Original paper

Effects of the substructure thickness, the resin cement color and the finishing procedure on the color and translucency of zirconia-based ceramic restorations

Ayse Seda Ataol[1,A–F], Gulfem Ergun[2,A,D–F], Mevsim Yayman[3,B–D]

[1] Zoom Dental Clinic, Ankara, Turkey
[2] Department of Prosthodontics, Faculty of Dentistry, Gazi University, Ankara, Turkey
[3] Department of Prosthodontics, Faculty of Dentistry, Selcuk University, Konya, Turkey

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl*. 2023;60(1):137–144

Address for correspondence
Ayse Seda Ataol
E-mail: sedaataol@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
None declared

Received on October 15, 2021
Reviewed on April 12, 2022
Accepted on April 21, 2022

Published online on March 31, 2023

Cite as
Ataol AS, Ergun G, Yayman M. Effects of the substructure thickness, the resin cement color and the finishing procedure on the color and translucency of zirconia-based ceramic restorations. *Dent Med Probl.* 2023;60(1):137–144. doi:10.17219/dmp/149356

DOI
10.17219/dmp/149356

Abstract

Background. The ability to simulate the natural appearance of teeth in dental restorations is one of the most important factors that make treatment successful.

Objectives. The present study evaluated the effects of the substructure thickness, the resin cement color and the finishing procedure on the color and translucency of bilayer zirconia-based ceramic restorations.

Material and methods. Yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP) CAD/CAM blocks (dimensions of 6.0 × 5.5 × 0.4 mm, 6.0 × 5.5 × 0.8 mm, and 6.0 × 5.5 × 1.6 mm) veneered with the fluorapatite-containing ceramics were used. For polishing, the surfaces of half of the test specimens were adjusted with a blue-belted diamond porcelain bur and a white polishing rubber, and the other half were glazed. The test specimens were then cemented with 2 different colors of the same self-adhesive resin cement to the resin composite. A spectrophotometer was used to measure the L*, a*, and b* color attributes of the specimens. Additionally, the ΔE values were calculated to determine color differences between each group and the control. Data was analyzed using the multifactorial repeated-measures analysis of variance (ANOVA) and subgroup analysis ($p < 0.005$).

Results. It was found that the highest substructure thickness resulted in the lowest color change (ΔE = 1.24) ($p < 0.005$). However, a substructure thickness of 0.8 mm showed less color change (ΔE = 1.39) than the 0.4-mm thickness (ΔE = 3.85) in the translucent resin cement/polished subgroup, as measured against a gray background ($p = 0.001$).

Conclusions. The most significant factor in masking the abutment color in zirconia-based restorations is the thickness of the substructure. The surface finishing procedure or the resin cement color do not have a primary effect on the color change or translucency.

Keywords: zirconia, color, surface finishing, resin cements, substructure thickness

Introduction

Metal-supported porcelain restorations show long-term success, given their good mechanical properties.[1] However, from an aesthetic point of view, metal infrastructures have some negative aspects, such as preventing light transmission[2] and metallic color reflection in the gingival region.[3,4] For this reason, metal-supported porcelain restorations, which have been accepted as the gold standard in dentistry for many years, are now being replaced with more aesthetic alternatives, such as zirconia-supported porcelain restorations.[1,5] In these restorations, the zirconia infrastructure provides high strength, while the veneer porcelain helps to achieve a natural appearance.[6]

The translucency of a ceramic material influences the natural appearance of the restoration and affects the esthetics of a restoration. A 1-mm thick zirconia ceramic substructure material has a visible light transmission between 20% and 50%. Therefore, zirconia is defined as a semi-translucent material.[7,8] On the other hand, in cases where discolored teeth, metallic core materials, and titanium abutments need to be masked, the light transmittance of zirconia appears to be a disadvantage rather than an advantage.[6,9] Under these conditions, zirconia cannot mask the dark color, and the final color of the restoration is affected by the substructure color.[9,10] Therefore, the thickness of the veneer and core materials affect the final appearance of ceramic restorations.[11] Wang et al. reported that an increase in zirconia thickness reduces the translucency of the restoration after comparing the light transmittance of dental ceramics with different thicknesses.[12] Similarly, Tabatabaian et al. investigated the effect of zirconia substructure thickness and background type on masking ability and reported that zirconia substructures should be at least 0.4 mm thick to obtain ideal coverage in masking A3.5 colored composite resins.[9] In a study by Tabatabaian et al., the masking ability of zirconia of various thicknesses on white and black backgrounds was evaluated.[6] It was found that 1-mm thick zirconia had the acceptable masking ability, but the required thickness for ideal masking should be 1.6 mm.

