The optical influence of resin cement shade and ceramic thickness on glass-ceramic systems

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Abstract

This in vitro study aimed to evaluate the influence of cement shade and ceramic thickness on the final shade of translucent CAD/CAM ceramics. Four thicknesses of ceramic specimens were prepared from IPS e.max CAD and Vita Suprinity PC blocks shade A1. The experimental groups were 1.0 mm, 1.5 mm, and 2.0 mm thick, and a control group was in 4 mm of thickness. Four specimens were prepared for each thickness in experimental groups. A plastic mold was cut into 12x12x0.2 mm squared shape in order to prepare the cement specimens. Four cement specimens were prepared from each shade (Yellow and Translucent; Multilink N). The 2 mm-thick titanium background was prepared to simulate the titanium abutment of the implant. The cement specimen was sandwiched between ceramic and titanium background with glycerin between each specimen. The color measurement was performed by spectrophotometer (Ultrascan Pro, Hunterlab). The color difference (ΔE) between experimental and control groups was calculated. Two-way ANOVA was used to determine the effect of cement shade and ceramic thickness. ($\alpha = 0.05$). The ΔE values were decreased with increasing of ceramic thickness. No significant difference in color was found between two cement shades (Y, T). The clinically acceptable results ($\Delta E \leq 3$) were found with 1.5 and 2.0 mm-thick ceramic specimens in both systems (e.max, VS). Clinically acceptable results ($\Delta E < 3$) were observed in at least 1.5mm-thick ceramics with resin cement on titanium background. Cement shade had no effect on the color of the ceramics on the titanium background.

Keywords: Resin cement, Spectrophotometer, Color, CAD/CAM, Ceramic, Titanium abutment

1. Introduction

With the rising of the social media era, esthetics turns to be one of the major requests of patients for cosmetic dental restoration. It is always a great challenge for the dentist to create a perfect smile and natural-looking prostheses (Glauser et al., 2004; Kohal, Att, Bachle, & Butz, 2008). The four main factors that influence the patient's satisfaction are color, translucency, surface, and contour. Therefore, restoration material selection is crucial for a preferable outcome. Ceramic is considered as the material of choice for anterior teeth to fulfill esthetics and function. However, the perfect color matching between ceramic restoration and the adjacent natural tooth is still a challenge for dentists.

Ceramic is developed to overcome the undesirable optical properties of metal and metal-ceramic restorations). Without metal substructure, light transmission is allowed to mimic natural-looking properties in restoration (Li, Yu, & Wang, 2009). Ceramic material also provides translucency depth as natural teeth by light scattering from small particles with different refractive indices (Azer et al., 2011; Rosenblum & Schulman, 1977). Therefore, a variety of ceramic materials have been introduced to improve the esthetic limitation and widely used in dental implant restoration especially in the esthetic area (Conrad, Seong, & Pesun, 2007). Lithium disilicate glass-ceramic (ex. IPS e.max CAD) is reported to be highly translucent due to the crystalline component. Zirconia-reinforced lithium silicate glass-ceramic (ex. Vita Suprinity PC) is the new combination between glass-ceramic with 10% in weight of zirconia in order to enhance the strength of the material (Kelly & Benetti, 2011). Due to the highly translucent properties, it is reported that the optical appearance of restoration can be affected by the underlying structure, luting material and the restoration thickness (Chaiyabutr et al., 2011; Nakamura et al., 2002; Vichi, Ferrari, & Davidson, 2000). The previous study demonstrated that the 1.5-mm-thick all-ceramic material (IPS e.max Press) on the titanium abutment is esthetically questionable (Dede et al., 2013). Another study showed that with the 2.5-mm-thick CAD/CAM ceramics on titanium background, the results were esthetically unacceptable (Jirajariyavej, Wanapirom, & Anunmana, 2018). Therefore, all-ceramic restoration on titanium abutment without cement coverage is still questionable for anterior teeth. In the 1980s, computer-aided design and computer-aided manufacturing (CAD/CAM) system were created for the purpose of the dental restoration with a single appointment (Allen, Schenkel, & Estafan, 2004).

