INFLUENCE OF COLORING TECHNIQUES AND CEMENT OPACITY ON THE OPTICAL PROPERTIES OF HIGH TRANSLUCENT MONOLITHIC ZIRCONIA

by

Chao-Chieh Yang

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Tien-Min Gabriel Chu

David Brown

Kamolphob Phasuk
Chair of the Research Committee

John A. Levon
Program Director

Date

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INTRODUCTION

Traditional porcelain-fused-to-metal restorations have been considered the gold standard for fixed dental prostheses (FDP). [1, 2] Due to increased esthetic demands, however, all-ceramic crowns were introduced as an alternative option for highly esthetic restoration in an effort to overcome the limitations of metal-ceramic materials. [3,4] Among the all-ceramic materials, the yttria-stabilized tetragonal zirconia polycrystalline ceramic, commonly containing 3-mole% yttria, has been widely accepted as a promising material to restore posterior teeth and multi-unit fixed dental prostheses. [2] The increasing popularity of using 3-mole% yttria-stabilizing zirconia as a restorative material is due to its superior mechanical properties, excellent biocompatibility, reduction of bacterial adhesion, radiopacity, and high esthetic potential.[5–7] Although zirconia appears to be the most suitable all-ceramic material for FDPs, there is still not enough information for the clinician about optical characteristics of high translucent zirconia.

OBJECTIVE

Specifically, the research objectives included investigating the following:

- Evaluate the effect of the coloring liquid on the resulting optical properties of a monolithic high translucent zirconia.
- Compare the effect of the different coloring procedures on the resulting optical properties of a monolithic high translucent zirconia.

- Evaluate the cumulative effect of cement color on the resulting optical properties of a monolithic high translucent zirconia with variation of different brand zirconia blocks.

- Compare the effect of the cement color on the color of monolithic high translucent zirconia with the effect of the cement color on the color of the E-max lithium disilicate ceramics.

STATEMENT OF HYPOTHESIS

- There is no significant difference in optical properties between the high translucent monolithic zirconia ceramics with different color staining techniques.
- The use of various shades of resin cement does not have any effect on the optical properties of high translucent monolithic zirconia ceramics.
- The effect of cement color on the color of high translucent monolithic zirconia is more significant than on the color of lithium disilicate.

ALTERNATIVE HYPOTHESIS

- There is a significant difference in optical properties between the high translucent monolithic zirconia ceramics with different color staining techniques.
- The use of various shades of resin cement has an effect on the final optical properties of high translucent monolithic zirconia ceramics.
- The effect of cement color on the color of high translucent monolithic zirconia is less significant than on the color of lithium disilicate.

REVIEW OF LITERATURE

CLASSIFICATION OF CERAMIC

Ceramic, by definition, is an inorganic, nonmetallic, solid material, composed of metal, nonmetal, or metalloid atoms held in ionic or covalent bond. Most frequently, they are oxides, nitrides, and carbides. Dental ceramics consists of silicate glasses, porcelains, glass ceramics, highly crystalline solids, or the newly introduced resin-matrix ceramics.

When today's clinicians choose a ceramic restoration material for a particular clinical situation, they have to face complex decision processes because of the numerous products available as well as the continuously introduced new products. The selection of the material is not usually based on the evidence provided by the literature or understanding of the material characteristics.[1] A classification system of ceramic is useful, especially when clinicians have to make decisions based upon what type of restoration, location, and cement selection. Several classifications are recommended focusing on the formulation of material, sintering temperature, process method, fracture resistance, fabrication techniques, esthetic appearance, clinical indication and translucency. [1-5]

There are two classification systems, based on microstructure, that are frequently used. Kelly and Benetti et al.[6] proposed a classification system based on glass content, described as follows: (1) predominantly glassy materials, (2) partial-filled glassed and (3) polycrystalline ceramics without glass. Gracis et al.[1] improved the Kelly classification system by adding newly introduced resin-matrix ceramics, coded as "ceramics" by the American Dental Association, classifying ceramic restoration to three families based on

the presence of specific attributes in their formulation, as follows: (1) glass-matrix ceramics (2) polycrystalline ceramics (3) resin-matrix ceramics.

1. Predominantly glassy materials

Feldspathic

The feldspathic ceramic has been common in dentistry for about 100 years.[7] In dentistry, feldspathic ceramic belongs to the amorphous aluminosilicate glasses family, derived primarily from feldspar, and composed of silicon oxide and aluminum oxide. In feldspathic glasses, the amorphous aluminosilicate network is formed by silicon-oxygen-silicon bonds, and is occasionally broken up by large alkali metal ions, such as sodium, or potassium. There are two primary phase fields of potash feldspar leucite found in commercial feldspathic veneering ceramics, which, dependent upon the amount, not only increase the strength of ceramic, but also increase the expansion coefficient to make this porcelain suitable for veneering metal structures. [3-5]

2. Partial-filled glass (leucite, lithium disilicate)

2.1 Leucite content feldspathic glass ceramic.

Glass ceramics have improved properties by introducing crystal structure into the glass matrix. Instead of growing the crystals in the glassy matrix, some ceramic systems mix the crystals with the glassy matrix prior to firing. Leucite crystals are the first filler to be used for the dental ceramic. IPS Empress (Ivoclar Vivadent) is one of the common leucite content feldspathic glass ceramics, and was developed in 1983.[8] It was a heat press precerammed and precolored ceramic, indicated for single unit restorations, inlays and veneers. One of the advantages of this material is the characteristic so-called

dispersion strengthening, in that leucite crystals act as “roadblocks” in preventing crack propagation. In addition, using heat and pressure technique in the casting process overcomes the issue of additional ceramic shrinkage. IPS Empress provides the flexure strength of 126 MPa, with subsequent heat treatments increasing the strength to the 160- to 182-MPa range.[8]

2.2 Lithium disilicate glass ceramics

Lithium disilicate ceramic is a glass ceramic material, introduced initially by Ivoclar Vivadent Inc. as IPS Empress II. This material provides a high flexural strength by increasing the content of lithium disilicate crystals to 70 percent-micron embedded in a glassy matrix. [9] This material is composed of a higher amount of crystal, resulting in a higher flexural strength of 360 MPa, which has better mechanical properties compared to Lucite glass ceramic.[10] Moreover, lithium disilicate crystal owns a low refractive index, which provides the excellent optical property of IPS Empress II. A further development for lithium disilicate restoration is IPS E-max for either press or computer aided design/ computer –assisted manufacture that contents zirconium dioxide that has improved mechanical properties.[1]

Due to higher flexural strength it can be used for inlay, onlay, anterior or posterior crowns, and three unit fixed dental prostheses in the anterior region.[11, 12] There is clinical evidence showing that a lithium disilicate single crown yields an excellent survival rate in short term and long term.[12, 13] However, the evidence shows using lithium disilicate as posterior fixed dental prosthesis the survival rate is still not promising.[14]

2.3 Glass-infiltrated ceramic: alumina, alumina and magnesium, alumina and zirconia

There are three types of ceramics available for glass infiltrated ceramic: alumina-based (Al_2O_3), spinel-based ($MgAlO_4$), and zirconia-toughened alumina (12CeTZP-Al_2O_3). In-Ceram, the first glass infiltrated alumina, was introduced in 1989 by utilizing the slip-casting technique. Al_2O_3 slurry is packed and sintered on a refractory die. A sintered porous Al_2O_3 skeleton is formed and later glass-infiltrated with molten lanthanum glass. [4] The molten glass flows into pores by capillary action and temperature resulting in a interpenetrating networking microstructure, formed by crystalline infrastructure and glass. The In-Ceram Zirconia was introduced as a modification of In-Ceram Alumina, adding partially stabilized zirconia to strengthen the ceramic. In-Ceram Spinel was introduced in 1994, also processed with slip-casting technique. The flexural strength of In-Ceram Zirconia, In-Ceram Alumina and In-Ceram Spinel is around 650 MPa, 600 MPa and 378 MPa respectively. However, the In-Ceram Zirconia and In-Ceram Alumina have high degrees of opacity due to the high refractive index and the porosity of the material. Therefore, the veneered feldspathic ceramic is usually needed to achieve better clinical results.[15, 16]

CEMENT EFFECTS ON ALL CERAMIC RESTORATION

Shade matching in dentistry is critical to the esthetic success of tooth-color restorations. In a 1984 survey, more than one-third of patients did not like their smile because they did not like the tooth color.[17] Ceramic restorations provide various tooth color options, but illuminations, polishing, and the color and opacities of luting cement

may affect the resultant shade of definitive restorations. In addition, increasing the translucency of the ceramic material increases the color effect of luting cement.[18] It has been adequately demonstrated that the shade perceived for lithium disilicate restorations is affected by the color and opacity of the luting cement.[18-20] Giovanni et al[21] found opaque cement, such as zinc phosphate cement, may affect the final color of Lava™ all ceramic restorations. However, there is currently very little information available about the effect of cement color on the final result of monolithic translucent zirconia crown. Thus, understanding how the luting cement opacity affects the resultant colors of full contour zirconia crown is important to the esthetic success of these restorations.

HIGHER TRANSLUCENT ZIRCONIA

Recently, there has been considerable interest in translucent zirconia because of the high potential of combinations of optical and mechanical properties. Higher translucency is required in order to fabricate a more esthetic full contour zirconia crown. Fundamentally, translucency is highly dependent upon the amount of light scattering, absorbing, reflecting and transmitting. [22, 23] The interior reflection and refraction result in an opaque zirconia, and the internal light scattering is the result of including pores, impurities, defects, anisotropic crystal structure, and grain boundaries.[24-26] Therefore, the translucency of zirconia is affected by the sintering process, sinterability of starting powder, sintering atmospheric condition, sintering temperature, the amount and type of additives, particle size of starting powder, grain number and size.[15, 22, 27-31] There are several processing techniques that have been proposed to fabricate more translucent

zirconia including: hot pressing[28], hot isostatic pressing(HIP)[32], spark plasma sintering (SPS)[26, 29, 31, 33, 34], and use of a smaller sintering particle.

