The effect of thickness on the contrast ratio and color of veneering ceramics

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Abstract

Objectives: The objectives of this study were to evaluate the effect of thickness on the contrast ratio and color of two veneering ceramics.

Materials and methods: Square shaped specimens (15mm x15 mm) were prepared from A3 shade of Vita VM9 (V) and IPS e-max Ceram (E) at four different thicknesses i.e., 0.6mm,0.8mm,1.2mm,1.5mm (n=5). All specimens were finished flat on a milling machine to the required dimension using 100 μm diamond coated disc. The contrast ratio (CR= Y_b / Y_w) and color difference ($\Delta E = [(L^*_1-L^*_2)^2 + (a^*_1-a^*_2)^2 + (b^*_1-b^*_2)^2]^{1/2}$ were measured with a spectrophotometer and calculated. The statistical analyses for the mean contrast ratio (CR) of all groups were performed by two-way ANOVA and Tukey multiple comparison test at α=0.05. Color differences (ΔE^*) were compared between different thicknesses for the same brand and between different brands at the same thicknesses.

Results: The results showed that the mean CR increased significantly with the increase in thickness from 0.6 to 1.5mm for both veneering ceramics; the CR of V 0.6 (0.61±0.01) was the lowest whereas CR of V 1.5 (0.87±0.00) and E 1.5 (0.87±0.01) were the highest. The brands did not significantly influence the mean contrast ratio in each thickness of veneering ceramics. For both veneering ceramics, a decrease in L*and an increase in a*were observed when the thickness increased. No influence of increasing thickness on b*was observed.

Conclusions: The contrast ratio of two veneering ceramics was significantly influenced by thickness irrespective of the brands. L* and a* were influenced by thickness but not b*. When the thickness of the veneering ceramic was increased in both the brands, color changes were observed as an increase in ΔE^* value.

Key words: contrast ratio, color difference, veneering ceramics, thickness, translucency, shade instching

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Introduction

All-ceramic systems have been mainly developed to overcome the esthetic deficiencies of metal-ceramic restorations due to an increase in light reflectivity from opaque porcelain needed to mask the metal substrate.[1] Since an increase in demand for esthetically pleasing restorations, all-ceramic materials can be made to match natural tooth structure accurately in terms of color, surface texture and translucency.[2]Increasing the crystalline content of dental ceramics provides greater strength but it generally results in greater opacity.[3] Most all-ceramic systems require the combination of two layers of ceramic materials, a strong ceramic core and a weak veneering porcelain.[2,4] The overall shade of all-ceramic restorations is determined not only by the color of ceramic materials, but also by their thicknesses. The other factors that can affect the overall shade of all-ceramic restorations are the thickness and color of luting agents, the color of the underlying tooth structure, porcelain brand, firing conditions, processing technique,etc.[3,5-7]

Color is a psychophysical sensation that results when the human visual system responds to the light reflected from objects in a scene. Translucency is the degree to which light is transmitted rather than absorbed or reflected. The highest translucency is transparency while the lowest is opacity. Color of dental materials is often expressed in L*a*b* coordinates. These coordinates, obtained from spectral reflectance measurements with a spectrophotometer, provide a numerical description of the color position in a 3 dimensional color space. The L* coordinate is a measure of the lightness-darkness of the specimen. The greater the L* is, the lighter the specimen. The a* coordinate is a measure of chroma along the red-green axis. A positive a* relates to the amount of redness, and a negative a* relates to the greenness of a specimen. The b* coordinate is a measure of the chroma along the yellow-blue axis; that is, a positive b* relates to the amount of yellowness, while a negative b* relates to the amount of blueness of the specimen. Each tooth color is a unique combination of a* (reddish) color and an b* (yellowish or bluish color) in combination with an L*(brightness) component and has a unique place in the color space.[8]

The ΔE* values (as shown in Equation 2) are used to describe whether the changes in the overall shade are perceivable to a human observer. When ΔE* are greater than 2 units, all observers can apparently detect color difference between 2 colors. Based on the study of Johnston and Kao, a value of 3.7 could be used as threshold for a clinical shade match and a value of 6.8 can be used as threshold for a clinical mismatch.[9] Thresholds for perceptibility were lower than thresholds for acceptability for metal-ceramic crowns differing in their chroma.[10]