For dental implant, titanium has long been the top choice for both fixture and abutment because of its biocompatible property and well-documented mechanical result with 10-year survival rate (Buser et al., 2012; Vichi et al., 2000). Nevertheless, many studies reported the grayish appearance of the metallic shade of titanium under the ceramics (Dede et al., 2016; Jirajariyavej, Wanapirom, & Anunmana, 2018; Nakamura et al., 2002). Moreover, it has reported that titanium abutment can shift the peri-implant tissue color to be more grayish shade especially in the patient with thin biotype (Park, 2007). Corciolani et al. (2010) reported that if the soft tissue around the implant is more than 2 mm, the color differences decrease. Therefore, the proper design of implant restoration with titanium abutment in anterior teeth is controversy.

Since a variety of cement shades has been available, the influence of cement shade to all-ceramic restoration has been evaluated. Some authors addressed that titanium abutment shade can be covered by white opaque cement, yet the all-ceramic shade might be shifted from the desired shade (de Azevedo Cubas et al., 2011). Resin cement with the same shade but different brand causes a different result when performed with 1.5-mm-thick lithium disilicate (Dede, Ceylan, & Yilmaz, 2017). The ceramic thickness of more than 1.5 mm has been reported to be helpful to prevent the color shifting from an underlying structure (Vichi et al., 2000) (Vichi et al., 2000). Hence, the effects from the color of resin cement along with background to final shade have evaluated.

For the color analysis in dentistry, a spectrophotometer is used in order to provide higher reproducibility and better accuracy compared to human eyes (Paniz et al., 2014). The CIE-LAB (Commission Internationale d' Eclairage) color scale is operated in the spectrophotometric analysis. The tooth color difference is calculated by the equation $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$. With three dimensions of color determination; L* represents the lightness from 0 (black) to 100 (white), a* and b* represent green/red and yellow-blue dimension (Chu, Devigus, & Mieleszko, 2004; Rosenstiel, Land, & Fujimoto, 2006). For teeth and oral cavity, an average discernable color difference (ΔE) has reported as 3.7 (Johnston & Kao, 1989). The CIELAB (ΔE_{ab}) is first described in 1976 and has been conducted for visual or tool evaluations. Recently, the CIEDE2000 has been developed to improve visual and tool correlation (Lee, 2005).

This study aimed to evaluate the optical effect of cement color and ceramic thicknesses on the final shade of CAD/CAM glass-ceramics with titanium background.

2. Objectives

To study the optical effect of cement shade and ceramic thickness on the color difference (ΔE) of CAD/CAM all-ceramic.

3. Materials and Methods

Two shades of resin cement, two types of ceramic and titanium background were prepared in this study. The type, brand and shade of resin cement, ceramic, and background material are shown in Table 1 and 2.

Table 1 Cement and abutment materials used in the study

Material	Type	Manufacturer	Shade
Multilink	Resin cement	Ivoclar Vivadent AG	Yellow, translucent
Titanium	Titanium grade V	Miracle metal	-

Table 2 Ceramic restorative materials in the study

Material	Type	Manufacturer	Shade	LOT#
IPS e.max® CAD	Lithium disilicate glass-ceramic	Ivoclar Vivadent AG	A1	V35454
Vita Suprinity® PC	Zirconia-reinforced lithium silicate glass-ceramic	VITA Zahnfabrik	A1	46162

Ceramic specimen preparation

Two types of translucent CAD/CAM ceramics shade A1 were prepared; lithium disilicate glass-ceramic (IPS e.max CAD (e.max)) and Zirconia-reinforced lithium silicate glass-ceramic (Vita Suprinity PC (VS)). The ceramic blocks were sliced into 12 specimens per each type to thickness of 1.0 mm, 1.5 mm and 2.0 mm for study groups (n=4) and 4.0 mm for a control group, using a medium grit diamond wafering blade (PACE technologies) with a low-speed precision sectioning cutter (IsoMet®, Buehler, Lake Bluff, IL, USA). One side of each specimen was grounded and polished under water cooling with 600, 800, 1000, and 1200 grits abrasive paper on a grinder-polisher machine (Phoenix Beta, Buehler, IL, USA) at 100 rev/min for 15 s. A digital micrometer (Digital micrometer, IP65, Mitutoyo MC, Kawasaki, Japan) was used to verify the thickness at the center of the specimens. The IPS e.max CAD was sintered for crystallization in a vacuum furnace according to the manufacturer's recommendation (Programat P300; Ivoclar Vivadent AG). There was no glazing process in order to reduce thickness variation (Figure1).

