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Original research article

Effects of dipping time in coloring liquids and surface finishing technique on the color of monolithic zirconia

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Abstract

Purpose: The objective of this study was to investigate the effects of liquid coloring in different dipping times and finishing procedures on the color difference of pre-colored and liquid-colored monolithic zirconia ceramics.

Materials and Method: 240 zirconia specimens were grouped according to shades of a coloring liquid (A1, A2, and A3), dipping time (3, 5, and 7 minutes), and surface finishing procedures (glaze and mechanical polishing) (n=10). CIE L*, a*, and b* values of the specimens were measured and color differences (ΔE) were calculated. The data were analyzed with a three-way analysis of variance (ANOVA) and Tukey HSD test (α=.05).

Results: Coloring with liquids, dipping time, and finishing procedures significantly affected the CIE L*, a*, and b* values ($P<.001$). Dipping in coloring liquids decreased the a* and b* values. Higher L* values were obtained in glazing groups than in mechanical polishing groups. The ΔE values among the experimental groups varied from 7.10 to 27.52. The highest color difference was observed in 7 min dipping in A3 liquid and mechanically polished group.

Conclusion: The color difference between the pre-colored and liquid-colored zirconia ceramics is not within acceptable limits. Dipping in coloring liquids and surface finishing affect the color of liquid-colored monolithic zirconia.

Keywords: Dental polishing; color; prosthesis coloring; zirconium

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Introduction

Zirconia based restorations are produced either with veneering porcelain or without this layer called full contour monolithic zirconia ceramics. Elimination of the veneering porcelain layer by using monolithic zirconia restorations prevents chipping, fracture, and delamination. Also, these restorations seem to be the better choice because of their high strength with a thin thickness, causing minimal wear on the opposite teeth, requiring less tooth preparation, and exhibiting durability and long-term clinical success.[1,2] Although zirconia has many advantages, it is often a challenging clinical situation to imitate the color of natural teeth with this material because of its opaque nature, brightness, and low saturation.[3] Therefore, coloring and surface finishing procedures are important for these restorations to mimic the esthetic appearance of the natural teeth in terms of color and surface texture.

Adding and painting techniques are used to color zirconia ceramics.[2-4] In the adding technique, metal oxides are added to the powder during the production of the block to obtain pre-colored green-stage zirconia.[2-4] The painting technique can be used in two ways. One is painting pre-sintered zirconia surface with a brush and the other is directly dipping the pre-sintered zirconia into acid-based or aqueous coloring liquids.[2,4,5] The acid-based liquids for coloring zirconia contain a

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strong acid solution and can release acid vapors.[3,5] To eliminate the disadvantages of acid-based coloring liquids, liquids with no acid components, namely aqueous coloring liquids, were used as a safer alternative.[6] Although coloring liquid applications have become popular, some studies state that the mechanical properties of zirconia ceramics can be decreased by this technique[4,6,7] because coloring liquids may affect the microstructure of the material.[5] On the other hand, there is a lack of knowledge on how the color of monolithic zirconia restorations with different surface finishing is affected by the dipping time in aqueous liquids. Kim and Kim[8] reported that the increase in the number of coloring liquid applications affected the lightness, chroma, and opalescence of monolithic zirconia and translucency parameters, and these optical parameters could not be controlled by this technique. In another study, Giti and Hojati[1] stated that prolonged application of A2 coloring liquid reduced the lightness, and the zirconia material became reddish and yellowish.

Dipping time is a crucial factor in obtaining the desired color and it is often difficult to control.[9] Because this coloring technique has a risk of producing non-uniform colored material[5,10], lighter areas can be seen after clinical adjustments depending on the diffusion depth of the liquid.[5,11] Besides, there is not any reported standardization on optical color, translucency, and opalescence parameters of the monolithic zirconia restorations.[8] Thus, knowledge of the appropriate dipping time for each color of zirconia would be beneficial for clinical applications. The purpose of the present study is to investigate the effects of different dipping times and surface finishing procedures on the color comparison of pre-colored and liquid-colored zirconia ceramics. The null hypothesis of the study was that there would be no difference in the color of pre-colored and liquid-colored zirconia ceramics after applying different dipping times and surface finishing procedures such as glazing and mechanical polishing.

