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How home bleaching agents affect the color and translucency of CAD/CAM monolithic zirconia materials

Murat ALKURT[1], Zeynep YESİL DUYMUS[1,2] and Şeyma YILDIZ[1]

[1] *Department of Prosthodontics, Faculty of Dentistry, Recep Tayyip Erdogan University, Fener Main St, Rize, 53100, Turkey*
[2] *Department of Prosthodontics, Faculty of Dentistry, Atatürk University, Erzurum, 25240, Turkey*
Corresponding author, Murat ALKURT; E-mail: muratalkurt@hotmail.com

To assess the effect of 10% carbamide peroxide (CP) and 6% hydrogen peroxide (HP) home bleaching agents on the translucency and color of monolithic zirconia. Ninety disc specimens were fabricated (diameter, 10 mm) from multi-layered (ML), ultra translucent multi-layered (UTML), and super translucent multi-layered (STML) zirconia blocks at three thicknesses (0.4,1,1.5 mm) (n=5). The samples were divided into two subgroups, which were treated with 6% HP (45 min per day) or 10% CP (8 h per day) for 14 days. The color of specimens was measured before bleaching (T0) and after bleaching on the third (T3), seventh (T7), and 14th (T14) day. Color (ΔE) and translucency (TP) changes were calculated. The thickness varieties used in the samples and the bleaching agent types used created statistically significant differences only in TP and ΔE_{00}, respectively (p<0.05). Bleaching agents can affect TP and ΔE. Patients who have zirconia restorations should be careful when using home bleaching agents.

Keywords: Bleaching, Color, Translucency, Zirconia

INTRODUCTION

Office and home bleaching treatments to improve esthetic appearance and modify tooth discolorations have become popular. This is because they are effective and non-invasive[1)]. Office bleaching (which uses a relatively high concentration) is carefully and attentively performed by the professional in the dental office environment[2)]. In contrast, low concentration home bleaching agents can be applied by the patient *via* gel form within the boundaries of a special tray[2)]. However, the weaker home bleaching products must be applied for longer to achieve the same effect as office bleaching[3,4)].

Generally, hydrogen and carbamide peroxide bleaching agents are used to treat tooth discoloration[5)]. Hydrogen peroxide breaks down into reactive oxygen molecules and hydrogen peroxide anions[6,7)]. These molecules penetrate hard dental tissue and react with double, long-chain, and unsaturated, dark chromophore molecules[3,5)]. Carbamide peroxide is considered a safe alternative bleaching agent that breaks down into hydrogen peroxide and urea, which can be further separated into carbon dioxide and ammonia[4,8)]. During the chemical reaction, the amount of ammonia product transformed from urea is uncertain, but the presence of high pH ammonia in the environment facilitates the bleaching effect[5,9)]. The home type of carbamide peroxide uses a wide range of concentrations (from 10% to 35%) and application periods (from 2 to 8 h per day)[10)]. Relative to carbamide peroxide, hydrogen peroxide is a stronger agent that decomposes reactive oxygen and hydrogen peroxide[6,7)]. Hydrogen peroxide is used in both office type and at-home bleaching[11)].

Because of the increasing esthetic requirements of patients and clinicians, a wide variety of esthetic materials are produced along with the advancement of CAD/CAM technology[12)]. Recently, monolithic zirconia materials are becoming popular in dental restoration products due to their superior structural properties (higher strength and hardness), no requirement for a porcelain veneering layer, and rapid and fast production time. However, monolithic zirconia is not considered the most esthetic ceramic due to its opacity level[12-17)].

Conventional 3Y-TZP contains 5.18% by weight yttria (3 mol% yttria), 0.25% alumina (Al_2O_3), and 90% or more tetragonal zirconia[18)]. To improve the translucency feature, manufacturers made changes in the structure of zirconia material. The material was transformed into a more translucent structure by increasing the yttria ratio of 4 mol% (4Y-PSZ) or 5 mol (5Y-PSZ) in the zirconia structure and increasing the amount of cubic phase (c phase)[13)]. Also, decreasing the tetragonal phase and increasing the cubic phase increase resistance to thermal aging and prevents the negative effects of low-temperature degeneration (LTD)[19)].

The translucency of the monolithic zirconia material varies depending on the manufacturer[20)]. The grain size, grain boundaries, porosity and defects, sintering temperature and process, amount of yttria content, and the additives greatly affect translucency[12,21,22)]. With the increase in the grain size of zirconia material, the value of translucency increases[23)]. As the particle size increases, the reflection of light at the boundaries around the particles decreases and the amount of light transmission increases[24)]. However, the increase in particle size negatively affects the durability of the material in intraoral conditions[25)]. If the particle size is more than 1 µm, the return from the tetragonal phase to

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the monoclinic phase increases spontaneously, and the resistance to LTD decreases[26].

In the literature, there are many studies addressing the optical properties of zirconia material and its various thicknesses[12,20,23,27,28]. These studies found that the amount of light reaching the restoration decreased due to the increase in the thickness of the zirconia material. Also, they concluded that the restorations made with monolithic Y-TZP ceramics could be produced up to 0.5–0.9 mm without sacrificing the strength and color of the material[12,20,23,27,28].

