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Research / Araştırma Makalesi

Effects of Surface Finishing Methods, Zirconia Brands, and Bleaching Techniques on Color Change and Translucency of Monolithic Zirconia Restorations: A Comparative Study

Yüzey İşlem Yöntemleri, Zirkonya Tipleri ve Beyazlatma Tekniklerinin Monolitik Zirkonya Restorasyonların Renk Değişimi ve Translusensisi Üzerine Etkileri: Karşılaştırmalı Bir Çalışma

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ABSTRACT

Background: This study aimed to investigate the effects of different surface finishing methods (glaze and polishing), various zirconia brands (multilayer, ultra translucent, and super translucent), and different bleaching methods (office and home bleaching) on the color change, whiteness change, and translucency parameters of different monolithic zirconia.

Methods: The researchers prepared 180 samples using three types of monolithic zirconia blocks with different translucent properties. The samples were divided into groups based on surface treatments (glaze and polishing) and bleaching methods (office and home bleaching). Color measurements were taken before and after the surface treatments and bleaching procedures using a spectrophotometer. The color change (ΔE00), whiteness change (ΔWI), and translucency parameters were calculated based on the measurements.

Results: The statistical analysis revealed that zirconia brands, surface finishing methods, and bleaching procedures significantly affected the color change, whiteness change, and translucency parameters of the monolithic zirconia samples. In terms of bleaching methods, the ΔE00 and ΔWI values of office bleaching were significantly higher than home bleaching in the MLG group ($p<0.05$). However, there was no significant difference between office and home bleaching in other zirconia groups ($p>0.05$).

Conclusion: The results of the study indicate that zirconia brands, surface finishing methods, and bleaching procedures have an impact on the color change, whiteness change, and translucency parameters of monolithic zirconia restorations. The study suggests that careful consideration should be given to the selection of zirconia brands, surface treatments, and bleaching methods to achieve optimal aesthetic outcomes in prosthetic restorations.

Keywords: Zirconia brands; Finishing; Bleaching Agents; Color Change; Whiteness change

ÖZ

Amaç: Bu çalışmanın amacı, farklı yüzey bitirme yöntemlerinin (glaze ve polisaj), çeşitli zirkonya çeşitlerinin (çok katmanlı, ultra translusent ve süper translusent) ve farklı beyazlatma yöntemlerinin (ofis ve ev tipi ağartma) farklı monolitik zirkonyaların renk değişimi, beyazlık değişimi ve translusensi parametreleri üzerindeki etkilerini araştırmaktır.

Gereç ve Yöntemler: Farklı translusent özelliklere sahip üç tip monolitik zirkonya blok kullanarak 180 örnek hazırladı. Örnekler yüzey işlemlerine (glaze ve cilalama) ve beyazlatma yöntemlerine (ofis ve ev tipi ağartma) göre gruplara ayrılmıştır. Renk ölçümleri, yüzey işlemleri ve beyazlatma prosedürlerinden önce ve sonra spektrofotometre kullanılarak alınmıştır. Ölçümlere dayanarak renk değişimi (ΔE00), beyazlık değişimi (ΔWI) ve translusensi parametreleri hesaplanmıştır.

Bulgular: İstatistiksel analiz, zirkonya çeşitlerinin, yüzey bitirme yöntemlerinin ve beyazlatma prosedürlerinin monolitik zirkonya örneklerinin renk değişimini, beyazlık değişimini ve yarı saydamlık parametrelerini önemli ölçüde etkilediğini ortaya koymuştur. Beyazlatma yöntemleri açısından, MLG grubunda ofis ağartmasının ΔE00 ve ΔWI değerleri ev tipi ağartmasına göre anlamlı derecede yüksektir ($p<0.05$). Ancak, diğer zirkonya gruplarında ofis ve ev tipi beyazlatma arasında anlamlı bir fark yoktur($p>0.05$).

Sonuç: Çalışmanın sonuçları, zirkonya çeşitlerinin, yüzey bitirme yöntemlerinin ve beyazlatma prosedürlerinin monolitik zirkonya restorasyonların renk değişimi, beyazlık değişimi ve translusensi parametreleri üzerinde etkili olduğunu göstermektedir. Çalışma, protetik restorasyonlarda optimum estetik sonuçlar elde etmek için zirkonya çeşitlerinin, yüzey işlemlerinin ve beyazlatma yöntemlerinin seçimine dikkat edilmesi gerektiğini önermektedir.

Anahtar Kelimeler: Zirkonya çeşitleri; Bitirme İşlemleri; Beyazlatma Ajanları; Renk değişimi

1. INTRODUCTION

The development of prosthetic materials in dentistry aims to provide the patient with the best function, phonation, and aesthetics while ensuring their integrity with natural dental tissues. A natural appearance can be achieved with prosthetic restorations that are biocompatible with dental tissues, meet patients' aesthetic expectations, and are resistant to masticatory forces.[1] All-ceramic materials have become a popular alternative to metal-ceramic restorations to achieve a more natural appearance in fixed prosthetic restorations, which represent most dental prosthetic treatments.[2] Due to its durability, zirconia, in particular, can be used in various prosthetic restorations. Although zirconia has high mechanical properties due to its high opacity, restorations with improved aesthetic properties can be prepared by applying a veneer layer of translucent ceramics. Therefore, new techniques are being developed to produce monolithic zirconia restorations that do not require a veneer.

