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RESEARCH AND EDUCATION

Effect of brand and shade of resin cements on the final color of lithium disilicate ceramic

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ABSTRACT

Statement of problem. Resin cements are available in various shades from different manufacturers. However, there is no standard for the optical properties of these cements, which may result in differences in the color of translucent ceramic restorations.

Purpose. The purpose of this in vitro study was to evaluate the effects of different shades and brands of resin cements on the color of a lithium disilicate ceramic.

Materials and methods. Ten ceramic disks (11×1.5 mm, shade A2) were fabricated from lithium disilicate high-translucency blocks. Eighty cement disks (11×0.2 mm) were fabricated from 4 brands (Maxcem; Variolink; Clearfil; and RelyX) of resin cements in translucent and universal (shade A2) shades. Color measurements of ceramic specimens were made without (control) and with each brand/shade of resin cement material (test) with a spectrophotometer, and International Commission on Illumination Lab (CIELab) color coordinates were recorded. Color differences (ΔE_{00}) between the control and test groups were calculated. ΔE_{00} results were analyzed by 2-way ANOVA and subsequent pairwise testing. Comparisons were performed using the Student *t* test, and then all *P* values were corrected with the step-down Bonferroni procedure (α=.05).

Results. The effect on the ΔE_{00} values (*P*<.001) of the brand and shade of resin cement materials was significant. Both shades of RelyX cement groups had significantly lower and Variolink_translucent cement group had significantly higher ΔE_{00} results than other brands (*P*<.05). Only RelyX_translucent and RelyX_universal were significantly different from each other for comparisons within brands (*P*<.05). The effect of RelyX_universal cement on the ceramic was not visually perceptible ($\Delta E_{00} \leq 1.30$). Clinically unacceptable results (ΔE_{00}>2.25) were observed only for Variolink_translucent cement (2.36).

Conclusions. Same-shade resin cements from different manufacturers had different effects on the color of lithium disilicate ceramic. The effects of different shades of resin cements from the same manufacturer on the color of lithium disilicate ceramic were statistically different for only RelyX, which may also be considered clinically different based on clinical acceptability thresholds for color difference values (ΔE_{00}). Accordingly, this effect may be considered clinically different for Variolink but not clinically different for Maxcem and Clearfil. (J Prosthet Dent 2017;117:539-544)

Ceramic restorations have become an essential treatment option, especially in the anterior region, because of their favorable optical properties.[1-6] The natural appearance of a dental restoration depends not only on size, shape, and surface form but also on translucency and color.[4-7] Many ceramic systems are available with different mechanical and physical properties. Ceramic systems with greater strength typically have a less natural and more opaque appearance as a result of increased crystalline content.[5,8] The more translucent ceramic systems like lithium disilicate permit greater light transmission through the core material and provide a lifelike appearance.[3,6] However, the translucency of ceramic materials increases the complexity of color matching, and the final color may easily be affected by different factors. The color of underlying tooth, abutment, and luting cement may affect the final color of a ceramic restoration as much as the material itself.[3-6,9-16]

Resin luting cements provide adequate esthetics, low solubility with oral fluids, excellent mechanical properties, and strong integrity between tooth and ceramic restoration, thus increasing clinical success.[5,11] They are

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Clinical Implications

Clinicians should keep in mind that different brands of resin cement in the same shade may have different effects on the color of translucent lithium disilicate ceramic restorations.

available in different shades for final color management of ceramic restorations.[3,6,16,17] The color match of a ceramic restoration to the adjacent natural dentition is a complex process, and matching errors may cause a remake of the restoration.[2,18] The shade of resin cement may cause difficulties in color matching with ceramic restorations during the luting process.[18] Previous studies have reported that, if the underlying tooth color and the thickness of the ceramic restoration are optimum, concerns regarding luting cement color would be minimal.[3,7,9,13-17] However, the cement color may become influential when the thickness of ceramic restoration decreases to less than 1.5 mm or the restoration is placed on a dark underlying tooth or abutment to mask the color and prevent undesirable results.[3,9,13] Additionally, resin cements may appear brighter after the polymerization process.[19,20] Detectable color differences may also occur between some composite resin materials and their nominal shade guide color.[18,21] For these reasons, the effect of luting cement on final color may be tested using clinical evaluation pastes.[3,17,22]