Materials and Method

Uncolored monolithic zirconia blocks (InCoris TZI; Sirona Dental Systems, Bensheim, Germany) and pre-colored (A1, A2, A3) monolithic zirconia blocks (InCoris TZI C; Sirona Dental Systems, Bensheim, Germany)

Figure 1. Monolithic zirconia blocks and cut-out samples

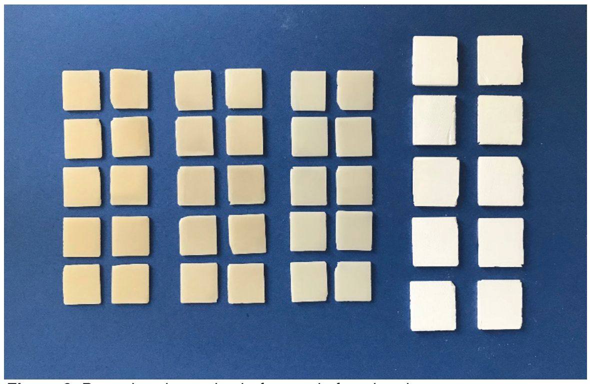

Figure 2. Pre-colored samples before and after sintering

Figure 3. Samples dipped in coloring liquid

(Table 1) were cut using low-speed cutting machine (IsoMet 1000 Precision Saw; Buehler Ltd., Lake Bluff, IL, USA) taking into consideration sintering shrinkage (Figure 1). After sintering, rectangular specimens of 15×12 mm in dimensions and 1±0.2 mm in thickness were obtained (Figure 2).

All specimens were adjusted using silicon carbide papers which have different grain sizes (150-180-220-320-1000 grits) to obtain uniform thickness. Then 180 specimens were prepared from colorless zirconia blocks and randomly divided into 9 groups each including 20 specimens. Each group was liquid-colored with A1, A2, and A3 coloring liquids (Sirona Dental Systems, Germany) for 3, 5, and 7 minutes dipping times (Figure 3). After the dipping procedure, the specimens were dried and sintered in a sintering furnace (InFire HTC; Sirona Dental Systems, Bensheim, Germany). Twenty specimens from each pre-colored A1, A2, and A3 zirconia blocks were prepared and sintered. After the sintering process, the final thicknesses of the zirconia specimens were adjusted to 1±0.2 mm (Figure 4). A total of 240 specimens for 12 groups were prepared.

Twenty specimens of each group were divided into two groups (n=10) for surface finishing procedures. Ten specimens in each group were mechanically polished by Eve Diapol ceramic polishing kit (Diamond polishing system, Eve Ernst Vetter, Pforzheim, Germany). The kit has 3 different polishing rubber for smoothing (blue-coarse grit), pre-polishing (pink-medium grit), and high-shine polishing (grey-fine grit). Specimens were polished for 30 seconds with 10000 rpm fixed rotation speed. Glazing was applied to 10 specimens of each group according to the manufacturer's instructions. Glaze powder and liquid (IPS Ivocolor, Ivoclar Vivadent, Schaan, Liechtenstein) were homogenously mixed and a thin layer was applied to the specimens with a brush. Then the firing procedure was performed by heating in a porcelain furnace (Programat P300, Vita Zahnfabrik, Bad Säckingen, Germany). Specimens were cleaned with ultrasonic cleaner for 10 minutes before color measurements. CIE L*, a*, and b* values were measured by using a spectrophotometer (Vita Easyshade Advance 4.0, Vita Zahnfabrik, Bad Säckingen, Germany). Measurements were recorded in standard illuminant (D65) over a white and black background. Each value was measured 3 times and average L*, a*, and b* values were used to calculate the color difference (ΔE) using the following equation ([12]):

$$\Delta.E = [(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)2]^{1/2}$$

Statistical analysis

SPSS (IBM SPSS Statistics for Windows, Version 23, IBM Corp., Armonk, NY, USA) and JASP (Computer software, Version 0.12, University of Amsterdam, Netherlands) software were used for statistical analysis of L*, a*, and b* values. The normal distribution of data was verified using the Shapiro-Wilk test. Also, additional skewness/kurtosis statistics were used for the confirmation of normal distribution. The homogeneity of variances was controlled with the Levene Test. Color, finishing procedure, and dipping time were the independent variables.