After reviewing the literature, it has been observed that monolithic zirconia, which is intended for aesthetics, has compatibility problems with adjacent teeth after prolonged glazing or polishing[3,4]. In addition to the material type, the surface finish is also important for the restoration's aesthetic appearance. Therefore, the surface of dental restorations is smoothed via glazing and polishing processes for optimal esthetics. In addition to the roughness of the shade of restorations, surface texture, ceramic type and brand, cubic content, thickness, surface treatment protocol, and exposure to food and beverages have also been observed to be affected.[5-8] The final polishing process applied can affect the final color of the restoration.

Various bleaching products and techniques have been introduced to achieve color change. Bleaching techniques can be classified according to whether the bleaching is performed in the dental office, at home, or both. While 30-35% hydrogen peroxide (HP) or carbamide peroxide (CP) can be used for 15-60 minutes of in-office bleaching, 10-16% CP can be used at home for 1-4 weeks of bleaching.[9] The deterioration of the structural and superficial properties of restorative materials due to the action of chemical agents may affect the clinical longevity of aesthetic restorations.[2] Türkün et al.[10] concluded that bleaching does not have a significant impact on restorative materials. The effect of hydrogen peroxide-based bleaching agents on the physical properties of various restorative materials, including surface roughness, gloss, shade, and microhardness properties, has been evaluated[11]. While studies have shown that bleaching agents have adverse effects on materials such as

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glass ionomers, resin-modified glass ionomers, and polyacid-modified composites, there is limited information on the changes that may occur depending on the type and surface properties of monolithic zirconia.[12,13]

Color stability is one of the most important factors in the aesthetic success of dental restorations. The (ΔE) formula is used to determine the color stability of restorations and numerically express the perceived color difference between two measurements.[14] The CIELAB color space, ΔE00 total color difference, and TP 00 translucency formulas are widely used in dentistry.[15,16] However, the material's whiteness is determined by a special whiteness index (WID) for dental studies, which focuses on CIELAB.[17] The main differences between a material after it has been modified in the mouth and before it has been modified are measured and calculated using a spectrophotometer.

This study aims to investigate the effect of two different surface finishing methods (glaze, polish), different zirconia brands (multilayer, ultra translucent, and super translucent) and different bleaching methods (office and home bleaching) on the color change, whiteness change and translucency parameters (TP) of different monolithic zirconia. The null hypothesis (H0) tested is that the zirconia brand, surface treatment, and bleaching method have no effect on color change and TP.

MATERIAL AND METHODS

The materials used in the study, the manufacturers, and the contents of the materials are listed in **Table 1**.

Table 1. Materials and surface finishing methods used in the study.

Material	Code	Manufacturer	Composition
Multilayer	ML	Kuraray, Noritake Dental Inc., Tokyo, Japan	$ZrO_2 + HfO_2 + Y_2O_3$) >99%, (Y_2O_3) 4%, (HfO_2) ≤5%, other oxides ≤1%
Supertranslucent	ST	Kuraray, Noritake Dental Inc., Tokyo, Japan	($ZrO_2 + HfO_2 + Y_2O_3$) >99 %, (Y_2O_3) 5.3 %, (HfO_2) ≤5 %, other oxides ≤1 %
Ultratranslucent	UT	Kuraray, Noritake Dental Inc., Tokyo, Japan	(ZrO_2 + HfO_2 +Y2O3) >99 %, (Y_2O_3) 5.4 %, (HfO_2) ≤5 %, other oxides ≤1 %
Surface Finishing Methods	**Code**	**Manufacturer**	**Procedures**
Glaze	G	IPS Ivocolor Glaze Paste	The samples were placed in the glaze in a thin layer once more.
Polishing	P	EVE Diacera (EVAErnst, VetterGmbH	The polishing kit 3000 rpm pressure was applied for 20 seconds
Bleaching Methods	**Code**	**Manufacturer**	**Procedures**
Office	O	SDI, Bayswater, Victoria, Australia	The bleaching process was applied for a total of 24 minutes
Home	H	SDI, Bayswater, Victoria, Australia	The treated surfaces of the monolithic zirconia samples for 45 minutes a day every week

2.1. Preparation of Samples

Using three types of monolithic zirconia blocks with different translucency properties (Katana Zirconia Multi-Layered [ML], Katana Zirconia SuperTranslucent Multi-Layered [ST], Katana Zirconia Ultra SuperTranslucent Multi-Layered [UT; Kuraray, NoritakeDentalInc. , Tokyo, Japan]) and a CAD/CAM system (Yenadent D43, Yenadent Ltd, Istanbul, Turkey), 180 specimens were prepared, 60 from each group, with a diameter of 15 mm and a thickness of 1 mm. The thickness of the specimens was checked using a digital caliper (TorQ 150 x 0.01 mm Digital Caliper, China).

2.2. Application of Surface Treatments to Samples

Two different surface treatments—glaze (G) and polish (P) — were applied to the prepared zirconia specimens. Each zirconia group was divided into two subgroups based on their surface treatments.

The monolithic zirconia samples (Katana ML, ST, UT) separated for glazing were placed in the oven (Vacumat 6000 MP, VitaZahnfabrik) for glazing by applying a thin layer of glaze (IPS, Ivocolor Glaze Paste, Ivoclar Vivadent) on only one surface according to the manufacturer's recommendation.

