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RESEARCH AND EDUCATION

Effect of coping thickness and background type on the masking ability of a zirconia ceramic

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ABSTRACT

Statement of problem. The masking ability of zirconia ceramics as copings is unclear.

Purpose. The purpose of this in vitro study was to evaluate the effect of coping thickness and background type on the masking ability of a zirconia ceramic and to determine zirconia coping thickness cut offs for masking the backgrounds investigated.

Material and methods. Thirty zirconia disks in 3 thickness groups of 0.4, 0.6, and 0.8 mm were placed on 9 backgrounds to measure CIELab color attributes using a spectrophotometer. The backgrounds included A1, A2, and A3.5 shade composite resin, A3 shade zirconia, nickel-chromium alloy, nonprecious gold-colored alloy, amalgam, black, and white. ΔE values were measured to determine color differences between the specimens on the A2 shade composite resin background and the same specimens on the other backgrounds. The color change (ΔE) values were compared with threshold values for acceptability (ΔE=5.5) and perceptibility (ΔE=2.6). Repeated measures ANOVA, the Bonferroni test, and 1-sample *t* tests were used to analyze data (α=.05).

Results. Mean ΔE values ranged between 1.44 and 7.88. The zirconia coping thickness, the background type, and their interaction affected the CIELab and ΔE values (*P*<.001).

Conclusions. To achieve ideal masking, the minimum thickness of a zirconia coping should be 0.4 mm for A1 and A3.5 shade composite resin, A3 shade zirconia, and nonprecious gold-colored alloy, 0.6 mm for amalgam, and 0.8 mm for nickel-chromium alloy. (J Prosthet Dent 2018;119:159-165)

The need to reproduce the beauty of natural teeth has led to the evolution of new ceramic coping materials such as zirconia.[1,2] Zirconia copings have an advantage over metal copings because of their adequate translucency,[3,4] whereas zirconia ceramics show acceptable mechanical properties.[5,6] Zirconia substructures can be layered with porcelains to fabricate zirconia-based ceramic restorations. These popular restorations have the benefits of both high strength and appropriate translucency.[7]

A translucent coping may have a negative effect on esthetic outcomes under some clinical conditions such as discoloration, metal posts and cores, and shaded dental core materials.[8] Under these conditions, the color of the background may compromise the final color of the restoration.[9,10] Because zirconia is a semitranslucent material,[8] the optical property of a zirconia coping may be critical when a zirconia-based crown is placed on a colored background.[11] Investigators have evaluated the translucency of zirconia ceramics.[12-15]

Two methods have been used to determine the translucency of dental ceramics, an absolute translucency measurement and a relative translucency measurement.[11,16-18] The absolute translucency measurement method determines the percentage of light transmission through a ceramic.[13] The relative translucency measurement method evaluates a contrast ratio or a translucency parameter of a ceramic[11]; here, CIELab values are determined by a spectrophotometer when a ceramic is placed on white and black backgrounds, and the color difference (ΔE) is calculated.[16] The ΔE value is compared with thresholds for acceptability and perceptibility to evaluate the visibility of color difference.[19-21] In the same way, the color masking ability of a ceramic can be estimated on different backgrounds.[10,11]

Suputtamongkol et al[9] reported that background color could affect the final color of zirconia-based crowns with 0.4-mm-thick copings. Kumagai et al[15] compared 0.3- with 0.5-mm-thick copings in zirconia-based restorations and reported a significant ΔE color difference at

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Clinical Implications

The background core material may affect the color of zirconia-based restorations. This study identified zirconia coping thicknesses to mask common core materials and to eliminate the effect of background on esthetics.

the cervical area. Oh and Kim[11] showed that zirconia-based restorations with 0.4-mm coping thicknesses might not be color matched with natural teeth when placed on gold alloy posts and cores. Choi and Razzoog[10] studied the masking ability of 0.4-mm-thick zirconia with and without porcelain veneer on 4 backgrounds and concluded that zirconia without veneer had a degree of masking ability, whereas the porcelain veneer might modify the resulting color. Wang et al[16] reported that an increase in the thickness of zirconia decreased its relative translucency. Chang et al[22] assessed the effects of resin cements on the color of Empress and Katana crowns and stated that types of cement could create perceptible color differences in specific combinations of die material, cement, and ceramic crown. Malkondu et al[23] revealed that the cement type and zirconia thickness influenced the color of 0.6- and 0.8-mm-thick monolithic zirconia.