Instrumental color matching has become essential to quantifying color in dentistry because of better accuracy with objective, standardized results, and the mathematical expression of color parameters.[2,6,12,16,23] The color parameters are usually recorded using the International Commission on Illumination L*a*b* (CIELab) color space system, which allows a color determination in 3-dimensional space. L* represents the coordinates for lightness, with values ranging from 0 (black) to 100 (white), and a* and b* are the coordinates for the red-green axis and yellow-blue axis, respectively.[5,12,24-26] The CIELab color difference formula (ΔE_{ab}) has been used for visual or instrumental evaluations since it was first described in 1976. The CIEDE2000 color difference formula (ΔE_{00}) is a more recent formula and was introduced to improve the correlation between visual judgments and instrumental color difference values.[23,24,27]

The purpose of this study was to evaluate the effect of different shades and brands of resin cement on the color of lithium disilicate ceramic. The null hypothesis was that the effect of different brands of resin cement in the same shade on the color of lithium disilicate ceramic would be similar. The second null hypothesis was that resin cements in different shades from the same manufacturer would not affect the color of lithium disilicate ceramic differently.

Table 1. Materials used

Material	Code	Type	Manufacturer	Shade
IPS e.max Press (high translucency)	Lds.ht	Heath pressed lithium disilicate ceramic	Ivoclar Vivadent AG	A2
Maxcem Elite	Max_Un Tr	Dual polymerized self-etch, self-adhesive resin luting cement	Kerr Hawe	Universal (A2) Translucent
Clearfil Esthetic	Cle_Un Tr		Kuraray Medical Inc	
RelyX Unicem	Rel_Un Tr		3M ESPE	
Variolink II	Var_Un Tr	Dual-polymerized resin luting cement	Ivoclar Vivadent AG	

Cle, Clearfil; Lds. ht, lithium disilicate high-translucency; Max, Maxcem; Rel, RelyX; Un/Tr, universal/translucent; Var, Variolink.

MATERIAL AND METHODS

Ten disk-shaped ceramic core specimens were fabricated (Vita A2 shade) from a heat-pressed lithium disilicate ceramic with high-core translucency (Lds.ht) (IPS e.max press; Ivoclar Vivadent AG), according to the manufacturer's instructions (Table 1).[5,17,28] One side of each core disk was sequentially ground with 600-, 800-, 1000-, and 1200-grit silicon carbide papers (Wetordry; 3M ESPE) using a sanding machine (Phoenix Beta; Buehler) at 100 rpm/min for 15 seconds under water cooling. The thicknesses of specimens were controlled with a digital micrometer (Digimatic Caliper; Mitutoyo), and the dimensions were adjusted to 11×0.8 ±0.01 mm.[14] Core specimens were placed in a mold with a disk-shaped cavity (11×1.5 mm), and A2 shade veneering ceramic (IPS e.max Ceram; Ivoclar Vivadent AG) was layered onto the nonground surfaces. Layering and firing procedures were repeated until each ceramic specimen's final thickness was adjusted to 1.5 ±0.01 mm; the specimens were then autoglazed.[5]

Eighty disk-shaped (11×0.2 mm) cement specimens were prepared in shades of translucent (Tr) and universal-A_2 (Un) from 4 different brands of dual-polymerizing resin cements (Table 1). A hard plastic plate was pierced with a sharp punch, and 10 disk-shaped cavities were obtained to standardize the shape and dimensions of the specimens. Each brand and shade of resin cement material was mixed and prepared according to the manufacturer's recommendations. The mixed cements were placed in the cavities between 2 polyester strips under glass sheets and polymerized with a polymerizing light unit (Hilux LED 550; Benlioglu Dental) at 750 mW/cm^2 for 20 seconds on each side. Ten specimens were obtained for each brand and shade of resin cement material.[3-5,9,14] The cement specimens were then immersed in distilled water at 37°C ±1°C for 24 hours for complete polymerization.[5,29]

Color coordinates of ceramic specimens were measured with a digital spectrophotometer (Vita Easy

