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INFLUENCE OF THE BACKGROUND COLOR AND THICKNESS OF ZIRCONIA REINFORCED GLASS CERAMICS ON THE OPTICAL PROPERTIES COMPARED TO LITHIUM DISILICATE GLASS CERAMICS

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ABSTRACT

Statement of problem. Optical properties of contemporary all ceramic restorations are influenced by background color and thickness has dearth of information.

Purpose. The purpose of this study was to evaluate the influence of the background color and thickness of zirconia reinforced glass ceramics on the optical properties compared to lithium disilicate glass ceramic.

Materials and methods. Fifty six ceramics rectangular plates were made from zirconia reinforced glass ceramic and lithium disilicate glass ceramic plates (n=28). The dimensions of the plates were (14 x 12 mm). The plates of each group were divided into two subgroups of two different thicknesses 1.0, 1.5 mm (n=14). Again, specimens were divided into two divisions according to composite background shade into division (A2 and C3). The ceramic plates of each materials and thicknesses were optically connected with drop of distilled water to either two composite background shades. The color change ΔE between ceramic-composite assembly and ceramic plates was measured for all tested group. The data were analyzed with 3-way ANOVA followed by Bonferroni's post-hoc test (α= 0.05).

Results. ANOVA revealed that background color, ceramic type and thickness had a statistically significant effect on mean ΔL ($p<0.05$). The interaction between the three variables was not statistically significant ($p=0.968$).

Conclusion. Zirconia reinforced lithium silicate ceramics could decrease the effect of color change of dark background more significantly than lithium disilicate glass ceramic.

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INTRODUCTION

Since introduction of metal ceramic restorations as restorative material it becomes the material of choice as it combines the high mechanical properties being able to withstand heavy occlusal forces with good optical properties and adequate color matching to the natural tooth. Due to their excellent biocompatibility, marginal adaptation and long-lasting clinical performance, it is considered as the gold standard restoration in fixed prosthodontics. However, it had some drawbacks including difficulty of developing "natural- like" appearance of tooth due to metallic underlying structure which need to be masked by overlying opaque porcelain. The metallic facial margins display represent another esthetic challenge with great esthetic limitation because the lack of translucency. With the increase in the demand for possessing a beautiful smile and white teeth in recent years, management of discolored teeth has high importance in aesthetic dentistry. Depending on the severity of discoloration, there are several treatment options including vital and non-vital bleaching, micro abrasion, composite and porcelain veneers, porcelain crowns and sometimes a combination of them.

All-ceramic restorations are more translucent and thus have more aesthetic properties than restorations with metal substrates and can be used in aesthetic areas properly. It has been proven that porcelain veneers are very efficient for treating discolored teeth, and they last for a long time if they bond properly to the tooth structure. Although limiting the preparation to enamel leads to more efficient bonding, the porcelain restoration should be also thick enough to mask the discoloration. However, in treating a deeply discolored tooth, a full coverage crown might be the ultimate option. There are several factors that determine the final aesthetic properties of an all-ceramic restoration in vivo: Color of the ceramic, thickness, the thickness and the color of the luting agent and the color of underlying tooth structure.[1]

From the early 1990s, various leucite-reinforced glass ceramic materials offered anterior single-unit esthetics using either the staining or the cut-back and layering technique. Empress pressed-leucite porcelain was the most esthetic material, but it was typically a weak material when used in the posterior region, especially in the case of a full-coverage restoration. Better esthetics with greater strength was achieved with the development of IPS Empress, although this initially met with disastrous results because of the difficulty in getting the two coefficients to match the thermal expansion coefficient of the layering porcelain made of fluorapatite. In these restorations ceramists stacked layering powder-liquid ceramic, but cracking was a problem.[2]

Lithium disilicate, Empress 2, has been re-introduced as e.max and is available either in a pressable or a CAD-CAM form. This seems to be the ideal material because instead of cutting back the core and laying powder or liquid ceramic on top, the preparation is milled to anatomic form and stained, making this an extremely hard restoration. The whole crown is made up of lithium disilicate, which makes it monolithic rather than a bilayer ceramic, and accounts for its improved strength and esthetics. The lithium disilicate restoration can be bonded to the tooth with resin cement.[2]

