Dental Research Journal

Original Article

Masking ability of a zirconia ceramic on composite resin substrate shades

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ABSTRACT

Background: Masking ability of a restorative material plays an important role to cover discolored tooth structure; however, this ability has not yet been well understood in zirconia-based restorations. This study assessed the masking ability of a zirconia ceramic on composite resin substrates with different shades.

Materials and Methods: Ten zirconia disc specimens, with 0.5 mm thickness and 10 mm diameter, were fabricated by a computer-aided design/computer-aided manufacturing system. A white substrate (control) and six composite resin substrates with different shades including A1, A2, A3, B2, C2, and D3 were prepared. The substrates had a cylindrical shape with 10 mm diameter and height. The specimens were placed onto the substrates for spectrophotometric evaluation. A spectrophotometer measured the L*, a*, and b* values for the specimens. ΔE values were calculated to determine the color differences between the groups and the control and then were compared with a perceptional threshold (ΔE = 2.6). Repeated measures ANOVA and Bonferroni tests were used for data analysis ($P < 0.05$).

Results: The mean and standard deviation of ΔE values for A1, A2, A3, B2, C2, and D3 groups were 6.78 ± 1.59, 8.13 ± 1.66, 9.81 ± 2.64, 9.61 ± 1.38, 9.59 ± 2.63, and 8.13 ± 1.89, respectively. A significant difference was found among the groups in the ΔE values ($P = 0.006$). The ΔE values were more than the perceptional threshold in all the groups ($P < 0.0001$).

Conclusion: Within the limitations of this study, it can be concluded that the tested zirconia ceramic could not thoroughly mask different shades of the composite resin substrates. Moreover, color masking of zirconia depends on the shade of substrate.

Key Words: Color, spectrophotometry, visual perception, ceramic

Received: July 2016
Accepted: June 2017

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INTRODUCTION

Metal ceramic restorations have been well applied in dentistry because of excellent mechanical properties[1,2] although they have some complications. However, achieving a natural looking appearance is more difficult with metal ceramic restorations than all-ceramic restorations because metal substructures avoid light transmission and may show a metal color.[3,4] This caused an increase in use of all-ceramic restorations in esthetic dentistry.[5] Among all-ceramic restorations, zirconia-based restorations have presented acceptable physical and mechanical properties.[6,7] Nonetheless, the high translucency of a

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Website: www.drj.ir
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How to cite this article: Tabatabaian F, Shabani S, Namdari M, Sadeghpour K. Masking ability of a zirconia ceramic on composite resin substrate shades. Dent Res J 2017;14:389-94.

restoration is not always an advantage, for example, in cases with discolored teeth, metallic core materials, and colored dental substrates.[5,8] In the mentioned cases, a restorative material with proper masking ability of the background substructures is clinically implicated to achieve optimal esthetic outcomes.

An approach to estimate the masking ability of dental ceramics is to determine ΔE color differences in CIELAB color system. In this approach, the color attributes of L*, a*, and b * define lightness, red-green value, and yellow-blue value, respectively. These color attributes are measured through spectrophotometry. The ΔE value is calculated to determine a color difference or change. Limits have been introduced for the perceptional threshold and the acceptable clinical threshold based on the ΔE value.[5] The acceptable clinical threshold is more than the perceptional threshold, due to mouth optical conditions.[9-11] If the color difference between a restoration and adjacent tooth is more than the threshold, a color mismatch can be diagnosed by the human eyes. The perceptional threshold of ΔE has been considered from 1 to 5.5 in different studies.[5,12-14] If the ΔE of a material with different substrates is less than the threshold, it can absolutely mask the substrates.[5,8]

Based on the amount of strength and visible light transmittance (VLT), there are four types of zirconia ceramics in the market including high strength/low translucency (HS/LT), low strength/high translucency (LS/HT), and two intermediate types. The VLT percentage is a minimum of 37% in HS/LT zirconia and a maximum of 49% in LS/HT zirconia in a 1 mm thickness.[15] The HS/LT zirconia is used in zirconia-based restorations as a core or framework, whereas the LS/HT zirconia can be used for monolithic restorations. Due to relative translucency of zirconia framework, a substrate may compromise the masking ability of zirconia-based restorations.