Color and translucency greatly affect the esthetics of dental restoration[29]. The color is expressed by $L^*a^*b^*$ range system, according to Commission Internationale de'Eclairge (CIE). The CIE $L^*a^*b^*$ [L^* lightness or brightness; (+)a^* redness or (−)a^* greenness; (+)b^* yellowness or (−)b^* blueness] color range system is an analysis system that allows us to measure color in three dimensions[30]. Lately, a new CIEDE2000 color formula was introduced and it showed better fit than CIELab formula for evaluation of color difference. Also, it allowed to correction for variations in color perception using Lightness, Chroma, Hue and Chroma-Hue interaction[31].

When two objects are compared in terms of color evaluation, 50:50% perceptibility threshold is defined as the color difference seen by 50% of the observers. Likewise, 50:50% acceptability threshold has been defined as the acceptability of the color difference by 50% of the observers[32]. According to researchers[32,33], the 50:50% perceptibility and acceptability threshold was determinedΔEab=1.2 and ΔEab=2.7 for the CIELab (ΔE_{ab}) system, respectively. However, the perceptibility and acceptability thresholds were found to be 0.8 and 1.8, respectively, under parametric factors set to 1 K_L:1, K_C:1, K_H:1 in CIEDE2000 (ΔE_{00}) system[33].

The translucency parameter (TP) identifies the differences between the reflected colors of a uniform thickness material on a black and white background[34]. As the amount of light transmittance from a material increases, its translucency increases[35]. Translucency is influenced by numerous factors such as grain size and density, crystal structure, type of content, pigment, opacity, porosity, and oxygen space distribution (including number and size)[36].

The effect of bleaching agents on restorative materials and how this affects their physical and mechanical properties remains somewhat unclear. There are many contradictory results about materials' color, hardness, and roughness[11,37-39]. Because of the popularity of bleaching restorations, more studies are needed that address possible bleaching changes in restorations[11].

There are many studies addressing how bleaching treatments affect adhesion to dental hard tissue, the cytotoxic effects on the dental cell, and changes in enamel microstructure and material properties[40-43]. However, there are limited studies on the effects of home bleaching on prosthetic restoration materials. Thus, in this *in vitro* study, we assess the effect of 10% carbamide peroxide (CP) and 6% hydrogen peroxide (HP) home bleaching agents on the color differences (ΔE_{00}) and TP of monolithic zirconia-based materials. We hypothesize that the color and translucency of monolithic zirconia materials are not affected by the application of home bleaching agents.

MATERIALS AND METHODS

Specimens preparation

Two home bleaching agents (10% carbamide peroxide and 6% hydrogen peroxide) and three monolithic zirconia were used. The materials used, their contents, and manufacturers are shown in Table 1.

A total of 90 disc-shaped (10 mm diameter) monolithic zirconia samples were prepared in thicknesses of 0.4, 1, and 1.5 mm (n=5). The thickness of the samples was determined in accordance with the recommendations of the manufacturers (minimum laminate thickness 0.4 mm, minimum restoration occlusal thickness 1.5 mm).

In the digital design, each sample was placed at right angles to the blocks. Thus, it was ensured that each sample had the same layers. Then, the productions were made with the CAD-CAM device. Before the sintering process, the sample surfaces were sanded in one direction with 600, 800 and 1200-grain silicon carbide paper for 15 s in dry conditions. Thus, the

Table 1 Material, Type, Content and Manufacturer

Material	Type	Content	Manufacturer
Katana Multi Layered (ML)	Zirconia	90–95% ZrO_2, 5–8% Y_2O_3, Other <2%	Kuraray Noritake Dental, Tokyo, Japan
Katana Super Translucent Multi Layered (STML)	Zirconia	88–93% ZrO_2, 7–10% Y_2O_3, Other<2%	Kuraray Noritake Dental
Katana Ultra Translucent Multi Layered (UTML)	Zirconia	87–92% ZrO_2, 8–11% Y_2O_3, Other<2%	Kuraray Noritake Dental
Opalescence Go	Hydrogen Peroxide (HP)	6% Hydrogen peroxide, Potassium, Nitrate, Fluroide, Water and Carbapole	Ultradent Products, South Jordan, UT, USA
Opalescence Pf	Carbamide peroxide (CP)	10% Carbamide peroxide, Potassium, Nitrate, Fluroide, Water and Carbapole	Ultradent Products

samples, which were standardized in size and provided surface parallelism, were sintered in accordance with the manufacturer's instructions. The thicknesses of the samples were checked with a digital caliper. These steps were carried out by only one operator. All samples were stored in distilled water before bleaching.

Bleaching application

Six percent hydrogen peroxide (45 min per day) and 10% carbamide peroxide (8 h per day) were applied to the samples for 14 days. These bleaching products were employed according to the manufacturer's instructions. Following each daily bleaching, samples were washed under tap water with the help of a brush to remove the bleaching agent and stored in distilled water.