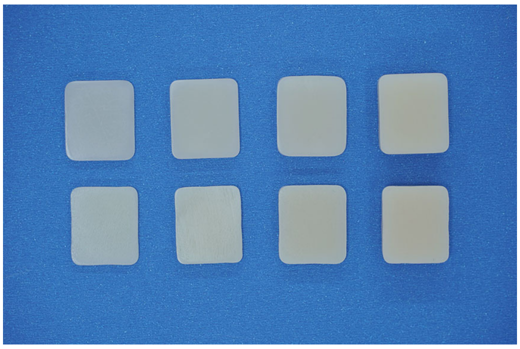

Figure 1 the 1.0, 1.5 and 2.0mm (study groups) and 4.0 mm (control) -thick e.max (A1) (from left to right; top) the 1.0, 1.5 and 2.0mm (study groups) and 4.0 mm (control) -thick VS (A1) (from left to right; bottom)

Background specimen preparation

Titanium (Ti) grade V was used to perform as the implant abutment. The specimen was cut into 2 mm thick by a medium grit diamond wafering blade (PACE technologies) with a low-speed precision sectioning cutter (IsoMet®, Buehler, Lake Bluff, IL, USA). The thickness precision was ensured by measuring at the center of the specimen with the digital micrometer. A specimen was then immersed in an ultrasonic cleaner (Quantrex 210H; L&R Manufacturing Company) with distilled water for 10 minutes (Figure 2).

Figure 2 Titanium background specimen

Cement specimen preparation

A hard plastic plate was cut to 12×12×0.2 mm-diameter squared space with the purpose of creating a 0.2 mm cement space. The resin cement (Multilink N) in yellow(Y) and translucent (T) shades was used in the study. The resin cement was applied to the space between two plastics in order to make a precise thickness. The 3 kg load was applied to the metal plate on top of plastic for 60 s then the cement was cured by a LED light curing unit at 750 mW/cm^2 for 20 s at both sides. Eight cement specimens were removed from the plastic plate, four specimens from T and four from Y shade. Completed polymerization was conducted under 37°C ± 1°C incubator for 24 hrs.

Spectrophotometric analysis

The color measurement was performed using a spectrophotometer (Ultrascan Pro, Hunterlab) by a single operator. The spectrophotometer was calibrated according to manufacturer's instruction before measurement. Each shade of cement was inserted between each ceramic and background orderly. Glycerin was applied between each specimen to reduce light scattering. The polished side of the ceramic specimen was placed at the tip of the spectrophotometer. For each ceramic type and shade, the control group was measured first, followed by the experimental group with each shade of cement with titanium at the last layer. Spectrophotometric analysis was performed in each group under CIE (Commission International del'Eclairage), scaling to three dimensions of color where; L* represents brightness from black (0) to white (100), a* represents red (+a*), and green (-a*) and b* represents yellow (+b*) or blue (-b*). The color difference (ΔE) between the control and the experimental group was automatically calculated by EasyMatch QC program using the three values (L*, a*, b*) from the spectrophotometer measurement based on the equation $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{½}$. In the previous studies, dental professionals have observed a slight intraoral color distortion between the samples with values ranging from 2.6 to 3.7 (Ragain & Johnston, 2000). The ΔE value that is greater than 3 was considered clinically noticeable by dentists (Dede et al, 2013).

The statistical analysis was evaluated by SPSS statistical software (IBM SPSS statistics version 23.0; SPSS Inc.). Two-way analysis of variance (ANOVA) was conducted to analyze two variables, cement shade, and thickness of ceramics. Post hoc test was performed for multiple comparisons (α=.05).