Ceramic systems which offer strength typically have a less natural and more opaque appearance as a result of increased crystalline content. The more translucent ceramic systems like lithium disilicate permit greater light transmission through the core material and provide a lifelike appearance. However, the translucency of ceramic materials increases the complexity of color matching, and the final color may easily be affected by the underlying abutment and the shade of luting cement used. Moreover, translucency has been emphasized as one of the primary factors in controlling the esthetic outcome because it makes ceramic restorations appear more natural.[3] As translucency permits the passage of light and also disperses light, it could be described as a state between complete opacity and transparency, the light being diffused rather than reflected or absorbed. Errors in brightness among teeth are considered the most noticeable esthetic error because the human eye is more sensitive to the differences in value (brightness) than hue or chroma. Therefore, the variables between ceramic type, thickness and shade of underlying foundation considered important factors that may play role in solving many esthetic challenges and needs further study. The null hypothesis will be no difference in the optical properties (color change and translucency parameter) between different ceramic thicknesses and different background for both zirconia reinforced glass ceramics and lithium disilicate.

MATERIAL AND METHODS

A slow-speed diamond saw (ISOMET 4000, Buehler Ltd., Lake Bluff, IL) was used under a constant flow of water, which serve as a lubricant and coolant to create fifty six ceramics rectangular plates (14 x 12 mm) from zirconia reinforced glass ceramic plates (Vita Suprinity, Vita Zahnfabrik, Bad Säckingen, Germany), and lithium disilicate glass ceramic (IPS e.max CAD, Ivoclar Vivadent, Schaan, Lichtenstein) (n=28 each group). The plates within each group were divided into two subgroups (n=14) of two different thicknesses 1.0, 1.5 mm during cutting the ceramic plate sample. Each block was firmly hold by special clamp holder to fix the block during the ceramic plate samples preparation. Fig. (1). A digital caliper was used to check that the specimen's thickness having the same thickness of 1.0 and 1.5 mm. Vita Akzent® plus glaze material and finishing agent was applied over Vita Suprinity ceramic plate and crystal glaze material was applied over surface of the IPS e.max CAD ceramic plate for glazing of specimens. A honeycomb tray and IPS object fix (Ivoclar Vivadent, Schaan, Lichtenstein) was used to fix the Vita suprinity plates and IPS e.max CAD plates over the firing tray to avoid contamination of specimen during crystallization. Crystallization and glazing was performed using programat furnace (Ivoclar Vivadent, Schaan, Lichtenstein Programat® EP 3010). Each group of ceramic plates was crystallized and glazed following manufacture instructions.

Fig. (1) Isomet disc used in sectioning ceramic blocks.

For construction of composite samples which represent the background for the ceramic sample plate, a Teflon disc with rectangular central opening of 14 x 12 mm and thickness of 2 mm was constructed. It has an outer holding assembly in form of metal copper ring of 3.1 cm in outer diameter, 2.5 cm in inner diameter and 2 mm thickness fig (2). Fifty six of composite rectangular plates of two shades (A2 and C3) stimulating different tooth backgrounds were constructed using Tetric N-Ceram composite resin. Each composite resin plate has 2 mm thick, and (14 x 12 mm) in dimension. The Teflon mold former was placed over transparent glass slab then composite resin plate was constructed by packing the material inside the rectangular opening of the mold, the surface was then covered with a matrix (#686 Mylar; Hawe Neos Dental, Bioggio, Switzerland) to avoid polymerization inhibition by oxygen. The specimens were covered with another transparent glass slab to obtain a smooth, bubble-free surface, and then polymerized through the transparent glass slab for 40 seconds using a light-polymerizing unit with wavelength range of 420-480 nm and light intensity (1200-2000 mw/cm) LED curing light LY- A180 (Demetron; Demetron Research Corp, Danbury, Conn), the light cure was placed with light emission window close as possible to the surface of the composite plate. Subsequently, the glass slab was removed and the specimens were further cured for another 20 seconds from all sides. The composite specimens were polished with silicone polishers and soflex discs.