Color and translucency measurements

The color differences (ΔE_{00}) and TP of the samples were measured using a spectrophotometer device (VITA Easyshade Advance 4.0®, Vita Zahnfabrik, Bad Säckingen, Germany), before bleaching application (T0) and on the third (T3), seventh (T7), and 14th (T14) day after the bleaching application. In these measurements, the CIE $L^*a^*b^*$ color system was used. Before each measurement phase, the device was calibrated according to the manufacturer's recommendations, and the L^*, a^*, b^* values were recorded three times at the center of each specimens followed by obtaining average values of L^*, a^*, b^* parameters. The spectrophotometer probe tip was placed perpendicular to the center of each specimens and held until completion of the measurement. A coupling substance (glycerol, $C_3H_8O_3$) (Vetec Química Fina, Riode Janeiro, Brazil) with a refractive index of 1.47 was used to minimize light scattering by eliminating the presence of an air layer between the specimen and the background. The measurements were performed by only one dental research assistant. The color differences in the measurements were performed over a neutral gray background (L^*=50.30, a^*=1.41, b^*=2.37), while TP measurements were performed on both black (L^*=13.53, a^*=0.06, b^*=−0.52) and white backgrounds (L^*=89.51, a^*=−0.97, b^*=8.16).

Color differences in coordinate system (ΔE_{00}, according to CIEDE2000 formula), and TP variances were calculated using the following formulas:

$$\Delta E_{00}=[(\Delta L`/K_LS_L)^2+(\Delta C`/K_cS_c)^2+(\Delta H`/K_HS_H)^2 +R_T(\Delta C`/K_cS_c)(\Delta H`/K_HS_H)]^{1/2}$$

$\Delta L`$ (differences in lightness), $\Delta C`$ (differences in chroma), $\Delta H`$ (differences hue); RT (rotation function) accounts for the interaction between hue and chroma in the blue region; SL, SC, and SH adjust for variation in the $L^*a^*b^*$ coordinate system; and K_L, K_C, and K_H correcting (weighting) the metric difference for experimental conditions (K_L=1.0, K_C=1.0, K_H=1.0).

$$TP: [(L^*b-L^*w)^2+(a^*b-a^*w)^2+(b^*b-b^*w)^2]^{1/2}$$

b: black, w: white

Objective measurement of color and translucency changes as a result of bleaching treatments allows us to determine the degree of bleaching of monolithic zirconia material colored according to compare different bleaching methods and concentrations of agents used. Also, the repeatability and statistical evaluation of the results are among the important advantages of such color analysis methods[44]. In this study, the $L^*a^*b^*$ color range system and CIEDE2000 formula was used.

Statistical analysis

Statistical analyses were done using SPSS Statistics 20.0 (SPSS, Chicago, IL, USA) with a 95% confidence interval and p=0.05 significance level. Shapiro-wilk test was performed to evaluate the distribution of data. Due to the normal distribution, repeated measure analyses of variance (ANOVA) test was used as a parametric test. Comparisons between groups were made with the Tukey HSD *post-hoc* test.

RESULTS

Material thickness and type had significant effects on bleaching agent-induced changes in TP value ($p<0.05$). However, when comparing carbamide peroxide and hydrogen peroxide bleaching agents, we detected no significant differences in bleaching agent-induced changes in TP ($p>0.05$).

The application time of the bleaching agents significantly affected the change in translucency (ΔTP) ($p<0.05$). Also, we detected statistically significant differences when comparing the application times of the bleaching agent and the types and thicknesses of the material ($p<0.05$).

Before the application of bleaching agent (T0), among the monolithic zirconia materials tested, the UTML group had the highest TP value (0.4 mm 21.6±0.94), and the ML group had the lowest TP value (1.5 mm 8.42±0.61). At different application times of bleaching agents, the highest translucency change (ΔTP) was observed at a thickness of 0.4 mm, and the lowest translucency change (ΔTP) was observed at a thickness of 1.5 mm (Fig. 1 and Table 2).

The present study detected no significant effect of thickness on ΔE_{00} ($p>0.05$). We detected a significant difference in the effect of the bleaching agent and the type of material on ΔE_{00} value ($p<0.05$). According to the *post-hoc* test, ΔE_{00} value was more affected by carbamide peroxide agent than hydrogen peroxide agent ($p<0.05$). Also, among the tested monolithic zirconia groups, the ΔE_{00} value was highest for the UTML group ($p<0.05$). There was no significant difference in ΔE_{00} when comparing ML and STML ($p>0.05$).