In addition to material thickness, the application of glaze porcelain and the cement used can also affect the optical properties of zirconia-supported restorations.[3] The final smooth finish of porcelain surfaces is provided by the application of glaze. Although it is generally accepted that glazed porcelain provides optimal surface quality, it is sometimes necessary for occlusal adjustments during the adaptation of the restoration. In these cases, repeated firing of the restoration will not be practical, so the refinishing of porcelain surfaces on which surface adjustments have been made is done intraorally.[12] Studies have evaluated the color stability of dental ceramics, concluding that accurate finishing procedures could provide surface texture similar to a glazed surface. Therefore, intraoral polishing procedures as an alternative to glazing have also been suggested.[13,14]

Regarding the role of cements on color, a study by Fazi et al. evaluated the effects of four different cements on the color of zirconia-supported ceramics, concluding that opaque cements should be avoided in areas where porcelain thickness decreases in restoration.[15] Although cements have significant effects on the final color of all-ceramic restorations, their effects on zirconia-based restorations are not yet fully known.[3] Since spectrophotometers and colorimeters can show fewer color differences than the human eye can distinguish, detectable and acceptable clinical ΔE threshold values have been defined.[7] The ΔE value obtained is compared with these threshold values to evaluate the visibility of the color difference. Threshold ΔE values between 1 and 5.5 have been reported in the studies. Although these color differences cannot be perceived by the clinician, a ΔE value of less than 2.6 indicates ideal color difference, while a value of less than 5.5 indicates acceptable color changes.[16,17]

Although zirconia-based restorations have aesthetic advantages compared with metal-ceramic restorations, it is still complex to achieve a natural appearance with zirconia-based restorations due to different factors, such as the cement used, zirconia coping, veneering ceramic, laboratory procedure, and surface finishing procedure.[7] This study simulated three variables of a bilayer zirconia ceramic restoration, such as veneering ceramic and core and luting cement. Substructure thickness, color of resin cement, and surface finishing procedure were the parameters used in the evaluation of color change and translucency.

This study aimed to analyze the effect of (i) self-adhesive resin cements with different colors and opacity, (ii) semi-opaque zirconia substructure stabilized with yttrium in different thicknesses, and (iii) glaze porcelain application and mechanical polishing processes on color and light transmission of bilayer zirconia-supported ceramic restorations. The null hypothesis of this study was that the examined material thickness, different polishing protocols, and resin cement color/opacity would affect both color and translucency of zirconia-based ceramic restorations.

Material and methods

Study design

This in vitro study aimed to test the color difference between bilayer Yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP) CAD/CAM blocks with different material configurations of thickness, finishing protocols, and resin cements with different colors and opacity. A sample size of n = 12 was used for each group (Fig. 1). The material configuration groups were as follows: color and opacity of resin cement (universal A2 and transparent), finishing protocol (mechanical grinding and glaze), and substructure thickness (0.4 mm, 0.8 mm, and 1.6 mm).