4. Results and Discussion

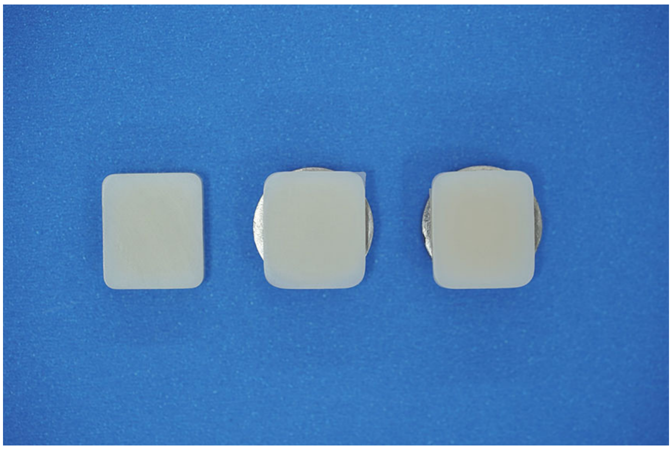

Figure 3 the 4.0 mm-thick e.max (control) and 1.0mm, 2.0mm-thick e.max with resin cement on titanium background (from left to right)

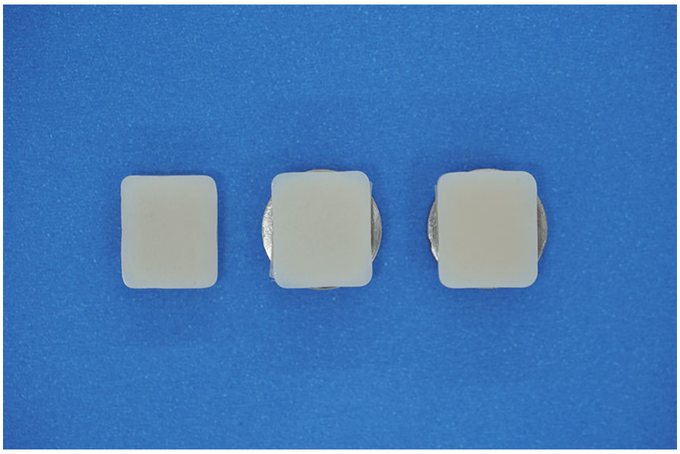

Figure 4 the 4.0 mm-thick Vita Suprinity (control) and 1.0mm, 2.0mm-thick Vita Suprinity with resin cement on titanium background (from left to right)

Figure 3 shows the 1.0 and 2.0 mm-thick e.max specimen on titanium background compared with the control (left). The 1.0 mm-thick ceramic with resin cement presented more greyish shade while the 2.0 mm-thick ceramic presented a similar color to the control specimen. Figure 4 shows the 1.0 and 2.0 mm-thick Vita Suprinity on titanium background compared with the control (left). The 1.0 mm-thick ceramic with resin cement presented more white greyish shade while the 2.0 mm-thick ceramic presented the similar color to the control specimen.

Table 3 ΔE value (Mean ± SD) and P-value of cement shade and thickness (2-way ANOVA)

Ceramics	**Cement Shade**	**Thickness (mm.)**			**P-value**
		1.0	**1.5**	**2.0**	
IPS e.max CAD	Yellow	3.90 ± 0.84^{Aa}	2.57 ± 1.70^{Aa}	1.74±0.45Ab	.000
	Translucent	3.58 ± 0.67^{Aa}	2.18 ± 0.46^{Bb}	1.57±0.30Ac	<.001
P-value		.155	.000	.585	
Vita Suprinity PC	Yellow	3.31 ± 0.63^{Aa}	2.35 ± 0.93^{Aa}	1.38±0.55Ab	.000
	Translucent	3.18 ± 0.59^{Aa}	2.47 ± 0.93^{Ab}	1.27±0.44Ab	.000
P-value		.842	.697	.708	

Statistical comparison of ΔE among cement shade and thickness were shown as superscripts, the value with the same letters are considered as no significantly different (P>0.05).
The capital letters refer to the differences of ΔE value between cement shade groups and lower case letters refer to difference between thickness groups.