Three-way ANOVA was used to analyze the effects of color shade, dipping time, and surface finishing on L*, a*, and b* values and Delta E (ΔE, color difference). The Tukey HSD test (α=.05) was used to compare the differences between experimental groups.

Results

Three-way ANOVA results for the effect of color shades, dipping time, and surface finishing on the L*, a*, and b* values are shown in Tables 2, 3, and 4. The main effects and interactions of the three variables were statistically significant (P<.05).

The A1 pre-colored and glazed group had the highest mean L* value (97.22±0.79) and the A3 pre-colored and mechanical polishing group had the lowest mean L* value (71.69±0.41) among the groups. L* values of glazed groups were higher than mechanical polishing groups, except for the group that was dipped in A1 coloring liquid for 5 minutes.

The A3 pre-colored and mechanical polishing group

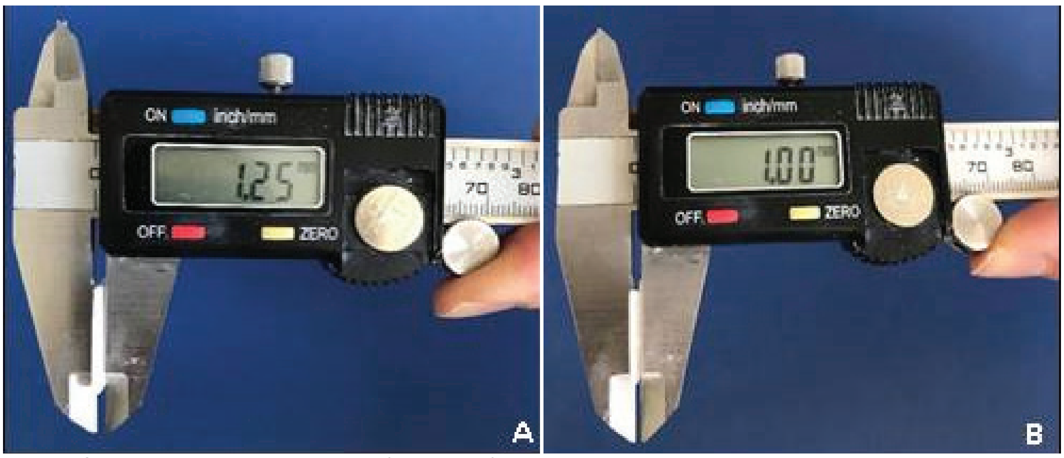

Figure 4. *Checking the samples' thickness both before (A) and after (B) sinterization*

Table 1. *Zirconia blocks and coloring liquids that used in the study.*

Material type	Brand name	Composition	Lot. No.	Manufacturer
Monolithic Zirconia	InCoris TZI C	ZrO_2		
	A1	HfO_2 ≥ 99.0%	3314000132	Sirona Dental Systems, Germany
	A2	Y_2O_3	2018235982	
	A3	Y_2O_3 >4.5 -≤ 6.0%	3314000203	
	InCoris TZI	HfO_2 ≤ 5%	3314000152	
		Al_2O_3 ≤ 0.5%		
		Other oxides≤0.5%		
Coloring Liquid	InCoris TZI			
	A1		6339522	Sirona Dental Systems, Germany
	A2		6339548	
	A3		6339563	

Table 2. *Color shades, surface finishings, and dipping time effect on L* value.*