Table 2. Mean ±SD of L*, a*, b* values

Cement Brand	Cement Shade	L*	a*	b*
Control (no cement)		90.99 ±0.76	0.51 ±0.22	22.38 ±1.61
Maxcem	Un	86.52 ±1.05	0.33 ±0.32	22.18 ±1.28
	Tr	87.34 ±1.54	-0.26 ±0.20	20.47 ±1.76
Variolink	Un	87.12 ±0.92	0.43 ±0.25	23.46 ±1.71
	Tr	87.16 ±1.05	-0.48 ±0.42	21.81 ±1.71
Clearfil	Un	87.66 ±0.73	-0.20 ±0.27	23.32 ±1.70
	Tr	87.98 ±0.85	0.13 ±0.55	21.77 ±1.76
Relyx	Un	89.21 ±1.37	0.79 ±0.39	22.82 ±2.27
	Tr	88.07 ±0.91	-0.26 ±0.48	20.80 ±1.48

Un/Tr, universal/translucent.

Shade; Vita Zahnfabrik). A polytetrafluoroethylene (PTFE; Teflon) mold was used to standardize the position of the specimens and the measuring tip of the spectrophotometer (6 mm) at the center of the specimens (11 mm). The mold also served as the standard white background for all measurements. The device was calibrated with the white calibration apparatus before the color measurements of each specimen group. The spectrophotometer recorded the measurements in the CIELab color space system. Initial color measurements were repeated 3 times for each specimen, and the means were recorded as L_0*, a_0*, and b_0*. After the initial color measurements, the color coordinates of the ceramic specimens were measured again with each brand and shade of cement, and the data were recorded as L_1*, a_1*, and b_1* (Table 2). To provide a good optical connection between the tested specimens, 1 drop of optical fluid (Cargille Optical Gel; Cargille Labs) with a refractive index of 1.52 was used.[3,5,28]

The C^*_{ab} values of the test groups were calculated by using the formula $[(a^2+b^2)^{1/2}]$. The color differences between the L*, a*, b* color coordinates of the ceramic specimens at the initial and second measurements were calculated by using the CIEDE2000 (ΔE_{00}) color difference formula[6,24,27]:

$$\Delta E_{00}=\sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2+\left(\frac{\Delta C'}{K_C S_C}\right)^2+\left(\frac{\Delta H'}{K_H S_H}\right)^2+R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)},$$

where ΔL*, ΔC*, and ΔH* are the differences in lightness (L), chroma (C), and hue (H) for a pair of specimens in ΔE_{00}, and R_T is the function (the so-called rotation function) that accounts for the interaction between chroma and hue differences in the blue region. Weighting functions S_L, S_C, and S_H adjust the total color difference for variation in the location of the color difference pair in L′, a′, b′ coordinates, and the parametric factors K_L, K_C and K_H are correction terms for experimental conditions. The parametric factors of the CIEDE2000 color difference formula were set to 1. Also, the perceptibility threshold was set at $\Delta E_{00} \leq 1.30$ units, and the clinical acceptability threshold was set at $\Delta E_{00} > 2.25$ units.[6,27]