The effects of background and cement on the color of porcelain veneers,[24,25] lithium disilicate ceramics,[26-29] and zirconia ceramics have been investigated.[9-12,15,30] Moreover, the importance of ceramic thickness for masking different backgrounds and obtaining optimal color has been reported.[9,13,15,16,25,29,31] However, limited information is available for the minimal zirconia coping thickness needed to mask the color of a specific background in zirconia-based restorations. Therefore, the purpose of this in vitro study was to evaluate the effect of coping thickness and background type on the masking ability of a zirconia ceramic and to determine the zirconia coping thickness needed to mask the backgrounds investigated. The null hypothesis was that coping thickness and background type would not affect the masking ability of zirconia ceramic.

MATERIAL AND METHODS

Considering the results of previous studies with an 80% power and a .05 level of significance, this study assigned 10 specimens to each thickness group. A total of 30 disk-shaped zirconia specimens were tested in 3 thickness groups of 0.4, 0.6, and 0.8 mm. A computer-aided design and computer-aided manufacturing (CAD-CAM) system (Coritec 250i; imes-icore GmbH) was used to mill zirconia blanks (Luminesse High Strength 98mm Discs; Talladium) to fabricate zirconia disks with 1-cm diameters and the specified 3 thicknesses. The specimens were colored with an A2 shade liquid (DD Bio ZX2 monolithic zero LZDD; Dental Direkt GmbH) with a 6-second dipping process. The specimens were sintered at 1480°C for 12 hours in a sintering furnace (iSINT HT; imes-icore GmbH) and were adjusted by using an adjustment/polishing kit (BruxZir; Glidewell Direct) to obtain the intended thicknesses (±0.02 mm). Specimens with unacceptable thicknesses were eliminated from the study. The specimens were cleaned in a solution of 98% ethanol and dried with compressed air.

Cylindrical backgrounds included A1 shade composite resin (A1), A2 shade composite resin (A2), A3.5 shade composite resin (A3.5), A3 shade zirconia (ZR), nickel-chromium alloy (NC), nonprecious gold-colored alloy (NPG), amalgam (AM), black (B), and white (W). All backgrounds were 1 cm in diameter and height.

In order to prepare the composite resin backgrounds, a light-polymerized composite resin (Z100 Restorative; 3M ESPE) with the A1, A2, and A3.5 shades was applied in layers to a polymeric mold. A light-polymerizing unit (Elipar FreeLight 2; 3M ESPE) was used to polymerize the composite resin incrementally for 40 seconds with an intensity of 800 mW/cm^2. The composite resin backgrounds were polished with 800-grit silicon carbide abrasive papers. Initially, to fabricate the background ZR, a cylindrical pattern was designed with software (Solidworks 2015; Dassault Systèmes). The same CAD-CAM system was used to mill a similar zirconia blank to prepare a zirconia cylinder based on the CAD. The zirconia cylinder was immersed in an A3 shade liquid for 10 seconds and sintered at 1520°C for 12 hours in the same sintering furnace. The background AM was made from an amalgam alloy (Dispersalloy Dispersed Phase Alloy Regular Set 3 Spill [800 mg] Yellow caps; Dentsply Sirona). It was triturated, placed in a mold, condensed, and burnished. To fabricate the W and B backgrounds, white and black polytetrafluoroethylene materials (Teflon; Omnia Plastica SpA) were milled using the same CAD-CAM system and polished using the same kit.

For the cast metal background specimens, 2 cylindrical patterns were formed using an acrylic resin (Duralay; Reliance Dental Mgf Co). The patterns were cast in a nickel-chromium alloy (VeraBond V; Aalba Dent, Inc) and a nonprecious gold-colored alloy (NPG; Aalba Dent, Inc) to prepare the backgrounds of NC and NPG. Both backgrounds were polished using a base metal polishing kit (Coral Stones; Shofu Inc).