Hot isostatic pressing (HIP) has been used to increase the zirconia translucency in early research.[35] In using this technique, the zirconia powders are heat sintered and subjected to pressures simultaneously in order to eliminate pore formation and increase grain size. Therefore, by reducing grain boundaries, this technique improves mechanical and optical properties of zirconia.[34]

The drawback of HIP technique is the larger grain size, which might reduce the translucency of zirconia. In an effort to overcome the problem, SPS has been successfully employed to restrain the grain grow for fabricating fine-grained translucent zirconia.[33]

CHIPPING OF ZIRCONIA VENEER

Traditional 3% yttria-stabilizing zirconia ceramics have poor translucency owing to both the large grain size and the inability to satisfy the esthetic requirement of mimicking natural tooth enamel. [8] In an effort to provide a more esthetic restoration, transitional 3% yttria-stabilizing zirconia is used as the core material (for the single crown) and framework (for multi-unit fixed prostheses), followed by veneering with a more translucent ceramic. Although using the bilayered technique greatly improves esthetic properties of the zirconia restoration, the difficulty of matching mechanical properties and behavior of the two different bilayered materials has been reported to be a critical issue for clinical use. The majority of clinical trials and systemic reviews showed a high incidence of esthetic ceramic veneer chipping for bilayered zirconia restorations. [36-39] Numerous explanations for veneer chipping have been proposed, including: (1)

residual stress from coefficient of thermal expansion mismatch,[40, 41] (2) grain transformation at interface during porcelain firing,[42] (3) rough surface combined with low temperature degradation,[43] and (4) inadequate cooling rate.[44]

COLORING OF ZIRCONIA

Two main techniques for coloring zirconia are available. One technique utilizes metal oxide mixed with the staining Y-TZP powder before sintering, and provides pre-colored zirconia blocks. The other way to color zirconia is infiltrating the partially-sintered zirconia block with chloride solutions of rare earth elements before final sintering to produce the human tooth shade.[45, 46] It is currently more popular to use the coloring liquid to fabricate a more esthetic restoration. However, there is no standardization of coloring techniques regarding color, translucency, and opalescence parameters of monolithic zirconia restorations. Research shows that altering the number of layers of coloring liquid, or using different liquid, affects the value and creates the color differences in the final zirconia restoration. [47-49] There is no current research testing the effect of coloring techniques on optical properties of high translucence zirconia. When coloring zirconia with liquid, there are two ways to apply the coloring liquid; one is submerging zirconia into the coloring liquid, and the other is using the brush to paint the coloring liquid on the surface of zirconia. Ahangari et al.[50] reported that both the submerging and painting techniques have an influence on the value of all ceramic crowns, and the submerging technique is better in reproducing a value closer to natural teeth. Kim et al.[47] found that increasing the number of coloring liquid applications reduced the lightness and opalescence of monolithic zirconia, making it more yellowish, but did not

affect the translucency. In previous studies[47], the sample thickness was 2 mm, which is not clinically relevant, and the traditional zirconia, which has a lower translucency, was used as the testing samples.

COLOR MEASUREMENT

In general, there are two ways to match the color, including the visual shade matching and color measurement instrument, which provides the numerical color data. It has been well studied that visual shade matching is subjective and affected by many factors.[51, 52] In general, there are two ways to match the color, including the visual shade matching and color measurement instruments which provide the numerical color data. Studies have adequately demonstrated that visual shade matching is subjective, and affected by many factors.[51, 52] Furthermore, the color measurement instruments provide a more objective and consistent color match.[53 54]

Spectrophotometers are most widely used for measuring color in dental research. This instrument is designed to measure spectral reflectance and express it in terms of three coordinate values (CIE L*, a*, b*), which provide a numerical description of the object's color within three-dimensional color space. The L* coordinate represents the lightness of an object, ranging from 0 to 100. The a* value represents the redness on the positive axis, or greenness on the negative axis, ranging from -90 to 70. The b* value represents the yellowness on the positive axis, or blueness on the negative axis, ranging from -80 to 100. Then the color difference Δ E between two specimens can be measured by comparing the differences of respective coordinate values (CIE L*, a*, b*) of each specimen.

The Δ E is used as a standard quantitative assessment for many shade matching research studies.[55-57] Ruyter et al.[57] reported that Δ E less than 3.3 is clinically acceptable. Douglas et al.[55] found that the predicted difference at which 50% of dentists could perceive a color difference (50/50 perceptibility) was 2.6 ΔE units, while the predicted difference at which 50% of the restorations would be remade due to color mismatch (clinically unacceptable color match) was 5.5 ΔE. The Δ E was in this study to evaluate the effect of the opacity of the cement on the final monolithic high translucent zirconia restoration.

METHODS AND MATERIALS

PART I CEMENT EFFECT TEST

SPECIMEN PREPARATION

Two types of high zirconia products were assessed in this study. (Table I). Lava Plus (3M™/ ESPE™, Maplewood, Minnesota, U.S.) and BruxZir Anterior 250 (Prismatik Dentalcraft Inc, Irvine, California, U.S.) were used as high translucence zirconia materials. 42 disc-shaped zirconia specimens were prepared with 12 mm (length) × 12 mm (width) from CAD/CAM material block using a cutting machine (Isomet 1000, Buehler, Illinois, USA)(Figure 1). The zirconia specimens were cut to account for the shrinkage factor of about 25% to achieve final thicknesses of 1mm. All the zirconia specimens were finished by using rotary silicon carbide papers with 300 rpm for 30 seconds at 400, 600, and 800 grits under water lubrication. After finishing, the zirconia specimens were submerged into A2 coloring liquid Zirconia Dyeing Liquid(3M™ ESPE™ Lava Plus High Translucency) for two minutes following the manufacturer's instructions. Then, all zirconia specimens were sintered using a furnace (Blue M, SPX Corp., PA) (Figure 2) following the manufacturers' instructions for each material (Table II) without glazing afterward. One type of lithium disilicate, E-max CAD (Ivoclar Vivadent, Schaan, Liechtenstein), was assessed in this study. 21 disc-shaped E-max specimens (Figure 3) were prepared with size 12 mm (length) × 12 mm (width) × 1 mm(thickness) from the E-max CAD (Ivoclar Vivadent, Schaan, Liechtenstein) ingots

(LT A2/ B32) using a cutting machine (Isomet 1000, Buehler, Illinois, USA). The lithium disilicate

specimens were finished by using rotary silicon carbide papers with 300 rpm for 30 seconds at 400, 600 and 800 grits under water lubrication. Then, lithium disilicate disks were sintered in a Programat CS furnace (Ivoclar Vivadent, Ontario, Canada) (Figure 4) according to manufacturer's recommendations (Table III) without glazing. All sintered specimens were then polished to achieve a final specimen thickness of 1 mm by using rotary silicon carbide papers with 300 rpm for 30 seconds at 800 and 1000 grit under water lubrication for 30 seconds on both sides before testing. The thickness of the specimens was measured and re-verified with a digital caliper (Mitutoyo Corp, Tokyo, Japan). All the specimens were further divided into three subgroups. Subgroup one was assembled with clear resin cement (PanV5, Kuraray Noritake Dental) and the foundation block; subgroup two was assembled with A2 resin cement (PanV5, Kuraray Noritake Dental) and the foundation block; subgroup three was assembled with the opaque resin cement (PanV5, Kuraray Noritake Dental) and the foundation block. There were seven specimens of each type of ceramic and cement color as displayed in the diagram below. The foundation blocks were made with light-polymerized materials in shade ND4, simulating the shade of the prepared tooth (IPS Natural Die Material Guide; Ivoclar Vivadent AG). The foundation blocks were prepared in size 12X12X5 mm, and polished using silicon carbide papers at 400, 600, 800, and 1000 grit for 30 seconds under water lubrication. Polished resin block was roughened with 200 grit silicon carbide papers, rinsed with ethanol, and air-dried.

CEMENTATION OF SPECIMENS

The cement layers were bonded to the roughened surface of the resin foundation block. Cement thicknesses of 100 μm was controlled by pressing between the surfaces of a cover glass and foundation block with the flat end of a micrometer after loading the mixed cement onto the foundation block. Then the cement was completely polymerized with a photo-polymerizing machine (Optilux 501; Kerr Corp) over the glass pad for 90 seconds, leaving the cement to set for 3 minutes. The power of the light polymerizing machine was verified by L.E.D radiometer. The intensity of visible polymerizing light was controlled on 900 mW/cm^2. The photo-polymerizing machine was calibrated before use. The cover glass then was carefully separated from the cement, leaving the cement intact on the foundation block. The thickness of the cement-resin block assemblies was re-verified with a digital caliper (Mitutoyo Corp, Tokyo, Japan), rinsed with ethanol and air-dried before test. The ceramic specimen was then optically connected to the cement layer without actual bonding to the ceramic surface. Color measurements were performed by positioning the flat surface of a spectrophotometer (CM-2600D, Konica Minolta Sensing Americas, Inc., Ramsey, NJ) (Figure 5) against the center of the flat ceramic surface of each specimen assembly with a black background (figure 6).

COLOR DIFFERENCE MEASUREMENTS

The color space by CIE-L*a*b*of all specimen assemblies was measured by a spectrophotometer (CM-2600D, Konica Minolta Sensing Americas, Inc., Ramsey, NJ) The standard of the device was controlled at a 10-degree observer angle, a 100-percent UV, and a standard illuminant D65 with wavelength range between 360 nm to 740 nm.

The spectrophotometer was calibrated before each measurement session with a white reflectance standard plate (figure7) at 23°C. The CIE-L*a*b* color space from each color measurement was calculated and recorded in terms of the three CIE coordinate values (L*, a*, b*). The color differences (Δ E) between two specimens that have color expressed in L*, a*, and b* was measured by comparing the control group Vita classic shade guide (VITA Zahnfabrik, Bäckingen, Germany) with the cemented groups (figure 8 and figure 9).