Shokry et al studied the effect of varying core and veneer thickness on the color parameters of 2 ceramic systems (IPS Empress and In-ceram Spinell) and found that ΔE* values increased when the combined thickness of the core and veneering materials was increased.[11] The authors concluded that the color of layered ceramic specimens was significantly influenced by the thickness of both core and veneer. Antonson and Anusavice studied the effect of thickness on the contrast ratio of dental core and veneering ceramics and found that the contrast ratio of dental core and veneer ceramics was a linear function of ceramic thickness.[6] Heffernan et al studied the influence of core material thickness on its translucency and the influence of core plus ceramic veneer thickness on the overall translucency of the specimens and concluded that there was a range of ceramic core translucency at clinically relevant core thicknesses.[12-13] In a study by Uludag and his colleagues, the color of specimens appeared darker, redder and more yellow for In-Ceram specimens but darker and greener for IPS Empress specimens due to an increase in dentin thickness.[14] Ozge et al concluded that as the ceramic thickness increased, significant reductions in L*values were recorded for IPS e-max Press and DC Zirkon specimens. For IPS e-max Press specimens, a significant increase in a* and b*values were also observed when the ceramic thickness was increased.[15] For DC Zirkon specimens, an increase in a* value was observed, but no significant differences were recorded for b*values. The mean ΔE* values increased as the thicknesses was increased for both types of all-ceramic specimens tested.[15]

Since human enamel has inherent translucency, esthetic restorations such as all-ceramics should reproduce the translucency of natural teeth.[16] All-ceramic systems have various strengthening compositions with different crystalline contents, refractive indices, and recommended fabrication dimensions.[17] There are various brands of veneering materials used in all-ceramic restorations which have different composition and different physical properties. There are limited publications regarding the thickness, contrast ratio and color difference of different veneering ceramics. The objectives of this study were to evaluate the effect of thickness on the contrast ratio and color of different veneering ceramics.

Materials and methods

Method of specimen preparation

A plastic mold, having a size of 18mmx 18mmx2.5mm was prepared. The IPS ceramic separating liquid was applied onto the mold and blow-dried so that the specimen would be easily separated later. Dentin powder (Shade A3 - Vita VM9; Vita Zahnfabrik, Germany) was mixed with Vita Modeling Liquid (approximately 1g of powder and 0.5ml of build-up liquid), condensed and hand-vibrated, and excess moisture was removed with absorbent tissue paper to minimize porosity. Then the specimens were fired in a furnace according to the manufacturer's guidelines.The IPS e-max Ceram Dentin A3 powder and IPS e-max Ceram Build up liquid (IvoclarVivadent, Liechtenstein), approximately 1 g of powder and 1ml of build-up liquid, was mixed into slurry and prepared similarly to the process previously mentioned. After firing, specimens of both brands were roughly ground with diamond bur and mounted in a plastic mold using dental plaster. Then the mounted surface was smoothened using sandpapers (100 up to 1000 grit) under running water to +0.1 mm of the designated thickness in order to obtain smooth parallel surface on one side. Then the other side of specimens was finished flat on a milling machine (Schick Dentalgerate S master 3; Vacalon, USA) using 80μm diamond disc.The specimens were ultrasonically cleaned in water for 10 minutes and then steam-cleaned. Finally the specimens were glazed using the glaze paste and fired according to the manufacturer's guidelines.Specimens were divided into four groups for each brand according to their different thicknesses, i.e., 0.6 mm, 0.8 mm, 1.2 mm and 1.5 mm. Five specimens were prepared for each thickness. The thickness was verified by digital caliper (Mitutoyo, Kawasaki, Japan) which had a recording accuracy of 0.05 mm. The mean value of the five measurements was taken.

