Influence of Abutment Materials on the Resultant Color of Heat-pressed Lithium Disilicate Ceramics

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The purpose of this study was to evaluate the influence of abutment materials on the color of IPS Empress 2 ceramic coping with different thicknesses. Ceramic coping specimens (12.0×12.0×0.8–2.0 mm) were fabricated from IPS Empress 2 material (Ingot-100, n=5/group). Abutment specimens were fabricated from a build-up composite, a gold alloy, or a silver-palladium alloy. Color was evaluated using a colorimeter according to the CIE L*a*b* system. The L*a*b* values of the ceramic coping specimens of different thicknesses on each abutment specimen were measured. Following which, the color difference (ΔE^*_{ab}) values between the ceramic coping specimens on various abutment specimens were calculated. Significant differences in ΔE^*_{ab} value were observed among different abutment specimens at certain ceramic coping thicknesses ($P<0.05$). Thus, it was concluded that the color of IPS Empress 2 coping material was influenced significantly by both the thickness of the coping and the color of the abutment material.

Key words: Color, Heat-pressed lithium disilicate ceramics, Abutment material

INTRODUCTION

All-ceramic restorative systems have been used successfully for metal-free restorations in clinical applications. Usually, the full coverage crown is applied to endodontically treated teeth that have been restored with an abutment build-up – and very frequently, these teeth are discolored. Against this background, abutment tooth color is a significant issue with all-ceramic restorative systems¹⁾. This helps to explain why tooth-colored materials are recommended for the post and core of the all-ceramic system^{2–5)}.

High-strength, all-ceramic restorative systems are available as both fixed partial dentures^{6,7)} and opaque all-ceramic copings^{8–12)}. The opaque all-ceramic coping reduces the color influence of the abutment teeth and luting agents. However, it must be noted that the size and volume of component ceramic particles affect the coping opacity, whereby a large number of particles with a size greater than the wavelength of visible light would cause an opaque effect¹³⁾. To date, all-ceramic restorative systems have been used with discolored abutment teeth to achieve excellent esthetics¹⁴⁾.

The IPS Empress 2 system (Ivoclar Vivadent AG, Schaan, Liechtenstein) is a high-strength, all-ceramic restorative system that utilizes heat-pressed ceramics. The strengthening component in the ceramic coping of IPS Empress 2 is lithium disilicate¹⁵⁾, and it is more translucent than other high-strength, all-

ceramic restorative materials^{10,11,16)}. The manufacturer recommended 0.8 mm for minimum thickness of the IPS Empress 2 ceramic coping. In general, thickness of coping in all-ceramic restorative systems must be greater than that of the layering material on the coping, and the color influence of the coping is predicted to increase with its thickness to yield the final color. However, the effects of coping thickness and abutment materials on the color of IPS Empress 2 have not been established previously.

The purpose of this study was to evaluate the influence of abutment materials on the color of IPS Empress 2 coping in various thicknesses. Color evaluation was based on the Commission Internationale d'Eclairage (CIE) 1976 L*a*b* uniform color space system using a colorimeter^{16–33)}.

MATERIALS AND METHODS

Table 1 lists the materials that were used in this study. The ceramic coping specimens (ceramic specimen) were fabricated from Ingot-100 of IPS Empress 2 material (E2). This material corresponded to shade A2 of the Vitapan classical shade guide (Vita Zahnfabrick, Bad Säckingen, Germany).

Wax patterns were made with a vinyl polysiloxane impression material (Exafine Putty Type; GC Corp., Tokyo, Japan) using square molds (12.0×12.0 mm) with a thickness of 0.9, 1.1, 1.3, 1.5, 1.7, 1.9, or 2.1 mm.

The wax patterns were invested and heated, and

Table 1 Materials assessed in this study

Trade name	Manufacturer	Lot number	Component	Abbreviation
<i>Ceramic material</i>				
IPS Empress2 Ingot-100	Ivoclar Vivadent AG	D62511	57-80 SiO ₂ , 0-5 Al ₂ O ₃ , 0.1-6 La ₂ O ₃ , 0-5 MgO, 0-8 ZnO, 0-13 K ₂ O, 11-19 Li ₂ O, 0-11 P ₂ O ₅ , 0-8 additional components (wt%)	E2
<i>Abutment materials</i>				
Unifil Core	GC Corp.	0312041	Fluoroaluminosilicate glass, Urethane dimethacrylate	COM
Casting Gold M.C. Type III	GC Corp.	0311211	75.0 Au, 3.0 Pd, 5.0 Ag, 16.0 Cu, 1.0 Others (wt%)	GOL
Castwell M.C. 12% Gold	GC Corp.	0401071	12.0 Au, 20.0 Pd, 46.0 Ag, 20.0 Cu, 2.0 Others (wt%)	PD
<i>Try-in agent</i>				
Liquid Strip	Ivoclar Vivadent AG	F63544	Glycerine	