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

Where, L* refers to lightness, a* refers to redness/greenness and b* refers to yellowness/blueness. Subscribe n refers non-colored specimens and Subscribe c refers to colored specimens.

PART II COLORING TECHNIQUES TEST

SPECIMEN PREPARATION

Lava Plus high translucent zirconia (3M™/ ESPE™, Maplewood, Minnesota, U.S.) was used in this part of study. 35 disc-shaped ceramic specimens (figure 10) were prepared with 12 mm (length) × 12 mm (width) from CAD/CAM material block using a cutting machine (Isomet 1000, Buehler, Illinois, USA). The specimens were cut to account for the shrinkage factor of about 25% to achieve a final thickness of 1mm. All the specimens were finished using rotary silicon carbide papers with 300 rpm for 30 seconds at 400, 600, and 800 grits under water lubrication on both sides. All the specimens were randomly divided into five groups. Group one specimens

remained uncolored as the control group. Group two specimens were submerged into A2 Zirconia Dyeing Liquid (3M™ ESPE™ Lava Plus High Translucency) for two minutes following the manufacturer's instruction (figure 11). In group three, instead of submerging the specimens in the coloring liquid, the A2 coloring liquid was applied on the outer surface of the specimens by a #3 round brush. Two layers of coloring liquid were applied on both sides of group three specimens. In group four the coloring liquid was applied in two layers on one side and four layers on the other side. In group five, the coloring liquid was applied in two layers on one side and six layers on the other side. There were 7 specimens in each group as displayed in the diagram below (figure 10). Then, all specimens were sintered using a furnace (Blue M, SPX Corp., PA, USA) following the manufacturer's instructions (Table III) without glazing afterward (figure 12). The sintered specimens were then polished to achieve a final specimen thickness of 1mm by using rotary silicon carbide papers with 300 rpm for 30 seconds at 800 and 1000 grit under water lubrication on both sides before testing. The thickness of the specimens was measured and re-verified with a digital caliper (Mitutoyo Corp, Tokyo, Japan). The values of CIE L*, a*, b* of all specimens were measured by spectrophotometer (CM-2600D, Konica Minolta Sensing Americas, Inc., Ramsey, NJ).

COLOR DIFFERENCE MEASUREMENTS

The color space by CIE-L*a*b*of all specimen assemblies was measured by a spectrophotometer (CM-2600D, Konica Minolta Sensing Americas, Inc., Ramsey, NJ). The standard of the device was controlled at a 10-degree observer angle, a 100-percent UV, and a standard illuminant D65 with wavelength range between 360 nm to 740 nm. Before each session of the measurement, the spectrophotometer was calibrated with a

white reflectance standard plate at 23°C. The CIE-L*a*b* color space from each color measurement was calculated and recorded in terms of the three CIE coordinate values (L*, a*, b*). The Δ E was measured between vita shade pad and zirconia samples. Determination of Δ E will be based on the following equations: 20ΔE(L*a*b*)=√((L*n-L*c)^2 +(a*n-a*c)^2 +(b*n-b*c)^2)

Where, L* refers to lightness, a* refers to redness/greenness, and b* refers to yellowness/blueness. Subscribe n refers non-colored specimens, and subscribe c refers to colored specimens.

TRANSLUCENT PARAMETER MEASUREMENT

The spectral reflectance of all specimens was measured by a spectrophotometer (CM-2600D, Konica Minolta Sensing Americas, Inc., Ramsey, NJ) against a white and black background. The translucency parameter developed by Johnson et al.[58] was used. This parameter is calculated from the differences between the color reflectance data of the white and black in visible range 380-780 nm, according to the following equation:

TP=√((L*B-L*W)^2 +(a*B-a*W)^2 +(b*B-b*W)^2)

Where, L* refers to lightness, a* refers to redness/greenness, and b* refers to yellowness/blueness. Subscribe B refers to color coordination under black background, and subscribe W refers to color coordination under white background.

OPALESCENCE PARAMETER MEASUREMENT

Spectral transmittance of all specimens was measured by a spectrophotometer (CM-2600D, Konica Minolta Sensing Americas, Inc., Ramsey, NJ). The opalescence

parameter, typically used to determine the opalescence of esthetic materials, was used in the study. [34,35] This parameter is calculated from the differences between the color transmitted data and the reflected color against a black background, according to the following equation: $OP=\sqrt{((a^*T-a^*R)^2+(b^*T-b^*R)^2)}$

Where, L* refers to lightness, a* refers to redness/greenness, and b* refers to yellowness/blueness Subscribe T refers to transmitted color, and R refers to reflected color.

STATISTICS METHODS

The Δ E, translucent parameter, and opalescence parameter were used for the coloring technique test to compare between non-color samples and colored zirconia samples. Comparisons between coloring techniques was performed using one-way ANOVA, followed by pair-wise group comparisons using Fisher's Protected Least Significant Differences. For cement effect test; the Δ E compared between the vita shade guide and the cemented zirconia sample. Comparisons between materials and between cement shades was performed using one-way ANOVA, followed by pair-wise group comparisons using Fisher's Protected Least Significant Differences. The distributions of the data was examined, and a transformation of the data (e.g. natural logarithm) or nonparametric was used in place of the ANOVA when necessary. A 5% significance level was used for all tests. With a sample size of seven specimens per treatment combination, the study has an 80% likelihood to detect a Δ E difference between groups of 2.5, assuming two-sided tests each conducted at a 5% significance level, and a within-group standard deviation of 1.5.

RESULTS

RESULTS OF CEMENT EFFECT ON CIE LAB VALUE

Results for CIE Lab value and delta E

The L* value, a* value, b* value and delta E for each group are listed in Tables IV to Table VII(c).

In L* value (SCI data), Lava- Plus zirconia showed the greatest L* value 115.262 (1.28) ranging from 114.71 to 115.26, while BruxZir shows the smallest value of 80.922 (0.919) ranging from 80.92 to 84.49. The L* value of E-max CAD ranged from only the SCI data were evaluated in this study because the SCE data is affected by the high level of scattering due to surface roughness. For E-max CAD and BruxZir, the L* value was significantly different among the cement groups ($p<0.0001$) (figure 13). For E-max CAD and BruxZir, the L* value of the opaque group was significantly higher than both the A2 cement group and the clear cement group (both $p<0.00001$). There was no significant difference for Lava-Plus among different cement groups in L* value ($P=0.4082$)

In a* value, Lava-Plus zirconia assemblies with clear cement showed the lowest mean a* value of 0.104(0.19), ranging from 0.10 to 0.13, while E-max CAD assemblies with A2 cement demonstrated the highest a* value of 0.71(0.225) ranging from 0.31 to 0.71. The a* value of BruxZir ranged from 0.56 to 0.63. For E-max CAD, the a* value differed significantly among the cement groups ($p<0.0001$), and the a* value of the opaque group was significantly higher than both A2 cement and clear cement (both

p<0.00001). There was no significant difference for Lava and BruxZir among cement groups in a* value (p=0.8631, 0.736 respectively) (figure 14).

In the b* value, Lava zirconia assemblies with clear cement showed the lowest mean b* value of -0.02 (1.02), ranging from -0.02 to 0.29, while E-max CAD assemblies with opaque cement showed the highest mean b* value of 13.797 (0.785), ranging from 8.71 to 13.8. The a* value of BruxZir ranged from 7.16 to 10.32. There was significant difference for E-max CAD and BruxZir among the cement groups in b* value (p<0.0001), and the opaque group was significantly higher than both A2 and clear cements in b* value (both p<0.0001). For Lava, b* value was not significantly different among cements (p=0.6481) (figure 15).

When comparing the delta E between the samples and Vita shade guide A2, the lowest **Δ** E 1.461 was observed in the E-max CAD assemblies with A2 cement. For E-max, **Δ** E was significant among the cements (p<0.0001), and the opaque group was significantly higher than both A2 and clear (Both p<0.0001). In BruxZir, Δ E varied significantly among the cements (p<0.0001). In contrast with E-max CAD, BruxZir-opaque assemblies were significantly lower than both A2 and clear cement groups (both p<0.0001). For Lava, Δ E did not differ significantly among different cement groups (p=0.5748) (figure16).

When the Δ E between each cement shade group was compared, it was found that E-max CAD shows the highest color variation between A2 cement assemblies and opaque cement assemblies with Δ E 8.86. The BruxZir groups demonstrated the lowest color differentiation between A2 cement assemblies and clear cement assemblies.

RESULTS OF STAINING EFFECTS ON CIE LAB VALUE

Results for CIE Lab value and Δ E are list in Tables VIII, VIII(a), (b), (c)and (d).

The L* value, a* value, b* value and Δ E for each group are listed in Table VIII.

The L* value of Lava zirconia increased with an increased number of staining liquid applications. The six-layered group showed the lowest mean L* value of 106.457 (0.685). The submerged group showed higher L* values than the painting groups. L* was significantly different among groups ($p<0.0001$) (figure 17). All painting groups were significantly lower than the no stain and the submerged group. All paired comparisons had $p<0.0001$.

The a* value of Lava zirconia increased with an increased number of staining liquid applications. The six-layered group resulted in the highest mean a*value of 1.05 (0.112), and the a* value was significantly different among groups ($p<0.0001$) (figure 18). The submerged group showed significantly lower a* values than the painting groups ($p<0.0001$).

The b* value of Lava zirconia increased with increased applications of staining liquid. The six-layered group resulted in the highest mean b* value of 7.133 (0.966). The submerged group resulted in significantly higher b* values than all painting groups ($p<0.0001$) (figure 19).