The other half of the monolithic zirconia groups were polished. Using a three-stage zirconia polishing kit micromotor (Ti-Max X600L; NSK, Tochigiken, Japan), zirconia specimens (Katana ML, ST, UT) were polished according to the manufacturer's instructions using the EVE Diacera polishing kit (EVA Ernst, Vetter GmbH) at 3000 rpm for 20 seconds. After polishing, the samples were ultrasonically cleaned (Bandelin Sonorex, Bandelin Electronic GmbH&Co, Berlin, Germany) in distilled water for 1 minute and air dried.

2.3. Application of Bleaching Agents to Specimens

The prepared samples were randomly divided into two groups (n=15) to apply different bleaching agents.

2.3.1. Office Type Bleaching Agent Group

In this study group, the monolithic zirconia group specimens were bleached with 37.5 % HP Pola Office+ (SDI, Bayswater, Victoria, Australia). According to the manufacturer's recommendations, the bleach was applied to the treated surfaces at 8-minute intervals and washed with distilled water at each intermediate step to renew the bleach on the surface. The bleaching process was applied for 24 minutes. One week later, the same procedures were applied to the monolithic zirconia samples, as recommended by the manufacturer. During this one-week waiting period, all samples were stored in distilled water.

2.3.2. Home Bleaching Agent Group

A home-bleaching agent, 22 % CP Pola Night (SDI, Bayswater, Victoria, Australia), was used on monolithic zirconia samples in this group. In line with the manufacturer's recommendations, a bleaching agent was applied to the treated surfaces of the monolithic zirconia samples for 45 minutes every day for a week. Afterward, the surfaces were washed with distilled water and kept in distilled water for the duration of the waiting period for the treatment.

2.4. Color Parameters of Monolithic Zirconia Samples

After the monolithic zirconia samples were numbered respectively, color measurements were made with a spectrophotometer (VITA Easyshade V, VITA Zahnfabrik, Bad Säckingen, Germany) in white, grey, and black special moldings with a 3 mm diameter hole in the middle of prepared 10x10x4 size and the L_0, a_0 and b_0 values were recorded. Then, after applying surface treatments and bleaching agents, the L, a, and b values of monolithic zirconia samples were measured again in moldings with gray, black, and white backgrounds. Care was taken to ensure that the measurements were made by the same observer, at the same time of day, and in the same measuring room. Standard D65 was used as the illumination during the measurements. Each measurement was taken three times from the center of the sample, and the values were averaged. After each measurement, the spectrophotometer was calibrated.

2.5. Calculation of Color Change, Translucency, and Parameters of Monolithic Zirconia Samples

The ΔE00 values were calculated using the CIEDE2000 formula below, using the color values (L_0, a_0, and b_0) of the samples prepared after the surface treatments on the specially prepared gray background and the color values obtained from the measurements on the gray background after the application of the bleaching agents (L, a and b). ΔE00 formula (I):

$$\Delta E_{00}^{*}=\sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2+\left(\frac{\Delta C'}{k_C S_C}\right)^2+\left(\frac{\Delta H'}{k_H S_H}\right)^2+R_T\frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}}$$

$$\Delta L' = L_2^* - L_1^*$$
$$\bar{L}=\frac{L_1^*+L_2^*}{2} \quad \bar{C}=\frac{C_1^*+C_2^*}{2}$$
$$a_1' = a_1^* + \frac{a_1^*}{2}\left(1-\sqrt{\frac{\bar{C}^7}{\bar{C}^7+25^7}}\right) \quad a_2' = a_2^* + \frac{a_2^*}{2}\left(1-\sqrt{\frac{\bar{C}^7}{\bar{C}^7+25^7}}\right)$$
$$\bar{C}'=\frac{C_1'+C_2'}{2} \text{ and } \Delta C' = C_2' - C_1' \quad \text{where } C_1'=\sqrt{a_1'^2+b_1^{*2}} \quad C_2'=\sqrt{a_2'^2+b_2^{*2}}$$
$$h_1' = \text{atan2}(b_1^*, a_1') \mod 360^\circ, \quad h_2' = \text{atan2}(b_2^*, a_2') \mod 360^\circ$$

$$\Delta h' = \begin{cases} h_2'-h_1' & |h_1'-h_2'| \le 180^\circ \\ h_2'-h_1'+360^\circ & |h_1'-h_2'| > 180^\circ, h_2' \le h_1' \\ h_2'-h_1'-360^\circ & |h_1'-h_2'| > 180^\circ, h_2' > h_1' \end{cases}$$

$$\Delta H' = 2\sqrt{C_1'C_2'}\sin(\Delta h'/2), \quad \bar{H}' = \begin{cases} (h_1'+h_2'+360^\circ)/2 & |h_1'-h_2'| > 180^\circ \\ (h_1'+h_2')/2 & |h_1'-h_2'| \le 180^\circ \end{cases}$$

$$T = 1-0.17\cos(\bar{H}'-30^\circ)+0.24\cos(2\bar{H}')+0.32\cos(3\bar{H}'+6^\circ)-0.20\cos(4\bar{H}'-63^\circ)$$
$$S_L = 1+\frac{0.015\left(\bar{L}-50\right)^2}{\sqrt{20+\left(\bar{L}-50\right)^2}} \quad S_C = 1+0.045\bar{C}' \quad S_H = 1+0.015\bar{C}'T$$
$$R_T = -2\sqrt{\frac{\bar{C}'^7}{\bar{C}'^7+25^7}}\sin\left[60^\circ\cdot\exp\left(-\left[\frac{\bar{H}'-275^\circ}{25^\circ}\right]^2\right)\right]$$

To evaluate the TP of the samples, the color values (L_b, a_b, and b_b) measured on a black background and the color values measured on a white background (L_w, a_w, and b_w) were calculated using the following formula. Similarly, the TP of the zirconia samples were calculated using the color values measured on a black background (L_b, a_b, and b_b) and the color values measured on a white background (L_w, a_w, and b_w) after applying bleaching agents. TP formula (II):

(II) TP= [(LB-LW) 2+(aB-aW) 2+(bB-bW) 2] $^{1/2}$.