Table 3 shows the mean and standard deviation of ΔE values of CAD/CAM all-ceramic material with two variables (cement shade and thickness). The 2-way ANOVA presented the significant difference between the color difference and interaction among ceramic thickness (P≤0.05). Significant differences were presented in every thickness, except 1.5 mm-thick e.max. However, no significant difference was found in cement shade for both ceramic types (P>0.05).

When the thickness is increased from 1.0 to 2.0, the mean of ΔE is decreased in both cement shades (Y, T). For both ceramic types (e.max, VS) with both cement shades (Y, T) the clinically acceptable values (ΔE<3) were presented in 1.5 and 2.0 mm of thickness.

The null hypothesis of this vitro study was rejected since cement shade and thickness affected the final shade of ceramics. Cement shade alone had no effect on the final shade of ceramics. In the other hands, ceramic thickness showed a significant effect on the mean ΔE values (P>0.05).

When considered the mean of ΔE values in both ceramics types (e.max, VS), the value in VS was lower than e.max. Although the ceramics were in the same shade (A1), but the shade was not equal. Since the characteristic of two types of glass-ceramic was different, e.max is lithium disilicate glass-ceramic while VS is zirconia-reinforced lithium silicate glass-ceramic. Similarly, other studies showed a different optical effect. Chu et al (2007) reported the significant difference of contrast ratio among three ceramic systems, which were in the same shade. Oh et al (2018) showed the different light transmission in different types of glass-ceramics even ceramics were in the same shade. The investigators reported that it significantly affected the shade of resin cement below.

The precision of spectrophotometric measurement has been questioned by investigators (Dede et al., 2016; Nakamura et al., 2002). There was non-reflected light back to the window of a colorimeter, which is called edge loss error (Bolt, Bosch, & Coops, 1994). The machines that were mentioned including a colorimeter (The ShadeEye NCC Chromameter; Shofu Inc.) and a hand-held digital spectrophotometer (VITA Easy shade; VITA Zahnfabrik). Accordingly, a xenon flash spectrophotometer (Ultrascan Pro) with xenon arc and 400-700 nanometers-wavelength covering was selected in this study.

Several studies have been performed on the optical effect of metal background to ceramic restorative materials since the titanium is commonly used for implant abutment. The previous study found the dark greyish color on glass-ceramic with titanium background. The greater similarity to the control was reported in 2.5 mm-thick ceramic (Jirajariyavej, Wanapirom, & Anunmana, 2018). While some studies reported that at least 1.5 mm-thickness of leucite-reinforced ceramic was able to cover the metal abutment shade (Nakamura et al., 2002; Vichi et al., 2000). Correspondingly, the present study showed the clinical acceptable results of color difference value in 1.5 and 2.0 mm-thick ceramics with both cement shade (ΔE< 3). Therefore, the all-ceramic restoration with a thickness of less than 1.5 mm should be compromised when used with titanium abutment.

Resin cement is the key material to bond the restoration with implant abutment. Although the shade of resin cement might affect the final shade of restoration, it also can cover the shade of underlying structure since various shades were available. The earlier study conducted to find out the masking ability of resin cement. Resin cement with the same shade from different manufacturers presented different effects on the final color of lithium disilicate ceramic (Dede et al., 2007). There was a report of the color shift in ceramic with various shade of cement (Kurklu et al., 2013). The present study used the different shades of resin cement from the same manufacturer. Contradictory, the result showed no significant differences between translucent and yellow shade (P>0.05). Therefore, the shade of cement does not affect the final color of the ceramics. Different types of resin cement in high and low translucent ceramic is suggested for further study.

5. Conclusion

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

1. Clinically acceptable results ($\Delta E < 3$) presented in at least 1.5mm- thick of highly translucent CAD/CAM glass-ceramics with resin cement on titanium background. Therefore, the proper thickness of ceramic should be carefully selected for the all-ceramic restoration with a metal background.
2. The color of resin cement presented no significant difference ($P \geq .05$) in at least 1.0 mm- thick CAD/CAM glass- ceramics.

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