Some studies have evaluated the optical behavior of different glass and zirconia ceramics.[8,15-18] Some investigations have assessed the effect of various factors on the final color of zirconia-based restorations including dental substrates,[19-22] luting agents,[23] veneering ceramic,[24-26] glaze,[24] and laboratory procedures.[27] Suputtamongkol *et al*.[19] reported that the color of a substrate (metal or composite cores) could affect the final color of zirconia-based restorations though the color differences were not beyond the perceptional threshold. Choi and Razzoog[20] evaluated the masking ability of zirconia ceramic with and without porcelain veneer and concluded that the unveneered zirconia ceramic was rather capable to mask the different tested substrates. Oh and Kim[22] revealed that substrate shade, ceramic thickness, and coping brand influenced the final color of zirconia-based restorations. Tabatabaian *et al*.[21] advised to consider the substrate impact when zirconia ceramic thickness was 0.5 mm.

Masking ability of zirconia ceramics has been measured on a black and white background in the previous studies.[8,20,22] A dental substrate may be masked by cement or ceramic. Masking a dental substrate with cements may not be achievable, and cements can only correct minor esthetic problems.[21] Therefore, masking ability of zirconia ceramic on different shades of substrates should be clearly determined. The aim of this *in vitro* study was to evaluate the masking ability of a zirconia ceramic over the different shades of composite resin substrates. The null hypothesis of the study was that the zirconia ceramic ability to mask different composite shades would be the same.

MATERIALS AND METHODS

Considering results of a previous study,[20] an 80% power, and a 0.05 level of significance, this study needed ten specimens. Ten zirconia discs were milled with a computer-aided design/computer-aided manufacturing system (CORiTEC 250i, imes-icore GmbH, Eiterfeld, Germany) from zirconia blanks (Luminesse High Strength/Low Translucency, Talladium, Valencia, CA, USA). The discs were 0.5 mm in thickness and 10 mm in diameter. All the zirconia discs were sintered at 1500°C for 12 h in a sintering furnace (iSINT HT, imes-icore). A digital micrometer (293 MDC-MX Lite, Mitutoyo Co, Tokyo, Japan) with the accuracy of 0.002 mm was used to evaluate the thicknesses of the discs. The discs were adjusted/polished (BruxZir polishing kit, Glidewell Direct, Irvine, CA, USA) to a thickness of 0.5 ± 0.01 mm. The polished zirconia discs were cleaned in an ultrasonic bath (Elmasonic S-30, Dentec, North Shore, Australia) containing 98% ethanol for 15 min and were dried.

Seven cylindrical substrates with different shades including white, A1, A2, A3, B2, C2, and D3 with 10 mm diameter and height were fabricated.

A Teflon material (PTFE, Omnia Plastica SPA, Busto Arsizio, Italy) in white color was milled to fabricate the white substrate. Then, a cylindrical hollow pattern was milled from the same Teflon material according to the mentioned dimensions to use as a mold for making the composite resin substrates. Light-polymerized composite resin (Z100, 3M ESPE, St. Paul, MN, USA) with the mentioned shades was applied in layers to the mold. A light-polymerizing unit (Elipar FreeLight 2, 3M ESPE) polymerized the composite resin incrementally (five layers of 2 mm thickness) for 40 s with an intensity of 800 mW/cm^2. The substrates were polished with 800 grit silicon carbide abrasive papers for 10 min. The substrates were cleaned in the same ultrasonic bath.