The WID was obtained using the L*, a*, b* coordinate values in the CIE L*a*b* system. The dental whiteness index formula is shown below. Whiteness index formula (III):

(III) WID=0.511L*-2.324a*-1.100b*

2.6. Scanning Electron Microscopy (SEM) Evaluations

Additional samples were prepared for each test group, and the gold-coated samples were analyzed with a scanning electron microscope (JSM-6610, Jeol) at ×20,000 magnification at 20 kV. The images were analyzed for typical surface features to indicate the source or cause of the failure.[18]

2.7. X-Ray Diffractometer Analysis

The bioactivity of the X-ray diffractometer was tested using a 40 kV, 30 mA power supply. The X-ray diffraction device parameters were set as follows: a scanning range of 10°-35°^{2}, a scanning speed of 2°/min, and a thin film incidence angle of 1°.

2.8. Power Analysis

Power and sample size were analyzed in G*Power v3.1.9.7 (www.psychologie.hhu.de) for "fixed effects, special main effects, and interactions". The required sample size per group to detect a medium effect size of f=0.25 with alpha 0.05, power 0.80, number of groups 12, numerator df 2, and number of samples 158 resulted in 13,16 samples per group. Therefore, it was decided to prepare 15 samples per zirconia group.

2.9. Statistical Analysis

Data were statistically analyzed using statistical software (IBM SPSS Statistics for Windows v14.0; IBM Corp). The Shapiro-Wilk test ($p < 0.05$) was used to test for normal data distribution. Box plots were also examined for outliers. Three-way measures ANOVA tests were used to evaluate the interaction of the three independent variables (zirconia brand, surface finishing procedure, and bleaching method) and the effects of each tested variable on the color change, whiteness change, and translucency parameters. Mean values were evaluated using Bonferroni-adjusted post hoc tests (alpha = 0.05) when significant differences were defined.

3. RESULTS

The three-way ANOVA tests (**Table 2**) revealed a difference in the mean value of ΔE00 that was significantly influenced by zirconia brands and surface finishing and bleaching procedures (p<.001). Likewise, the three-way ANOVA test (**Table 2**) revealed a difference in the mean value of ΔWI that was significantly affected by zirconia brands and surface finishing and bleaching procedures (p= 0.006). Moreover, the three-way ANOVA test (**Table 3**) revealed a difference in the mean value of TP that was significantly affected by zirconia brands and surface finishes and bleaching procedures (p=0.001). Regarding the MLG group, it was observed that the ΔE00 and ΔWI values of office bleaching were significantly higher than those of home bleaching (p<0.05). Furthermore, it was observed that there was no significant difference between office and home bleaching in terms of ΔE00 and ΔWI values in other zirconia groups (p>0.05).

Table 2. Three-way ANOVA test for the influence of zirconia brand, surface finishing methods, and bleaching methods on ΔE00 and ΔWI.

Source	Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	ΔE00	55.388[a]	11	5.035	7.899	**<.001**
	ΔWI	415.984[b]	11	37.817	8.619	**<.001**
Intercept	ΔE00	657.843	1	657.843	1032.026	**<.001**
	ΔWI	3277.397	1	3277.397	746.945	**<.001**
Zirconia brand	ΔE00	12.772	2	6.386	10.018	**<.001**
	ΔWI	76.916	2	38.458	8.765	**<.001**
Surface finishing methods	ΔE00	.255	1	.255	.399	.528
	ΔWI	11.781	1	11.781	2.685	.103
Bleaching methods	ΔE00	21.945	1	21.945	34.428	**<.001**
	ΔWI	186.966	1	186.966	42.611	**<.001**
Zirconia brand* surface finishing methods	ΔE00	2.785	2	1.393	2.185	.116
	ΔWI	76.454	2	38.227	8.712	**<.001**
Zirconia brand * bleaching methods	ΔE00	4.067	2	2.034	3.190	**.044**
	ΔWI	16.894	2	8.447	1.925	.149
Surface finishing methods * bleaching methods	ΔE00	.807	1	.807	1.266	.262
	ΔWI	.447	1	.447	.102	.750
Zirconia brands * surface finishing methods* bleaching methods	ΔE00	12.757	2	6.378	10.006	**<.001**
	ΔWI	46.526	2	23.263	5.302	**.006**
Error	ΔE00	107.088	168	.637		
	ΔWI	737.140	168	4.388		
Total	ΔE00	820.319	180			
	ΔWI	443.0521	180			
Corrected Total	ΔE00	162.476	179			
	ΔWI	115.3124	179			

[a]R Squared = .341 (Adjusted R Squared = .298)
[b]R Squared = .361 (Adjusted R Squared = .319)

Table 3 compares the effect of different surface treatments (glaze and polish) applied to the same zirconia group in the same bleaching process in the vertical direction. When comparing all zirconia groups within themselves, it was observed that there was no significant difference between the ΔE00 values of the glazed and polished samples (p>0.05). Furthermore, when comparing all zirconia groups within themselves, it was observed that the ΔWI values obtained in the glazed groups of the samples that underwent glaze and polish processes were significantly higher than the ΔWI values obtained in the polished groups (p<0.05).

