Day1	10.9	2.4	<0.05
Day 3	12.0	3.2	<0.05
Day 7	13.3	3.9	<0.05
Recommended bleaching applications (14 days)	15.3	4.1	<0.05
Control group	27.1	3.1	>0.05

#The postcoloration Δ*E* values on darker shades compared to the initial stage, *The statistically significant Δ*E* values compared to the pretreatment (postcoloration) stage. SD: Standard deviation

differences for each study groups as well as the control group represented by Δ*E* values together with statistical differences. Both spectrophotometric and histogram evaluation showed, ZWB had a significant increase of lightness (Δl_s: 24.6, Δl_h: 46.3) decrease of chroma (Δc_s: −2.9, Δc_h: 79) and increase in hue (Δh_s: 6.8, Δh_h: 74.8) that proves ZWB has the highest bleaching efficacy compared to the other products ($P < 0.05$). PN achieved similar results as increase in lightness (Δl_s: 23.8, Δl_h: 51.1 - Δh_s: 8.1, Δh_h: 68.5) and hue, decrease in chroma (Δc_s: −2.3, Δc_h: 67.6) [Tables 2-4]. Therefore statistical difference between ZWB group and PN group was insignificant ($P > 0.05$). The increase in lightness (Δl_s: 6.9, Δl_h: 10.4 - Δh_s: 4.9, Δh_h: 19.7) and hue, decrease in chroma (Δc_s: −0.4, Δc_h: 19.1) and change in Δ*E* values (ΔE_s: 8.5, ΔE_h: 29.3) for the HS group found relatively low compared to the other groups ($P < 0.05$). Although initial application increased Δ*E* values (Δ*E*: 19.1) for ZWB group, significant reduction in increase rates observed after the 3th, 7th and final applications [Table 3]. Similar to this, in PN group; the increase rate after the first application, slightly decreased in the next sessions. Contrary to these findings, in all other groups except HS group; slow but stable increase in Δ*E* values has been monitored ($P > 0.05$). In addition, the change in Δ*L*, Δ*c*, Δ*h*, and Δ*E* values for the remaining groups found similar and differences between these values

Table 4: Histogram values of *L*c*h* and Δ*E* values (RGB) according to the experimental groups

Product	Pretreatment			Recommended applications			
	L_h (R)	c_h (G)	h_h (B)	ΔL_h	Δc_h	Δh_h	ΔE_h
PN	125.3±8.6	97.4±2.6	97.9±4.7	51.1	67.6	68.5	109.0
BW	131.0±5.3	98.8±5.4	90.7±3.9	41.4	63.7	69.0	102.6
R3	127.6±6.8	100.6±4.7	99.7±4.4	27.9	50.2	50.5	76.5
HS	135.4±6.6	93.8±7.0	95.8±5.3	10.4	19.1	19.7	29.3
ZWB	135.4±9.8	99.1±6.5	97.1±3.7	46.3	79.0	74.8	118.2
IH	128.1±9.2	99.8±5.8	98.0±5.4	27.4	47.3	48.3	72.9
YO	134.7±7.7	91.8±5.7	93.8±3.5	16.5	51.5	43.5	69.4
OP	138.6±8.4	95.9±8.1	89.8±8.3	26.0	59.9	64.4	91.7
WP	125.7±5.5	100.9±7.7	96.4±5.5	35.7	51.6	54.3	83.0
NWE	130.9±6.2	97.9±3.9	97.4±3.7	25.9	56.4	57.3	84.5
Control point	255	255	255	0	0	0	0

Sub-symbol "h" represents the histogram results.
RGB: Red-Green-Blue Color Scale

in comparison to their increase rates were statistically negligible ($P > 0.05$).

The data acquired from each SG according to time of use has been demonstrated in Tables 2–4 separately. In SG-1; PN has the highest and HS has the lowest Δ*E* value changes amongst the SG-1 after both spectrophotometric and histogram evaluations [Tables 2-4]. Besides, the statistical difference in histogram results between PN and BW is insignificant ($P > 0.05$). For SG-2; ZWB showed the highest Δ*E* value changes when compared to the other two products ($P < 0.05$). Likewise, the differences between the values of IH and YO were found statistically insignificant ($P > 0.05$). In SG-3; although OP has higher Δ*E* values than NP and NWE, the statistical analysis showed there were no differences within the group.