All backgrounds were cleaned in an ethanol solution and dried. The CIELab values of the backgrounds were measured with a spectrophotometer[32] (SpectroShade Micro; MHT Optic Research AG) (Table 1).

A silicone putty material (Speedex; Coltène Inc) was molded to the spectrophotometer to exclude external light, supply a seat for the backgrounds, and replicate the

Table 1. Measured color attributes of backgrounds

Color Attribute	A1	A2	A3.5	ZR	NC	NPG	AM	B	W
L*	65.2	63.4	62.1	71.2	11.9	12.6	25.4	7.3	93.2
a*	0.2	0.5	1.4	3.8	-1.1	-0.2	-0.5	-0.7	-1.6
b*	15.5	18.4	19.2	14.0	1.5	5.7	4.9	-1.1	0.8

L*, brightness; a*, red-green; b*, yellow-blue. A1-A3.5, shade composite resins; AM, amalgam; B, black; NC, nickel-chromium alloy; NPG, nonprecious gold-colored alloy; W, white; ZR, A3 shade zirconia.

conditions for all specimens. The zirconia specimens were placed on the backgrounds without an intermediate.[10,16] The CIELab values (L^*, brightness; a^*, red-green value; b^*, yellow-blue value) of the specimens were measured using the spectrophotometer. Color difference values were calculated to compare the CIELab values of a specimen on a background with its CIELab values on the background A2. The ΔE was calculated using this formula $[\Delta E^*_{ab}=([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{1/2}]$. Thresholds for acceptability (ΔE=5.5) and perceptibility (ΔE=2.6) were assumed in order to evaluate masking ability.[10,11,21]

Statistical software (IBM SPSS Statistics v21; IBM Corp) was used to analyze data. The Kolmogorov-Smirnov test showed a normal distribution of data in all groups (P>.05). Repeated measures ANOVA was used to compare the CIELab and ΔE values among the groups. Pairwise comparisons of the groups were conducted using the Bonferroni test. With statistical software (Stata; StataCorp LLC) using the 1-sample t test, the ΔE values were compared with the acceptability and perceptibility thresholds, and the acceptable and ideal masking abilities were then assessed considering the zirconia thickness and background type (α=.05 for all tests).

RESULTS

The mean ±SD CIELab and ΔE values for the zirconia coping thickness groups of 0.4, 0.6, and 0.8 for the tested backgrounds are presented in Figures 1 to 4 (Supplemental Table 1). The repeated measures ANOVA results showed that the zirconia coping thickness, the background type, and their interaction affected the CIELab and ΔE values (P<.001) (Table 2). Pairwise comparisons of the ΔE values were performed by using the Bonferroni test with 2 orders: for each background between different thickness groups (order 1) and in each thickness group between different backgrounds (order 2). According to order 1, significant differences were found in the ΔE value between 0.4 and 0.8 for A1 (P=.009), A3.5 (P=.032), NC (P<.001), AM (P<.001), B (P<.001), and W (P=.048); and between 0.6 and 0.8 for NC (P=.004), AM (P=.023), B (P<.001), and W (P=.017). According to order 2, significant differences were found in the ΔE value in the group of 0.4 between B and each of the other backgrounds (P<.001), W and each of the other backgrounds (P<.001), ZR and NC (P<.001), ZR and AM (P<.001), A3.5 and AM (P=.032), NC and NPG (P<.001), and NPG and AM (P<.001); in the group of 0.6 between B and each of the other backgrounds (P<.001), W and each of the other backgrounds (P<.001), A3.5 and ZR (P=.048), ZR and NC (P<.001), ZR and AM (P<.001), NC and NPG (P<.001), and NPG and AM (P=.033); and in the group of 0.8 between B or W and each of the other backgrounds (P<.001), and between B and W (P=.028).