Table 3. Three-way repeated ANOVA test for the influence of zirconia brand, surface finishing methods, and bleaching procedure on TP values.

Parameter		Type III Sum of Squares	df	Mean Square	F	Sig[a].
TP	Bleaching procedure	5.182	1.000	5.182	4.228	**0.41**
	Bleaching procedure *Zirconia	2.079	2.000	1.039	.848	.430
	Bleaching procedure *Surface	3.064	.1000	3.064	2.500	.116
	Bleaching procedure *Zirconia* Surface	18.251	2.000	9.126	7.446	**.001**

[a]Tests of Within-Subjects Effects Huynh-Feldt significant values. It was determined that the sphericity assumption was not met, p < 001 and Greenhouse-Geisser adjustment was higher than 0.75, therefore, Huynh-Feldt values were considered.

The mean values and SD of the ΔE00, ΔWI, and TP zirconia brands after the glazing and polishing procedure and the application of different bleaching procedures are presented in **Tables 4, 5**, and **6. Table 5** compares ΔE00 and ΔWI values between the zirconia groups to which the same surface and bleaching treatments were applied.

Table 4. Mean and standard deviation ΔE00 and ΔWI values of three different zirconia with two different bleaching procedures after two different surface finishing procedures.

Parameter	Zirconia Brand	Surface Finishing Procedure	Bleaching Procedure	
			OFFICE	HOME
ΔE00	Multilayer	Glaze	3.17±0.90a,x	1.86±0.82b,x
		Polishing	2.26±1.08a,x	1.32±1.05a,x
	Supertranslucent	Glaze	1.95±1.04a,x	1.81±0.66a,x
		Polishing	1.88±0.83a,x	1.48±0.52a,x
	Ultratranslucent	Glaze	1.73±0.52a,x	1.19±0.28a,x
		Polishing	1.98±0.81a,x	1.25±0.56a,x
ΔWI	Multilayer	Glaze	-7.20±0.75a,x	-4.26±1.16**b,x**
		Polishing	-5.69±1.86a,y	-3.09±1.50a,y
	Supertranslucent	Glaze	-5.76±1.68a,x	-4.86±1.81a,x
		Polishing	-3.28±1.57a,y	-3.34±1.47 **a,y**
	Ultratranslucent	Glaze	-5.50±1.19a,x	-4.23±1.18 **a,x**
		Polishing	-3.36±1.30a,y	-2.38±1.33 **a,y**

a. b. Different letters indicate a significant difference in the same group in a horizontal direction (p<0.05 statistically significant) (OFFICE- HOME DIFFERENCE)
x.y different letters indicate significant differences (p<0.05) within the same zirconia group according to different surface treatments for the same bleaching process in the vertical direction (Glaze- Polish DIFFERENCE).

Table 5. Mean and standard deviation ΔE00 and ΔWI values of three different zirconia with two different bleaching procedures after two different surface finishing procedures.

Parameter	Surface Finishing Procedure	Bleaching Procedure	Zirconia Brand		
			Multilayer	Supertranslucent	Ultratranslucent
ΔE00	Glaze	OFFICE	3.17±0.90a	1.95±1.04**b**	1.73±0.52**b**
		HOME	1.86±0.82a	1.81±0.66a	
	Polishing	OFFICE	2.26±1.08a	1.48±0.52 **b**	1.25±0.56 **b**
		HOME	1.32±1.05a	1.88±0.83a	
ΔWI	Glaze	OFFICE	-7.20±0.75a	-5.76±1.68**b**	-5.50±1.19 **b**
		HOME	-4.26±1.16a	-4.86±1.81a	
	Polishing	OFFICE	-5.69±1.86a	-3.28±1.57**b**	-3.36±1.30**b**
		HOME	-3.09±1.50a	-3.34±1.47a	

a, b, c different letters indicate significant differences between zirconias in the same surface treatment group and in the same bleaching process in the horizontal direction (0.05/3= 0.016. padj. sig. <0.016)

Table 6. Mean and standard deviation TP values of three different zirconia with two different surface finishing procedures before and after two bleaching procedures. Bonferroni adjustment test p<0.05 statistically significant.

Zirconia Brand	Surface Finishing Procedure	Bleaching Procedure	Translucency Parameters		P value
			TP1	TP2	
Multilayer	Glaze	OFFICE	7.91±0.48^{a}	6.30±0.87^{b}	**<.001**
		HOME		7.99±0.97^{a}	.133
	Polishing	OFFICE	8.75±0.86^{a}	7.80±0.91^{b}	**.008.**
		HOME		7.73±0.97^{a}	.524
Supertranslucent	Glaze	OFFICE	8.19±1.35^{a}	7.62±1.98^{a}	.192
		HOME	6.19±1.01^{a}	6.21±1.67^{a}	.951
	Polishing	OFFICE	7.93±1.25^{a}	7.57±1.60^{a}	.418
		HOME	8.06±1.27^{a}	7.76±1.08^{a}	.240
Ultratranslucent	Glaze	OFFICE	7.67±1.05^{a}	7.08±1.49^{a}	.184
		HOME		6.40±0.77^{a}	.099
	Polishing	OFFICE	7.13±1.01^{a}	6.87±0.96^{a}	.972
		HOME		6.28±1.07^{a}	.488

Different letters a and b in the horizontal direction indicate a significant difference between the translucency values measured before and after the bleaching agent.