With more layers of staining liquid applications, the Δ E value decreased. The six-layered group showed the lowest mean Δ E value of 22 (0.78) (figure 20). Δ E varied among the different groups ($p<0.0001$). The submerges group showed higher Δ E than all painting groups.

Results for Translucent parameter and Opalescence parameter

The translucency parameter of the submerged group showed the highest value of 0.88 (0.81), while the two- layered group showed the lowest value of 0.309 (0.356). The translucent parameter did not differ significantly among groups (p=0.3619).

TABLES AND FIGURES

TABLE I

Materials used in this study

Materials	**Description**	**Manufacturer**
IPS E-max CAD LT A2/ B32	High translucent glass ceramic	**Ivoclar Vivadent, Schann, Liechtenstein,**
Lava™ Plus	High translucent zirconia	3M™/ ESPE™, Maplewood, Minnesota, U.S.
BruxZir Anterior 250 A2	High translucent zirconia	Prismatik Dentalcraft Inc, Irvine, California, U.S.
Lava™ Plus High Translucency Zirconia Dyeing Liquid	Dyeing liquid for high translucent zirconia	3M™ ESPE™, Maplewood, Minnesota, U.S.
Panavia V5	Dual cure resin cement	Kuraray Noritake Dental, Tokyo, Japan
IPS Natural Die Material	Light-curing shaded die material	Ivoclar Vivadent, Schann Liechtenstein,

TABLE II

The sintering cycle in degree Celsius for the other Zirconia

Lava Plus	**BruxZir Anterior**
2 h in open, cold furnace or at room temperature	2 h in open, cold furnace or at room temperature
20 °C/min to 800 °C	15°C/min to 1200oC
10 °C/min to 1450 °C	60 minutes at 1200°C
120 min at 1450 °C	2°C/min to 1300°C
Cooling rate 15 °C/min to 800 °C	10°C/min to 1530°C
Cooling rate 20 °C/min to 250 °C	150 minutes at 1530°C
	Cooling Rate 15°C/min to room temperature

TABLE III

The sintering cycle in degree Celsius for IPS E-max CAD

Stand by temp	Closing time (mm:ss)	Temperature increase	Holding temp. (°C)	Holding time (mm:ss)	Vaccum on temp (°C).	Vacuum off temp (°C)	Long-term cooling (°C)
403	06:00	90/30	820/840	00:10/07:00	550/820	820/840	700

TABLE IV

The mean, standard deviation, minimum and maximum for E-max group

group	Variable	N	Mean	Std Dev	Minimum	Maximum
A2	L	21	85.17	0.53	84.02	86.38
	a	21	0.71	0.23	0.23	1.16
	b	21	8.82	0.55	6.89	9.42
	ΔE	21	1.46	0.61	0.69	3.57
clear	L	21	85.31	0.55	83.91	86.68
	a	21	0.67	0.16	0.30	0.94
	b	21	8.72	0.54	6.84	9.37
	ΔE	21	1.61	0.58	1.04	3.71
opaque	L	21	92.43	1.16	91.47	97.14
	a	21	0.31	0.40	-1.31	0.67
	b	21	13.80	0.78	12.15	14.98
	ΔE	21	8.89	1.09	7.75	13.04

TABLE V

The one-way ANOVA statistical analysis of L* value of E-max group

Effect	Result	Estimate	StdErr	Probt	Sig
group	A2 & clear n.s.	-0.1400	0.2474	0.5735	
group	A2 < opaque	-7.2657	0.2474	<.0001	*
group	clear < opaque	-7.1257	0.2474	<.0001	*

TABLE V(a)

The one-way ANOVA statistical analysis of a* value of E-max group

Effect	Result	Estimate	StdErr	Probt	Sig
group	A2 & clear n.s.	0.04333	0.08630	0.6174	
group	A2 > opaque	0.4033	0.08630	<.0001	*
group	clear > opaque	0.3600	0.08630	<.0001	*

TABLE V(b)

The one-way ANOVA statistical analysis of b* value of E-max group

Effect	Result	Estimate	StdErr	Probt	Sig
group	A2 & clear n.s.	0.1005	0.1965	0.6110	
group	A2 < opaque	-4.9771	0.1965	<.0001	*
group	clear < opaque	-5.0776	0.1965	<.0001	*

TABLE V(c)

The one-way ANOVA statistical analysis of ΔE of E-max group

Effect	Result	Estimate	StdErr	Probt	Sig
group	A2 & clear n.s.	-0.1509	0.2451	0.5404	
group	A2 < opaque	-7.4284	0.2451	<.0001	*
group	clear < opaque	-7.2775	0.2451	<.0001	*

TABLE VI

The mean, standard deviation, minimum and maximum for Lava group

group	Variable	N	Mean	Std Dev	Minimum	Maximum
A2	L	21	114.71	1.67	111.50	117.10
	a	21	0.12	0.18	-0.19	0.47
	b	21	-0.02	1.03	-2.11	2.23
	del_E	21	31.68	1.80	28.22	34.41
clear	L	21	115.26	1.28	112.60	117.20
	a	21	0.10	0.20	-0.29	0.51
	b	21	0.29	1.09	-1.10	2.35
	del_E	21	32.11	1.31	28.96	34.16
opaque	L	21	115.18	1.27	112.40	117.20
	a	21	0.13	0.18	-0.16	0.43
	b	21	0.14	1.03	-2.26	1.92
	del_E	21	32.08	1.31	28.88	34.74

TABLE VII

The mean, standard deviation, minimum and maximum for BruxZir group

group	Variable	N	Mean	Std Dev	Minimum	Maximum
A2	L	21	80.92	0.92	78.67	82.24
	a	21	0.62	0.20	0.24	0.93
	b	21	7.16	0.65	6.16	8.49
	del_E	21	4.74	0.60	3.80	6.15
clear	L	21	81.11	0.97	78.83	83.00
	a	21	0.56	0.19	0.30	0.97
	b	21	7.17	0.55	6.46	8.81
	del_E	21	4.60	0.61	3.48	6.13
opaque	L	21	84.49	0.88	82.98	86.29
	a	21	0.58	0.36	0.15	1.53
	b	21	10.32	1.21	9.19	15.24
	del_E	21	1.58	0.98	0.51	5.53

TABLE VII(a)

The one-way ANOVA statistical analysis of L* value of BruxZir group

Effect	Result	Estimate	StdErr	Probt	Sig
group	A2 & clear n.s.	-0.1857	0.2848	0.5168	
group	A2 < opaque	-3.5700	0.2848	<.0001	*
group	clear < opaque	-3.3843	0.2848	<.0001	*

TABLE VII(b)

The one-way ANOVA statistical analysis of b* value of BruxZir group

Effect	Result	Estimate	StdErr	Probt	Sig
group	A2 & clear n.s.	-0.01143	0.2640	0.9656	
group	A2 < opaque	-3.1552	0.2640	<.0001	*
group	clear < opaque	-3.1438	0.2640	<.0001	*

TABLE VII(c)

The one-way ANOVA statistical analysis of Δ E of Lava group

Effect	Result	Estimate	StdErr	Probt	Sig
group	A2 & clear n.s.	0.1437	0.2320	0.5381	
group	A2 > opaque	3.1641	0.2320	<.0001	*
group	clear > opaque	3.0204	0.2320	<.0001	*

TABLE VIII

The mean, standard deviation, minimum and maximum for Part II experiment

Group	Variable	N	Mean	Std Dev	Minimum	Maximum
2x2	Translucent	7	0.31	0.36	0.11	1.10
	Opalescence	7	0.70	0.19	0.43	0.91
	L	7	111.13	0.55	110.50	111.80
	a	7	0.33	0.14	0.15	0.53
	b	7	4.61	0.50	3.79	5.47
	ΔE	7	27.12	0.57	26.29	27.81
2x4	Translucent	7	0.38	0.43	0.03	1.21
	Opalescence	7	0.70	0.21	0.46	0.90
	L	7	108.54	0.50	107.60	109.00
	a	7	0.88	0.11	0.71	1.02
	b	7	5.39	0.50	4.69	5.99
	ΔE	7	24.30	0.24	23.97	24.69
2x6	Translucent	7	0.55	0.75	0.08	2.21
	Opalescence	7	0.79	0.16	0.56	1.11
	L	7	106.46	0.69	105.50	107.30
	a	7	1.05	0.11	0.84	1.20
	b	7	7.13	0.97	6.11	8.69
	ΔE	7	21.62	0.68	20.78	22.83
no stain	Translucent	7	0.46	0.05	0.41	0.53
	Opalescence	7	0.25	0.09	0.13	0.36
	L	7	118.04	0.20	117.70	118.30
	a	7	-0.43	0.11	-0.60	-0.31
	b	7	-4.36	0.52	-5.15	-3.65
	ΔE	7	36.13	0.29	35.74	36.50
Submerge	Translucent	7	0.88	0.81	0.16	2.50
	Opalescence	7	0.61	0.28	0.15	0.96
	L	7	113.46	0.96	111.60	114.40
	a	7	0.26	0.18	0.06	0.56
	b	7	0.57	0.59	-0.08	1.43
	ΔE	7	30.11	0.96	28.57	31.51

TABLE VIII(a)

The one-way ANOVA statistical analysis of L* value of Part II experiment

Effect	Result	Estimate	StdErr	Probt	Sig
group	2x2 > 2x4	2.5857	0.3353	<.0001	*
group	2x2 > 2x6	4.6714	0.3353	<.0001	*
group	2x2 < no stain	-6.9143	0.3353	<.0001	*
group	2x2 < submerge	-2.3286	0.3353	<.0001	*
group	2x4 > 2x6	2.0857	0.3353	<.0001	*
group	2x4 < no stain	-9.5000	0.3353	<.0001	*
group	2x4 < submerge	-4.9143	0.3353	<.0001	*
group	2x6 < no stain	-11.5857	0.3353	<.0001	*
group	2x6 < submerge	-7.0000	0.3353	<.0001	*
group	no stain > submerge	4.5857	0.3353	<.0001	*