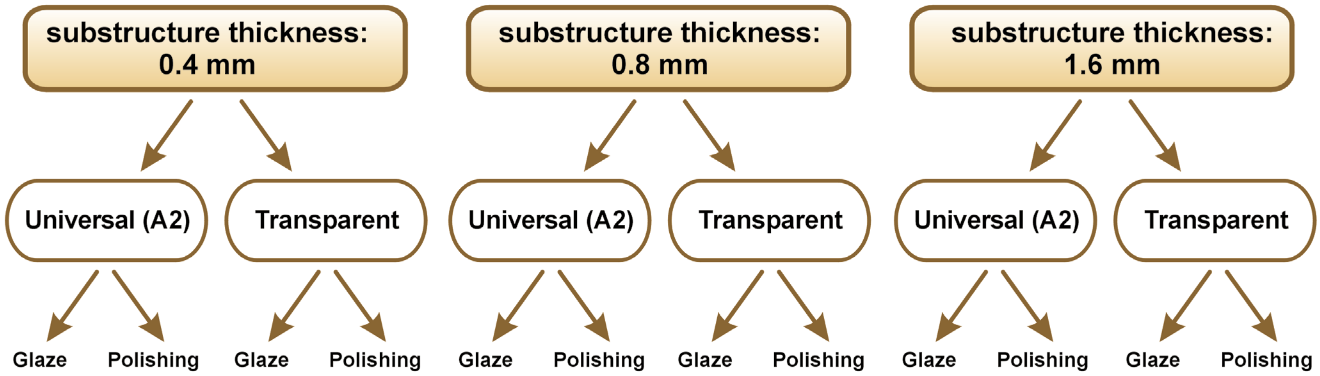

Fig. 1. Study plan and subgroups

Preparation of the yttrium-stabilized zirconia substructure test specimens

The Y-TZP CAD/CAM blocks (IPS e.max ZirCAD, MO 2/C 15; Ivoclar Vivadent AG, Schaan, Liechtenstein) were cut using a precision cutting device (MICRACUT 201; Metkon Instruments Inc., Bursa, Turkey) and a diamond cutting disc (15LC, 11-4255, 127 × 0.4 mm; IsoMet Diamond Wafering Blades, Buehler, USA) (dimensions of 7.5 × 6.9 × 0.5 mm, 7.5 × 6.9 × 1 mm and 7.5 × 6.9 × 2 mm) simulating the substructure of bilayer restorations. The surfaces of the test specimens were polished with 800 and 1200 grit SiC paper (English Abrasives & Chemicals Ltd., Stafford, UK) under running water by the same researcher for 10 s with each SiC paper. Sample thicknesses were checked using a digital caliper (Digitaler Messscheiber; Alpha Tools, Bahag AG, Mannheim, Germany). Before sintering, the samples were cleaned with pressurized steam. All of the test specimens were sintered in a sintering furnace (MoS-B 160/2, Protherm Furnaces; Alser Teknik Seramik Inc., Ankara, Turkey) for 7 h and 20 min at 1,500°C, according to the manufacturer's recommendations. Final test specimen dimensions were measured as 6.0 × 5.5 × 0.4 mm, 6.0 × 5.5 × 0.8 mm, and 6.0 × 5.5 × 1.6 mm, with 20% shrinkage resulting from the sintering process. Sintered zirconia test samples were cleaned with 96% ethanol.

Application of the fluorapatite-containing veneer ceramic to the zirconia specimens

Fluorapatite layering ceramic powder (IPS e.max Ceram Dentin A2/TI1; Ivoclar Vivadent AG) and liquid (IPS e.max Ceram Allround Build Up Liquid; Ivoclar Vivadent AG) were mixed and applied to sintered yttrium-stabilized zirconia test specimens. It was applied by the manual layering technique into aluminum molds with dimensions of 6.5 × 6.5 × 1.4 mm, 6.5 × 6.5 × 1.8 mm, and 6.5 × 6.5 × 2.6 mm and fired in a porcelain furnace (Programat P310; Ivoclar Vivadent AG) according to the instructions. After firing, layering porcelain was added to the missing areas in the mold due to shrinkage (of around 20%) in the porcelain and then fired again. The surfaces of the ceramic samples were adjusted with a blue-belted diamond porcelain bur (Sigmadent, Istanbul, Turkey) and white polishing rubber (Nais Dental Polishers, Sofia, Bulgaria) to standardize the surfaces of the specimens; the procedure was performed for 10 s under water cooling by the same practitioner in a circular motion (rather than in one direction) until the desired dimensions were obtained.

Application of glaze to the test specimens

Glaze paste (IPS Ivocolor Glaze Paste; Ivoclar Vivadent AG) and liquid (IPS Ivocolor Allround Mixing Liquid; Ivoclar Vivadent AG) were applied to half of the test specimens using a brush and fired in the same porcelain furnace according to the manufacturer's instructions.

Preparation of the resin composite test specimens

To imitate tooth color, a resin composite (Charisma Smart A3; Heraeus Kulzer, Hanau, Germany) was placed in a 6.0 × 6.5 × 10 mm plexiglass mold (Ostim, Ankara, Turkey) by the application of a layering technique and polymerized for 20 s, according to the manufacturer's instructions, with a light device (LED.F; Woodpecker Medical Instrument Co., Guilin, China).