the ingots pressed into invested forms according to the manufacturer's instructions. The investment ring was then cooled and divested by air abrasion with 50- μ m aluminum oxide at 0.2 MPa pressure. The specimens were subsequently cleaned with hydrofluoric acid (Invex liquid, Ivoclar Vivadent AG, Schaan, Liechtenstein) in an ultrasonic bath for 10 minutes, and the surface reaction layer was removed with 50- μ m aluminum oxide at 0.1 MPa pressure.

The ceramic surfaces were ground with 800-grit silicon carbide (SiC) abrasive paper (New Maruto Lap ML-110, Maruto Instrument Co. Ltd., Tokyo, Japan) to obtain thicknesses of 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, and 2.0 mm. Minimum specimen thickness was set at 0.8 mm – the lowest thickness value recommended by the manufacturer for the IPS Empress 2 coping. Subsequently, the ceramic specimens were cleaned ultrasonically in distilled water for five minutes and air-dried. Each group consisted of five ceramic specimens.

Abutment specimens were fabricated from a composite build-up material (Unifil Core, GC Corp., Tokyo, Japan), a gold alloy (Casting Gold M.C. Type III, GC Corp., Tokyo, Japan), and a silver-palladium alloy (Castwell M.C. 12% Gold, GC Corp., Tokyo, Japan).

The composite build-up material was spatulated according to the manufacturer's instructions, filled into a silicone mold (12.0 $\times$ 12.0 $\times$ 7.0 mm), covered with a glass plate, and exposed using a photocuring unit (Optilux 501, Kerr Corp., Orange, Calif., USA) for 90 seconds on each side. The surface was then ground with 800-grit silicon carbide (SiC) abrasive paper (New Maruto Lap ML-110) to a thickness of

6.0 mm (COM). As for the metallic specimens, they were fabricated from wax patterns made using a silicone mold (12.0 $\times$ 12.0 $\times$ 1.5 mm). They were composed of either gold or silver-palladium alloy, and the casting surfaces were ground with 800-grit silicon carbide (SiC) abrasive paper (New Maruto Lap ML-110) to a thickness of 1.2 mm (GOL and PD, respectively).

Color evaluation was based on the CIE 1976 L*a*b* uniform color space system. The L*a*b* values of the ceramic specimens – of different thicknesses – placed on each abutment specimen were measured. Try-in agent (Liquid Strip, Ivoclar Vivadent AG, Schaan, Liechtenstein) was applied to minimize the influence of light refraction by eliminating any air between the ceramic specimen and abutment specimen²²⁾, which might otherwise interfere with accurate color measurement (Fig. 1). Three points on each specimen were measured using the 'Analyze mode' of the colorimeter (ShadeEye NCC, Shofu Inc., Kyoto, Japan), and the L*a*b* values recorded accordingly (Fig. 1). In addition, the color difference (ΔE^*_{ab}) values of the ceramic specimens on different abutment specimens were calculated as follows:

$$\Delta E^*_{ab} = \{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\}^{1/2}$$

where $\Delta L^* = L^*_1 - L^*_0$, $\Delta a^* = a^*_1 - a^*_0$, and $\Delta b^* = b^*_1 - b^*_0$

Two-way analysis of variance (ANOVA) and Tukey-HSD test ($P < 0.05$) were used to analyze the differences in ΔL^* , Δa^* , Δb^* , and ΔE^*_{ab} values of the ceramic specimens placed on each abutment specimen (hereinafter referred to as COM-GOL, COM-PD,

Fig. 1 Measurement of ΔE^*_{ab} values of ceramic specimens on different abutment specimens.

and GOL-PD). All statistical analyses were performed using SPSS statistical software package, version 12.0 (SPSS Inc., Chicago, Ill, USA).

RESULTS

The $L^*a^*b^*$ values of abutment specimens are summarized in Table 2. Two-way ANOVA revealed that ΔL^* , Δa^* , and Δb^* values were influenced by both abutment material ($F=12.4, 1060.3, 49.1, p=0.001, 0.001, 0.001$) and thickness ($F=4.2, 158.2, 14.9, p=0.01, 0.001, 0.001$) (Tables 3-5). An interaction was not indicated only ΔL^* values ($F=0.93, p=0.524$).