A digital spectrophotometer (SpectroShade Micro, MHT, Verona, Italy) was used for color measurements.[28] A putty silicone impression material (Speedex, Coltene, Altstatten, Switzerland) was adjusted to the mouth piece of the spectrophotometer to match the conditions of color measurement for all specimens and to avoid external lights. The substrates and specimens were placed at the center of the mold [Figure 1]. The spectrophotometer was initially calibrated by the white and green calibration plates. The discs were placed onto the substrates with a water drop in between for prevention of light refraction.[29] Each disc was placed on each of the seven substrates and the color measurements were conducted. The color measurements were performed at the center of specimens spotted on the monitor screen of spectrophotometer. The color attributes of L*, a*, and b* were measured for specimens [Figure 2]. ΔE values were calculated to determine the color differences of a disc over the tested substrates. Comparing the substrates of A1, A2, A3, B2, C2, and D3 with the white substrate (W), the ΔE values were measured. This formula was employed to calculate $\Delta E_{W\text{-}A1}$, $\Delta E_{W\text{-}A2}$, $\Delta E_{W\text{-}A3}$, $\Delta E_{W\text{-}B2}$, $\Delta E_{W\text{-}C2}$, and $\Delta E_{W\text{-}D3}$: $\Delta E^*_{ab} = ([L^*_2 - L^*_1]^2 + [a^*_2 - a^*_1]^2 + [b^*_2 - b^*_1]^2)^{½}$. The perceptional threshold of ΔE = 2.6 was hypothesized in this study.[11-14]

A normal distribution of data was confirmed by Kolmogorov–Smirnov test ($P > 0.05$). Repeated measures ANOVA test was used (Statistical Package for the Social Sciences version 21, SPSS Inc., Chicago, IL, USA) to compare the L*, a*, b*, and ΔE values among the groups. Pair-wise comparisons of the groups were conducted by Bonferroni test. A software

Figure 1: Representative the mold as a seat of the substrates and specimens for spectrophotometry.

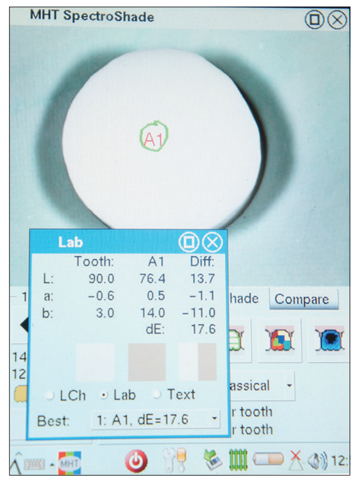

Figure 2: The monitor screen of spectrophotometer for a color measurement.

(STATA, StataCorp LP, Lakeway, TX, USA) compared the ΔE values with the perceptional threshold using one-sample *t*-test. The tests were accomplished at 0.05 level of significance.

RESULTS

The means and standard deviations of the L* values for the groups of W, A1, A2, A3, B2, C2, and D3 are shown in Table 1. Repeated measures ANOVA showed a significant difference among the groups ($F = 45.22$, $P < 0.0001$) [Table 2]. Pair-wise comparisons of the groups using Bonferroni test indicated significant differences between the groups [Table 3]. The L* value decreased in all the groups compared to the control. The decrease of L* value was the highest in C2.

The means and standard deviations of the a* values for all the groups are shown in Table 1. Repeated measures ANOVA showed a significant difference among the groups ($F = 124.204$, $P < 0.0001$) [Table 2]. Pair-wise comparisons of the groups using Bonferroni test indicated significant differences between the groups [Table 3]. The a* value increased in all the groups compared to the control, except A1. The increase of a* value was the highest in A3.

The means and standard deviations of the b* values for the studied groups are shown in Table 1. Repeated measures ANOVA showed a significant difference among the groups ($F = 85.884$, $P < 0.0001$) [Table 2]. Pair-wise comparisons of the groups using Bonferroni test indicated significant differences between the groups [Table 3]. The b* value increased in all the groups compared to the control. The increase of the b* value was the highest in A2.

The means and standard deviations of the ΔE values for the groups of A1, A2, A3, B2, C2, and D3 are shown in Table 1. Repeated measures ANOVA showed a significant difference among the groups ($F = 6.377$, $P = 0.006$) [Table 2]. Pair-wise comparisons of the groups using Bonferroni test indicated significant differences between the groups [Table 3]. The ΔE values of the groups were significantly more than the perceptional threshold of ΔE = 2.6 using one-sample *t*-test.($P < 0.0001$).