Cementation of the ceramic test specimens to the resin composite test specimens

The surfaces of the zirconia test specimens veneered with layering porcelain were sandblasted with 50-μm aluminum oxide particles for 10 s under 60 psi at a distance of 0.5 mm in a sandblaster (Heraeus Kulzer Combilabor, CL FSG 3; Heraeus Kulzer). All specimens were cleaned ultrasonically in distilled water for 10 min. The zirconia ceramic test specimens were cemented to the resin composite test specimens in accordance with the manufacturer's instructions, using two different colors of the same self-adhesive resin cement (Panavia SA Cement Plus Universal [A2] and Transparent, Kuraray Noritake Dental Inc., Okayama, Japan). To standardize the cement thicknesses, 0.13 mm thick perforated teflon fabric (Haksan Industry Materials, Ankara, Turkey) was used. During cementation, the specimens were placed on a metal weight mechanism (Ostim, Ankara, Turkey), and 9.4 kg of force was applied to them throughout the polymerization period.

Color measurements

Color measurements were made before and after the cementation of all ceramic test specimens to the resin composites. A spectrophotometer device (CR-321 Chroma Meter, Konica Minolta, Tokyo, Japan) was used for color measurements with black, gray, and white backgrounds. For the evaluation of color measurement, the CIE L*a*b* color system, which was standardized by the International Commission on Illumination, named Commission internationale de l'éclairage, was used. The CIE L*a*b* system defines color in 3 axes: L*; a*; and b*. The L* axis indicates the degree of lightness, darkness, brightness, or black/white – pure white is 100 L*, while pure black is 0 L*. The a* and b* axes represent the chromatic properties of the color. The a* value indicates the red-green ratio of the color and the b* value indicates the yellow-blue ratio. If the a* value is positive, it is red; if it is negative, it is green. If the b* value is positive, it represents yellow; and if it is negative, it represents blue. The color difference is defined by ΔE. In the calculation of ΔE, the following formula is used (Equation 1):

$$\Delta E_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

If the color change value was $\Delta E \leq 3.7$, it was clinically acceptable.[18,19]

Light transmittance

A spectrophotometer (CR-321 Chroma Meter; Konica Minolta, Tokyo, Japan) was used to measure the light transmittance of the test specimens. Light transmittance was measured using white and black backgrounds. The light transmittance values were calculated using the following formula (Equation 2):

$$TP = \sqrt{\left(L^*_B - L^*_W\right)^2 + \left(a^*_B - a^*_W\right)^2 + \left(b^*_B - b^*_W\right)^2} \quad (2)$$

where:
TP – translucency parameter;
W – color coordinates against a white background; and
B – coordinates against a black background.

Statistical analysis

Post-hoc power analysis was performed with the ClinCalc online post-hoc power calculator. This calculator uses various equations to calculate the statistical power of a study after the study is performed. The study had a power of 86.5–99.9% to produce a significant difference with $N = 24$ participants in terms of ΔE universal A2 (0.4 mm) black background and ΔE translucent (0.8 mm) gray background with 0.05 type 1 error.

All analyses were performed using IBM SPSS Statistics for Windows, v. 24.0 (IBM Corp., Armonk, USA). The conformity of continuous variables to a normal distribution was tested with the Shapiro–Wilk test. Descriptive statistics were used to describe continuous variables: mean (*M*); standard deviation (*SD*); minimum (min); median (*Me*); and maximum (max). The Mann–Whitney *U* test was used to compare two independent and non-normally distributed variables.

The Wilcoxon test was used to compare dependent and non-normally distributed variables. The Friedman test was used when more than two variables did not fit the dependent and normal distribution. Statistical significance was set at a *p*-value of 0.05.

Results

The color of resin cement (A2 or translucent) used did not make a sigignificant difference in terms of the final color of the restoration with different finishing procedures and substructure thicknesses ($p > 0.05$), except for 2 subgroups (Tables 1–4).

The ΔE was statistically significantly higher for the universal A2 resin cement than translucent resin cement in the 0.8 mm polishing gray background group ($p = 0.009$) (Table 2). In contrast, ΔE was significantly higher for translucent resin cement than for universal A2 resin cement in the 0.4 mm glaze white background group ($p = 0.015$) (Table 3).

Polishing procedure did not have a significant effect on the color of the test specimens with a white background (Table 3). Conversely, polishing significantly increased the color change as compared with glaze in the 0.4 mm substructure thickness subgroup of universal A2 resin cement with a black background and translucent resin cement with a gray background ($p = 0.002$ and $p = 0.028$, respectively). In addition, a statistically significant higher color change was achieved with glaze as compared with polishing in the 0.8 mm substructure thickness subgroup of translucent resin cement with a gray background ($p = 0.041$).