Fig. (2) Assembled mold former for background fabrication

After preparation of samples and their backgrounds, spectrophotometer (Agilent Cary 5000 UV-Vis-NIR, Agilent Technologies, USA) was used to measure the color difference after 24 hours with changing the composite (A2, C3) backgrounds. Ceramic specimens with specific thickness was optically connected using drop of distilled water (refraction index close to 1.7) 24 to the A2 background firstly and then to C3 background. The addition of the distilled water was performed to enhance the optical contact during the spectrophotometric measurement, which served to minimize the loss of light through the margins of the specimens (known as edge-loss), with standard light source D65. Each specimen, along with the tested background, was placed in a specimen holder inside a black box, which served to eliminate the impact of external light, the specimen to be measured was placed in the center of the display screen, the spectrophotometric measurement was obtained in means of L* a* & b* for each specimen assembly and ΔE (difference color) was calculated between the all groups, subgroups and divisions using the following equation:

$$\Delta E^* = \sqrt{(L^*a - L^*b)^2 + (a^*a - a^*b)^2 + (b^*a - b^*b)^2}$$

Where ΔE* is color change, a: ceramic only, b: ceramic-background assembly, L*: is a measure of the Lightness of an object, ranging from 0 (Black) to 100 (White), a*: is a measure of of redness ($a > 0$) or greenness ($a < 0$) and b*: is a measure of yellowness ($b > 0$) or blueness ($b < 0$).

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Data were presented as mean, median, standard deviation, minimum, maximum (α=0.05). For parametric data; Three-way Analysis of Variance (ANOVA) was used to study the effect of background color, ceramic type, thickness and their interaction on mean color changes and translucency parameter. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. For non-parametric data; Mann-Whitney U test was used to compare between the two background colors, the two ceramic types as well as the two thicknesses.

RESULTS

Lowest ΔE value among all tested groups obtained with Suprinity at 1.5 mm thickness with A2 composite background, while highest ΔE value among all tested groups obtained with e.max at 1 mm with C3 composite background as shown in (table 1).

The results showed that ceramic type, thickness, and background color had a statistically significant effect on mean ΔE. The interaction between the three variables had no statistically significant effect on mean ΔE. Since the interaction between the variables is non-statistically significant, so thickness eliminates the effect of the background for both Suprinity and E.max. As illustrated in (table 2).

Comparing ceramic types, either with A2 or C3 background colors at 1 as well as 1.5 mm thicknesses; Suprinity showed statistically significantly lower mean ΔE than e.max. Also, comparing thicknesses, either with background color A2 or C3 using Suprinity or e.max; 1 mm thickness showed statistically significantly higher mean ΔE than 1.5 mm thickness. Comparing background colors, either with Suprinity or e.max at 1 as well as 1.5 mm thicknesses; A2 showed statistically significantly lower mean ΔE than C3 as shown in (table 3) and fig. 3.

TABLE (1) Descriptive statistics for ΔE values

Group Ceramic type	Subgroup Thickness	Division Background color	Mean	SD	Median	Minimum	Maximum	95% CI	
								Lower bound	Upper bound
Suprinity (S)	1 mm	S1 A2	4.05	0.40	3.93	3.66	4.64	3.56	4.55
	1.5 mm	S1.5 A2	2.03	0.33	1.99	1.72	2.49	1.63	2.44
e.max (E)	1 mm	E1 A2	6.99	0.56	7.30	6.11	7.44	6.30	7.68
	1.5 mm	E1.5 A2	4.54	0.51	4.62	3.97	5.19	3.90	5.17
Suprinity (S)	1 mm	S1 C3	5.66	0.53	5.47	5.01	6.34	5.01	6.32
	1.5 mm	S1.5 C3	4.50	0.55	4.23	4.07	5.37	3.81	5.18
e.max (E)	1 mm	E1 C3	7.65	0.61	7.74	6.81	8.32	6.89	8.41
	1.5 mm	E1.5 C3	6.10	0.54	6.28	5.50	6.82	5.42	6.78

TABLE (2) Three-way ANOVA analysis for the effect of different variables on mean ΔE

Source of variation	Type III Sum of Squares	df	Mean Square	*F*-value	*P*-value
Background color	24.8	1	24.8	94.8	<0.001*
Ceramic type	50.9	1	50.9	194.8	<0.001*
Thickness	32.3	1	32.3	123.5	<0.001*
Background color x Ceramic type x Thickness interaction	0.002	1	0.002	0.006	0.936

: Significant at P ≤ 0.05

TABLE (3) Three-way ANOVA test for comparison between ΔE of the different interactions