A statistically significant difference was observed in the effect of bleaching agent application times on the ΔE_{00} value of the materials ($p<0.05$). Also, a statistically significant difference was observed between the application time of bleaching agent and type of material ($p<0.05$). When the effect of bleaching agent application times on ΔE_{00} value was evaluated, there was a statistically significant difference between days 3 and 7 ($p<0.05$). However, there was no statistically significant difference in terms of ΔE_{00} value on the seventh and 14th days of application ($p>0.05$) (Fig. 2). According to the

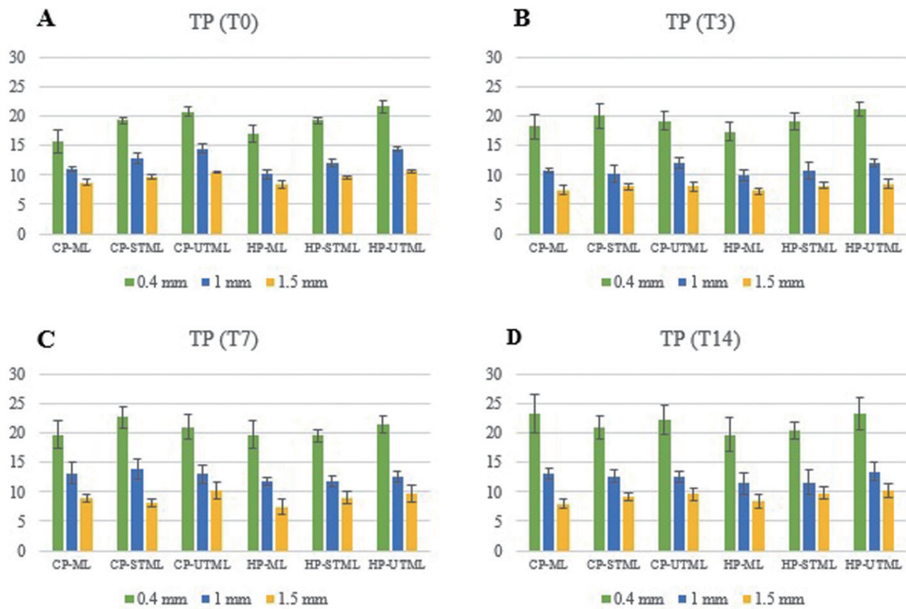

Fig. 1 Comparing TP changes between initial and different days of bleaching application.

Table 2 The mean value and standard deviation of TP before bleaching (T0), 3 days (T3), 7 days (T7) and 14 days (T14)

	Bleaching agent	Material	Thickness	T0 (Sd)	T3 (Sd)	T7 (Sd)	T14 (Sd)
Mean, standard deviation (Sd)	Carbamide Peroxide	ML	0.4	**15.8 (1.95)**^{A,a}	**18.2 (2.15)**^{A,a}	**19.7 (2.30)**^{A,b}	**23.3 (3.30)**^{A,b}
			1.0	11.0 (0.28)^{B,a}	10.7 (0.47)^{B,a}	13.2 (1.92)^{B,b}	13.1 (0.89)^{B,b}
			1.5	8.75 (0.48)^{C,a}	7.37 (0.79)^{C,a}	8.87 (0.71)^{C,b}	7.93 (0.72)^{C,b}
		STML	0.4	**19.3 (0.48)**^{A,b}	**20.1 (2.07)**^{A,ab}	**22.7 (1.78)**^{A,b}	**21.0 (1.98)**^{A,b}
			1.0	12.9 (0.90)^{B,b}	10.2 (1.55)^{B,ab}	13.8 (1.65)^{B,b}	12.6 (1.02)^{B,b}
			1.5	9.59 (0.37)^{C,b}	7.99 (0.50)^{C,ab}	8.14 (0.55)^{C,b}	9.14 (0.56)^{C,b}
		UTML	0.4	**20.8 (0.80)**^{A,c}	**19.2 (1.52)**^{A,b}	**21.0 (2.10)**^{A,c}	**22.2 (2.47)**^{A,c}
			1.0	14.5 (0.72)^{B,c}	12.0 (0.93)^{B,b}	13.0 (1.54)^{B,c}	12.5 (0.95)^{B,c}
			1.5	10.5 (0.14)^{C,c}	7.98 (0.70)^{C,b}	10.2 (1.43)^{C,c}	9.58 (1.15)^{C,c}
	Hydrogen Peroxide	ML	0.4	**17.0 (1.45)**^{A,a}	**17.4 (1.62)**^{A,a}	**19.7 (2.30)**^{A,b}	**19.7 (2.89)**^{A,b}
			1.0	10.1 (0.82)^{BC,a}	10.0 (0.91)^{BC,a}	11.7 (0.66)^{BC,b}	11.5 (1.84)^{BC,b}
			1.5	8.42 (0.61)^{C,a}	7.21 (0.62)^{C,a}	7.43 (1.33)^{C,b}	8.39 (1.14)^{C,b}
		STML	0.4	**19.3 (0.49)**^{A,b}	**19.1 (1.45)**^{A,a}	**19.5 (0.98)**^{A,b}	**20.4 (1.53)**^{A,b}
			1.0	12.0 (0.71)^{BC,b}	10.7 (1.34)^{BC,a}	11.7 (0.87)^{BC,b}	11.6 (2.02)^{BC,b}
			1.5	9.55 (0.33)^{C,b}	8.23 (0.51)^{C,a}	9.01 (1.14)^{C,b}	9.74 (1.03)^{C,b}
		UTML	0.4	**21.6 (0.94)**^{A,c}	**21.2 (1.16)**^{A,b}	**21.4 (1.50)**^{A,c}	**23.3 (2.79)**^{A,c}
			1.0	14.3 (0.41)^{B,c}	12.1 (0.66)^{B,b}	12.5 (0.97)^{B,c}	13.4 (1.61)^{B,c}
			1.5	10.6 (0.33)^{C,c}	8.43 (0.73)^{C,b}	9.73 (1.36)^{C,c}	10.2 (1.27)^{C,c}