The 1-sample t test compared the means of the ΔE values with the acceptable (ΔE≤5.5) and ideal masking ability (ΔE≤2.6). The null hypothesis of ΔE≤5.5 was rejected for B in 0.4 and 0.6 (P<.001). Hence, this zirconia ceramic had acceptable masking ability on A1, A3.5, ZR, NC, NPG, AM, and W, with a minimum thickness of 0.4 mm, and on B, with a minimum thickness of 0.8 mm. The null hypothesis of ΔE≤2.6 was rejected for NC in 0.4 (P=.002) and 0.6 (P=.042), AM in 0.4 (P=.005), and B and W in all thickness groups (P<.001). Thus, this ceramic had ideal masking ability on A1, A3.5, ZR, and NPG, with a minimum thickness of 0.4 mm, on NC with a minimum thickness of 0.8 mm, and on AM with a minimum thickness of 0.6 mm. The tested thicknesses could not indicate the ideal masking ability on B and W.

DISCUSSION

Based on the results, which showed significant differences in the CIELab and ΔE values related to zirconia coping thickness and background type, the null hypothesis of the study was rejected. The thickness needed for acceptable masking ability was 0.4 mm for A1, A3.5, ZR, NC, NPG, AM, and W and 0.8 mm for B. The thickness needed for ideal masking ability was 0.4 mm for A1, A3.5, ZR, and NPG, 0.6 mm for AM, and 0.8 mm for NC, and this thickness could be more than 0.8 mm for B and W. The results can be explained considering the relative translucency of zirconia ceramic and the color characteristics of the backgrounds. Zirconia as a semi-translucent material has a degree of light transmission.[8] A background may manifest its color properties under the zirconia ceramic and may affect the resulting color. The resulting color is a product of the colors of the ceramic and background. As the backgrounds demonstrated different CIELab color attributes (Table 1), the ΔE values depended on the color difference between the A2 background (control) and each of the backgrounds (Fig. 4). A greater color difference between a background and the control required a greater thickness. This may explain the differences in the thickness needed between the backgrounds for ideal masking ability (B > NC > AM > NPG). The thickness needed for the A1, A3.5, and ZR was the lowest because of their slight color differences compared with the control. An increase in ceramic thickness decreases ceramic translucency[16] and reasonably reduces the background effect. This was shown by

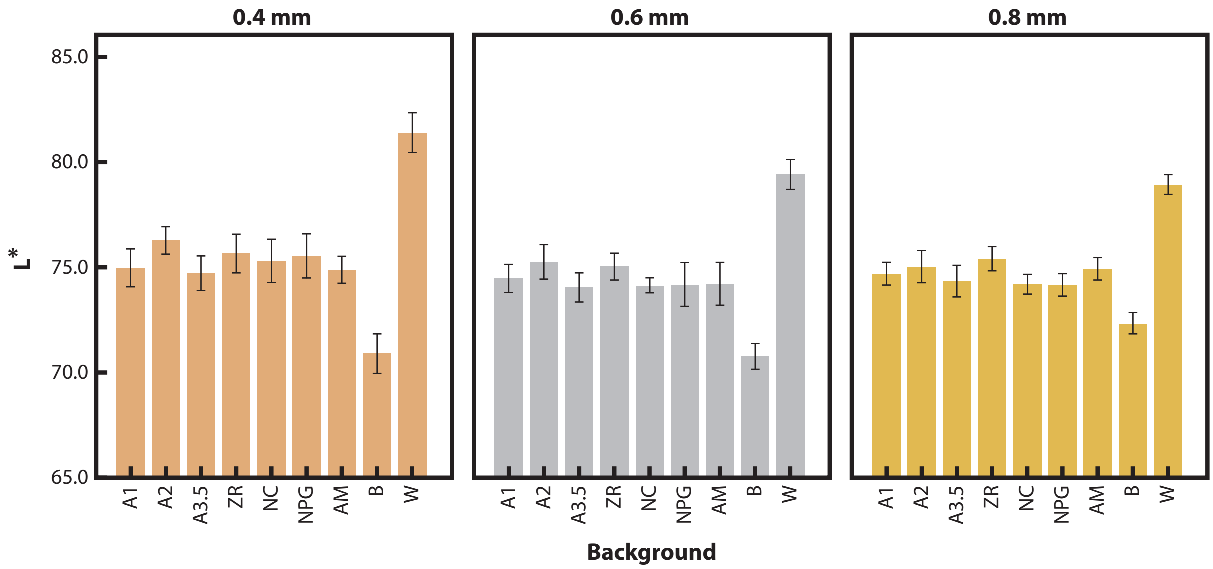

Figure 1. Mean ±SD L* values.