Measurement of Contrast Ratio

A spectrophotometer (Color flex, model 4510, Hunter Lab, VA, USA) was used for the contrast ratio measurement. The specimens were measured with 45°/0° geometry. Data was analyzed with a software to calculate luminous reflectance with CIE illuminant D65 and the 2-degree observer function. The instrument was calibrated against the white and black standard discs before each measurement session. Each specimen was placed at the specimen port having a diameter of 13 mm. Three measurements were made over the white reference backing (Y_w) and then the black backing (Y_b), resulting in a total of six measurements per specimen. The contrast ratio was then calculated using Equation 1.

$$CR = Y_b/Y_w \quad (1)$$

Where Y_b is the measured reflectance of a material over black background and Y_w is the measured reflectance of a material over white background. The color difference in CIELAB units is given by Equation 2;

$$\Delta E^* = [(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2} \quad (2)$$

Where L*, a*, and b* are the lightness, chroma in red-green axis (a*), and chroma in blue-yellow axis (b*) which result from the measured color of a material over the white and black backgrounds.The color differences (ΔE*) between each thickness of the same brand and between the same thickness of different brands were calculated using Equation2.

Statistical Analyses

The data was analyzed using TWO-WAY ANOVA to find the differences in contrast ratio and Tukey HSD was performed to find significant differences between the means of these groups. All statistical tests were performed at α=0.05.

Results

The mean contrast ratio (CR) values of two veneering ceramics at different thicknesses are shown in Table 1. The results from two-way ANOVA showed that the mean contrast ratio of two veneering ceramics were significantly influenced by an increase in thickness. The brand of veneering ceramic had no significant influence on their contrast ratio. Vita VM9 specimen of thickness 0.6 mm had the lowest contrast ratio whereas Vita VM9 and IPS e-max Ceram of thickness 1.5 mm had the highest contrast ratio.

The mean L*,a*,b* values of two veneering ceramics are shown in Table 2. An increase in a* and a decrease in L* were observed when the thickness of two veneering ceramics were increased. No significant change in b* was observed. The color changes (ΔE*) of these veneering ceramics as a result from varying the thicknesses are presented in Table 3. For both brands, ΔE* increased as the thickness was increased. The increases from 0.6 mm to 1.2-1.5 mm caused a significant change in ΔE* for both veneering ceramics. The color differences between brands were also evident, ranging from 2.7 to 3.7 units.

Discussion

In esthetic dentistry, translucency is a major concern because a restoration relies on relatively opaque core material to provide

Table 1 The mean contrast ratio values of Vita VM9 and IPS e-max Ceram

Thickness (mm)	Contrast ratio	
	Vita VM9	IPS e-max Ceram
0.6	0.61±0.01[a]	0.64±0.01[a]
0.8	0.69±0.01[b]	0.70±0.01[b]
1.2	0.81±0.01[c]	0.81±0.01 [c]
1.5	0.87±0.01[d]	0.87±0.01 [d]

(The same superscript letter indicates no significant difference was found between groups)

Table 2 The mean L*,a*,b* values of two veneering ceramics

Group	L*	a*	b*
Vita VM9 0.6 mm	78.3±0.4	2.72±0.13	20.39±0.45
Vita VM9 0.8 mm	75.39±0.50	3.52±0.18	21.38±.20
Vita VM9 1.2 mm	71.69±0.16	4.64±0.08	21.68±.10
Vita VM9 1.5 mm	69.78±.16	4.74±.06	20.82±.26
IPS e-max Ceram 0.6 mm	79.79±.56	1.84±.17	22.42±.37
IPS e-max Ceram 0.8 mm	76.98±14	2.76±.45	24.51±.32
IPS e-max Ceram 1.2 mm	74.35±.66	3.55±.35	23.45±.71
IPS e-max Ceram 1.5 mm	72.85±.55	3.84±.17	22.77±.21

Table 3 ΔE* values obtained between different thicknesses of two veneering ceramics

Thickness (mm)	Brands	
	VITA VM 9	IPS e-max Ceram
0.6 and 0.8	3.63	3.14
0.6 and 1.2	5.79	6.97
0.6 and 1.5	7.23	8.73
0.8 and 1.2	2.94	3.88
0.8 and 1.5	4.6	5.76
1.2 and 1.5	1.67	2.09

strength and it has overlying veneering porcelains to provide esthetics.[18] In this study, materials tested represent commonly used veneers that are available in clinical practice. IPS e-max Ceram contains nano-fluorapatite crystals (less than 300nm in length and approx 100 nm in diameter) which is claimed to appear similar to those of vital teeth.[19] Vita VM9 has fine distribution of the leucite crystals (particle size 4 µm) in the glass phase which exhibits excellent refractive and reflective properties similar to enamel, as claimed by the company.