TABLE VII(b)

The one-way ANOVA statistical analysis of a* value of Part II experiment

Effect	Result	Estimate	StdErr	Probt	Sig
group	2x2 < 2x4	-0.5471	0.07112	<.0001	*
group	2x2 < 2x6	-0.7186	0.07112	<.0001	*
group	2x2 > no stain	0.7571	0.07112	<.0001	*
group	2x2 & submerge n.s.	0.07429	0.07112	0.3046	
group	2x4 < 2x6	-0.1714	0.07112	0.0223	*
group	2x4 > no stain	1.3043	0.07112	<.0001	*
group	2x4 > submerge	0.6214	0.07112	<.0001	*
group	2x6 > no stain	1.4757	0.07112	<.0001	*
group	2x6 > submerge	0.7929	0.07112	<.0001	*
group	no stain < submerge	-0.6829	0.07112	<.0001	*

TABLE VIII(c)

The one-way ANOVA statistical analysis of b* value of Part II experiment

Effect	Result	Estimate	StdErr	Probt	Sig
group	2x2 < 2x4	-0.7857	0.3428	0.0291	*
group	2x2 < 2x6	-2.5243	0.3428	<.0001	*
group	2x2 > no stain	8.9643	0.3428	<.0001	*
group	2x2 > submerge	4.0371	0.3428	<.0001	*
group	2x4 < 2x6	-1.7386	0.3428	<.0001	*
group	2x4 > no stain	9.7500	0.3428	<.0001	*
group	2x4 > submerge	4.8229	0.3428	<.0001	*
group	2x6 > no stain	11.4886	0.3428	<.0001	*
group	2x6 > submerge	6.5614	0.3428	<.0001	*
group	No stain < submerge	-4.9271	0.3428	<.0001	*

TABLE VIII(d)

The one-way ANOVA statistical analysis of Δ E value of Part II experiment

Effect	Result	Estimate	StdErr	Probt	Sig
group	2x2 > 2x4	2.7286	0.2912	<.0001	*
group	2x2 > 2x6	5.1143	0.2912	<.0001	*
group	2x2 < no stain	-6.4714	0.2912	<.0001	*
group	2x2 < submerge	-2.1286	0.2912	<.0001	*
group	2x4 > 2x6	2.3857	0.2912	<.0001	*
group	2x4 < no stain	-9.2000	0.2912	<.0001	*
group	2x4 < submerge	-4.8571	0.2912	<.0001	*
group	2x6 < no stain	-11.5857	0.2912	<.0001	*
group	2x6 < submerge	-7.2429	0.2912	<.0001	*
group	no stain > submerge	4.3429	0.2912	<.0001	*

FIGURE 1. Isomet 1000, a cutting machine.

FIGURE 2. Blue M for zirconia sintering.

Part I Cement Effect Test

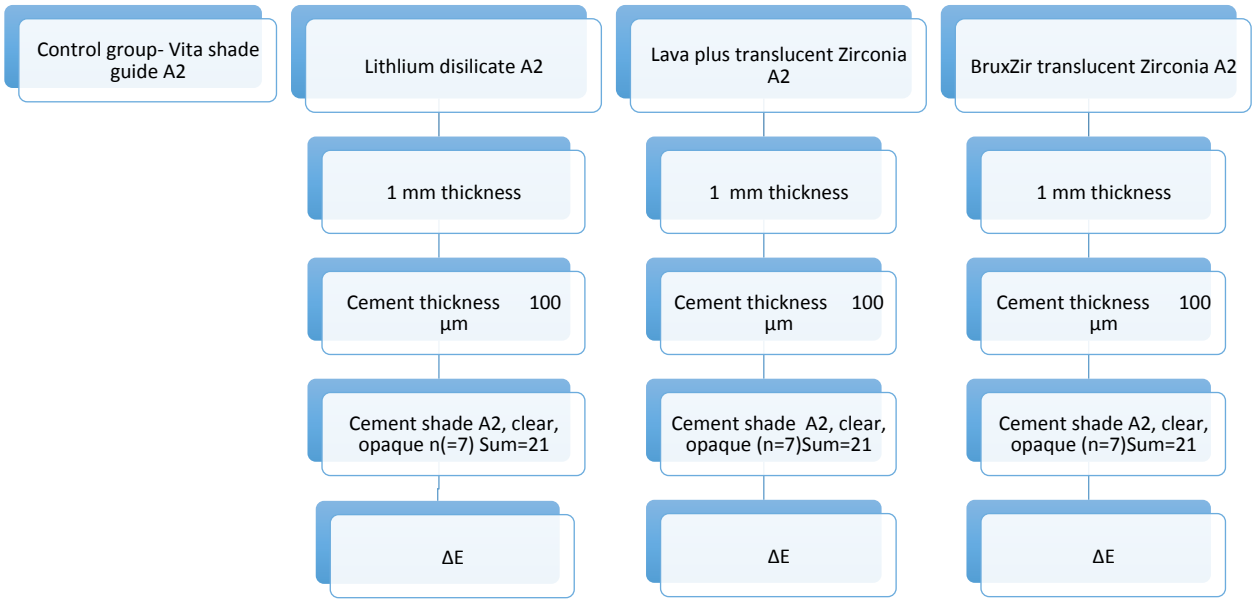

FIGURE 3. Diagram of the number of specimens Part I.

FIGURE 4. Programmat S1 for IPS E-max CAD sintering.

FIGURE 5. CM-2600 D, a spectrophotometer, used to evaluate light reflectance.

FIGRUE 6. Black background for translucency parameter testing.

FIGURE 7. White background for translucency parameter testing.

FIGURE 8. Foundation blocks with cement.

FIGURE 9. Specimens for experiment part I, before sinter and after sinter **Part II**

Coloring Technique Test

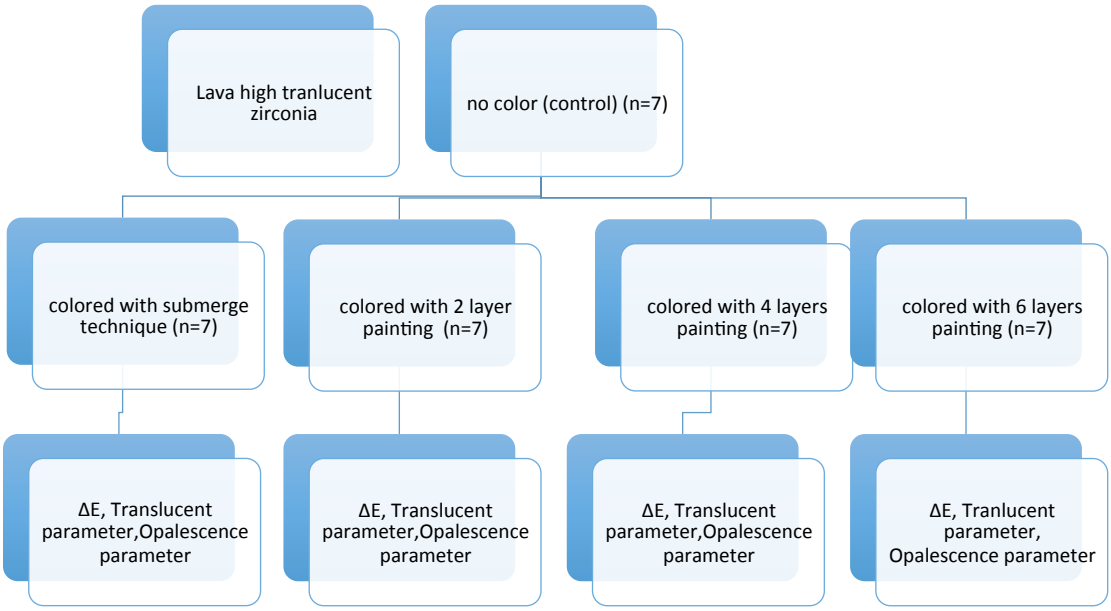

FIGURE 10. Diagram of the number of specimens Part II.

FIGURE 11. Submerge Coloring technique.

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FIGURE 12. Specimens for experiment part II.

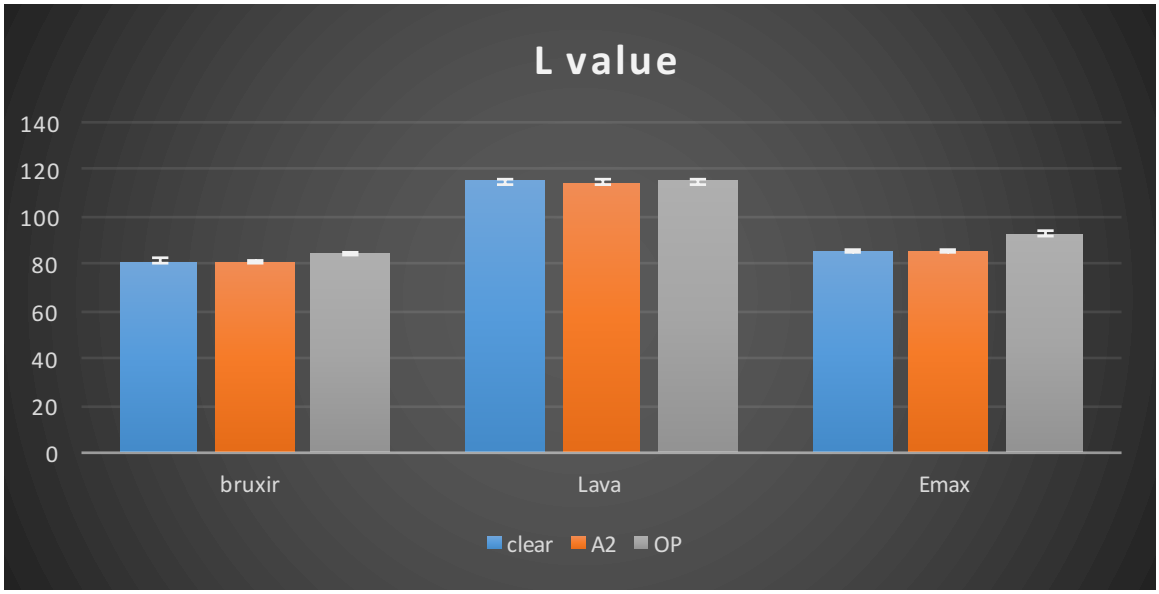

FIGURE 13. The L* value of Part I experiment specimens.