Mean ± SD n=10		**Dipping time**			
Color	Finishing	Control (Pre-colored)	3 min	5 min	7 min
A1	Glaze	97.22	93.00	91.40	88.53
		(± 0.79)^{A,a,1}	(± 0.66)^{A,b,2}	(± 1.59)^{A,b,2}	(± 2.34)^{A,c,1}
	Mechanical polishing	92.84	77.67	91.71	85.92
		(± 0.85)^{A,a,1}	(± 0.95)^{B,c,2}	(± 1.53)^{A,a,1}	(± 2.28)^{B,b,1}
A2	Glaze	92.72	95.74	94.15	82.84
		(± 0.63)^{A,b,2}	(± 3.08)^{A,a,1}	(± 0.73)^{A,b,1}	(± 0.53)^{A,c,2}
	Mechanical polishing	86.71	82.62	74.78	75.09
		(± 2.18)^{B,a,2}	(± 0.65)^{B,b,1}	(± 0.78)^{B,b,2}	(± 0.50)^{B,b,3}
A3	Glaze	87.86	89.90	81.30	88.16
		(± 0.26)^{A,a,3}	(± 0.63)^{A,a,3}	(± 0.65)^{A,b,3}	(± 0.75)^{A,a,1}
	Mechanical polishing	71.69	83.31	73.79	78.69
		(± 0.41)^{B,d,3}	(± 0.56)^{A,a,1}	(± 0.84)^{A,c,2}	(± 0.83)^{B,b,2}

Mean L values of surface finishing groups with the same superscript uppercase letters are not significantly different in the same color and dipping time groups (P>.05). Mean L* values of dipping time groups with the same superscript lowercase letters are not significantly different in the same color and surface finishing groups (P>.05). Mean L* values of color groups with the same superscript numbers are not significantly different in the same surface finishing and dipping time groups (P>.05).*
SD:Standard deviation

Table 3. *Color shades, surface finishings, and dipping time effect on a* value.*

Mean ± SD n=10		**Dipping time**			
Color	Finishing	Control (Pre-colored)	3 min	5 min	7 min
A1	Glaze	2.78	0.32	0.24	0.63
		(± 0.16)^{A,a,3}	(± 0.22)^{B,b,2}	(± 0.25)^{B,b,2}	(± 0.45)^{B,b,1}
	Mechanical polishing	2.78	2.47	0.88	1.60
		(± 0.07)^{A,a,3}	(± 0.30)^{A,a,2}	(± 0.49)^{A,c,2}	(± 0.30)^{A,b,2}
A2	Glaze	6.20	-0.13	1.08	1.15
		(± 0.19)^{A,a,2}	(± 0.28)^{B,c,2}	(± 0.34)^{B,b,1}	(± 0.32)^{B,b,1}
	Mechanical polishing	5.69	1.91	4.01	3.81
		(± 0.15)^{A,a,2}	(± 0.34)^{A,c,3}	(± 0.48)^{A,b,1}	(± 0.28)^{A,b,1}
A3	Glaze	8.56	0.96	1.21	-0.28
		(± 0.18)^{B,a,1}	(± 0.36)^{B,b,1}	(± 0.38)^{B,b,1}	(± 0.19$^{)B,c,}$2
	Mechanical polishing	9.36	3.69	4.05	3.82
		(± 0.10)^{A,a,1}	(± 0.35)^{A,b,1}	(± 0.59)^{A,b,1}	(± 0.50)^{A,b,1}

Different superscript uppercase letters show that mean a values of surface finishing groups were significantly different in the same color and dipping time groups (P>.05). Different superscript lowercase letters show that mean a* values of dipping time groups were significantly different in the same color and surface finishing groups (P>.05). Different superscript numbers indicate that mean a* values of color groups were significantly different in the same surface finishing and dipping time groups (P>.05). *SD: Standard deviation*

Table 4. *Color shades, surface finishings, and dipping time effect on b* value.*

Mean ± SD n=10		**Dipping time**			
Color	Finishing	Control (Pre-colored)	3 min	5 min	7 min
A1	Glaze	27.70	22.72	20.53	23.85
		(±0.75)^{A,a,3}	(± 1.43)^{B,b,2}	(± 2.25)^{B,b,2}	(± 1.43)^{B,b,1}
	Mechanical polishing	28.13	27.48	25.15	28.03
		(± 0.50)^{A,a,3}	(± 0.95)^{A,a,2}	(± 2.47)^{A,b,3}	(± 1.75)^{A,a,3}
A2	Glaze	37.76	18.75	25.05	25.78
		(± 0.74)^{A,a,2}	(± 1.65)^{B,c,3}	(± 1.13)^{B,b,1}	(± 1.39)^{B,b,1}
	Mechanical polishing	37.73	29.54	30.53	32.24
		(± 0.44)^{A,a,2}	(± 1.05)^{A,c,2}	(± 1.57)^{A,b,c,2}	(± 0.68)^{A,b,2}
A3	Glaze	48.25	28.65	25.72	24.58
		(± 0.81)^{A,a,1}	(± 0.86)^{B,b,1}	(± 1.34)^{B,c,1}	(± 1.66)^{B,c,1}
	Mechanical polishing	44.39	34.32	32.94	35.62
		(± 0.44)^{A,a,1}	(± 0.94)^{A,b,1}	(± 1.84)^{A,b,1}	(± 1.62)^{A,b,c,1}