The results of our study also indicated that there was a statistically significant change in the color of the tested specimens due to substructure thickness ($p > 0.05$). For both universal A2 and translucent resin cement, a lower color change was observed in the 1.6 mm substructure thickness subgroup compared with 0.4 mm and 0.8 mm thicknesses with black backgrounds ($p < 0.05$). Polishing of the 1.6 mm substructure in the universal A2 resin cement subgroup and glaze in the translucent resin cement subgroup resulted in a lower color change than 0.4 mm substructure thickness with both gray and white backgrounds ($p < 0.05$). Additionally, the 0.8 mm substructure thickness had a greater color change than the 0.4 mm in the subgroup, which was cemented with a translucent resin cement/polished subgroup and measured with a gray background ($p = 0.001$).

Table 1. Multiple comparison of the mean color change (ΔE) values among different substructure thickness, resin cement color and surface finishing procedure subgroups (black background)

Parameter	Resin cement color	Surface finishing procedure	Substructure thickness			*p*-value
			0.4 mm	0.8 mm	1.6 mm	
ΔE	universal A2	polishing	3.8[b]	3.62[a]	1.24[ab]	<0.001*
		glaze	2.02[d]	3.99[cd]	2.07[c]	0.001*
	p-value	–	0.002*	0.388	0.099	–
	translucent	polishing	3.77[e]	3.94[f]	1.61[ef]	0.001*
		glaze	2.49[g]	4.14[gh]	2.21[h]	0.001*
	p-value	–	0.099	0.754	0.071	–

* statistically significant; the letters in superscript indicate statistically significant differences among the resin cement color and the substructure thickness.

Table 2. Multiple comparison of the mean color change (ΔE) values among different substructure thickness, resin cement color and surface finishing procedure subgroups (gray background)

Parameter	Resin cement color	Surface finishing procedure	Substructure thickness			*p*-value
			0.4 mm	0.8 mm	1.6 mm	
ΔE	universal A2	polishing	4.22[ab]	2.15[bf]	2.34[a]	0.017*
		glaze	2.57	1.62	2.48	0.205
	p-value	–	0.050	0.239	0.695	–
	translucent	polishing	3.85[c]	1.39[cf]	2.1	0.001*
		glaze	3.12[d]	2.29[e]	2.04[de]	0.017*
	p-value	–	0.028*	0.041*	0.937	–

* statistically significant; the letters in superscript indicate statistically significant differences among the resin cement color and the substructure thickness.

Table 3. Multiple comparison of the mean color change (ΔE) values among different substructure thickness, resin cement color and surface finishing procedure subgroups (white background)

Parameter	Resin cement color	Surface finishing procedure	Substructure thickness			*p*-value
			0.4 mm	0.8 mm	1.6 mm	
ΔE	universal A2	polishing	2.78[a]	1.97	1.45[a]	0.039*
		glaze	2.09[b]	1.53	1.8	0.779
	p-value	–	0.099	0.239	0.158	–
	translucent	polishing	2.25	2.25	1.32	0.125
		glaze	2.82[b]	1.55[b]	2.23[b]	0.001*
	p-value	–	0.754	0.136	0.050	–

* statistically significant; the letters in superscript indicate statistically significant differences among the resin cement color and the substructure thickness.

Table 4. Multiple comparison of the mean translucency parameter (TP) values among different substructure thickness, resin cement color and surface finishing procedure subgroups

Parameter	Resin cement color	Surface finishing procedure	Substructure thickness			*p*-value
			0.4 mm	0.8 mm	1.6 mm	
TP	universal A2	polishing	0.84	0.77	1.08	0.338
		glaze	0.71	0.92	0.87	0.205
	p-value	–	0.433	0.433	0.338	–
	translucent	polishing	0.70	0.77	0.98	0.558
		glaze	1.24	1.13	0.91	0.779
	p-value	–	0.060	0.136	0.694	–

The highest translucency value was observed in a test group with a glazed 0.4 mm substructure cemented with translucent resin cement, and the lowest was a polished one. However, substructure thickness, resin cement color, and surface finishing procedure had no statistically significant effect on the translucency parameter of test specimens ($p > 0.05$) (Table 4).