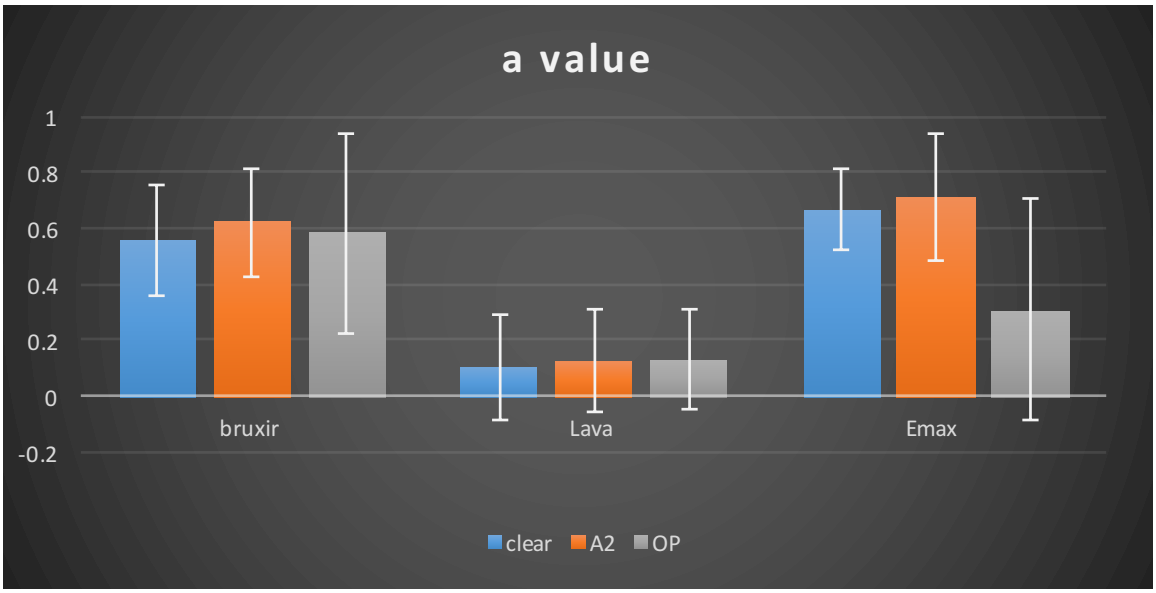

FIGURE 14. The a* value of Part I experiment specimens.

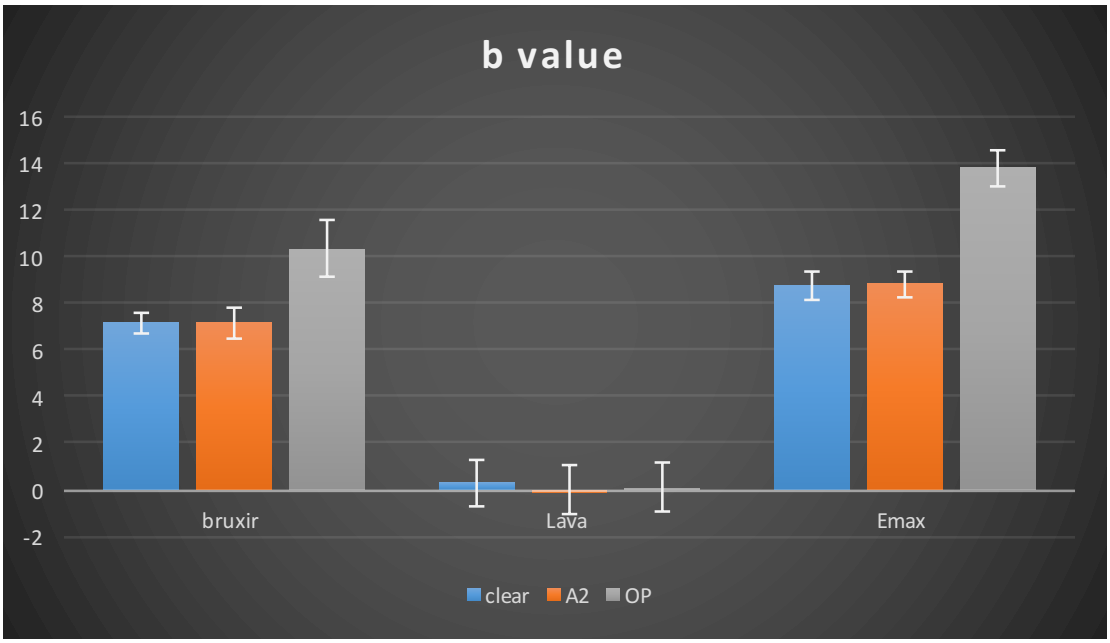

FIGURE 15. The b* value of Part I experiment specimens.

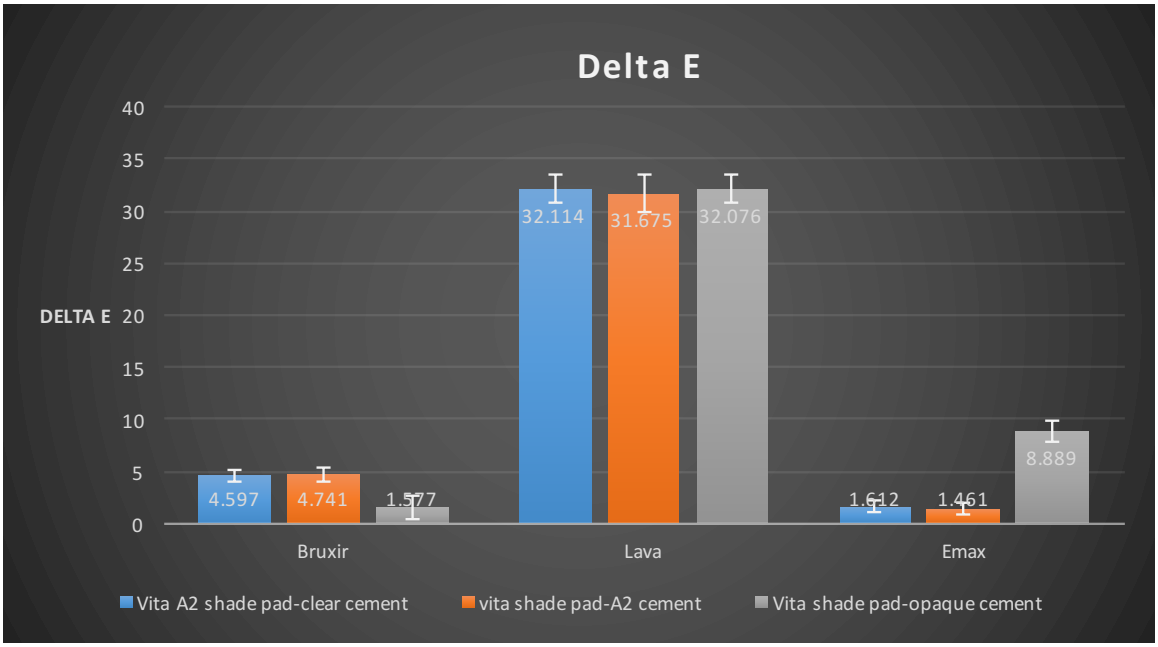

FIGURE 16. The Δ E value of Part I experiment specimens.

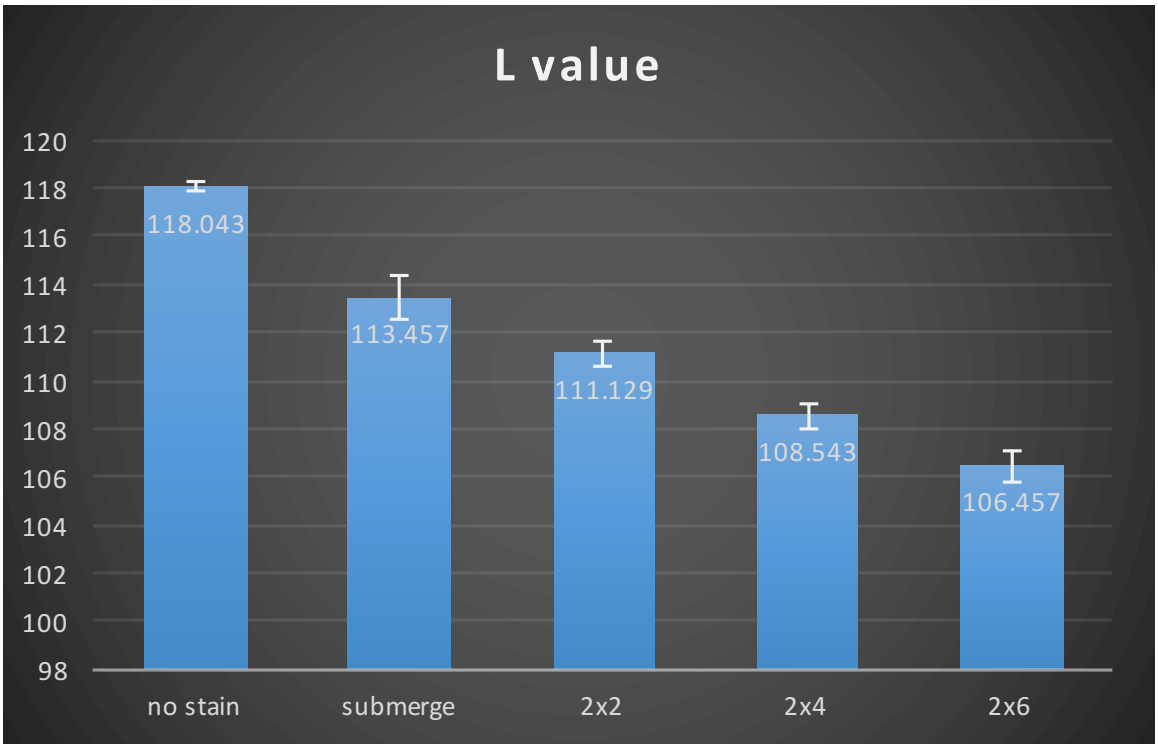

FIGURE 17. The L* value of Part II experiment specimens.