DISCUSSION

First of all, this study performed an evaluation about the bleaching effectiveness of different home-bleaching systems with similar CP concentrations. Although both short- and long-term clinical efficacy of home bleaching procedures using CP have been well-documented[27-31] the data about the multiple comparison of this protocol with both software and spectrophotometric analyses are relatively insufficient.[32,33] The digital imaging analysis reveals the fact that even if a highly standardized photographic procedure is adopted, some factors remain that affect the lightness and color.[21,34] Therefore, a photographic procedure to standardize the measuring process has to be performed and that includes a 200 × 200 grit pure white circular spot in each picture as a neutral reference point.[17,35] By this way, color deflections, shadows caused by camera flash and volume of daylight can be eliminated and measurements can be calculated using a standard image-editing software program (Adobe Photoshop CS4, Adobe, San Jose, CA, USA).[34,35]

In this study, software analyses were performed to validate the results and minimize the user-induced errors.[22,36] Because the lack of validation in past studies; the deviations and differences in measurement process, probably effected the results.[37,38] Although Lehmann *et al*. demonstrated that both traditional and advanced spectrophotometer devices showed excellent repeatability and similar results, validation with an objective software was required because of the substantial deviations of the calculated color coordinates from the spectrophotometric reference system.[18] In this study, although all products under evaluation were home-bleaching systems with similar CP concentrations, it could be observed that there were differences in efficacy between these products, mainly due to the application time and different active ingredients except CP in these products.[39,40] Contrary to expectations, it is shown in this study that the application time of the bleaching gel is not directly related with the bleaching efficacy of the systems.[41] Furthermore, the statistical insignificant difference between SG-1 and SG-2, shows 1 h of application time is enough to achieve desired level of bleaching. In the light of these facts, the continuation of color change is relatively not related with the time of use of bleaching product and it is in agreement with other *in-vitro* studies.[42,43] Similar to this, Sulieman *et al*. showed that the bleaching efficacy is highly dependent on duration of exposure, if the CP concentration and the catalysts in the composition are identical.[44]

In addition most of the studies in scientific literature, investigate the bleaching products either in comparison with combined techniques (office + home vs. office + home)[45,46] or different techniques (home vs. office vs. over-the-counter).[43,47] Such studies generally focused on the assessments about *in-vivo*/*in-vitro* bleaching efficiencies of home-bleaching systems, compare the products with negative control groups.[45,48] Few of them tried to compare the home-bleaching products with a positive control group (active bleaching agent) to evaluate the effectiveness of a home-bleaching system against an office bleaching system.[20] In this

manner, none of these studies explain the bleaching efficiencies of office and home-based products used in combined techniques separately. Moreover, in these combined techniques home-bleaching gels were used to be applied after office bleaching technique to enhance the bleaching.[29] As a consequence, the efficacy of home-bleaching gels could not be measured accurately, because the saturation point of enamel was reached.[49] Therefore, in this study home-bleaching gels compared with both each other and office bleaching product. This reveals the fact that, home-bleaching gels are as effective as office bleaching products when used alone in bleaching treatments. Klukowska *et al*. in their study, their results seem to confirm our findings.[49]

In the present study, ZWB proved to bleach faster than other home-bleaching products and relatively similar to office-based control group. Although all products contain approximately 16% CP, Zaris include a higher level of HP (5.6%) and catalyst which leads a long lasting bleaching effect.[50] Because HP is known to penetrate tissues faster than CP, our results seem logical and confirms previous studies.[44,51]

CLINICAL RELEVANCE

Tooth bleaching with home-bleaching products include CP were similarly effective as office bleaching products. It could be suggested the use CP concentrations instead of high level HP for vital tooth bleaching, in accordance with the American Dental Association guidelines to assure both the safety and the efficiency of bleaching treatments.[52] Although application time of the home-bleaching products has a minor influence on bleaching efficacy, concentration of the active ingredients such as carbopol affects the peroxide secretion rate.

CONCLUSIONS

The bleaching efficacy of home-based products are as effective as professional office-based products if used properly. The results of this trial allow the following conclusions: All bleaching products performed a satisfactory bleaching efficiency while 16% CP gels whiten faster compared with 15% CP gels. The application time did not alter the efficiency of bleaching while 4 h use decrease the ΔE values. Both spectrophotometric and digital image analyses presented sufficient and objective evaluation of the bleaching efficiency and validated each other's findings.

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	Source of Support: Nil. **Conflict of Interest:** None declared