Saudi Dental Journal (2019) 31, 284–289

King Saud University

Saudi Dental Journal

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

The influence of different shades and brands of resin-based luting agents on the final color of leucite-reinforced veneering ceramic

Rashin Giti [a,*], Amirhossein Barfei [b], Mina Mohaghegh [a]

[a] *Department of Prosthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran*
[b] *Undergraduate Student, Student Research Committee, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran*

Received 19 October 2018; revised 25 February 2019; accepted 28 February 2019
Available online 8 March 2019

KEYWORDS

Color difference;
Resin shade;
Ceramic veneer

Abstract *Objectives:* This study aimed to evaluate the influence of different shades and brands of resin-based luting agents on the final color of a leucite-reinforced veneering ceramic.

Methods: This in-vitro study was done on 36 ceramic discs (IPS Empress I, 11 × 0.5 mm, A2 shade) and 36 cement disks (11 × 0.2 mm) made of Panavia SA Cement Plus (Kuraray Medical Inc.) and Choice2 (Bisco Inc., Schumburg) brands in translucent, universal A2, and opaque shades (n = 6 per each color in each resin cement brand). Color parameters ($CIEL^*a^*b^*$) of ceramic specimens were calculated without and with each brand/shade of resin-based luting agents by using a spectrophotometer, and put into CIELab formula. The color differences (ΔE) between the two sets of measurements were calculated and analyzed with two-way ANOVA and Tukey's post hoc test ($\alpha = 0.05$).

Results: Both the resin-based luting agent shade ($P < 0.001$) and brand ($P = 0.023$) significantly affected the color differences. ΔE values were significantly different between Panavia-opaque and Choice2-opaque ($P < 0.001$). No significant difference existed between ΔE of the two brands in A2 ($P = 0.178$) and translucent shades ($P = 0.079$). The ΔE values of Panavia-A2 was significantly different from the translucent and opaque shades of the same brand. Moreover, the ΔE of Choice2-translucent shade was significantly lower than that of A2 and opaque shades. The ΔE values were higher than the clinically-acceptable threshold in all groups ($\Delta E > 3.7$) except for Choice2-translucent ($\Delta E = 3.37$).

* Corresponding author at: Department of Prosthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.
E-mail address: giti_ra@sums.ac.ir (R. Giti).

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sdentj.2019.02.045

Conclusions: The final color of leucite-reinforced veneering ceramic can be affected by the same shades of resin-based luting agents from different brands and different shades of resin-based luting agents from the same brand.

1. Introduction

The superior optical properties of ceramic restorations have promoted them to one of the most favorable treatments, particularly in anterior teeth (Ardakani et al., 2015). Glass ceramic restorations without metal substrate better simulate the natural structure of the tooth, since they allow more light transmission (Vichi et al., 2000; Karaagaclioglu and Yilmaz, 2008; Turgut and Bagis, 2013; Dede et al., 2017).

Ceramic systems with higher strength and better mechanical properties typically contain more crystalline, which gives them artificial and opaque appearance (Dede et al., 2017; Farzin et al., 2018). The more translucent the ceramic system is (e.g. IPS Empress I and IPS e.Max), the higher light transmission is possible, and the more lifelike the appearance would be (Dede et al., 2013; Kürklü et al., 2013). Multiple factors contribute to the ultimate esthetic value of dental ceramic restorations, namely color, translucency, fluorescence, surface texture, and shape (Vichi et al., 2000; de Azevedo Cubas et al., 2011; Kürklü et al., 2013). The final color of ceramic restorations is determined by the ceramic thickness, color and thickness of the luting agent, and color of the underlying tooth structure (Vichi et al., 2000).

Compared with the crown restorations, porcelain laminate veneer is known to be a more conservative treatment option, whose 0.5–1-mm thickness gives it a far better translucent appearance (Magne et al., 1999; Heffernan et al., 2002). They can be used for diastema closure, treatment of structural defects and mild morphological anomalies, as well as esthetical improvement of mildly-discolored teeth. However, color matching would be more complicated as the ceramic translucency increases (Belser et al., 1997; Guess and Stappert, 2008).