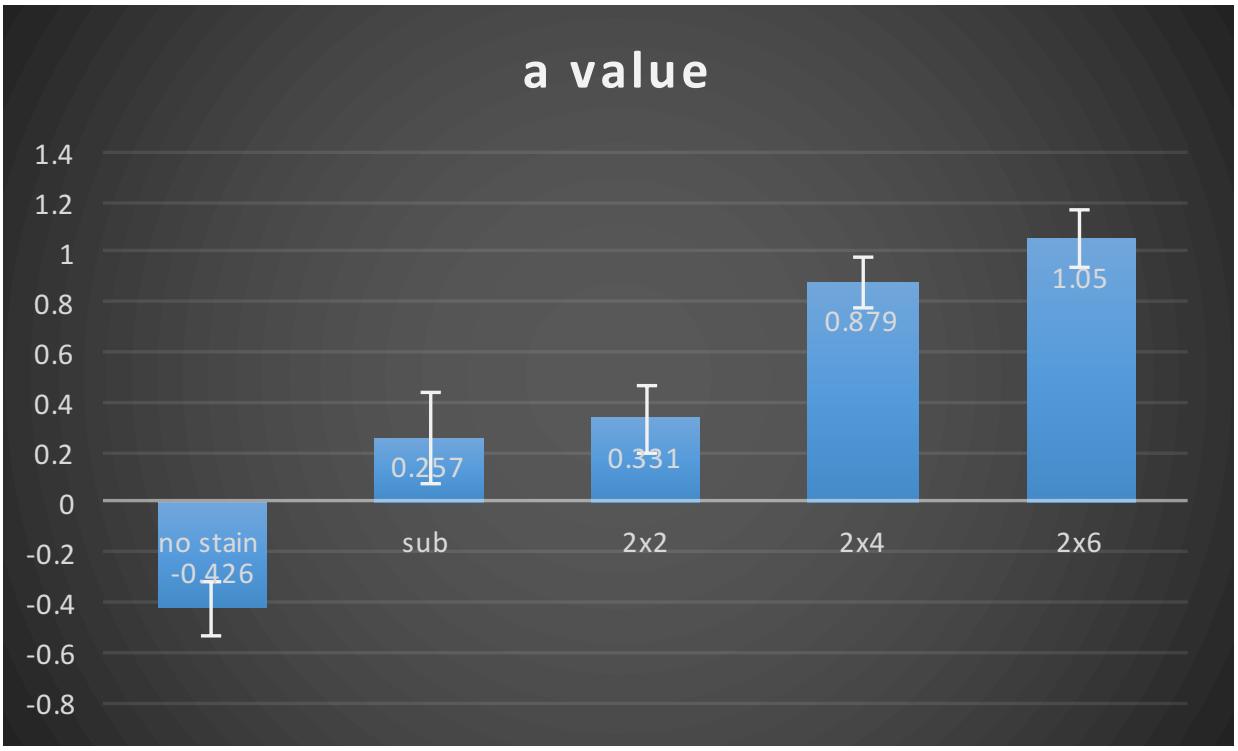

FIGURE 18. The a* value of Part II experiment specimens.

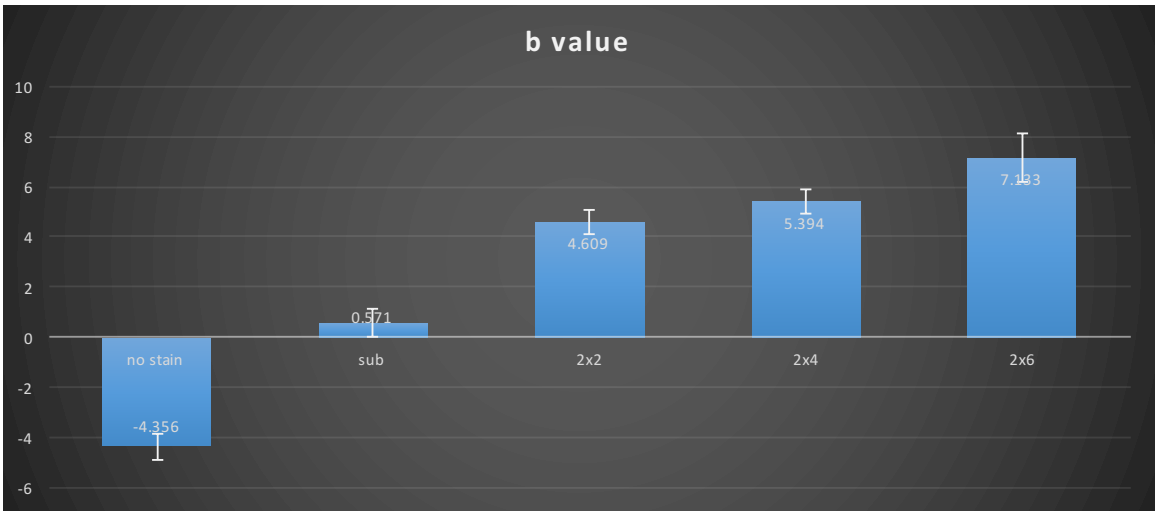

FIGURE 19. The b* value of Part II experiment specimens.

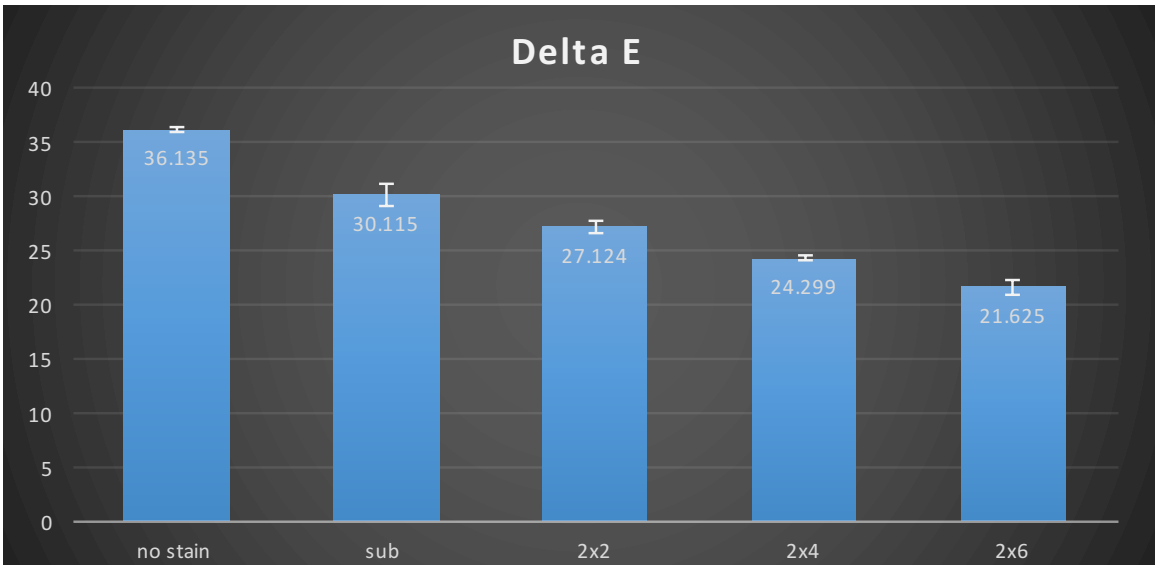

FIGURE 20. The Δ E value of Part II experiment specimens.

DISCUSSION

Part I Cement effect on full contour zirconia

Zirconia material has been a popular material in dentistry because of its high strength, high biocompatibility, and potential in esthetic restoration. Considering the development of CAD/CAM technology and digital dentistry, full contour zirconia restoration can provide a non-metal prosthodontic solution, with lower laboratory cost and higher durability, without the common problem of chipping in the veneering layer associated with veneered restoration. However, there is still limited information regarding esthetic and optical properties of full contour zirconia restoration.

In the present study, the effects of cement color on the post-cementation color of high translucent zirconia and lithium disilicate were evaluated. Based on the result of the present study, the null hypothesis that the use of a various shade of resin cement does not have any effect on the optical properties of high translucent monolithic zirconia ceramics was rejected. In order to reproduce the color of the natural tooth, the color parameter of final restoration should be predictable and similar to the natural tooth. The use of composite resin cement affects the optical outcome of high translucent ceramic material.[18-20, 59] The result of the present study found a statistical difference in L* value between using opaque cement and using A2 or clear cement for E-max CAD, indicating that opaque cement increased the value of final restoration of E-max CAD; this is consistent with the results of a previous study[59]. The result also showed a significant difference in L* value between using opaque cement and using A2 or clear cement for BruxZir samples. This is different from previous studies, which indicated that using

composite luting cement was shown not to significantly darken the final color of zirconia material[19, 60]. However, both previous studies did not use high translucent zirconia, but rather used traditional zirconia.[19, 60]

For the results of the a* value, we found a large standard deviation within the opaque cement group, while lower standard deviation was found in the A2 cement group and the clear cement group. Because the E-max CAD samples' color is pre-colored from the manufacturer, the large standard deviation might be the result of the not uniform opaque cement layer. Therefore, in clinical practice, when using opaque cement to cement a high translucent restoration, the not uniform cement layer under the restoration could have a strong impact of the color of the final restoration.