When in-office bleaching was performed, MLG showed a significantly higher ΔE00 value than STG and UTG (padj. sig.<0.016), while no significant difference was observed between the ΔE00 values of the STG and UTG groups (padj. sig.>0.016). Similarly, MLP showed a significantly higher ΔE00 value than STP and UTP when in-office bleaching was performed (padj. sig.<0.016). At the same time, there was no significant difference between the ΔE00 values of the STP and UTP groups (padj. sig.>0.016). Table 6 compares the initial translucency value (TP1) and the translucency value after the bleaching process (TP2) in zirconia that were subjected to the same surface treatment and bleaching treatment. According to the table, the TP1 value obtained before in-office bleaching in the MLG group was significantly higher than the TP2 value obtained after the procedure (p<.001). Similarly, the TP1 value obtained before in-office bleaching in the MLP group was significantly higher than the TP2 value obtained after the procedure (p=.008). In the other groups, although there was a decrease in the translucency values of the samples after bleaching, this difference was not statistically significant (p>0.05).

The effects of home and office bleaching agents were compared side by side in SEM images (**Figures 1, 2, 3, 4, 5, and 6**). It was observed that office-type bleaches roughened the surface more than home-type bleaches. **Figure 1** shows ML samples with glaze applied. The glazed samples showed a rougher surface compared to the polished samples in **Figure 2**. STG samples are shown in **Figure 3**. As with ML, the ST samples with polishing show a rougher surface compared to **Figure 4**. UT samples are shown in **Figures 5-6**. The UTG samples in **Figure 5** show a rougher texture compared to the UTP samples in **Figure 6**.

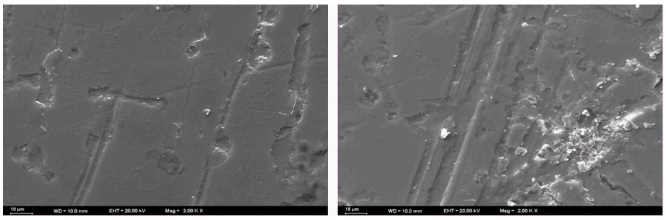

Figure 1. SEM images of MLG samples a. Home Bleaching b. Office Bleaching.

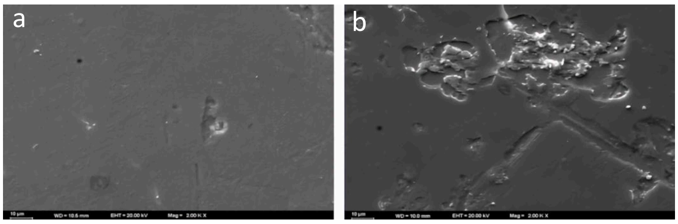

Figure 2. SEM images of MLP samples **a**. Home Bleaching **b**. Office Bleaching.

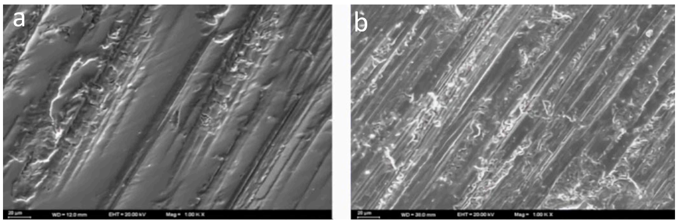

Figure 3. SEM images of STG samples **a**. Home Bleaching **b**. Office Bleaching.

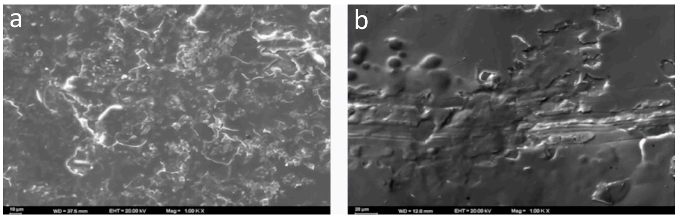

Figure 4. SEM images of STG samples **a**. Home Bleaching **b**. Office Bleaching.

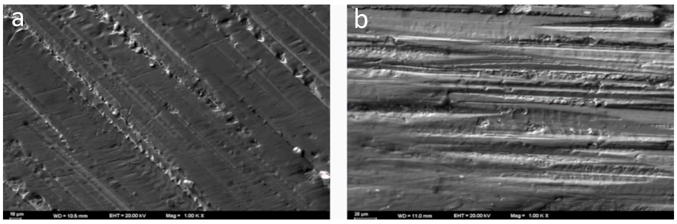

Figure 5. SEM images of UTP samples **a**. Home Bleaching **b**. Office Bleaching.

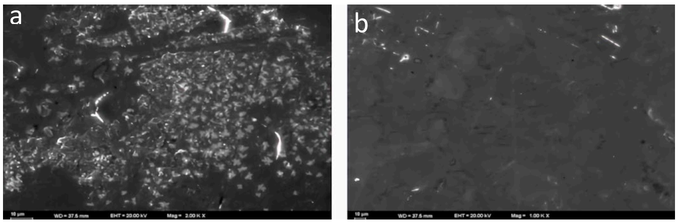

Figure 6. SEM images of UTG samples **a**. Home Bleaching **b**. Office Bleaching.