In the same color and dipping time groups, mean b values of surface finishing groups with the same superscript uppercase letters are not significantly different (P>.05). In the same color and surface finishing groups, mean b* values of dipping time groups with the same superscript lowercase letters are not significantly different (P>.05). In the same surface finishing and dipping time groups, mean b* values of color groups with the same superscript numbers are not significantly different (P>.05). *SD: Standard deviation*

Table 5. *Delta E values of the experimental groups.*

Mean (±SD) n=10		Dipping time		
Color	Finishing	3 min	5 min	7 min
A1	Glaze	7.10 (±0.79)^{B,b,2}	9.90 (±0.87)^{A,b,3}	9.90 (±1.87)^{A,a,3}
	Mechanical polishing	15.22 (±0.92)^{B,a,2}	27.22 (±0.46)^{A,a,1}	7.26 (±2.15)^{C,b,3}
A2	Glaze	20.47 (±1.71)^{A,a,1}	13.79 (±1.21)^{C,a,2}	16.37 (±0.79)^{B,a,2}
	Mechanical polishing	9.96 (±0.74)^{B,b,3}	14.14 (±0.45)^{A,a,2}	13.02 (±0.30)^{A,b,2}
A3	Glaze	21.12 (±0.95)^{B,a,1}	24.60 (±0.17)^{A,a,1}	25.28 (±1.59)^{A,b,1}
	Mechanical polishing	16.40 (±0.89)^{B,b,1}	12.81 (±2.01)^{C,b,3}	27.52 (±1.63)^{A,a,1}

*Same superscript uppercase letters indicate that mean Delta E values of dipping time groups were not significantly different in the same color and surface finishing groups (P>.05). Same superscript lowercase letters indicate that mean Delta E values of surface finishing groups were not significantly different in the same color and dipping time groups (P>.05). Same superscript numbers indicate that mean Delta E values of color groups were not significantly different in the same surface finishing and dipping time groups (P>.05). *SD: Standard deviation*

had the highest mean a* value (9.36±0.10), while the group that dipped in A3 coloring liquid for 7 minutes and glazed had the lowest mean a* value (-0.28±0.19). The glazed groups had lower a* values than the mechanical polishing groups, except for the control groups.

The A3 pre-colored and glazed group had the highest mean b* value (48.25±0.81), while the group that dipped in A2 coloring liquid for 3 min and glazed had the lowest mean b* value (18.75±1.65). Except for the control groups, the glazed groups had lower b* values than the mechanical polishing groups.

The color comparison of different shades of pre-colored and liquid-colored zirconia specimens is shown among the experimental groups in Table 5. The group that dipped in A1 coloring liquid for 3 min and glazed had the lowest ΔE value (7.10±0.79) and the group that dipped in A3 coloring liquid for 7 min and mechanically polished had the highest ΔE value (27.52±1.63). Generally, the ΔE values of the mechanical polishing groups were lower than the glaze groups.

Discussion

This study aimed to investigate the effects of dipping time in coloring liquids and surface finishing techniques on the color of monolithic zirconia. Coloring and surface finishing procedures are highly important for the aesthetics of the restorations. The null hypothesis was that the coloring liquids and surface finishing would not cause a color difference between pre-colored and liquid-colored zirconia after applying different dipping times and surface finishing procedures such as glazing and mechanical polishing. However, this study showed that coloring liquids and surface finishing had an effect on the color of zirconia and significant color differences were obtained, so the null hypothesis was rejected.