Table 2 The $L^*a^*b^*$ values of the abutment specimens

Abutment specimen	L^*	a^*	b^*
COM	71.2 (0.1)	2.5 (0.1)	12.9 (0.1)
GOL	74.2 (0.1)	7.1 (0.1)	17.1 (0.0)
PD	72.2 (0.1)	1.7 (0.1)	8.1 (0.1)

The s.d. values are shown in parentheses.

Table 3 The ΔL^* values of the ceramic specimens on different abutment specimens

Thickness of ceramic specimen	0.8	1.0	1.2	1.4	1.6	1.8	2.0 mm
COM-GOL	0.5	0.8	0.6	0.4	0.7	0.4	0.4
	(0.8)	(0.6)	(0.2)	(0.4)	(0.1)	(0.1)	(0.5)
COM-PD	1.1	1.1	1.3	0.9	0.9	0.4	0.9
	(0.4)	(0.6)	(0.2)	(0.4)	(0.2)	(0.3)	(0.3)
GOL-PD	0.7	1.0	0.6	0.6	0.2	0.4	0.4
	(0.4)	(0.7)	(0.3)	(0.3)	(0.1)	(0.2)	(0.3)

The s.d. values are shown in parentheses.

Table 4 The Δa^* values of the ceramic specimens on different abutment specimens

Thickness of ceramic specimen	0.8	1.0	1.2	1.4	1.6	1.8	2.0 mm
COM-GOL	3.4	2.4	2.0	1.6	1.1	1.1	0.7
	(0.2)	(0.3)	(0.1)	(0.3)	(0.1)	(0.2)	(0.1)
COM-PD	0.2	0.3	0.4	0.4	0.5	0.2	0.4
	(0.1)	(0.2)	(0.0)	(0.2)	(0.1)	(0.1)	(0.1)
GOL-PD	3.2	2.7	2.4	2.0	1.6	1.3	1.1
	(0.0)	(0.2)	(0.1)	(0.2)	(0.1)	(0.3)	(0.1)

The s.d. values are shown in parentheses.

Table 5 The Δb^* values of the ceramic specimens on different abutment specimens

Thickness of ceramic specimen	0.8	1.0	1.2	1.4	1.6	1.8	2.0 mm
COM-GOL	1.2	0.5	0.1	0.2	0.3	0.2	0.4
	(0.7)	(0.6)	(0.1)	(0.1)	(0.2)	(0.2)	(0.3)
COM-PD	1.5	1.2	1.4	1.3	1.2	0.7	1.1
	(0.5)	(0.5)	(0.3)	(0.2)	(0.2)	(0.3)	(0.4)
GOL-PD	2.7	1.6	1.5	1.4	0.8	0.6	0.7
	(0.4)	(1.0)	(0.2)	(0.2)	(0.4)	(0.1)	(0.4)

The s.d. values are shown in parentheses.

Fig. 2 The ΔE^*_{ab} values of ceramic specimens on different abutment specimens. Horizontal bars indicate significant differences ($p < 0.05$).

Two-way ANOVA run on ΔE^*_{ab} values revealed that the interaction between abutment material and thickness ($F=8.7$, $p=0.001$) was significant, and that the ΔE^*_{ab} values were affected by both the type of abutment material ($F=64.2$, $p=0.001$) and thickness ($F=65.8$, $p=0.001$). Therefore, the ΔE^*_{ab} values were further analyzed by one-way ANOVA and Tukey-HSD test ($P < 0.05$) (Fig. 2).

At 0.8 mm thickness, the ΔE^*_{ab} values of COM-GOL and GOL-PD were greater than that of COM-PD. At 1.0 and 1.8 mm thicknesses, GOL-PD was greater than COM-PD. At 1.2 and 1.4 mm thicknesses, GOL-PD was greater than COM-GOL and COM-PD. At 1.6 mm thickness, GOL-PD was greater than COM-GOL. At 1.0 mm thickness or more, the ΔE^*_{ab} values were not significantly different between COM-GOL and COM-PD. At 2.0 mm thickness, there were no significant differences.

DISCUSSION

Recently, all-ceramic restorations have led to a number of advances in reconstructive dentistry. Without a supporting metal substructure, the main breakthrough has been in achieving light scattering and transmission that gives the illusion of natural teeth¹⁾. In particular, opaqueness can be prevented in the cervical area such that no metal color is visible even if marginal gingival recession occurs. Moreover, leveraging on the development of adhesive techniques, inlay, onlay and laminate veneer restorations have become possible. Likewise, fixed partial dentures have been realized through the development of high-strength, all-ceramic restorative systems^{6,7)}.