Among the advantages of resin-based luting agents are the low solubility, strong bond to the dental structure, and superb mechanical properties (Dede et al., 2013; Turgut and Bagis, 2013). The wide variety of available resin-based luting agents helps managing the ultimate color of ceramic restorations (Kürklü et al., 2013; Wang, 2015). Yet, the resin cement shade complicates the procedure of color matching of ceramic restorations during cementation (de Azevedo Cubas et al., 2011). Previous research reported that the optimum color of the underlying tooth and appropriate thickness of the ceramic restoration would minimize the effect of cement shade. The resin-based luting agent shade even matters more if the ceramic restorations is of low thickness (<1.5 mm, like veneers), or when the restoration is supposed to camouflage a discolored tooth or a dark abutment (Vichi et al., 2000; Barath et al., 2003; Azer et al., 2006; Wang, 2015).

The resin-based luting agents shade gets brighter after polymerization (Kucukesmen et al., 2008). Moreover, some resin cements are likely to appear in a clinical shade notably different from their nominal shade guide color. Hence, it would be better to clinically test the effect of cement color in try-in pastes (Douglas and Brewer, 1998; Xing et al., 2010).

Various investigations have focused on the effect of shades of the resin-based luting agents on the porcelain veneer restorations. Some studies found that different thicknesses of ceramic materials and different shades of resin-based luting agents caused significant color difference in veneer restorations (Xing et al., 2010; Kürklü et al., 2013; Turgut and Bagis, 2013). However, some others reported that the ultimate color of IPS Empress all-ceramic material was not significantly influenced by different shades of resin-based luting age (Azer et al., 2006; Turgut and Bagis, 2013).

Various shades and types of resin-based luting agents are available, each of which is likely to influence the final color of ceramic veneer restoration differently. This fact besides the contradictory findings of the previous studies resulted in designation of the present research to investigate the effect of different shades and brands of resin-based luting agents on the final color of leucite-reinforced veneering ceramic. The null hypothesis was that the brand and shade of resin cement would not affect the final color of leucite-reinforced veneering ceramic.

2. Material and methods

2.1. Specimen preparation

In this in-vitro study, 36 disk-shaped specimens (11×0.5 mm) were made of a heat-pressed leucite-reinforced glass ceramic of A2 shade (IPS Empress1; Ivoclar Vivadent, Liechtenstein) according to the manufacturer's instructions. The specimens were made by eliminating 0.5-mm-thick wax with a diameter of 11 mm. The specimens were heat-pressed at 920 °C (IPS eEmpress EP 600 system). One side of the specimens were covered with a layer of neutral-shade glaze and fired at 765 °C. A digital micrometer (Digimatic Caliper; Mitutoyo) was used to control the thickness of specimens, and set the dimensions to $11 \times 0.5 \pm 0.01$ mm. Meanwhile, 36 disk-shaped cement specimens (11×0.2 mm) were made of two different brands of Choice 2 and Panavia SA Cement Plus ($n = 18$ per brand), in translucent, universal A2, and opaque shades ($n = 6$ per shade). Table 1 shows a detailed list of the employed materials.

To obtain cement specimens of standard shape and dimensions, 10polytetrafluoroethylene molds were used with an 11×0.2-mm cavity in the middle. The materials of each brand and shade of resin-based luting agent were mixed as recommended by the manufacturers. The achieved cements were put in the cavities between two polyester strips under the glass sheets. Each side of the complex was polymerized with a polymerizing light unit (Hilux LED 550; Benlioglu Dental) at 750 mW/cm^2 for 20 s. Six specimens were prepared for each brand and shade of resin cement materials. Finally, 24-hour

Table1 The manufacturer and chemical composition of used ceramic material and resin cements.

Material	Manufacturer	Composition	Type
IPS Empress I	Ivoclar Vivadent, Liechtenstein	Leucite-reinforced glass ceramic (K_2O-Al_2O_3-SiO_2)	Heat-pressed
Panavia SA Cement Plus	Kuraray Medical, Japan	Bisphenol A diglycidylmethacrylate, triethylene glycol dimethacrylate, 2-hydroxyethyl methacrylate, sodium fluoride, Silanated barium glass filler, Silanated colloidal silica, 10-Methacryloyloxydecyl dihydrogen phosphate, Hydrophobic aromatic dimethacrylate, Hydrophobic aliphatic dimethacrylate dl-Camphorquinone	Dual-Cure Self-etch, Self-adhesive
Choice 2	Bisco, USA	Glass Filler, Amorphous Silica, Bisphenol A Diglycidylmethacrylate, Urethane Dimethacrylate, Triethylene Glycol Dimethacrylate, Tetrahydrofurfuryl Methacrylate	Light-cure Total etch

storage of the specimens in distilled water (37 ± 1 °C) was considered to ensure complete polymerization.