The selection of a tooth shade is the first step in tooth color replication. Unexpected results may be obtained from the shade guides and photographs used for clinical shade selection. Therefore, electronic devices such as colorimeters and spectrophotometers should be used when performing an objective intraoral shade selection.[13,14] Spectrophotometers allow more easy and more accurate transmission of color in dentistry.[15] The color measurement can be affected by the ambient light and display features of the color measuring device. According to the CIE standards, D65 illuminant is accepted as a standard condition for color measurements.[16] In this study, L*, a*, and b* values were measured with a portable spectrophotometer under the D65 lighting and then the color difference of pre-colored and liquid-colored zirconia ceramics was calculated.

The thickness of zirconia also affects its optical properties. When evaluating the effect of zirconia thicknesses on color, L* and b* values decreased, and a* values increased as thickness decreased.[17-19] The manufacturer's instruction for the thickness of monolithic restorations is 1 mm for occlusal and incisal areas and 0.8 to 1 mm for buccal and lingual areas. In this study, the zirconia specimens' thicknesses after sintering were set as 1±0.2 mm that of frequently used thickness for monolithic restorations.

Monolithic zirconia restorations can be colored either by colorant addition into zirconia powder during block production or by dipping the uncolored pre-sintered block into coloring liquids before the sintering procedure. Also, these restorations can be colored after sintering by external staining[6,4,20] with a brush. The brushing method has some benefits, such as being able to color different areas efficiently, but it needs technical sensitivity. However, it has been reported that when the coloring is correctly applied by dipping in liquids, natural tooth colors can be successfully replicated.[5,21-23] Differences in the liquid application may have an effect on the color of the zirconia material. In this study, colorless and pre-colored monolithic zirconia blocks were used. Pre-colored zirconia groups were used as control, and colorless zirconia specimens were colored by dipping in coloring liquids. Then the color difference between pre-colored and liquid-colored specimens using different dipping times was calculated for each color group. To provide a specific color to uncolored zirconia, applying a dipping time of 5 minutes in the relevant coloring liquid is recommended by the manufacturer. In the present study, 3 min, 5 min, and 7 min dipping times were applied to evaluate the effect of shorter and longer dipping times on the color comparison of pre-colored and liquid-colored zirconia specimens. The effects of different dipping times were investigated in previous studies, and it had been reported that longer dipping times caused perceptible color differences, making it difficult to obtain the desired shade.[4,7] Because of perceptible color differences, the use of coloring liquids is thought to give unpredictable results.[9] In this study, the highest ΔE value was measured in the 7 min mechanical polishing group (27.52±1.63) for A3 shade. Acceptable color difference limits differ among studies. Dougles *et al.*[24] determined the acceptable threshold as 5.5, Ghinea *et al.*[25] 3.5, and Paravina *et al.* 2.66.[26] The ΔE values obtained in this study were higher than these threshold values. Another factor that affects the color difference is the surface finishing method. It was stated that mechanically polished surfaces yielded comparable surfaces with glazed surfaces when diamond pastes were used at the final stage of the polishing.[27] In the present study, Eve Diapol ceramic polishing kit was used at the final finishing of the zirconia surfaces and the conventional powder/liquid system was used for glazing. The results of the study showed that when the zirconia ceramic surface is finished by glazing for A1 and A3 shade, 3 min dipping time causes a lower color difference. However, if the surface is mechanically polished, 7 min dipping time can be beneficial for A1 shade, 3 min for A2 shade, and 5 min for A3 shade.

The color differences are determined by the changes of L*, a*, and b* values. L*, a*, and b* values indicate the lightness, the red-green (+a to -a), and yellow-blue (+b to –b) axis, respectively.[1] Kim and Kim[8] reported that an increasing number of coloring liquid applications reduced the L* value and opalescence parameter of monolithic zirconia and made it more yellowish. However, only a single color of coloring liquid was applied to zirconia specimens which were 2 mm in thickness. Giti and Hojati[1] investigated the effect of thickness and different liquid-coloring applications on the final color parameters of monolithic zirconia. It was reported that the lightness of the zirconia specimens (1 mm in thickness) decreased after two and three times coloring liquid applications. a* and b* values were 8.92 and 41.12 (twice application) and 9.20 and 41.57 (three times application), respectively. This meant that the values increased and zirconia specimens became reddish (+a) and yellowish (+b). When comparing the results of the study, it should be considered that the coloring liquid was applied to zirconia specimens with a brush and the surface finishing method was not reported. Surface finishing of zirconia is important for prolonging the lifetime of the restoration, protecting the opposing teeth from wear, and achieving more esthetic restoration.[27,28]