Table 1: Measures of color attributes in the seven substrate shade groups

Substrate shade	Color attribute	Mean±SD	Minimum	Maximum	95% CI
White	L*	88.35±1.46	85.4	90.5	87.31-89.39
	a*	−0.40±0.42	−1.1	0.3	−0.70-−0.10
	b*	3.38±0.36	2.9	4.1	3.12-3.64
A1	L*	82.30±1.13	80.6	84.0	81.49-8311
	a*	−0.49±0.28	−0.8	0.0	−0.69-−0.29
	b*	6.20±0.52	5.5	6.9	5.82-6.58
	ΔE	6.78±1.59	3.30	8.59	5.64-7.91
A2	L*	81.14±1.59	78.0	82.8	80.01-82.27
	a*	0.82±0.52	0.4	2.2	0.45-1.19
	b*	6.81±0.54	6.1	7.8	6.43-7.19
	ΔE	8.13±1.66	6.14	11.03	6.94-9.31
A3	L*	79.49±1.81	77.1	82.4	78.19-80.79
	a*	1.96±0.49	1.3	3.2	1.61-2.31
	b*	6.74±0.57	5.8	7.6	6.33-7.15
	ΔE	9.81±2.64	4.81	13.06	7.92-11.70
B2	L*	79.32±2.36	73.0	82.1	77.63-81.01
	a*	0.73±0.46	0.2	1.9	0.40-1.06
	b*	6.36±0.44	5.9	7.0	6.05-6.67
	ΔE	9.61±1.38	7.88	12.76	8.62-10.60
C2	L*	79.00±1.65	76.4	81.9	77.82-80.18
	a*	0.13±0.57	−0.3	1.4	−0.28-0.54
	b*	5.42±0.56	4.6	6.4	5.02-5.82
	ΔE	9.59±2.63	3.99	13.46	7.71-11.48
D3	L*	80.55±1.25	78.5	82.0	79.66-81.44
	a*	0.92±0.51	0.4	2.2	0.55-1.29
	b*	5.05±0.89	4.1	7.2	4.41-5.69
	ΔE	8.13±1.89	3.92	10.56	6.78-9.48

SD: Standard deviation; CI: Confidence interval

Table 2: The results of repeated measures ANOVA (Greenhouse-Geisser test)

Source	Type III sum of squares	df	Mean square	*F*	*P*
L*	636.196	1.944	327.326	45.22	<0.0001
Error (L*)	126.621	17.493	7.239		
a*	43.862	2.718	16.137	124.204	<0.0001
Error (a*)	3.178	24.463	0.13		
b*	88.821	3.675	24.171	85.884	<0.0001
Error (b*)	9.308	33.073	0.281		
ΔE	72.001	2.207	32.630	6.377	0.006
Error (ΔE)	101.617	19.859	5.117		

DISCUSSION

The results of the study showed that there were significant differences among the groups in the L*, a*, b*, and ΔE values and the measured ΔE values were more than the perceptional threshold ($P < 0.0001$). The studied zirconia ceramic could not thoroughly mask the composite resin substrate shades and the zirconia ceramic ability to mask different composite shades was not the same. Therefore, the null hypothesis of the study was refuted.

The L* values decreased in all the groups compared to the control [Table 1] with the highest in Group C2. Regarding zirconia ceramic as a semi-translucent material, it is reasonable that the shade C2 causes the highest decrease in this color attribute due to the low L* value of the composite resin shade C2.

The a* value increased in all the groups compared to the control [Table 1] with the highest in Group A3. Knowing that the shade A3 has the most red color shift among the tested shades, the derived result seems rational due to the a* value of the composite resin shade A3 and its show under the zirconia ceramic.

The b* values increased in all the groups compared to the control [Table 1]. The increase of the b* value was the highest in Group A2, whereas there was no statistically significant difference between the Groups of A2 and A3 in the b* value. This may be due to the yellow color tendency of the shades of A2 and A3, which impacts the color of zirconia ceramic.