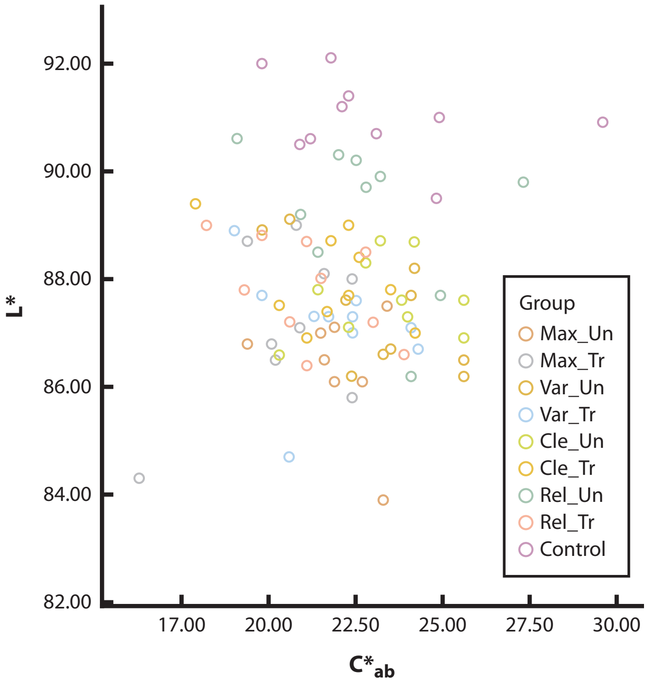

Figure 1. Distribution of L* and C^*_{ab} values. Cle, Clearfil; Max, Maxcem; Rel, RelyX; Var, Variolink.

Color variation data were statistically analyzed. The Levene test of homogeneity was used for evaluating the normal distribution of the variables, and a normal distribution was found ($P<.001$). The ΔE_{00} results were then analyzed using 2-way ANOVA and subsequent pairwise testing to address the stated hypotheses, involving comparisons of differences between the 2 shades for every brand and between every pair of brands for each shade. Each selected comparison was performed using the Student *t* test, and all *P* values were corrected by using the step-down Bonferroni procedure (α=.05). All computational work was performed with statistical software (IBM SPSS Statistics v20.0; IBM Corp).

RESULTS

The L* and C^*_{ab} values of the test groups are shown in Figure 1. All of the L* and most of the C*ab values of the test groups were lower than those of the control group. The 2-way ANOVA results are shown in Table 3, and the mean ±SD values, and Student *t* test comparison results of the ΔE_{00} values for the test groups are presented in Table 4.

Two-way ANOVA results showed that both resin cement shade (P=.016) and brand ($P<.001$) were significant for color differences. The Student *t* test comparisons of ΔE_{00} values for different brands of resin cements in the same shade showed significant differences between RelyX universal (Rel_Un) and Un shades of other brands and Rel_Tr and Tr shades of other brands, and Rel's ΔE_{00}

Table 3. Two-way ANOVA results of mean ΔE_{00} values

Source	SS	df	MS	F	P
Cement brand (A)	8.547	3	2.849	31.490	<.001
Cement shade (B)	0.549	1	0.549	6.068	.016
A×B	0.621	3	0.207	2.287	.086
Error	6.514	72	0.090		
Total	295.046	80			

Table 4. Statistical summary of measured color difference (ΔE00)[a]

Cement	Un (mean ±SD)	Tr (mean ±SD)
Maxcem	1.88 ± 0.37^{Aa}	1.98 ± 0.22^{Aa}
Variolink	2.09 ± 0.19^{Aa}	2.36 ± 0.27^{Ba}
Clearfil	2.02 ± 0.28^{Aa}	1.93 ± 0.40^{Aa}
RelyX	1.15 ± 0.35^{Ba}	1.53 ± 0.27^{Cb}

Un/Tr, universal/translucent. [a]Values with same superscript letters not significantly different (*P*>.05). Superscript uppercase letters show differences between same-shade resin cements from different brands, and lowercase letters show differences between two shades within each brand.

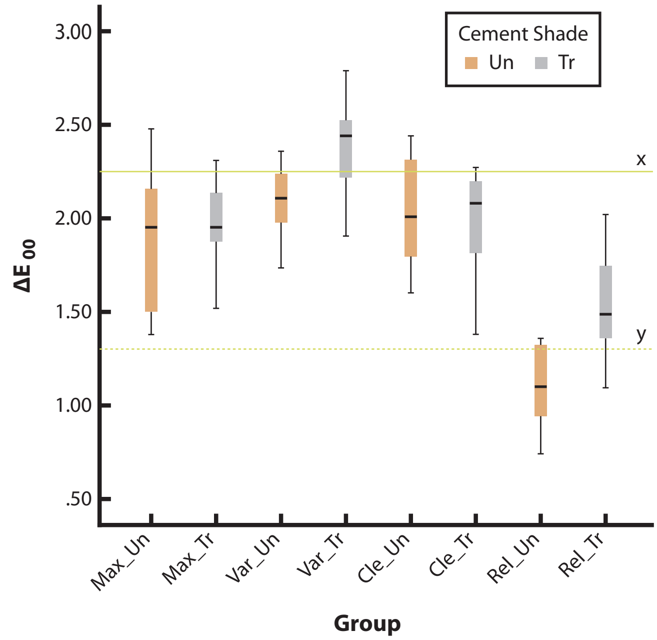

Figure 2. Mean ΔE_{00} values of test groups. Visual perceptibility threshold (ΔE_{00}=1.30) indicated as line y, and clinical acceptability threshold (ΔE_{00}=2.25) shown as line x. Cle, Clearfil; Max, Maxcem; Rel, Relyx; Un/Tr, universal/translucent; Var, Variolink.