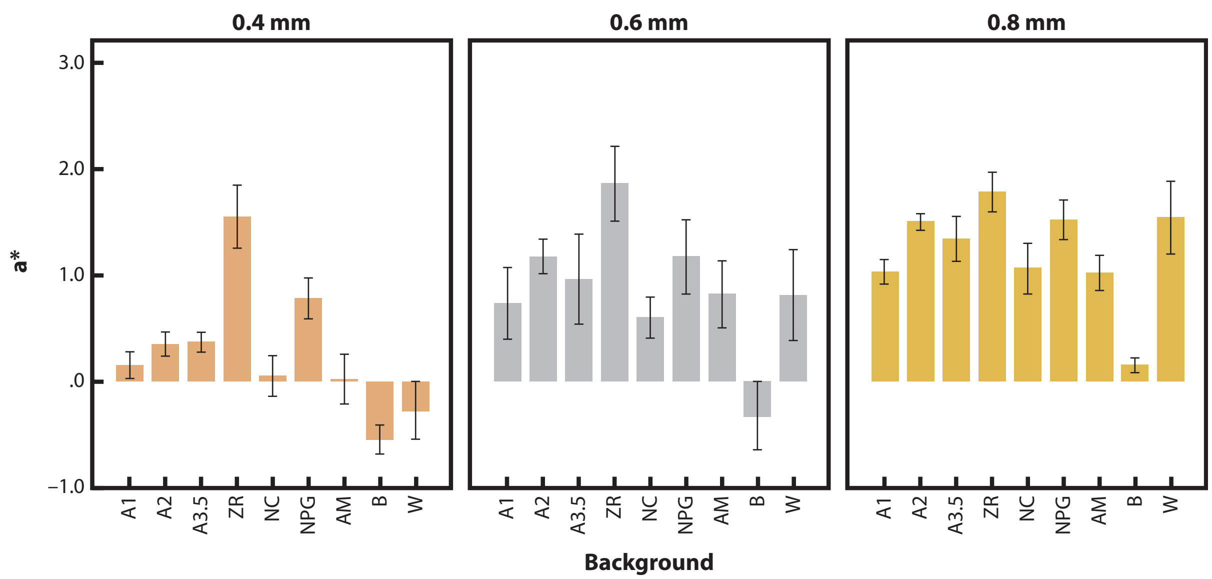

Figure 2. Mean ±SD a* values.

the present study, in which an increase in the thickness from 0.4 to 0.8 mm decreased the ΔE values (Fig. 4).

Azer et al[24] reported that both ceramic thickness and background could affect the color of a ceramic laminate veneer. This was confirmed by the present study, although the translucency of zirconia ceramic is less than that of ceramic laminate veneer. Suputtamongkol et al[9] assessed the color of zirconia-based crowns with 0.4 to 1 mm coping thicknesses placed on nickel-chromium and composite resin cores. The cores could affect the final color of the restorations with 0.4-mm coping thicknesses.[9] The results of the present study on the compromised ideal masking ability of the 0.4-mm-thick zirconia coping on nickel-chromium alloy supported the results of Suputtamongkol et al,[9] although they reported a greater ΔE value for composite resin cores than for nickel-chromium cores. This contrasting result may be due to the different shaded composite resins used in the studies.