Subgroup / Thickness	Division / Background color	(Group 1) Suprinity Mean	SD	(Group 1) e.max Mean	SD	*P*-value *(Between ceramic types)*
1 mm	A2	4.05	0.40	6.99	0.56	<0.001*
1.5 mm		2.03	0.33	4.54	0.51	<0.001*
P-value *(Between thicknesses)*		<0.001*		<0.001*		
1 mm	C3	5.66	0.53	7.65	0.61	<0.001*
1.5 mm		4.50	0.55	6.10	0.54	0.003*
P-value *(Between thicknesses)*		0.001*		<0.001*		
1 mm	*P*-value *(Between background colors)*	<0.001*		0.049*		
1.5 mm		<0.001*		<0.001*		

: Significant at P ≤ 0.05

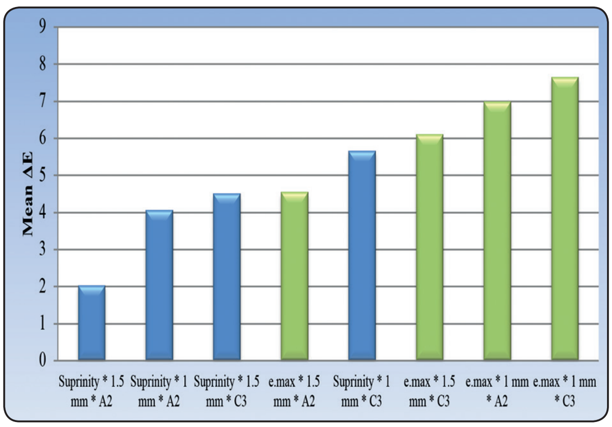

Fig. (3) Bar chart representing ascending mean values for ΔE of the different interactions

DISCUSSION

The data support rejection of the null hypothesis of the study, that there would be no difference in the optical properties between different ceramic thicknesses and different background for both zirconia reinforced glass ceramics and lithium disilicate.

Zirconia reinforced lithium silicate ceramics (Vita Suprinity) used in this study as it is newly developed generation of glass ceramic materials which combines the high strength of zirconia (ZrO_2) and the merits of glass ceramic, the incorporation of zirconia of about 10 % by weight which improve the mechanical properties of the material and result in material with flexural strength of 494.5 MPa while lithium disilicate is 435.0 MPa[4]. Lithium disilicate glass ceramic has lower brittleness index compared to zirconia reinforced lithium silicate ceramic and hence, lithium disilicate glass ceramic have superior machinability. Manufacture assumed that the Vita Suprinity has excellent esthetic properties including high translucency, fluorescence and opalescence, esthetically pleasing results.[5]

The other ceramic material used in this study is IPS e.max CAD which was introduced in 2006 as a lithium disilicate glass ceramic prepared for CAD/CAM use. The material supplied in a "blue state," where it is composed primarily of lithium metasilicate (Li_2SiO_3), which is easier to mill and results in lower bur wear. After the milling process is completed, the material is heat treated and glazed in one step, forming the final lithium disilicate restoration. IPS e.max CAD has been increasingly used over the several years due to its esthetic nature and impressive strength. In this partially crystallized form the material exhibits moderate flexural strength of 130 MPa and fracture toughness at 0.9-1.25 MP A $m^{1/2}$, After tempering the mechanical properties of the material change dramatically The fully crystalized form of IPS e.max CAD has been shown to possess a recorded flexural strength of 262-360 MPa and a fracture toughness of 2.0 - 2.5 MPa.[6]

Both ceramic materials were sectioned into rectangular plates (12 x 14 mm) in dimensions which corresponded to dimension of the material blocks with 2 different thickness 1.0 and 1.5 mm. The thickness of a typical ceramic crown is approximately 1.0 mm at the cervical and gradually increases to 2.0 mm near the incisal edge with average thickness at axial wall 1.5 mm.[7] Both thickness used in this study 1.0 mm, which is the minimal thickness of all ceramic restoration at cervical area and 1.5 which is the average thickness of the ceramic material at the axial walls.

The shade used in this study of either materials Vita Suprinity and IPS e.max CAD is A2 shade, as it is one of the most common tooth shade used, Elamin et al[8] screened the shade of central incisor of 227 patients, their age ranged from 15 to 72 years and found that Shade (A) type represented in 78.5% of the patient, Alrifai and Alharby[9] survey central incisors of 90 person from 3 different ethnic groups (Polish, Saudi Arabian and Taiwanese) and found that one of the most common shades noticed were A2. Background used in this study was made from Tetric N-Ceram composite of 2 different shades A2 and C3 representing light and dark background to stimulate different clinical situations. Two backgrounds under ceramic plates were used to evaluate the effect of background on the final color and the ability of ceramic to mask color of the background, Niu et al[10] stated that the color differences were always above the clinically perceptible level when using 1.0 mm thick glass ceramics, and such differences could not be masked sufficiently by changing the cement shade. Many previous studies demonstrated that the color of underlying substrate structures and cement shade may have minimal influence on the resultant color if the ceramic thickness is 2 mm or more.