It has been demonstrated in our study that the Lava Plus zirconia group had high L* value and low a* and b* values, indicating Lava-Plus restoration has higher value and presents a more green and blue color result. There was no statistical difference among the cement groups, which corroborated a study by Chang, et al.,[19] which showed that cement seemed to have a minimum influence on the color. Therefore, the result showed that the choice of cement does not affect the esthetic outcome while using Lava Plus zirconia. Instead, in the second part of our study, the staining techniques resulted in a more dramatic effect on the esthetic outcome of the Lava Plus zirconia that we will discuss in the second part of the discussion.

The use of Δ E to investigate minimally 50/50 perceptibility and 50/50 acceptability of color difference are still being debated. Kuehni, et al[61] propose differences in Δ E <1 were not perceptible by the human eye. In 1989 Johnston, et al.[62] established the minimal acceptability limit as Δ E =3.7. In the present study, Δ E <1 were regarded as not

perceptible to the human eye; Δ E value greater than 1 and less than 3 units were considered perceptible by a skilled operator, but clinically acceptable.

Substantial differences were observed when comparing resultant shades of E-max CAD opaque cement assemblies to the Vita shade guide A2. The E-max CAD-opaque cement group showed that by using opaque cement on E-max CAD, the assembly would result in an unacceptable delta Δ E of 8.90 in the clinic. This change could be explained by the high translucency of E-max CAD, and had been described in previous studies[19, 59]. Therefore, the practice should be avoided in the clinic. Moreover, when placing an anterior E-max CAD crown the choice of cement should be closely approximated to the color of the final restoration.

The present study also showed that the difference of the cement opacity only has effects on the b* value but not the L* value of stained BruxZir zirconia. These results are in agreement with a previous report that the shade of the cement seemed to influence the color appearance of the restoration but not appreciably darken the final color of the zirconia crown.[60] Furthermore, using the opaque cement made the stained BruxZir zirconia color close to the target shade A2. This means that as using the BruxZir zirconia, the clinician can use opaque cement to achieve a better clinical outcome.

Part II Coloring technique effect on the full contour zirconia

From a dental technician's point of view, using translucent zirconia combined with individual coloring technique provides the possibility to match the color of different tooth areas. Compared to pre-sintered and post-sintered coloring techniques, the pre-sintered coloring technique would lead to a more natural result, and the color would stay

even after the occlusal adjustment.[63] However, there are only two studies published discussing the effect of pre-sintered staining procedures.[47, 50] In the second part of our study, the effect of staining technique on translucent zirconia was investigated, and based on the result of the present study, the null hypothesis that the different staining techniques do not have any effect on the optical properties of high translucent monolithic zirconia ceramics was rejected.

The result of this study demonstrated that the L* value decreased in all the stained groups, which was a predictable outcome. We also measured the value of the Vita shade guide A2 with L* value 88. Compared to the A2 color sample in Vita-shade guide, all the groups presented a higher value. This may be due to the fact that zirconia color is more opaque than veneer ceramic and human dentin.[64]As is known, the high scattering and reflectivity result in the opaque color of zirconia due to the high reflection index and large grain size. Additionally, there are statistical differences among different staining protocol groups. This finding was consistent with other studies. [50, 64]

Kim et al. investigated the color and translucency changes of monolithic zirconia with a different number of coloring liquid applications. The result showed that the increased number of coloring liquid applications with a single shade of A2 produced a darker and more yellowish monolithic zirconia. [47] The result of the present study exhibited that increased applications of coloring liquid produced a darker, more yellowish and more reddish monolithic zirconia specimen. Moreover, regardless of the number of coloring liquid applications, the painting techniques resulted in a darker, more yellowish and more reddish monolithic zirconia specimen than the submerging technique.

Ahangari et al.[50] compared the optical effect of the submerging the coloring technique and the painting technique on value changing in zirconia crowns. The result of the study showed the submerging group had less color differences and L* value changes compared to the painting technique. The author explained that the submerging technique resulted in a better penetration of the coloring liquid into the specimens, and led to a decrease in value and a decrease in the surface reflection.[50] In contrast, our study showed the painting technique groups produced less color difference than the submerging technique. However, Δ E for all stained groups when compared to A2 Vita shade guide were above the clinically acceptable level (Δ E>3.7), and all the specimens were prepared by following the manufacturer's recommendation. The result indicated that the instructions given by zirconia manufacturers to help technicians to obtain the desired color match between the selected shade and the final restoration are very limited and not sufficient to avoid color mismatch.

The ANOVA analysis showed that there was no significant difference among coloring protocol on the translucent parameter in monolithic specimens. This result was in line with the previous study,[47] indicating that coloring technique had no effect on translucency of high translucent zirconia.

This study has several limitations. First, only 1mm ceramic thickness was tested. The manufacturer suggested minimal thickness is 0.7 mm and the studies demonstrated that the cement has a different effect on the different thickness of high translucent material.[59] However, the recommended thickness is based on the in vitro chewing simulation study. Therefore, in the present study 1mm was implemented based on clinical

suggestions that have proven that the fracture resistance can be equal to metal ceramic restoration.[65] [66] Second, the cement layer of this study did not bond to the ceramic specimens but only to the foundation block. However, the pilot test of this methodology demonstrated with or without bonding to ceramic specimens did not affect the color of the ceramic assemblies. Third, even though the portable spectrophotometer has been used in most of the color studies, studies reported that the spectroradiometer provides more accurate color measurement and the spectrophotometer can be subject to error caused by the edge-loss effect by using small window to measure color.

SUMMARY AND CONCLUSIONS

Within the limitations of this study, it was concluded that:

- The opacity of the cement significantly affects the resulting color of E-max CAD restoration.
- Using opaque cement to place E-max CAD would result in an unacceptable color change and should be avoid clinically.
- The shade of the cement influences the color appearance of the BruxZir high translucent zirconia but not appreciably darken the final color of BruxZir high translucent zirconia crown.
- The shade of cement does not affect the esthetic outcome while using Lava plus zirconia.
- The results of the study demonstrated that the staining technique has an influence on value and final color of Lava-Plus high translucent. Therefore, it is recommended to consider staining technique as one of the influential factors on the final color of zirconia crowns.
- It is recommended to use the painting technique to stain zirconia in order to reproduce better color outcome.

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ABSTRACT

INFLUENCE OF COLORING TECHNIQUES AND CEMENT OPACITY ON THE OPITICAL PROPERTIES OF HIGH TRANSLUCENT MONOLITHIC ZIRCONIA

by

Chao-Chieh Yang

Indiana University School of Dentistry

Indianapolis, Indiana

Background: With the improvement of CAD/CAM technology and translucency of zirconia material, the full contour zirconia crown was introduced to offer dentists a metal free, high strength, and acceptable esthetic prosthesis option. In addition, it is claimed that it is possible to make a full contour high translucent zirconia crown close to natural tooth color by using coloring liquid. However, there is little information in the literature regarding the effect of coloring techniques and cement color on the optical properties of high translucent zirconia. Objective :1) To evaluate the effect of the coloring liquid technique on the resulting optical properties of a monolithic high

translucent zirconia 2) To evaluate the cumulative effect of the cement color on the resulting optical properties of a monolithic high translucent zirconia. Alternative hypothesis: There is a significant difference in optical properties between the high translucent monolithic zirconia ceramics with different color staining technique. In addition, the use of shaded resin cement has an effect on the final optical properties of high translucent monolithic zirconia ceramics. Materials and methods: 35 specimens of high translucent zirconia (11mm x11mm) with thickness 1mm was divided into 5 groups according coloring technique, as follows: no color, submerge, two layers of painting, four layers of painting, and six layers of painting. All specimens were measured for the Δ E, transparent parameter (TP), and opalescence parameter(OP) by spectrophotometer (CM-2600D) after firing. Forty-two specimens of high translucent zirconia (11mm x11mm) with thickness 1mm were divided into three groups according to cement color, as follows: clear, opaque, and A2. After firing and cementing with ND4 resin Block. The Δ E, TP and OP will be measured by spectrophotometer. Statistics: The data were analyzed with significant level set at 0.05 one way ANOVA followed by pair-wise group comparisons using Fisher's Protected Least Significant Differences.

Result: 1) The shade of cement significantly affected the mean value of ΔE of E-max CAD and BruxZir high translucent zirconia restoration. Using opaque cement combined with E-max CAD resulted in color difference that was above the clinically perceptible level (ΔE> 3.7). 2) With more layers of staining liquid application, the ΔE and value decreased. The six-layered group showed lowest mean delta ΔE value of 22 (0.78). ΔE

was significantly different among groups ($p<0.0001$). The submerged group showed higher ΔE than the all painting groups.

Conclusions: Based on the results of the study, the colors of BruxZir high translucent zirconia and E-max CAD restorations were affected by the shade of cement, whereas white opaque resin cement resulted in BruxZir high translucent zirconia more yellowish. The results of the study demonstrated that the staining technique has an influence on value and final color of Lava-Plus high translucent. Therefore, it is recommended to consider staining technique as one of the influential factors on the final color of zirconia crowns.

CURRICULUM VITAE

Chao-Chieh Yang

Feb 1984	Born in Changhua, Taiwan
Sep 2002 to June 2008	Doctor of Dental Surgery(DDS) Kaohsiung Medical University, School of Dentistry, Kaohsiung, Taiwan
July 2008 to Apr 2013	Private practice Taipei, Taiwan
May 2013 to May 2016	Certificate in Graduate Prosthodontics, Restorative Dentistry Indiana University School of Dentistry Indianapolis, IN
July 2014 to May 2017	Teaching Assistant, Prosthodontics, Indiana University School of Dentistry, Indianapolis, IN