Kumagai et al[15] showed a difference between the coping thicknesses (0.3 and 0.5 mm) in the ΔE at the cervical area of Lava zirconia-based crowns placed on 2 colored teeth. Though the present study evaluated different coping thicknesses, background type, and zirconia ceramic than the study of Kumagai et al,[15] both studies revealed the possibility of a color change with a thin zirconia coping. Oh and Kim[11] evaluated the color of

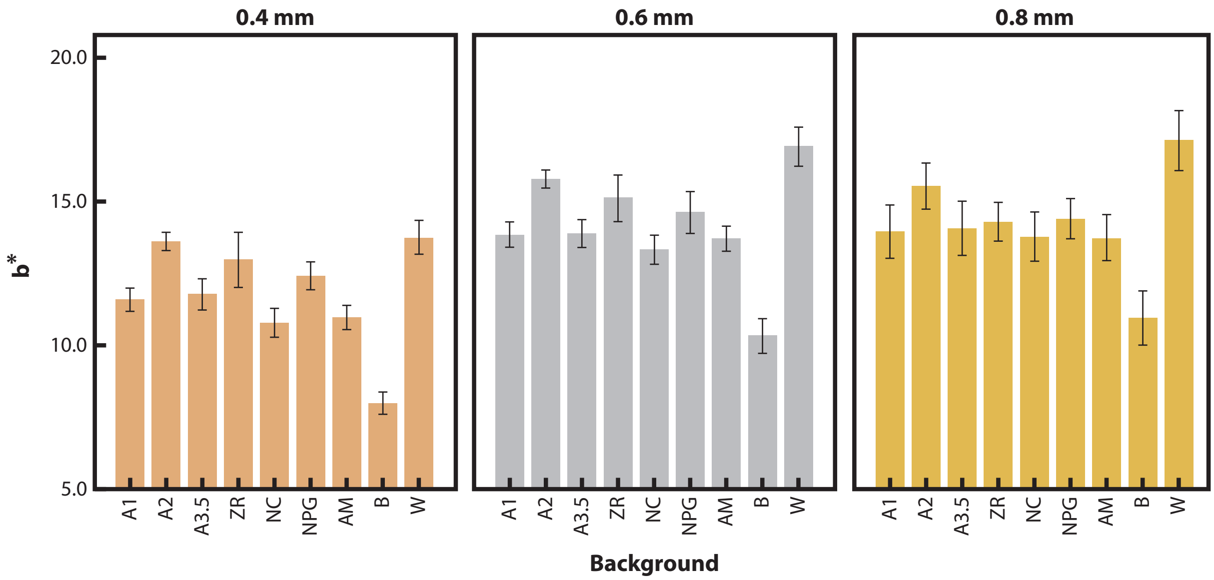

Figure 3. Mean ±SD b* values.

1- and 1.5-mm-thick Lava zirconia-based crowns with 0.4-mm-thick copings on gold alloy, nickel-chromium alloy, and composite resin abutments and concluded that the gold alloy caused a significant color change.[11] However, the present study revealed that the nickel-chromium alloy created a perceptible color difference. The use of a different brand of zirconia, different coping thicknesses, and an unveneered zirconia in the present study may explain this disagreement with the results of Oh and Kim.[11]

Baldissara et al,[14] Peixoto et al,[18] Malkondu et al,[23] Kürklü et al,[25] and Pires et al[29] reported a decrease in translucency as a result of an increase in ceramic thickness. This was confirmed by the current investigation. Choi and Razzoog[10] studied the masking ability of zirconia on 4 backgrounds and found a greater background-induced ΔE value for the black background than for the tooth-colored background. The current research found a similar trend; however, ΔE was measured differently in the studies. Comparing the background and the same background covered with a zirconia disk as in the study of Choi and Razzoog[10] seems not to be a logical method of measuring ΔE and masking ability.

Wang et al[16] estimated the translucency parameter for several glass and zirconia ceramics with various thicknesses on a black and white background and revealed a level of translucency in zirconia less sensitive to thickness than that in glass ceramics. An increase in thickness decreased the translucency parameter,[16] which was confirmed by the present study.

According to the present study, a background-induced color difference was greater for black and white backgrounds than for tooth-colored and metal alloy backgrounds. Not only does the difference between black and white backgrounds lead to an increased ΔE but this testing also does not simulate clinical conditions. There is a clinical need to mask the color difference between a shaded background and a natural tooth, but not between a black and white background. Spink et al[17] indicated that the contrast ratio recorded on black and white backgrounds was not a direct measure of translucency and should not be used below 50% light transmission. Considering the light transmission percentage of zirconia and the present study results, the result of Spink el al[17] is emphasized.