results were significantly smaller (*P*=.001). The Tr shade of Variolink (Var) cement was significantly higher than Tr shades of other brands (*P*<.001). When 2 shades of resin cements were compared for the same brand, a significant difference was observed between the Un and Tr shades of only Rel cement (*P*<.05).

When the mean ΔE_{00} values were evaluated, the Var_Tr cement (2.36) resulted in a clinically unacceptable value (ΔE_{00}>2.25) for Lds.ht ceramic. The ΔE_{00} value of Rel_Un (1.15) was within the visually imperceptible limits ($\Delta E_{00} \leq 1.30$) (Fig. 2). The ΔE_{00} values of other groups were in the range of visual perceptibility but clinical acceptability ($1.30 < \Delta E_{00} \leq 2.25$).

DISCUSSION

This in vitro study evaluated different brands and shades of resin cement for lithium disilicate ceramic restorations and compared their effects on the optical properties and final color of the ceramic. Both null hypotheses were rejected because the brand and shade parameters of resin cements significantly affected the color of lithium disilicate ceramic.

Resin cements in translucent or universal shades are commonly selected to lute translucent ceramic restorations. The results of the present study showed that using various brands and shades of resin cement not only led to differences in the CIELab color coordinates but also influenced the final color of lithium disilicate ceramic. The use of all tested resin cements resulted in a decrease in the lightness value of the ceramics, and most also caused a change in chroma. However, Var_Un and Rel_Un resin cements slightly increased the chroma of the ceramics (Fig. 1). Additionally, the use of the universal shade of resin cement caused a change toward yellow, and the translucent shade of cement caused a change toward blue in the color of ceramics (Table 2). The experimental design of the present study simulated a controlled clinical condition that does not involve a discolored or dark underlying background. Unacceptable color difference (ΔE_{00}>2.25) was determined for only Var_Tr (2.36) and visually perceptible differences for other test groups ($1.30 < \Delta E_{00} \leq 2.25$). Using Rel_Un resin cement may result in an imperceptible ($\Delta E_{00} \leq 1.30$) color difference for lithium disilicate ceramic under these conditions. These findings were in agreement with those of a previous study[12] which reported that resin cements in the same shade but of different brands exhibited different color parameters. The translucent (RelyX Veneer; 3M ESPE; Maxcem Elite, Kerr Hawe; Variolink II, Ivoclar Vivadent AG), and A_1 (Un) (RelyX Veneer, Maxcem Elite) shades of resin cements led to visually perceptible color differences ($2.0 < \Delta E_{ab} \leq 3.5$) for the A_1 shade of leucite-reinforced glass ceramic (IPS Empress Esthetic, Ivoclar Vivadent AG) of 1 mm in thickness.[12] The results of another study also reported that the yellow (Un) shade of 2 different resin cements (Variolink II, Nexus II; Kerr Hawe) did not match in the CIELab color space.[3] Previous studies and the present study reached a similar conclusion in that similar color reproduction with ceramic restorations may not always be possible when resin cements in the same nominal shade, but from different manufacturers are used.[3,6,12] However, another study indicated that similar shades of resin cements for 3 cement materials (Variolink Veneer; Ivoclar Vivadent AG, Panavia F; Kuraray Medical Inc, RelyX; 3M ESPE) had similar effects on the color of lithium disilicate ceramic (IPS e.max Press) in 1.4-mm thickness.[16] This discrepancy may be explained by the variations in the studies' experimental designs, including specimen preparation methods or the background materials and shades used.