The ΔE values were more than the perceptional threshold. Thus, the studied zirconia ceramic could

Table 3: Pair-wise comparisons between the studied groups with Bonferroni adjustment

Shade group	Color attribute	A1	A2	A3	B2	C2	D3
White	L*	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	a*	1	<0.0001	<0.0001	<0.0001	0.096	<0.0001
	b*	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.002
A1	L*		1	0.008	0.275	0.001	<0.0001
	a*		<0.0001	<0.0001	<0.0001	0.004	<0.0001
	b*		0.063	0.127	1	0.042	0.002
	ΔE		0.449	0.006	0.114	0.005	<0.001
A2	L*			0.531	1	0.117	1
	a*			<0.0001	1	<0.0001	1
	b*			1	0.047	<0.0001	0.001
	ΔE			0.401	1	0.611	1
A3	L*				1	1	1
	a*				<0.0001	<0.0001	<0.0001
	b*				0.434	0.004	0.002
	ΔE				1	1	0.106
B2	L*					1	1
	a*					0.001	0.008
	b*					0.001	0.001
	ΔE					1	1
C2	L*						1
	a*						<0.0001
	b*						1
	ΔE						0.235

not completely mask the composite resin substrate with different shades, and the color differences depended on the shade of substrate.

Suputtamongkol *et al*.[19] showed that the color of a background (metal or composite cores) could affect the overall color of posterior zirconia-based restorations, ranging from 1.2 to 3.1 of ΔE. Despite the differences between the mentioned study and the current study including zirconia brand and thickness, layered versus nonlayered zirconia, hypothesized thresholds, and tested substrates, both studies showed that the color of zirconia ceramic could be affected by its substrate.

Oh and Kim[22] in an *in vitro* study on color masking ability revealed the effects of substrate shade, overall ceramic thickness, and zirconia brand on the color of zirconia-based restorations. The substrates were prepared with gold alloy, nickel–chromium alloy, and four shades of composite resins (A1, A2, A3, and A4). In this study, the gold alloy substrate caused the most ΔE value (close to 5.5) among the tested substrates, and the composite substrates showed no significant difference in ΔE value. The result disparity between the Oh and Kim[22] study and the present study may be caused by the difference in the control groups (A2 composite for Oh and Kim study versus white for the current study).

Choi and Razzoog[20] investigated the color masking ability of a zirconia ceramic with and without veneering ceramic and disclosed that the unveneered zirconia ceramic (0.4 mm thickness) was rather capable to mask different tested substrates. The present study, which showed the effect of substrate shade on the color of zirconia ceramic (0.5 mm thick), did not absolutely confirm the result of Choi and Razzoog[20] research because of the differences in the studied zirconia ceramics and the control groups for measuring the ΔE and masking ability.

The results of this study showed that the composite resin substrate shades could change the color of zirconia ceramic. The quality and quantity of color changes depend on the shade of composite resin. It seems that the composite resin substrates alter the color of zirconia ceramic to their basic shades. Therefore, it can be recommended to choose the shade of composite resin core material according to the final color of the restoration. Although the substrate-induced color changes may be reduced by increasing the thickness of zirconia frameworks,[30,31] using suitable thickness of porcelain veneers,[32,33] and application of acceptable luting agents in zirconia-based restorations,[34] incorrect substrate shade selection may increase the possibility of a color mismatch.

Evaluation of the impacts of the factors such as cement and veneering ceramic is recommended for future studies. The limitations of this study included testing only one brand of unshaded zirconia ceramic and one brand of composite resin.

CONCLUSION

Within the limitations of this study, it can be concluded that the tested zirconia ceramic could not thoroughly mask different shades of the composite resin substrates. Moreover, color masking of zirconia depends on the shade of substrate.

Acknowledgments
The authors do not have any financial interest in the companies whose materials were included in this study.

Financial support and sponsorship
Nil.

Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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