With ceramic copings, one additional characteristic is opacity^{9–12)}. However, the influence of the color of abutment teeth on the E2 system has not been established previously. Therefore, we investigated this aspect of influence on E2 by measuring its $L^*a^*b^*$ values^{16–32)} with a reliable hand-held color-

imeter^{23–25,30,32)}. Following which, the influence of abutment material on the color of E2 of various thicknesses was evaluated by calculating and comparing the ΔE^*_{ab} , ΔL^* , Δa^* , and Δb^* values.

Among the ΔL^* values, only thicknesses of 1.2 and 1.6 mm revealed significant differences. On the other hand, for Δa^* values, those of COM-PD were consistently smaller than COM-GOL and GOL-PD at all thickness. For Δb^* values, GOL-PD was significantly larger than COM-GOL up to the thickness of 1.8 mm. Based on the results of this study, it was found that the condition of each abutment tooth exerted little influence on lightness. On the other hand, the influence on chroma and hue was substantial. In particular, GOL was greater than COM and PD in the a^* (red-green) value of the abutment specimen. Further, the b^* value (yellow-blue) of PD influenced the chroma and hue because the b^* value was smaller than COM and GOL.

In the ΔE^*_{ab} formula, brightness, chroma, and hue are of the same scale. However, the concept of ΔE^*_{00} (CIEDE 2000) that includes weighting functions on chroma and hue has been introduced in recent years³³⁾.

Alternatively, the acceptable ΔE^*_{ab} value according to the United States Public Health Service (USPHS) criteria is 3.7¹⁷⁾, while other sources recommend values ranging from 1.0 to 3.7^{18–32)}. Then, based on an evaluation according to stages¹⁶⁾, the clinically satisfactory value was reported to be 2.0. Therefore, in this study, 2.0 was adopted as the acceptable ΔE^*_{ab} value.

In the current study, no significant differences in ΔE^*_{ab} value were noted at 2.0 mm thickness. Further, it was at the thickness of 1.6 mm that the ΔE^*_{ab} value revealed 2.0 or less.

For high-strength, all-ceramic restorative systems, the strengthening components of the ceramic copings are alumina, zirconium oxide, and lithium disilicate^{10,15)}. In the case of E2, the strengthening component is lithium disilicate, with a particle size of 0.5 to 4.0 μm present at a volume of 65 to 75%¹⁵⁾. The microstructure of E2 also contains lithium orthophosphate crystals. It should be noted that the color and translucency of ceramics are influenced by the refractive index difference between the particle and coping matrix, as well as by the pigments in the material^{10,13)}. This is because these factors influence the diffusion and scattering of light. Wavelength of visible light is 0.4 to 0.7 μm , and ceramic materials can contain particles that are larger or smaller than this wavelength. Refraction and reflection occur infinitely on the surfaces of particles that are larger than the wavelength of light, thereby causing the light to diffuse. A similar phenomenon occurs as a result of the porosity of ceramic materials. The greater the refractive index difference between particle size and ceramic matrix, the greater the refrac-

tion and reflection of light, which leads to an opaque effect in ceramic materials^{10,13}.

The contrast ratio method is commonly used to compare relative translucency⁹. Contrast ratio is measured based on the luminous reflectance (Y) of a specimen on black (Yb) and white backings (Yw) to give a Yb/Yw value ranging from 0.0 (transparent) to 1.0 (opaque)^{10,11,15}. According to Höland *et al.*¹⁵, the contrast ratio of the coping material of E2 at a thickness of 1.0 mm was 0.55. As for Heffernan *et al.*¹⁰, the contrast ratio of the ceramic coping of E2 at a thickness of 0.8 mm was reported to be 0.72. In a subsequent study, when a layering material of 0.7 mm thickness was applied (definitive thickness: 1.5 mm), the contrast ratio was reported to be 0.78 before grazing and 0.77 after grazing¹¹. By these reports, color of the post and core was found to have a slight influence on E2 when the ceramic coping thickness was 0.8 mm or more.

In the present study, ceramic copings of E2 of 1.6 mm thickness or more prevented the evaluated abutment materials to exert any clinically unacceptable color influence. However, the layering material — like a color porcelain — is necessary on a ceramic coping. Moreover, the amount of abutment tooth reduction may pose a problem too. Taken together, it is almost impossible to have a setting of 1.6 mm thickness or more for ceramic copings. For the IPS Empress 2 ceramic coping, minimum thickness of 0.8 mm recommended by the manufacturer is appropriate. On this note, when selecting the abutment material, it is necessary to consider its influence on the final color as E2 is placed after the tooth is endodontically treated.

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