According to ANOVA; uppercase letters in vertical column indicate difference among material, thickness and bleaching agent (A,B and C different subset group, and BC intersection subset group between B and C). Lower letters in horizontal column indicate difference within T0, T3,T7 and T14 days (a,b and c different subset group, and ab intersection subset group between a and b).

previous study[32], CIEDE2000 (ΔE_{00}) has two different perceptibility and acceptability thresholds at 50:50%, 0.8 and 1.8 respectively. All ΔE_{00} data were evaluated according to perceptibility and acceptability thresholds (Table 3).

When evaluated ΔL\` (changes in lightness) and $\Delta C$\` (changes in chroma) parameter, significantly difference was observed in the effect of the bleaching agent type

Table 3 The mean value and standard deviation of ΔE_{00} after 3 days, 7 days and 14 days

	Bleaching agent	Material	Thickness	ΔE0-3 (Sd)	ΔE0-7 (Sd)	ΔE0-14 (Sd)
Mean, standard deviation (Sd)	Carbamide Peroxide	ML	0.4	1.26 (1.01)^{A,*}	2.07 (1.08)^{A,B,¶}	**3.53 (1.06)**^{B,¶}
			1.0	**1.63 (0.356)**^{A,B,*}	1.12 (0.377)^{A,*}	1.17 (0.601)^{A,*}
			1.5	3.13 (0.961)^{A,B,¶}	1.87 (0.451)^{A,B,¶}	**3.51 (1.54)**^{B,¶}
		STML	0.4	**2.46 (1.11)**^{A,B,¶}	1.95 (0.977)^{A,B,¶}	1.69 (0.912)^{A,B,*}
			1.0	**2.65 (0.489)**^{A,B,¶}	1.02 (0.579)^{A,*}	1.51 (0.737)^{A,B,*}
			1.5	2.59 (0.708)^{A,B,¶}	**3.49 (1.37)**^{A,B,¶}	3.05 (0.471)^{A,B,¶}
		UTML	0.4	**3.15 (0.859)**^{A,B,¶}	1.52 (1.10)^{A,B,*}	1.61 (0.62)^{A,B,*}
			1.0	**3.22 (0.499)**^{B,¶}	2.44 (1.05)^{A,B,¶}	1.94 (1.04)^{A,B,¶}
			1.5	**3.26 (0.43)**^{A,B,¶}	2.55 (1.54)^{A,B,¶}	2.80 (0.772)^{A,B,¶}
	Hydrogen Peroxide	ML	0.4	**2.49 (0.928)**^{A,B,¶}	2.04 (0.899)^{A,B,¶}	2.26 (0.814)^{A,B,¶}
			1.0	0.95 (0.501)^{A,*}	1.62 (0.353)^{A,B,*}	**1.98 (0.517)**^{A,B,¶}
			1.5	**1.51 (0.454)**^{A,B,*}	1.18 (0.502)^{A,*}	1.42 (0.23)^{A,*}
		STML	0.4	1.20 (0.94)^{A,*}	1.45 (1.06)^{A,*}	**1.81 (0.971)**^{A,B,¶}
			1.0	**1.79 (0.439)**^{A,B,*}	1.18 (0.951)^{A,*}	1.45 (0.581)^{A,B,*}
			1.5	**1.29 (0.6)**^{A,*}	1.22 (0.354)^{A,*}	1.19 (0.562)^{A,*}
		UTML	0.4	1.79 (0.967)^{A,B,*}	1.93 (1.43)^{A,¶}	**2.04 (0.855)**^{A,B,¶}
			1.0	**2.88 (0.817)**^{A,B,¶}	2.48 (0.888)^{A,B,¶}	1.99 (0.667)^{A,B,¶}
			1.5	**2.53 (0.745)**^{A,B,¶}	1.95 (1.20)^{A,B,¶}	1.64 (0.857)^{A,*}

According to ANOVA; uppercase letters indicate difference among material, thickness and bleaching within T3, T7 and T14 days. (A and B different subset group, and AB intersection subset group between A and B). Bold; highest change at ΔE_{00} value in group.