2.2. Color measurement

The color coordinates of ceramic specimens were measured by using a digital spectrophotometer (Vita EasyShade; Vita Zahnfabrik). Position of the specimens and the measuring tip of spectrophotometer (6 mm) was standardly adjusted at the center of the specimens (11 mm) by using a polytetrafluoroethylene mold (PTFE; Teflon), which also served as the standard white background for all measurements. Prior to color measurements in each group, calibration of the device was done with the white calibration apparatus. The spectrophotometer recorded the measurements in CIELab color space system. The L^*, a^* and b^* color value of each ceramic specimen was measured three times consecutively and the average was calculated as the initial color of the specimen. Then, the color coordinates of the ceramic specimens were measured again with each brand and shade of resin-based luting agents, and recorded as $L1^*$, $a1^*$, and $b1^*$. Optical connection between the tested specimens was created by using 1 drop of optical fluid (Cargille optical gel; Cargille labs) with a refractive index of 1.52 (Dede et al., 2013; Dede et al., 2017).

To measure the color difference between the initial and second measurements (ΔE) in each specimen, the obtained data were put in ΔE formula: ($\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{ø}$), where ΔL^*, Δa^*, and Δb^* refer to the difference in lightness, red/green axis, and yellow/blue axis, respectively. According to the previous studies, if the color difference of a material is $\Delta E = 0$ after the test requirements have been met, the color is defined as stable. A color difference of $0.5 \leq \Delta E \leq 1$ cannot be clinically perceived. A color difference of $1 \leq \Delta E \leq 2$ can be perceived only by 50% of observers; thus, most of the studies defined perceptibility threshold (PT) of color difference as $\Delta E = 1$. A value of $\Delta E \geq 3.7$ can be perceived by 100% of observers. Therefore, the $\Delta E = 3.7$ has been defined as the clinically-acceptable threshold (AT) (Khashayar et al., 2014).

2.3. Statistical analyses

Post-power analysis demonstrated that the sample size in each subgroup (n = 6) was sufficiently large for comparisons between the subgroups (Power value > 80%). Power analysis was done by using NCSS-PASS (2005). The color difference data (ΔE) were statistically analyzed by using SPSS software (IBM SPSS Statistics, v24.0; IBM Corp). The ΔE results were subjected to two-way ANOVA. Tukey's post hoc test was used to compare the three shades in each brand. Independent *t* test was employed to compare the two brands in each shade. $P < 0.05$ was considered to be statistically significant.

3. Results

Table 2 displays the mean and standard deviation (mean ± SD) of differences between the initial and second measures of each CIE coordinate (i.e. ΔL, Δa, and Δb) of the specimens of each brand in each shade. Table 3 shows the mean ± SD values and Tukey's post hoc test results of the ΔE values for the test groups. As displayed in Table 4, the results of two-way ANOVA showed that both the shade ($P < 0.001$) and brand ($P = 0.023$) of the resin-based luting agent significantly affected the color differences. A significant interaction was noted between the shade and brand of the resin-based luting agents ($P < 0.001$).

Table 2 Descriptive statistics (mean ± SD) for ΔL, Δa, and Δb values in the groups.

Cement Brand	Cement Shade	ΔL	Δa	Δb
Panavia SA Cement Plus	Opaque	0.35 ± 0.35	1.61 ± 0.69	5.21 ± 0.94
	Translucent	−0.88 ± 0.52	0.71 ± 0.26	4.01 ± 0.27
	A2	−4.16 ± 0.73	2.91 ± 0.60	7.4 ± 0.87
Choice2	Opaque	−1.3 ± 0.26	2.96 ± 0.08	8.16 ± 0.26
	Translucent	3.3 ± 0.96	0.21 ± 0.24	0.6 ± 0.25
	A2	−2.88 ± 0.63	4.08 ± 0.09	6.71 ± 0.39

Table 3 Statistical summary of measured color difference (ΔE).