The elemental analysis of the materials was conducted according to the EDX results, and elements such as Al, Ba, Ca, Si, Si, Zn, K, Na, K, and Na were observed on the surface of the glazed samples, except for the elements Zr, O, and C on the polished surfaces. In the graphs obtained, the Zr value is higher in ML samples compared to other monolithic zirconia samples (**Figures 7, 8, 9**).

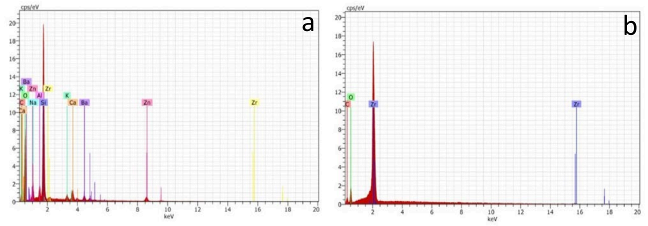

Figure 7. EDX images of **a**. MLG samples **b**. MLP samples.

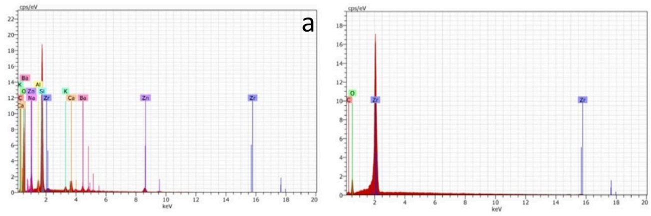

Figure 8. EDX images of **a**. STG samples **b**. STP samples.

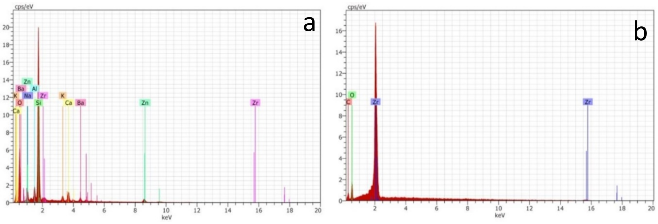

Figure 9. EDX images of **a**. UTG samples **b**. UTP samples.

4. DISCUSSIONS

When the data obtained from the study were evaluated, Hypothesis H01, which stated that the zirconia material and the bleaching agent used would not affect the material's color and translucency, was rejected. Hypothesis H02, which stated that the surface treatments applied after the bleaching agents would cause a in difference color, was accepted in accordance with the data obtained.

The study examined CIEDE2000, translucency, and whiteness thresholds to measure color changes after bleach application. Paravina et al.[19] found that the CIEDE2000 formula better reflects human color perception. They used the ΔE 00 formula to determine the color change.[15,20] The formula was postulated as ΔE 00 %50:50 PT ΔE 00 = 0.8, %50:50 AT is ΔE 00 = 1.8.[21] The TP 00 formula was used to determine the translucency of the materials. For 50:50% TPT, TPT 00 = 0.62 units, and 50:50% TAT, TAT 00 = 2.62 units[16]. At the same time, color and whiteness were evaluated using another specialized formula —the WID formula. According to the studies conducted by Perez et al. [17], 50:50% WPT was accepted as WID = 0.72 units and WID = 2.60 units. The formulas showed that was a color change after bleaching the zirconia, there was a change after bleaching the zirconia. The most noticeable color change was observed in the MLG group in the specimens in which the office bleach was applied (3.17±0.90). This shade change was higher than the acceptable shade change value. It was observed that there were more than ΔE 00 = 1.8 color changes in the samples with office bleaching in the MLP group (2.26±1.08). In other zirconia samples (ST and UT), color change values below the acceptable value were obtained. This difference is related to the presence of translucent cubic ZrO_2 crystals among the materials.[22,23] The result will give the dentist an idea of which monolithic zirconia to use for bleaching. ML bleaching showed more than a visible shade change. This clinical failure may lead to the replacement of the restoration.

Harada et al. [24] found that Katana HTML contained 5.6 % by weight of Y_2O_3, Katana ST contained 8.15 % by weight of Y_2O_3, and Katana UT contained 9.32 % by weight of Y_2O_3 and showed a cubic phase in proportion to the increase. In addition, ST and UT zirconia have a higher sintering temperature, which affects grain size and translucency.[25] Comparing the materials used in the study, ML (1500 °C, 2 hours) is sintered at a lower degree than ST and UT (1550°C, 2 hours). According to the study results, the difference in the structure of ML zirconia may affected the color change, transparency, and whiteness index. The previous study, a difference in colour change was obtained between two materials (IPS E.max and IPS E.max Press) with the same content. This was attributed to the difference in the size and length of the crystals.[26] In another study, it was reported that sintering above 1600℃ affected the grain size.[27] In the SEM images obtained, noticeably smoother areas were observed on the ML surfaces. SEM images do not correlate with color change. The difference between the surfaces can only be attributed to the difference in sintering temperature. SEM images obtained as a result of surface treatments are similar.