Discussion

For all parameters, the null hypothesis was accepted. A 1.6 mm substructure ceramic thickness met the clinically acceptable color change when considering the three analyzed backgrounds. Reducing the substructure thickness to 0.4 or 0.8 mm caused a greater color change than the clinically acceptable value, especially in subgroups with polishing and gray backgrounds (Table 2). However, 0.4 mm and 0.8 mm substructure thicknesses and glazed test specimens generally resulted in clinically acceptable color change values with each background (Tables 1–3). These results indicate that when clinically low substructure thickness is required, it will be clinically more appropriate to use glaze as a surface finishing process.

Translucent ceramic restorations should be restricted to abutments that are closely similar to the planned final color of the restorations. However, in the presence of clinically colored tooth tissue, it may be necessary to use opaque materials, such as zirconia ceramics, that can camouflage the color of abutment. However, in this case, the substructure thickness of zirconia ceramics can be decisive in the final color of the restoration. Previous studies have shown that the color of restorations is significantly affected by ceramic thickness.[11] Similarly, we found substructure thickness to be the most significant variable in color change, especially with black background (Table 1). Hence, the thickness was concluded to be a major determinant in achieving ideal clinical standards in this in vitro study. For both colors of resin cement, a lower color change was observed in the subgroup of 1.6 mm substructure thickness compared with 0.4 mm and 0.8 mm with a black background ($p < 0.05$). As expected, the highest values of ΔE were found with thin substructure thicknesses (0.4 mm). Additionally, 1.6 mm substructure thickness with polishing in the universal A2 resin cement subgroup and glazing in the translucent resin cement subgroup resulted in a lower color change than 0.4 mm substructure thickness with both gray and white backgrounds ($p < 0.05$). Taken together, these results indicate that a higher substructure thickness can better camouflage the abutment color.

Similar to our study, Tabatabaian et al. reported that masking ability increased as the zirconia ceramic thickness increased, with ideal masking ability at a minimum thickness of 1.6 mm.[9] In contrast, in studies by Fazi et al.[15] and Sinmazisik et al.,[20] core thickness surprisingly had no significant effect on ΔE. The reason for this may be related to the fact that the core thicknesses tested in the study by Fazi et al.[15] were less than the substructure thicknesses tested in our study. Further studies should support our data and reveal the minimal core thickness to minimize tooth background interferences on the final color of the restoration.

Generally, it has been reported that polishing surfaces after crown recontouring or occlusal adjustments should be avoided and reglazed before definitive cementation.[21,22] However, various polishing procedures could be used on ceramic surfaces to obtain structural resistance and a clinically acceptable smoothness compared with glazing.[22] In addition, surface texture influences the color of ceramic restorations. Thus, one of the aims of our study was to compare ΔE values before and after cementation among subgroups with surface finishing procedures. Our results did not indicate perceptible color changes between polishing versus glaze with white backgrounds across the tested ceramics (Table 3). These results were similar to those of a study by Akar et al.[19] The ΔE values after each surface treatment method may be affected by the opaque structure of the zirconia. Conversely, polishing increased color change compared with glaze in the 0.4 mm substructure thickness subgroup of Universal A2 resin cement with a black background and translucent resin cement with a gray background ($p = 0.002$ and $p = 0.028$, respectively). In addition, a higher color change occurred with glaze compared with polishing in the 0.8 mm substructure thickness subgroup of translucent resin cement with a gray background ($p = 0.041$). The difference between these groups was thought to be related to the background color used. On the other hand, ΔE values were above clinically acceptable values in groups with polishing and a 0.4 mm substructure thickness (Table 2). This suggests that the color camouflage effectiveness of the polishing process is low compared with glaze, especially with a low substructure thickness. In contrast, no significant differences were found between glazed and polished based on clinically acceptable color changes ($p < 0.05$), similar to a study by Aldosari et al. that evaluated surface roughness and color measurements of glazed or polished hybrid, feldspathic, and Zirconia CAD/CAM restorative materials after hot and cold coffee immersion; however, the values were within clinically acceptable values ($\Delta E \leq 3.7$).[22]

Both tested resin cements presented limited variations in ΔE when compared with one another. ΔE was higher for Universal A2 resin cement than translucent resin cement in the 0.8 mm polishing gray background group ($p = 0.009$) (Table 2). In contrast, E was higher for translucent resin cement than Universal A2 resin cement in the 0.4 mm glaze white background group ($p = 0.015$) (Table 3). This result shows that as the substrate thickness decreased, the translucent nature of the resin cement used changed the final restoration color more after cementation; that is, it was more affected by the substructure color in this test group. In general, similar to the study by

Fazi et al., most of the recorded ΔE values were below the limit of clinical acceptance and not statistically significant in terms of the color of cement used ($p > 0.005$), except for two subgroups. This suggests that choosing a cement shade of the same color as the ceramic (A2) or translucent might not affect the final ideal color of restorations.