Cement	A2 (mean ± SD)	Opaque (mean ± SD)	Translucent (mean ± SD)
Choice2	$8.38 \pm 0.55^{A,a}$	$8.79 \pm 0.26^{A,a}$	$3.37 \pm 0.96^{A,b}$
Panavia SA Cement Plus	$9.01 \pm 0.91^{A,b}$	$5.50 \pm 1.12^{B,a}$	$4.2 \pm 0.37^{A,a}$

In each column, mean values with different superscript uppercase letters were statistically significant (Independent *t* test).
In each row, mean values with different lowercase letters were statistically significant (Tukey's *post-hoc* test).

Table 4 Two-way ANOVA results of mean ΔE values.

Source	SS	d.f	MS	F	P
Cement Brand (A)	17.715	1	3.382	5.727	0.023
Cement Shade (B)	151.204	2	75.602	128.027	0.000
A × B	32.503	2	16.252	27.521	0.000
Error		30	0.591		–
Total	1746.250	36			–

SS: sum of square, d.f: degrees of freedom, MS: mean square.

The ΔE values of the two cement brands in the same shade were compared by using Tukey's post hoc test. The results revealed significant differences between the Choice2-opaque and Panavia-opaque ($P < 0.001$). But, the two brands were not significantly different in translucent ($P = 0.079$) and A2 shades ($P = 0.178$). Comparing the three shades of Choice 2 brand (Table 2) revealed the ΔE of translucent shade to be significantly different from that of the opaque ($P < 0.001$) and A2 shades ($P < 0.001$). However, in Panavia brand, the ΔE of A2 shade was significantly higher than opaque ($P < 0.001$) and translucent shades ($P < 0.001$). Evaluations also revealed that the mean ΔE values in all the study groups were higher than the clinical acceptability threshold ($\Delta E = 3.7$) except for Choice 2-translucent ($\Delta E = 3.37$) (Fig. 1).

4. Discussion

This in-vitro study compared the effects of different brands and shades of resin-based luting agents on the final color of

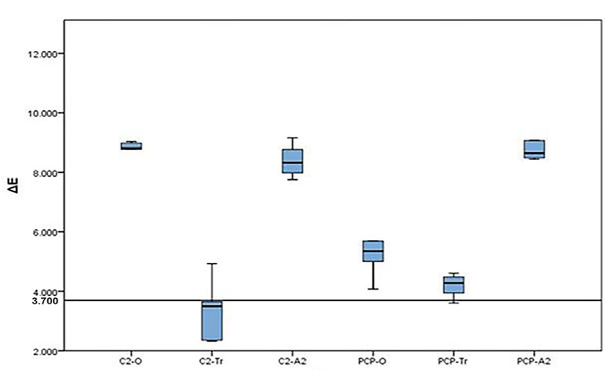

Fig. 1 Box plot for ΔE values of the tested groups (C2: Choice2, PCP: Panavia SA Cement Plus; O: Opaque, Tr: Translucent), the black horizontal line shows the clinical acceptability threshold of color difference ($\Delta E = 3.7$).

leucite-reinforced veneer restorations. The results rejected the null hypothesis, since both factors significantly affected the color of ceramic restorations. The present findings revealed that different resin-based luting agent brands in the same shade yielded different final restoration colors. Accordingly, the final color of opaque Panavia, which was a dual-cure resin-based luting agent was significantly different from that of the opaque Choice 2, which was a light-cure resin-based luting agent. But, the A2 and translucent shades of both resin cements had no significantly different effects on the final color of leucite-reinforced ceramic.

The opaque shade of Panavia SA cement Plus slightly increased the lightness of restoration; whereas, the opaque shade of Choice 2 decreased the lightness of restorations. Furthermore, the translucent shade of Panavia slightly decreased the lightness; while, the translucent shade of Choice 2 increased the lightness of restoration. The A2 shade of both resin-based luting agents decreased the lightness of restoration. Moreover, all the three shades of both resin-based luting agents increased the chromatic parameters (a^*, b^*) of leucite-reinforced ceramic veneer restoration, and changed the color towards yellow and red.