In the present study, L* values decreased with increasing dipping time. Also, with the application of coloring liquids, a* and b* values decreased when compared to pre-colored specimens. The group that had 5 min dipping had the closest a* values and those that had 7 min dipping time had closest b* values to the pre-colored group. Glazing resulted in higher L* and b* values and lower a* values than mechanical polishing. a* and b* values of mechanically polished groups were found to be similar to that of pre-colored groups. Due to variations in application, different results are obtained from different surface finishing procedures.

This *in vitro* study has some limitations. The color comparison of pre-colored and liquid-colored monolithic zirconia materials was evaluated in the study. To obtain the exact color match with these materials, it will be beneficial to compare the color parameters of pre-colored and liquid-colored zirconia ceramics with standard color parameters of color shades. Rectangular-shaped specimens cannot simulate clinical situations. Crown restorations are not uniform in thickness and do not have flat surfaces which are efficient factors in color measurement. To be able to draw more relevant conclusions for clinical use, further studies including different specimen thicknesses should be performed. Also, well-designed clinical studies are needed to evaluate the effects of material thickness, coloring technique, and surface finishing procedure on the optical properties of monolithic zirconia restorations.

Conclusion

Dipping time in coloring liquid and surface finishing techniques have an impact on the final color of monolithic zirconia. Furthermore, the color differences (ΔE) between the liquid-colored and the pre-colored groups were higher than perceptible and acceptable thresholds. Therefore, to achieve a good color-matching restoration with remaining dentition, using pre-colored zirconia blocks can be recommended instead of dipping into coloring liquids. Since glazed specimens have higher lightness than mechanical polishing groups, it can be assumed that glazing produces brighter surfaces.

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Renklendirme solüsyonunda bekletme süresi ve yüzey bitirme işlemlerinin monolitik zirkonyanın rengine etkisi

Özet

Amaç: Bu çalışmanın amacı, renklendirme solüsyonunda farklı sürelerde bekletmenin ve farklı yüzey bitirme işlemlerinin kendinden renkli ve renksiz monolitik zirkonya üzerindeki renk değişiminin incelenmesidir.

Gereç ve Yöntem: Monolitik zirkonyadan hazırlanan 240 adet örnek, renklendirme solüsyonunu rengine (A1, A2 ve A3), solüsyonda bekletme süresine (3, 5, ve 7 dakika) ve yüzey bitirme işlemlerine (glaze ve mekanik parlatma) göre gruplara ayrıldı (n=10). Örneklerin CIE L *, a * ve b * değerleri ölçüldü ve renk farklılıkları (∆E) hesaplandı. Veriler üç yönlü varyans analizi (ANOVA) ve Tukey HSD testi (α =.05) ile analiz edildi.

Bulgular: Solüsyon ile renklendirme, bekletme süresi ve yüzey bitirme işlemleri CIE L*, a* ve b* değerlerini (P<.001) önemli ölçüde etkiledi. Solüsyonla renklendirme uygulaması a* ve b* değerlerini azalttı. Glaze gruplarında mekanik polisaj gruplarından daha yüksek L* değerleri elde edildi. Gruplar arasındaki ∆E değerleri 7.10 ile 27.52 arasında değişmektedir. En yüksek renk farkı, A3 renkli solüsyonun 7 dk. uygulandığı ve mekanik polisaj uygulanan gruplarda gözlemlendi.

Sonuç: Kendinden renkli ve solüsyonla renklendirilmiş zirkonya örnekler arasındaki renk farkı kabul edilebilir sınırlar içinde değildir. Renklendirme solüsyonlarında bekletme ve yüzey bitirme işlemleri solüsyon ile renklendirilen monolitik zirkonyanın rengini etkilememektedir.

Anahtar Kelimeler: Diş parlatma; protezi renklendirme; renk; zirkonya