Translucency, a state between complete opacity and transparency, is an essential factor in the proper selection of ceramic materials that control natural aesthetics. As an intrinsic property of a material, translucency can be expressed as "absolute translucency", which measures the percentage of transmitted light, or as "relative translucency", using either the contrast ratio (CR) or the TP, which is calculated as the difference in luminance or color, respectively, when the material is evaluated on an ideal black and white background.[28] In their study, Alkurt et al.[29] applied home bleaching agents to monolithic zirconia specimens. While the highest translucency value was observed in UT samples, the lowest value was obtained in ML samples.

On the contrary, in this study, the highest translucency value was determined in ML samples, and the lowest value was determined in UT samples. This difference can be attributed to the difference in the HP ratios of the bleaching agents. Since the HP and CP percentages of the office and home bleaching agents used in our study are high, they may affect the surface of the material's glaze and provide higher translucency values. For home bleaching protocols, a 10% CP concentration is equivalent to 3.5% HP.[30] In a study examining the effects of prolonged exposure to bleaching agents on ceramic materials, it was found that such contact can lead to surface degradation similar to that observed in resin composites. The presence of free radicals, including H^+ and H_3O^+ generated by alkaline ions, infiltrates the material matrix, resulting in the dissolution of the ceramic glass network. This process contributes to the breakdown of SiO_2 and K_2O_2 components, as well as surface abrasion and the degradation of chromogens, ultimately leading to a decrease in surface light reflectivity.[31] The data indicated a reduction in translucency across all samples. In another study, polishing and glazing processes were applied to zirconia samples.[32] In the study in which colour changes were examined, the highest colour change was observed in the polished groups. The difference in this study may be due to the bleaching agent applied to the surface.

Murat et al.[33] aimed to investigate the effects of 16% carbamide peroxide (CP) on the relative translucency parameter and color stability of glazed and mechanically polished CAD-CAM glass ceramics. The study evaluated feldspathic ceramics (Vitablocs Mark II; Vita Zahnfabrik, Bad Säckingen, Germany), lithium disilicate (IPS e.max CAD), and zirconia- reinforced lithium silicate ceramics (Vita Suprinity). The results demonstrated that lithium disilicate ceramics (IPS e.max CAD) exhibited significantly lower translucency and ΔE00 values for both glazed and mechanically polished surfaces ($P<0.05$). Additionally, glazed surfaces of zirconia-doped ceramics (Vita Suprinity) showed greater color stability compared to mechanically polished surfaces ($P<0.05$). These findings and the present study suggest that the type of zirconia used significantly affects the ΔE00 values.

The bleaching procedure used in the current study was performed according to the manufacturer's recommended patient protocol. While seven days of bleaching is sufficient to achieve visible results with CP home bleaching products, other studies have used longer bleaching times.[3,34,35] The effect of the bleaching agent may be related to the penetration depth in the restorative material's surface. Kawamoto et al. [36] reported that the number of free radicals in the peroxide solution was related to the concentration. They stated that office bleaching gels of different concentrations are not only concentration dependent [37,38] and that the time and duration of application are as effective as concentration.[39] In the study, although the office type was applied with shorter duration and sessions than recommended by the company, there was no significant difference between them and the home type bleaching process. This situation is speculated to be related to the application times. However, all samples showed a difference in shade change and whiteness. The highest ΔE00 value was obtained in MLG samples. This difference may be due to the degree of sintering of the material and the effect of bleaching agents on the glaze layer.

After the bleaching process, the material and the surface finishing process affect the color change. Smooth surfaces reflect the incident beam, while rough surfaces scatter the light.[40] Previous studies have found that surface treatments affect light transmission and reflection by changing surface roughness and structure.[41,42,43] Surface treatments have been found to cause color changes by changing the L* value.[44] This study found no significant difference between surface treatments in color change and light transmittance values, but significant differences were found in the whiteness index. While the whiteness index was negative in all samples, these values were higher in the glazed samples. According to the EDX results, it was observed that the surface was contaminated in the processes where the glaze was applied, and elements other than those in the zirconia content were observed on the surface. The elements in the bleaching agent may have adhered to the glaze layer and caused discoloration.

Within the limitations, in vitro studies inherently cannot fully simulate clinical conditions. Saliva protects enamel from mineral loss and provides enamel remineralization.[4] However, in this study, samples were stored in distilled water after bleaching rather than in artificial saliva. Within these limitations, this study may be instructive for dentists. Patients may not be satisfied with the color of restorations after cementation. This study evaluates the effect of a bleaching agent and gives clinicians insight into how it will affect restorations when the patient has their natural teeth. Although the bleaching agent is usually applied before the restoration, the patient may wish to have their natural teeth bleached after a period, in which case the application of the bleaching agent can indicate the bleaching of the zirconia samples. With the increasing demand for dental bleaching, more in vitro and in vivo studies are needed to determine how home and in-office bleaching agents affect newly fabricated materials.

5. CONCLUSIONS

Within the limitations of the study, the following conclusions can be drawn.

1. The color change in Katana MLG samples may be due to surface contaminants.
2. Two different bleaching techniques had different effects on some color parameters.
3. Glazing and polishing surface treatments have no significant effect on the color change and translucency values but affect the whiteness index value.
4. The bleaching agents and surface treatments used may not change the material's structure. However, surface modification may cause color changes.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

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Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: EA (%60) KD (%40)
Veri Toplanması | Data Acquisition: EA (%50) KD (%40)
Veri Analizi | Data Analysis: EA (%40) KD (%60)
Makalenin Yazımı | Writing up: EA (%50) KD (%50)
Makale Gönderimi ve Revizyonu | Submission and Revision: EA (%60) KD (%40)

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