These findings were in agreement with what was found by the previous studies (Turgut and Bagis, 2013; Dede et al., 2017). Dede et al. (2017) observed that different brands of resin-based luting agents (Maxcem, Variolink, Clearfil, and RelyX) with the same shade had different effects on the final color of restoration. Likewise, Turgut and Bagis (2013) reported that the dual-polymerizable and light-polymerizable resin cement systems of the same colors created different final colors of leucite-reinforced IPS Empress Esthetic with 0.5 and 1 mm thickness. Similarly, Almeida et al. (2015) showed that the dual–polymerizing resin cement (RelyX ARC) had higher color variation than the light-polymerizing materials (RelyX Veneer and Filtek Z350 Flow) with the same color of A1 for cementation of 1-mm thick porcelain veneer, before and after thermal cycling (Almeida et al., 2015).

On the other hand Wang (2015) detected that similar shades of three resin-based luting agents (Variolink Veneer, Panavia F, and RelyX Veneer) had similar influence on the color change of IPS e.Max ceramic veneers with 0.6 mm thickness. These differences might be due to the variations in the design of studies such as ceramic and resin cement preparation methods, as well as the thickness and type of ceramic materials, and the shades of employed resin-based luting agents. Likewise, in the study by Perroni et al. (2017) there was no statistically significant difference in ΔE values between the two employed types of resin-based luting agents. Certainly they just used two light-polymerizing luting agents (Rely X Veneer and Tetric N-Flow), both in the translucent shade (Perroni et al., 2017).

Correct shade matching is also highly determined by the thickness of ceramic materials (Ruyter et al., 1987; Chen et al., 2005; Guess and Stappert, 2008). Perroni et al. (2018) found that the effect of luting agent shade on the color of porcelain veneer was significantly related to the thickness laminate veneer (Perroni et al., 2018). The bond durability in the conservative restoration of ceramic veneer is secured through bonding the ceramic to the enamel (Öztürk et al., 2013). Meanwhile, 0.5–0.8 mm is the safe range for reduction of the tooth structure in veneer restorations (Wang, 2015). In the current study, a disk of 0.5-mm thickness was used to evaluate the effect of resin-based luting agents on the final color of ceramic veneers.

The color of composite resin materials is highly bound to the refractive index and light transmittance characteristics of composite resin materials (Emami et al., 2005; Lee, 2008; Jalali et al., 2010). The filler, pigment and opaque content of the composite resin materials determine their rate of light absorption, scattering, and transmission (Powers and Paravina, 2004).

This study also showed that different shades of the same brands of resin cement could differently affect the final color of leucite-reinforced ceramic restorations. In Panavia SA Cement Plus, the opaque shade increased the lightness; while, the translucent and A2 shades decreased the lightness of ceramic. Nevertheless, all the three tested shades changed the ceramic color towards yellow and red color. In Choice 2 resin-based luting agent, the opaque and A2 shades decreased the lightness; whereas, the translucent shade increased the lightness of ceramic. Yet, the color alterations induced by all the three shades were towards yellow and red. The final color of Choice 2 in translucent shade was significantly different from that in A2 and opaque shades. Whereas, the final color of Panavia in A2 shade was significantly different from that in opaque and translucent shades.

Comparably, previous studies also reported that different shades of the same brand of resin-based luting agent could yield different final colors in ceramic restorations (Vichi et al., 2000; Turgut and Bagis, 2013; Wang, 2015). Dede et al. (2017) observed that different shades of resin-based luting agents had different effects on the final color of lithium disilicate ceramic restorations (Dede et al., 2017). Turgut and Bagis (2013) reported similar results regarding IPS Empress Esthetic ceramic restorations. Another study presented that the opacity of resin-based luting agents had more important impact on the final color of porcelain veneer restorations than their chroma and hue (Perroni et al., 2016).

Conversely, in a study by Azer et al. (2006), different shades of Variolink II resin-based luting agent (A1 and translucent) could not significantly affect the final color of 1.0-mm-thick IPS Empress ceramic restorations. Also Karaagaclioglu and Yilmaz (2008) reported imperceptible final color difference when using RelyX ARC in A1 and A3 shades to cement the leucite-reinforced IPS Empress ceramics (Karaagaclioglu and Yilmaz, 2008). The different results might be due to the variations in experimental designs of the studies and different thicknesses of employed ceramic veneers.