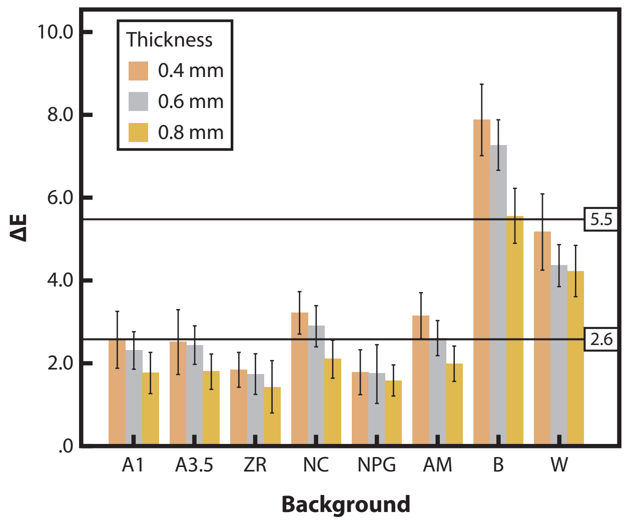

Figure 4. Mean ±SD ΔE values.

Based on the results of this study, to achieve excellent esthetic outcomes for zirconia-based restorations in

Table 2. Results of repeated measures ANOVA (Greenhouse-Geisser) for effects of coping thickness and background type on color attributes

Color Attribute	Source	Type III Sum of Squares	*df*	Mean Square	F	*P*
L*	Background	105174.957	4.868	21604.574	30417.936	<.001
	Thickness	11.078	2	5.539	3.426	.047
	Background×Thickness	120.799	9.736	12.407	17.468	<.001
	Error	93.357	131.441	0.710		
a*	Background	67.598	4.411	15.323	238.076	<.001
	Thickness	41.035	2	20.518	72.408	<.001
	Background×Thickness	8.071	8.823	0.915	14.214	<.001
	Error	7.666	119.109	0.064		
b*	Background	721.205	5.382	133.992	376.058	<.001
	Thickness	355.655	2	177.828	77.660	<.001
	Background×Thickness	19.352	10.765	1.798	5.045	<.001
	Error	51.781	145.326	0.356		
ΔE	Background	675.266	4.196	160.941	325.672	<.001
	Thickness	37.701	2	18.850	28.697	<.001
	Background×Thickness	16.952	8.391	2.020	4.088	<.001
	Error	55.983	113.285	0.494		

L*, brightness; a*, red-green value; b*, yellow-blue value; ΔE, color changes.

patients requiring a composite resin foundation, the appropriate foundation material should first be selected to match the shade of the restoration, if possible. When a customized post and core is the choice, using a gold-colored alloy or a zirconia ceramic has the advantage over a nickel-chromium alloy. In clinical situations with an existing core, options are available to compensate for the effect of background, including the use of an opaque cement, increased veneering porcelain thickness, and use of a proper thickness of zirconia coping. Color masking a background with cements may not be feasible because different shades are not available for all types of cement. Cement may also affect color unpredictably.[22,23,30] Increasing the thickness of the veneering porcelain has been reported[9-12] but a veneering porcelain needs greater thickness to mask a background than a zirconia coping because of its higher level of translucency.[13,16-18]

Using a zirconia coping with a proper thickness may be the best method of masking the background color and should be assigned based on mechanical and esthetic requirements.[33] As the results of this study are limited to the tested substances, more studies are recommended on other brands, types, and shades of zirconia ceramics and core materials.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. To achieve an ideal masking ability, the minimum thickness of a zirconia coping should be 0.4 mm for A1 and A3.5 shade composite resin, A3 shade zirconia, and nonprecious gold-colored alloy.
2. It should be 0.6 mm for amalgam and 0.8 mm for nickel-chromium alloy.

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