* >Perceptibility thresholds ΔE_{00}=0.8, ¶ >acceptability thresholds ΔE_{00}=1.8

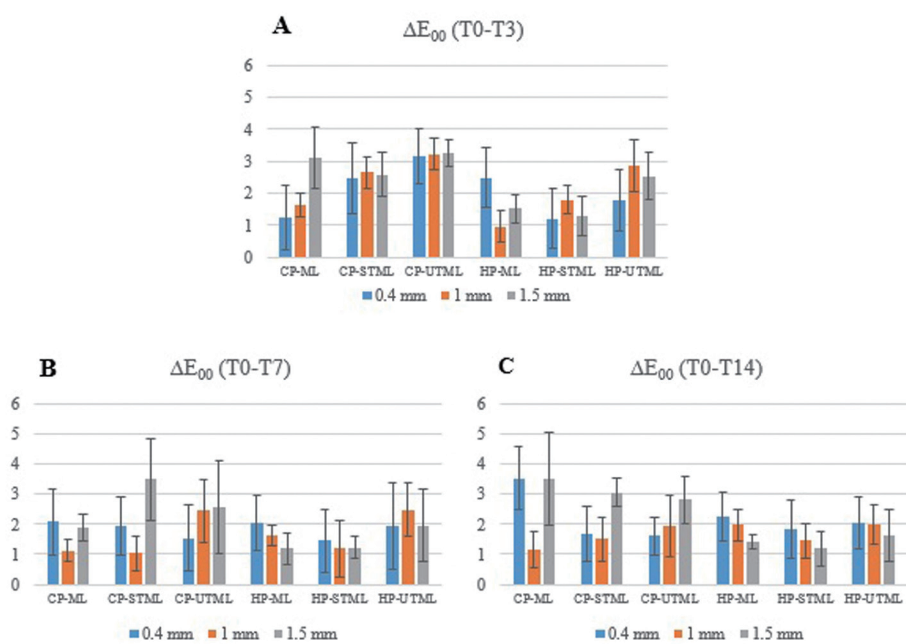

Fig. 2 Comparing ΔE_{00} changes between initial and different days of bleaching application.

and the type of material (p<0.05). However, $\Delta H`$ (changes in hue) parameter was only significantly affected by bleaching agent type ($p$<0.05). According to the *post-hoc* test, $\Delta L`$, $\Delta C`$ and $\Delta H`$ value was more affected by carbamide peroxide agent than hydrogen peroxide agent (p<0.05). Also, the $\Delta L`$ and $\Delta C`$ value were highest for the UTML group (p<0.05). There was no significant difference in $\Delta L`$ and $\Delta C`$ when comparing ML and STML

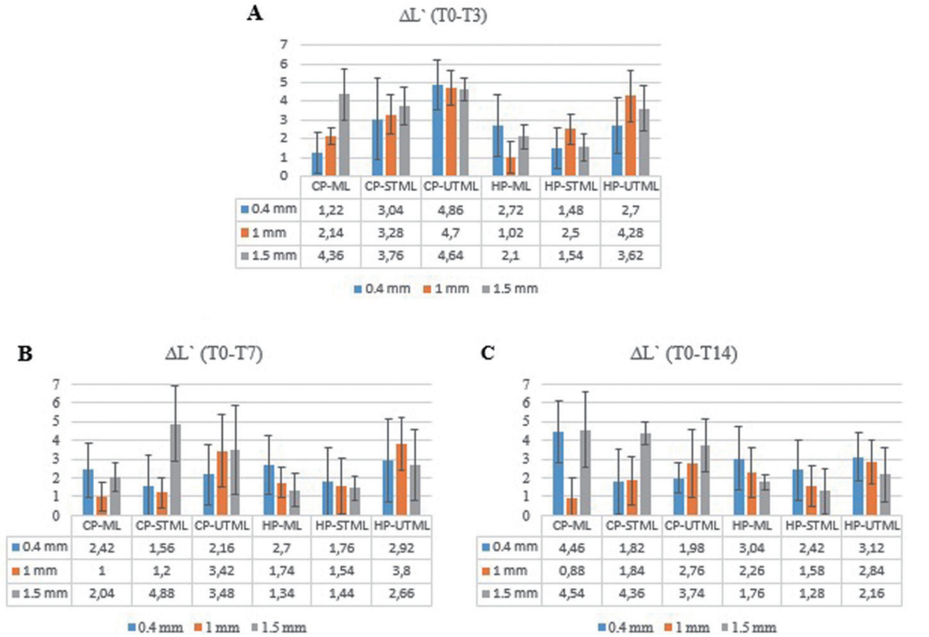

Fig. 3 Comparing ΔL`changes between initial and different days of bleaching application.