In the present study, different refractive index and light transmittance characteristics might explain the significant different effects of the three shades of the same resin cements and also the differences between the three shades of Panavia SA Cement Plus and Choice 2 resin-based luting agents. It informs the manufacturers about the significance of classification of common resin-based luting agents' shades and the importance of industrial standardization of these materials. In order to esthetically guarantee the outcome, clinicians can benefit from the trial insertion pastes to ensure the shade matching of veneer restorations before clinical application (Chadwick et al., 2008).

Trying to minimize the variations in the properties of the studied materials, all the ceramic and cement specimens were standardly fabricated. Considering the imperative role of the ceramic thickness and cement specimens in the final color of restorations, their values were adjusted to 0.5 and 0.2 mm, respectively. The present study also used a refractive index solution (optical gel) to connect the ceramic and cement specimens; it facilitated light transmission and eliminated the light scattering through the cement-ceramic specimen interface.

This study could not identically simulate a clinical situation, since we tested disk-shaped specimens rather than ceramic veneer restorations. Therefore, complete assessment of ceramic veneer restorations requires a clinical study which thoroughly considers the factors of ceramic thickness and different color of tooth structure.

5. Conclusions

Within the limitations of the present study, it can be concluded that the final color of leucite-reinforced veneering ceramic can be affected by the resin-based luting agents of the same nominal shade from different manufacturers, and different shades of resin-based luting agent from the same manufacturer. Moreover, clinically acceptable color difference was only seen in Choice2 specimens in translucent shade ($\Delta E \leq 3.7$).

Declarations of interest

The authors declared that there is no conflict of interest.

Funding

This work was supported by the Vice-Chancellery of Research, Shiraz University of Medical Sciences (Grant#1396-01-03-15246).

Acknowledgements

This article was based on the thesis by Amirhossein Barfei for partial fulfilment of DDS degree. Appreciations are expressed to Dr. Salehi from the Dental Research Development Center of School of Dentistry for the statistical analysis, and

Ms. Farzaneh Rasouli for improving the use of English in this manuscript.

References

Almeida, J.R., Schmitt, G.U., Kaizer, M.R., et al, 2015. Resin-based luting agents and color stability of bonded ceramic veneers. J. Prosthet. Dent. 114, 272–277.

Ardakani, M.T., Giti, R., Taghva, M., et al, 2015. Effect of a zirconia primer on the push-out bond strength of zirconia ceramic posts to root canal dentin. J. Prosthet. Dent. 114, 398–402.

Azer, S.S., Ayash, G.M., Johnston, W.M., et al, 2006. Effect of esthetic core shades on the final color of IPS Empress all-ceramic crowns. J. Prosthet. Dent. 96, 397–401.

Barath, V.S., Faber, F.J., Westland, S., et al, 2003. Spectrophotometric analysis of all-ceramic materials and their interaction with luting agents and different backgrounds. Adv. Dent Res. 17, 55–60.

Belser, U.C., Macne, P., Macne, M., 1997. Ceramic laminate veneers: continuous evolution of indications. J. Esthet. Restor. Dent. 9, 197–207.

Chadwick, R., McCabe, J., Carrick, T., 2008. Rheological properties of veneer trial pastes relevant to clinical success. British Dent. J. 204, E11.

Chen, J.H., Shi, C.X., Wang, M., et al, 2005. Clinical evaluation of 546 tetracycline-stained teeth treated with porcelain laminate veneers. J. Dent. 33, 3–8.

de Azevedo Cubas, G.B., Camacho, G.B., Demarco, F.F., et al, 2011. The effect of luting agents and ceramic thickness on the color variation of different ceramics against a chromatic background. Euro. J. Dent. 5, 245.

Dede, D.Ö., Armaganci, A., Ceylan, G., et al, 2013. Influence of abutment material and luting cements color on the final color of all ceramics. Acta Odontolog. Scandin. 71, 1570–1578.

Dede, D.Ö., Ceylan, G., Yilmaz, B., 2017. Effect of brand and shade of resin cements on the final color of lithium disilicate ceramic. J. Prosthet Dent. 117, 539–544.