The present study attempted to minimize the variations regarding the tested material itself. The experiment was designed to make reliable comparisons with previous investigations.[3,15] Standardized ceramic and cement specimens were used to compose all test groups. Therefore, potential variations on the optical properties of specimens were aimed to be prevented/minimized during fabrication procedures. The ceramic and cement specimens were connected by using a refractive index solution (Optical Gel) to provide a good light transmission and eliminate the light scattering through the cement-ceramic specimen interface.[3,5,28] As the thickness of the ceramic and cement specimens also plays a critical role in the final color of restorations, the ceramic and cement specimen thicknesses were adjusted to 1.5 and 0.2 mm respectively in present study.[17] Similar studies have shown that using digital devices for color measurements may increase the accuracy of measurements 94% more than visual determination techniques.[1,3,12,17] Therefore, all color measurements in the present study were performed with a spectrophotometer, positioning the specimens on a standardized white background. A strength of the present study was the use of the most recently developed CIEDE2000 color difference formula for calculating color change values. This formula can help ensure a more appropriate clinical interpretation of color variations in dentistry.[6,23,27]

The effect of the shape, direction, and quantity of a luting cement on the CIELab color coordinates of ceramic materials mostly relates to the composition and content of the cement.[21] The color and optical properties of composite resin materials are determined by the resin matrix, filler composition, and supplemental additives, including pigments and photoinhibitors.[20,28] That the Tr shade of each brand of resin cement caused higher color differences than the Un shade for lithium disilicate ceramic may be explained by variations in their compositions. In addition, the white background of the PTFE mold used during color measurements may have closer color coordinates to the Un than the Tr shades. The refractive index characteristics of composite resins are important factors that influence the color coordinates.[19,20,28] The light transmittance characteristics also affect the color of composite resin materials.[23,28] The amount of absorbed, scattered, and transmitted light of composite resins are substantially determined by the filler, pigment, and opaque content of the material.[25]

In the present study, the significantly different effects of resin cements in same shades from different manufacturers and also the differences between the 2 shades of RelyX cement may be explained by variations in their refractive index and light transmittance characteristics. This finding emphasizes the necessity of common shade classifications or industrial standardization for different manufacturers' resin cements, something which has also been mentioned in previous studies.[3,6] Therefore, evaluating the optical properties of resin cements with clinical evaluation pastes is recommended.[6,17]

The esthetic advantages of ceramic systems depend largely on their core translucency. The structure and amount of crystal content within the core matrix, the chemical nature, and the size of the particles affect the incident light wavelength (λ) and determine the translucency/opacity character of a ceramic material.[8] The influence of cement and background shades on the color of ceramic material systems has been mostly associated with the translucency of the core materials.[3,6-8,13-17] While more translucent ceramics chiefly transmit incoming light and reflect from the underlying color, the luting cements tested made only imperceptible ΔE_{00} values (>1.30) for lithium disilicate ceramic.

This study did not compare the thicknesses and shade parameters of the ceramic material or the effect of clinical evaluation pastes on color coordinates. These variables and other optical properties such as translucency, chroma, and hue angle should be evaluated in future in vitro and in vivo studies.

CONCLUSIONS

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

1. Resin cements of the same nominal shade from different manufacturers had different effects on the color of lithium disilicate ceramic disks.
2. The effect of translucent and universal shades of RelyX Unicem resin cement was significantly smaller than the effect of other tested resin cements in the same shade.
3. The effect of translucent shade of Variolink II resin cement was significantly higher than the effect of other tested resin cements in the same shade.
4. A significant difference was observed between universal and translucent shades for only RelyX Unicem cement. This effect was also clinically different, the effect of RelyX Un being visually imperceptible and that of Tr being visually perceptible, although clinically acceptable.
5. The effect of the tested resin cements on the color of lithium disilicate ceramic was mostly visually perceptible but clinically acceptable ($1.30<\Delta E_{00}\leq 2.25$), except for the universal shade of RelyX and translucent shade of Variolink II. When the translucent shade of Variolink II was used under lithium disilicate

ceramic, the color change with the ceramic was not clinically acceptable. The effect of the universal shade of RelyX cement on the color of lithium disilicate ceramic was not visually perceptible.

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