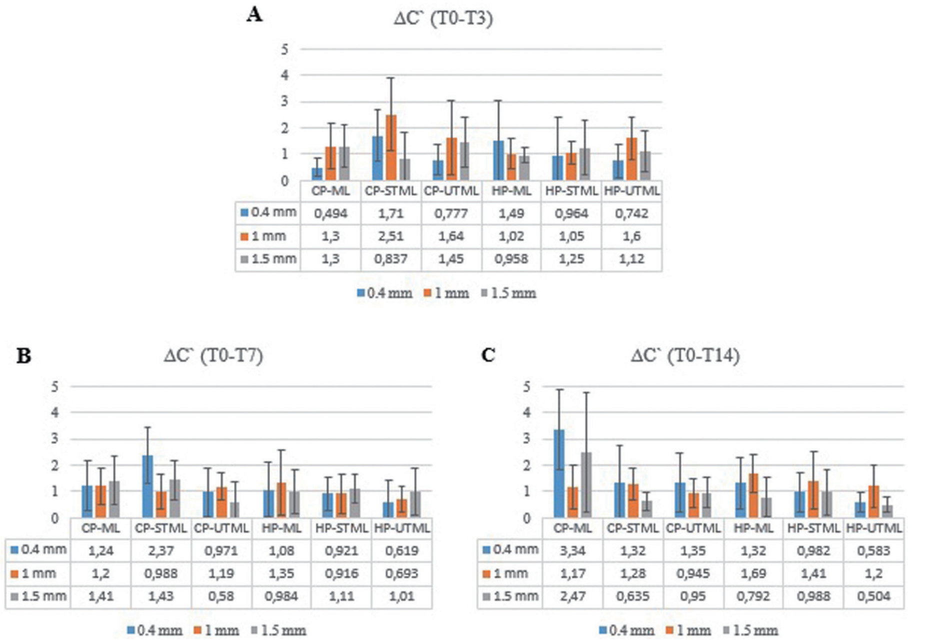

Fig. 4 Comparing ΔC`changes between initial and different days of bleaching application.

(p>0.05). However, there was no significant difference in ΔH` when comparing ML, STML and UTML (p>0.05).

When the effect of bleaching agent application times on ΔL` value was evaluated, there was a statistically significant difference between days 3 and 7 ($p$<0.05), while there was no statistically significant difference in terms of $\Delta L$` value on the seventh and 14th days of application (p>0.05) (Fig. 3). When the effect of bleaching agent application times on ΔC` value was evaluated there was no significant difference among days of 3, 7 and 14 ($p$>0.05) (Fig. 4). When the effect of bleaching agent application times on $\Delta H$` value was evaluated, there was a statistically significant difference between days 3 and 14 (p<0.05), while there was no statistically significant difference in terms of ΔH` value on the seventh and 14th days of application (p>0.05) (Fig. 5).

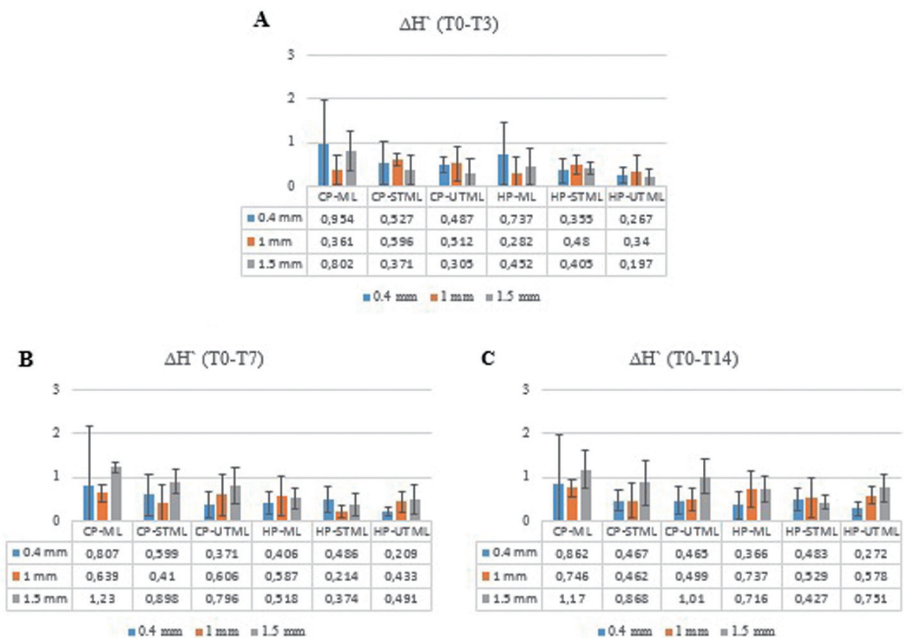

Fig. 5 Comparing ΔH\`changes between initial and different days of bleaching application.

DISCUSSION

Here we found that home bleaching agents affect the color and translucency of monolithic zirconia materials, and that changes in translucency are dependent on the type of bleaching agent used (the null hypothesis was accepted).

It is claimed that the opaque appearance of zirconia is responsible for the grain size and the existence of monoclinic, tetragonal and cubic phases with different refractive indices. One of the methods used to solve the optical deficiency in opaque zirconia is to increase the yttria dopant content, which leads to higher quantity of the cubic phase and translucency.