Wang et al. reported that a significant increase in translucency was found as a result of a decrease in ceramic thickness. The TP value of human dentin with a thickness of 1.0 mm has been determined to be 16.4 and that of human enamel to be 18.1.[23] In our study of bilayer zirconia ceramics, the TP, which ranged from 0.7 to 1.24, was less than that for human dentin and enamel. However, the results in Table 4 indicate that there are no statistically significant differences in the translucency of the tested specimens in terms of surface finishing procedure, resin cement color, or substructure thickness ($p > 0.05$). The highest translucency value was observed in the glazed 0.4 mm substructure test group cemented with translucent resin cement (1.24), and the lowest was in the polished one (0.7). Similar to our study, Tabatabaian et al.[9] and Wang et al.[23] reported that an increase in the material thickness decreased the TP. However, these differences were not statistically significant in our study. These differences could be related to the selected brand of zirconia or the difference in thickness of the tested substructure.

Although clinical studies are needed to confirm these findings, the results of our study suggest that significant color changes may occur after the cementation of a bilayer zirconia restoration, particularly when the thickness of the substructure is limited. This study provides additional evidence supporting the use of bilayer CAD/CAM zirconia ceramics to help overcome the clinical challenge of aesthetically masking dark abutments, such as metal abutments and discolored tooth substrates.

Limitations

This study had some limitations, such as the use of a specific brand of zirconia ceramic and resin cement. Additionally, the use of resin composite to imitate tooth color may not replicate the optical effects of natural teeth. Further investigation of these factors is needed.

Conclusions

As the substructure thickness increased, the effect of resin cement and surface finishing procedure on the resultant restoration color decreased. Overall, no significant difference was observed between glaze versus polishing for 0.8- and 1.6-mm substructure thicknesses in the final restoration color. Glaze should be preferred over polishing to achieve camouflage effectiveness in clinical situations where the substructure thickness is 0.4 mm. The color of the resin cement used did not have a significant effect on the final color of the bilayer zirconia restoration, regardless of the preferred substructure thickness and surface finishing procedure. The thickness of the substructure, surface finishing procedure, or color of resin cement did not affect the translucency of the tested bilayer zirconia restorations.

Ethics approval and consent to participate

Not applicable.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

ORCID iDs

Ayse Seda Ataol https://orcid.org/0000-0003-3990-179X
Gulfem Ergun https://orcid.org/0000-0001-9981-5522
Mevsim Yayman https://orcid.org/0000-0003-1669-6834

References

1. Harada R, Takemoto S, Hattori M, Yoshinari M, Oda Y, Kawada E. The influence of colored zirconia on the optical properties of all-ceramic restorations. *Dent Mater J*. 2015;34(6):918–924. doi:10.4012/dmj.2015-171
2. Tabatabaian F, Sharif MJ, Massoumi F, Namdari M. The color masking ability of a zirconia ceramic on the substrates with different values. *J Dent Res Dent Clin Dent Prospects*. 2017;11(1):7–13. doi:10.15171/joddd.2017.002
3. Tabatabaian F, Khodaei MH, Namdari M, Mahshid M. Effect of cement type on the color attributes of a zirconia ceramic. *J Adv Prosthodont*. 2016;8(6):449–456. doi:10.4047/jap.2016.8.6.449
4. Tuncel İ, Turp I, Üşümez A. Evaluation of translucency of monolithic zirconia and framework zirconia materials. *J Adv Prosthodont*. 2016;8(3):181–186. doi:10.4047/jap.2016.8.3.181
5. Shi JY, Li X, Ni J, Zhu ZY. Clinical evaluation and patient satisfaction of single zirconia-based and high-noble alloy porcelain-fused-to-metal crowns in the esthetic area: A retrospective cohort study. *J Prosthodont*. 2015;25(7):526–530. doi:10.1111/jopr.12344
6. Tabatabaian F, Dalirani S, Namdari M. Effect of thickness of zirconia ceramic on its masking ability: An in vitro study. *J Prosthodont*. 2019;28(6):666–671. doi:10.1111/jopr.12625
7. Tabatabaian F. Color in zirconia-based restorations and related factors: A literature review. *J Prosthodont*. 2018;27(2):201–211. doi:10.1111/jopr.12740
8. Bacchi A, Boccardi S, Alessandretti R, Rocha Pereira GK. Substrate masking ability of bilayer and monolithic ceramics used for complete crowns and the effect of association with an opaque resin-based luting agent. *J Prosthodont Res*. 2019;63(3):321–326. doi:10.1016/j.jpor.2019.01.005
9. Tabatabaian F, Taghizade F, Namdari M. Effect of coping thickness and background type on the masking ability of a zirconia ceramic. *J Prosthet Dent*. 2018;119(1):159–165. doi:10.1016/j.prosdent.2017.03.009
10. Dai S, Chen C, Tang M, et al. Choice of resin cement shades for a high-translucency zirconia product to mask dark, discolored or metal substrates. *J Adv Prosthodont*. 2019;11(5):286–296. doi:10.4047/jap.2019.11.5.286