Douglas, R.D., Brewer, J.D., 1998. Acceptability of shade differences in metal ceramic crowns. J. Prosthet. Dent. 79, 254–260.

Emami, N., Sjödahl, M., Söderholm, K.J.M., 2005. How filler properties, filler fraction, sample thickness and light source affect light attenuation in particulate filled resin composites. Dent. Mater. 21, 721–730.

Farzin, M., Giti, R., Asalforush-Rezaiye, A., 2018. The effect of multiple firings on the shear bond strength of porcelain to a new millable alloy and a conventional casting alloy. Materials 11, 478.

Guess, P.C., Stappert, C.F., 2008. Midterm results of a 5-year prospective clinical investigation of extended ceramic veneers. Dent. Mater. 24, 804–813.

Heffernan, M.J., Aquilino, S.A., Diaz-Arnold, A.M., et al, 2002. Relative translucency of six all-ceramic systems. Part II: core and veneer materials. J. Prosthet. Dent. 88, 10–15.

Jalali, H., Alizadeh, E.S., Sadighpour, L., et al, 2010. The effect of background and ceramic thickness on the color of an all-ceramic restorative system. J. Calif. Dent. Assoc. 38, 179–186.

Karaagaclioglu, L., Yilmaz, B., 2008. Influence of cement shade and water storage on the final color of leucite-reinforced ceramics. Oper. Dent. 33, 386–391.

Khashayar, G., Bain, P.A., Salari, S., et al, 2014. Perceptibility and acceptability thresholds for colour differences in dentistry. J. Dent. 42, 637–644.

Kucukesmen, H.C., Usumez, A., Ozturk, N., et al, 2008. Change of shade by light polymerization in a resin cement polymerized beneath a ceramic restoration. J. Dent. 36, 219–223.

Kürklü, D., Azer, S.S., Yilmaz, B., et al, 2013. Porcelain thickness and cement shade effects on the colour and translucency of porcelain veneering materials. J. Dent. 41, 1043–1050.

Lee, Y.K., 2008. Influence of filler on the difference between the transmitted and reflected colors of experimental resin composites. Dent. Mater. 24, 1243–1247.

Magne, P., Kwon, K.R., Belser, U.C., et al, 1999. Crack propensity of porcelain laminate veneers: a simulated operatory evaluation. J. Prosthet. Dent. 81, 327–334.

Öztürk, E., Bolay, Ş., Hickel, R., et al, 2013. Shear bond strength of porcelain laminate veneers to enamel, dentine and enamel–dentine complex bonded with different adhesive luting systems. J. Dent. 41, 97–105.

Perroni, A.P., Amaral, C., Kaizer, M.R., et al, 2016. Shade of resin-based luting agents and final color of porcelain veneers. J. Esthet. Restor. Dent. 28, 295–303.

Perroni, A.P., Bergoli, C.D., dos Santos, M.B.F., et al, 2017. Spectrophotometric analysis of clinical factors related to the color of ceramic restorations: a pilot study. J. Prosthet. Dent. 118, 611–616.

Perroni, A.P., Kaizer, M.R., Della Bona, A., et al, 2018. Influence of light-cured luting agents and associated factors on the color of ceramic laminate veneers: A systematic review of in vitro studies. Dent. Mater.

Powers, J.M., Paravina, R., 2004. Esthetic Color Training in Dentistry. Elsevier Mosby.

Ruyter, I., Nilner, K., Möller, B., 1987. Color stability of dental composite resin materials for crown and bridge veneers. Dent. Mater. 3, 246–251.

Turgut, S., Bagis, B., 2013. Effect of resin cement and ceramic thickness on final color of laminate veneers: an in vitro study. J. Prosthet. Dent. 109, 179–186.

Vichi, A., Ferrari, M., Davidson, C.L., 2000. Influence of ceramic and cement thickness on the masking of various types of opaque posts. J. Prosthet. Dent. 83, 412–417.

Wang, Y.N., 2015. The influence of resin cements on the final color of ceramic veneers. J. Prosthodont. Res. 59, 172–177.

Xing, W., Jiang, T., Ma, X., et al, 2010. Evaluation of the esthetic effect of resin cements and try-in pastes on ceromer veneers. J. Dent. 38, e87–e94.