In this study, Katana ML Kuraray Noritake 3Y-TZP (<15% *c* phase), Katana STML Kuraray Noritake 4Y-PSZ (>25% *c* phase) and Katana UTML Kuraray Noritake 5Y-PSZ (>50% c phase) were used as zirconia materials. The highest translucency value was observed in UTML, and the lowest translucency value was observed in the ML monolithic zirconia material. The difference in translucency values might be because the materials are different from each other (*c* phase). Similarly, Inokoshi *et al.*[45] reported significant correlation between *c* phase and translucency. This strong correlation has been attributed to the isotropic structure of c-ZrO_2 which has larger grain size than t-ZrO_2. Also, there are findings indicating that increasing the sintering temperature increases translucency in the studies performed[46,47]. The sintering temperature of zirconia affects the grain size and higher sintering temperature results in a larger grain size[48]. When compared in terms of sintering temperature of zirconia materials used in our study, the ML monolithic zirconia sintering temperature (1,500°C, 2 h) is lower than the UTML and STML monolithic zirconia sintering temperature (1,550°C, 2 h). The low translucency value of the ML zirconia might be due to the low cubic phase (<15% *c* phase) ratio and low sintering temperature (1,500°C, 2 h).

As a result of this study, it was observed that there was an inverse correlation between monolithic zirconia thickness and translucency value in accordance with previous studies[12,20,27,28]. The highest translucency value was 0.4 mm UTML monolithic zirconia, and the lowest translucency value was 1.5 mm ML monolithic zirconia. Also, our results were in accordance with Sen and Isler[49] study where different translucency monolithic zirconia was used (Highly Translucent, Super Translucent and Extra Translucent), and effects of the thickness of the monolithic zirconia on the translucency were measured. They concluded that there was a decrease in translucency value as the monolithic zirconia material thickness increased from 0.5 to 1.5 mm.

In this study, the effect of 10% carbamide peroxide and 6% hydrogen peroxide bleaching agents on monolithic zirconia materials were evaluated after 3, 7, and 14 days of treatment. It was observed that 10% carbamide peroxide and 6% hydrogen peroxide household bleaching agents had similar effects on translucency value. It was observed all materials with a thickness of 0.4 mm were found to increase translucency values. This might be because there is an inverse correlation between monolithic zirconia thickness and translucency value. When the materials were evaluated in terms of TP differences, ML was the most affected. This might be because the ML material is different in content (<15% *c* phase) and sintering temperature (1,500°C, 2 h). When evaluated 0.4-mm thick of all type monolithic zirconia materials, it was also concluded that there was an increase in the translucency between T0 and T14 days of application time of home bleaching agents. This increased translucency may be related to the ratio between depth of bleaching agent penetration form the surface and the thickness of the entire zirconia. As the thickness of the monolithic zirconia material decrease, home bleaching agent is more effective on TP.

The effects of 10% carbamide peroxide and 6% hydrogen peroxide bleaching agents on the color differences (ΔE_{00}) of different color monolithic zirconia materials were evaluated. It was determined that monolithic zirconia materials of different thickness had no effect on the ΔE_{00} changes. However, 10% carbamide peroxide was observed to be more effective on color differences than 6% hydrogen peroxide bleaching agent. In addition, in terms of the change in ΔE_{00}, the 10% carbamide peroxide bleaching agent-induced changes were mostly between days 0 and 3, and 6% hydrogen peroxide bleaching agent-induced changes were mostly between days 0 and 14. This might be because home bleaching agents might cause ΔE_{00} changes at different times due to the different application times (10% carbamide peroxide for 8 h per day *vs*. 6% hydrogen peroxide for 45 min per day)[50].

When evaluated ΔL`, $\Delta C$`, ΔH` parameter, it was observed that all parameters were more affected by 10% carbamide peroxide than 6% hydrogen peroxide bleaching agent. $\Delta L$` parameter was affected both application time and material type, similar to ΔE_{00} parameter. However, ΔC` parameter was not affected by application time of bleaching agent, and also, $\Delta H$` parameter showed no change at different type of monolithic zirconia material.

One limitation of the study is the inability to fully replicate the oral environment. Other limitations are using only one brand of zirconia material and two types of home bleaching agents. In future studies, we plan to test other brands of zirconia, other concentrations of home bleaching agents, and stronger office type bleaching treatments.

CONCLUSIONS

1. Application times affect bleaching agent-induced ΔE_{00}, ΔL`, $\Delta H$` and changes in TP.
2. Carbamide peroxide and hydrogen peroxide had different effects on the ΔE_{00}, ΔL`, $\Delta C$`, ΔH` value, but similarly affected the TP value.
3. Material thickness does not affect bleaching agent-induced ΔE_{00}, ΔL`, $\Delta C$` and ΔH` parameter, but has a significant effect on bleaching agent-induced changes in TP.
4. Bleaching agents affect the ΔE_{00}, ΔL`, $\Delta C$` and TP values of monolithic zirconia materials. Among the tested materials, the bleaching agents most affected the ΔE_{00}, ΔL`, $\Delta C$` and TP values of UTML zirconia.
5. According to Table 3, all ΔE_{00} value were higher than perceptibility thresholds (>0.8). However, some ΔE_{00} values were found to be higher than the acceptability thresholds (>1.8). Also, it was determined that higher ΔE_{00} value (>3.0) were seen in carbamide peroxide home bleaching agent groups.

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CONFLICT OF INTEREST

Author Murat ALKURT declares that he has no conflict of interest. Author Zeynep YESİL DUYMUS declares that she has no conflict of interest. Author Seyma YILDIZ declares that she has no conflict of interest.

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