Specimens of various thicknesses, i.e., 0.6, 0.8, 1.2 and 1.5mm, have been chosen for these veneering ceramics because in clinical situation the thickness of core ceramic specimens is mostly in the range of 0.4 to 0.8mm, and that of the veneer ceramic specimens is in the range of 0.7 to 1.1mm.[20] Shade A3 is also a common shade observed in daily clinical practice. Shade and translucency of veneering porcelains are vital factors that contribute to the color characteristics of the definitive restoration.[21] The translucency of ceramic materials depends on the scattering of light within the bulk material. The amount of light reflected, absorbed and transmitted depends on the material's chemical composition, number of particles and pores, and the sizes of the particles and pores compared to the incident light wavelength.[13-14,22] For maximal scattering and opacity, a great number of dispersed particles, slightly greater in size than the wavelength of light and with a different refractive index to the matrix, is required.

In this study, the mean contrast ratio of two veneering ceramics increased significantly with the increase in thickness from 0.6 to 1.5

mm ($P<0.05$), as the contrast ratio of Vita VM9 of 0.6mm (0.61±0.01) was the lowest and contrast ratios of Vita VM9 at 1.5 mm (0.87±0.01) and IPS e-max Ceram (0.87±0.01) were the highest. Brands did not significantly influence the mean contrast ratio of veneering ceramics because composition of both brands was glass-based. Although these veneering ceramics had different types of crystalline content, they might not have significant influence on the translucency of these veneering ceramic because of their limited amount incorporated in their composition. Leucite crystals also have the same refractive index as glass and they have a homogenous distribution within the glass matrix. The relationship between thickness and the contrast ratio was also determined in this study. According to the r^2 values, both the linear regression (r^2=0.98) and logarithmic equation (r^2=0.99) could be used to estimate the effect of increased thickness on the contrast ratio.

For both veneering ceramics, a decrease in L*and an increase in a* were observed when the thickness was increased. No significant influence of increased thickness was observed on b*. The result of this study was similar to the study done by Terzioglu et al in which the L* values of the specimens decreased significantly as the thickness increased.[8] This can be explained by the fact that there is an increase in the absorption of incident light when it passes through the thick specimens and , thus, lower L*values. The inverse relationship between porcelain thickness and L* is a function of the optical scattering and absorption coefficients of dentin porcelain.[23] a* values increased as the thickness increased indicating a shift towards red axis. b* values did not show significant change with the increase in thickness. The values of a* were also reported to increase when the thickness of the opaque layer was increased at the expense of the other translucent porcelain layer.[3] In the same study, significant increase in b* values was also found when the thickness of opaque layer was increased. [3] The influence of ceramic thickness on the shade matching of A1, A3 and C2 shade was also reported in one study that a significant increase of b* values was observed when thickness of specimen was increased.[24]

In this study, the tests were conducted on flat surfaced square shaped specimens, which could not simulate clinical condition. The results obtained in this study demonstrated that changes in thickness had an effect on the final shade of veneering ceramics but the study was limited to only 2 veneering ceramic systems (Vita VM9 and IPS e-max Ceram). However, the contrast ratio values obtained from this study are fundamental material properties and they are essential factor in esthetic dentistry. In order to obtain an optimum esthetic result of ceramic restorations, the information about optical properties of ceramic materials is necessary for proper selection and application of these materials.

In conclusion, Significant increases in contrast ratio of two veneering ceramics were detected when their thickness was increased from 0.6 to 1.5 mm, irrespective of the brands. L* and a* values of veneering ceramics were affected by the increase in thickness. As the thickness increased, the L* value decreased which created darker specimens for both brands. a* value also increased with increasing thickness. Color changes were observed for both veneering ceramics when their thickness was increased. These color changes were characterized by an increase in ΔE* values in both brands.

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