11. Fathi A, Farzin M, Giti R, Kalantari MH. Effects of number of firings and veneer thickness on the color and translucency of 2 different zirconia-based ceramic systems. *J Prosthet Dent*. 2019;122(6):565. doi:10.1016/j.prosdent.2019.08.020
12. Yilmaz C, Korkmaz T, Demirköprülü H, Ergün G, Ozkan Y. Color stability of glazed and polished dental porcelains. *J Prosthodont*. 2008;17(1):20–24. doi:10.1111/j.1532-849X.2007.00237.x
13. Gupta R, Parkash H, Shah N, Jain V. A spectrophotometric evaluation of color changes of various tooth colored veneering materials after exposure to commonly consumed beverages. *J Indian Prosthodont Soc*. 2005;5(2):72–78. doi:10.4103/0972-4052.16873
14. Acar O, Yilmaz B, Altintas SH, Chandrasekaran I, Johnston WM. Color stainability of CAD/CAM and nanocomposite resin materials. *J Prosthet Dent*. 2016;115(1):71–75. doi:10.1016/j.prosdent.2015.06.014
15. Fazi G, Vichi A, Ferrari M. Influence of four different cements on the color of zirconia structures of varying ceramic thickness. *Int Dent South Africa*. 2006;9(1):54–61. http://www.moderndentistrymedia.com/jan_feb2007/fazi.pdf. Accessed October 2, 2021.
16. Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. *J Prosthet Dent*. 2007;97(4):200–208. doi:10.1016/j.prosdent.2007.02.012
17. Khashayar G, Bain PA, Salari S, Dozic A, Kleverlaan CJ, Feilzer AJ. Perceptibility and acceptability thresholds for colour differences in dentistry. *J Dent*. 2014;42(6):637–644. doi:10.1016/j.jdent.2013.11.017
18. Hatim NA, Al-Tahho OZ. Comparative evaluation of color change between two types of acrylic resin and flexible resin after thermo cycling. *J Indian Prosthodont Soc*. 2013;13(3):327–337. doi:10.1007/s13191-013-0289-z
19. Akar GC, Pekkan G, Çal E, Eskitaşçioğlu G, Özcan M. Effects of surface-finishing protocols on the roughness, color change, and translucency of different ceramic systems. *J Prosthet Dent*. 2014;112(3):314–321. doi:10.1016/j.prosdent.2013.09.033
20. Sinmazisik G, Demirtas B, Tarcin B. Influence of dentin and core porcelain thickness on the color of fully sintered zirconia ceramic restorations. *J Prosthet Dent*. 2014;111(2):142–149. doi:10.1016/j.prosdent.2013.09.016
21. Alghazali N, Hakami AA, AlAjlan GA, et al. Influence of the arabic-coffee on the overall color of glazed or polished porcelain veneers – in vitro study. *Open Dent J*. 2019;13:364–370. doi:10.2174/1874210601913010364
22. Aldosari LI, Alshadidi AA, Porwal A, et al. Surface roughness and color measurements of glazed or polished hybrid, feldspathic, and zirconia CAD/CAM restorative materials after hot and cold coffee immersion. *BMC Oral Health*. 2021;21(1):422. doi:10.1186/s12903-021-01770-2
23. Wang F, Takahashi H, Iwasakı N. Translucency of dental ceramics with different thicknesses. *J Prosthet Dent*. 2013,110(1):14–20. doi:10.1016/S0022-3913(13)60333-9