In the current study the color difference (ΔE) was measured by instrumental spectrophotometer. Electronic color-measuring devices have the potential to improve the accuracy and reliability of shade selection. Spectrophotometers and colorimeters have integrated standardized illumination and are supposed to be unaffected by the ambient light.[11] Spectrophotometers measure and record the amount of visible radiant energy reflected or transmitted by an object one wavelength at a time for each value, chroma and hue present in the entire visible spectrum. The main components of all spectrophotometers are a source of optical radiation, an optical system for defining the geometric conditions of measurement, some means of dispersing light, a sample (tooth), a detector and a signal processing system that converts light into signals suitable for analysis. Such devices give control over external light conditions and the photo-optical measurement allows quantification of color using CIE Lab co-ordinates.[12]

Vita Suprinity showed statistically significant lower mean ΔE value than IPS e.max CAD, this result proved that Vita Suprinity less affected by the background color and to change in the thickness than IPS e.max CAD, so Vita Suprinity has higher inherent ability to mask the color of underlying structure than IPS e.max CAD. This results is in agreement with Volpato et al[13] who found that the color differences (ΔE) found in the IPS-Empress 2 + Eris ceramic veneering material was smaller than those found in the IPS-Empress system. The optical properties of the samples were affected by the presence of a ceramic material capable of masking the substrate color. Larger and irregular particles are integrated in the ceramic matrix, hindering the transmission of light and favoring light dispersion, which results in a decrease in translucence and an increase of the opacity of the ceramic. For maximum reflection and opacity, the particles should be slightly larger than the incident wavelength and present a refraction level different from the matrix where it is incorporated. The results showed that, at 1.0 mm thickness either Vita suprinity or IPS e.max CAD ceramics showed statistically significant higher mean ΔE than 1.5 mm regardless of the background shade used under the ceramics, this results are in agreements with Chaiyabtur et al[14] which found that the greatest ΔE value were obtained from 1.0 mm thickness ceramic crown, followed 1.5 mm thickness crown, then the lowest ΔE value was obtained from 2.5 mm thickness ceramic crown, so as the ceramic thickness increased, a significant decrease in ΔE value was recorded. Also Turgut and Bagis[15] results showed that the greatest color changes were obtained from 0.5 mm-thick ceramics, whereas 1.0 mm ceramics exhibited smaller color changes. Alqahtani et al[16] results showed that the mean values of ΔE for different ceramic materials used in this study were decreased when the thickness of ceramic increased from 0.5 mm to 0.7 mm, and the differences were significant. Volpato et al[13] found that the influence of the substrates was larger for the smallest thickness (1.5 mm), this could be explained by the smaller amount of particles present, facilitating the light transmission process.

The increased ΔE values among all studies with dark background under glass ceramics could be attributed to the translucency of the ceramic itself as ceramic allow passage of light through it to reach the dark background then reflected through the ceramic affecting the final color, the masking effect of a ceramic material depends on its translucency, which is determined by the material itself and the ceramic thickness.[17] Azer et al[18] is in contradiction with the current study, which showed that there is no clinical significant color difference (ΔE) between four resin core shades and two resin cement shades on the overall resultant color of IPS Empress all ceramic restorations, this disagreement could be attributed to use of different types of glass ceramic used.

CONCLUSIONS

Within the limitations of the current study, the following conclusions can be drawn:

1- Zirconia reinforced lithium silicate ceramics (Vita Suprinity) could decrease the effect of color change of dark background more significantly than lithium disilicate glass ceramic (IPS e.max CAD).

2- Increasing the thickness of both ceramic types could decrease color change with darker background.

3- The more darker the background, the more significant change in final color

4- Zirconia reinforced lithium silicate ceramics (Vita Suprinity) has less translucency than lithium disilicate glass ceramic (IPS e.max CAD) especially with increasing thickness of the samples.

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