EVALUATION OF THE OPTICAL PROPERTIES OF CAD-CAM GENERATED YTTRIA-STABILIZED ZIRCONIA AND GLASS-CERAMIC LAMINATE VENEERS

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Statement of problem. When feldspathic porcelain (FP) laminate veneers are used to mask tooth discoloration that extends into the dentin, significant tooth reduction is needed to provide space for the opaque layer and optimize the bonding of the restoration.

Purpose. The purpose of this study was to investigate the color effect of trial insertion paste (TP), composite resin abutment (CRA), and veneer regions on the optical properties of feldspathic porcelain (FP), yttria-stabilized zirconia (Y-TZP), and IPS e.max CAD HT (IEC) veneers.

Material and methods. A melamine tooth was prepared for a laminate veneer on a model, and a definitive cast was made. The definitive die was scanned by using the TurboDent System (TDS), then 30 CRA were machined and 10 veneers were fabricated for each ceramic material (FP, Y-TZP, IEC). The optical properties of different veneer materials, CRA (A1, A2, A3) and TP (bleach XL, opaque white, transparent, and yellow) were evaluated in the cervical, body, and incisal regions with a spectrophotometer. Results were analyzed by using 1-way ANOVA (.05).

Results. The color difference for all the veneers was affected by TP and CRA colors in different regions. The mean values for the Y-TZP veneer color coordinates (L*: 74 ±0.34, a*: 0.09 ±0.20, and b*: 17.43 ±0.44) were significantly different (P<.001) from those of IEC veneers (L*: 70.15 ±0.23, a*: -0.69 ±0.073, and b*: 11.48 ±0.30) and FP veneers (L*: 70.00 ±0.86, a*: -0.28 ±0.203, and b*: 13.86 ±1.08). There was no difference between IEC for L* and FP. Significant difference was detected (P<.001) in color coordinates among the 3 veneer materials for a* and b*.

Conclusions. The TP color affected the color difference for all veneer materials except the Y-TZP, while there was no effect on the CRA color. The magnitude of color coordinates changed as a function of TP color and veneer material. (J Prosthet Dent 2012;107:300-308)

CLINICAL IMPLICATIONS
The importance of trial insertion paste color is a function of veneer material, with IPS e.max CAD veneers being more sensitive than feldspathic porcelain. Selecting the luting cement color before cementation is important in achieving the desired esthetics for IPS e.max CAD HT veneers and is of some importance for feldspathic porcelain veneers. Luting cement color or substrate color had no effect on the observed shade of yttria-stabilized zirconia laminate veneers. The bond quality of zirconia veneers to the tooth is uncertain, and their long-term adhesion has not been clinically proven.

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When light interacts with a tooth, it may be reflected, scattered, or transmitted concurrent with the scattering of photons. The shade of dentin (the primary source of tooth color),

1 enamel structure (thickness and translucency), tooth dimension, and surface texture influence the optical properties of color, translucency, opalescence, and fluorescence.

2 Tooth color has been described as a combination of hue, chroma, and value. Translucency and intensity vary from the incisal region to the cervical region, with incisal, body, and cervical regions becoming progressively darker. This phenomenon is due to the decreasing thickness of the enamel from the incisal to the cervical regions as influenced by the underlying dentin.

3 The perceived color of a ceramic restoration is known to be affected by the shade of the ceramic material, its thickness, and, if it is not significantly opaque, the color of the underlying material. The restoration's color is known to be affected by ceramic firing temperature, the color of the prepared tooth, translucency and thickness of veneering porcelain, type of luting agent, surface glaze, layering technique, firing (temperature/time cycle), extrinsic colors, surface texture, thickness of luting agent, and type of ceramic substructure.

Zirconia is often considered the material of choice in restorative dentistry because of its superior mechanical properties, but it is opaque because of its density, elemental chemistry, and high crystallinity, which results in a relatively high refractive index (2.1 to 2.2). The esthetics of dental zirconia have been improved through the following procedures: infiltration (infiltration of machined restorations at the presintered stage with chloride solutions of rare earth elements to produce cores of various shades), precolored blocks (precolored at the microcrystalline powder state), thinner coping thickness, different colors for the liners, choice of zirconia material, grain size, and veneering technique. If the zirconia restoration is thin, then translucency and the final color of the restoration may be of concern. In such a situation, the color selection of luting cement (which is evaluated with preeminentation trial insertion paste) and the region (cervical, body, incisal) will be more important.

Ceramic laminate veneers have been shown to provide greater clinical longevity and enhanced esthetics and are more conservative than ceramic crowns. Minimal tooth preparation is required for these restorations; thus, achieving the optical properties of natural teeth with laminate veneers is a challenge.

The opaque nature of zirconia laminate veneers offers an advantage over traditional feldspathic porcelain in masking undesirable tooth colors due to age and/or tetracycline. Available data show that feldspathic porcelain requires more tooth reduction than zirconia to become sufficiently opaque to mask stains. The addition of veneering porcelain on zirconia copings to improve esthetics diminishes but does not eliminate their advantage over feldspathic porcelain in terms of tooth reduction. Furthermore, increasing the thickness of feldspathic porcelain veneers may impede light polymerization of the luting cement and compromise bonding to dentin. Unfortunately, bonding zirconia with resin cement is a challenge since it cannot be etched by hydrofluoric acid and, therefore, does not produce micromechanical retention to dentin.

The objectives of this study were to investigate the effect of trial insertion paste, composite resin abutment colors, and different veneer regions on the optical properties of feldspathic porcelain, CAD/CAM generated yttria-stabilized zirconia, and IPS e.max CAD laminate veneers. The null hypotheses tested were: 1) there is no effect of composite resin abutment color on the final color of the laminate veneers; 2) there is no consistent relationship between the color difference and ceramic thickness; 3) opaque white trial insertion paste would not mask a dark composite resin abutment; and 4) color coordinates would not be different for each laminate veneer material.

MATERIAL AND METHODS

A melamine maxillary left lateral incisor (Model #R861; Columbia Dentoform Corp, Long Island City, NY) was used for the veneer preparations (Fig. 1) and an index was fabricated before preparation to standardize the thickness of the veneers. The incisal overlapped preparation (IOP) was defined as 0.5-mm facial reduction and 1.5-mm incisal edge reduction. An impression of the prepared tooth with adjacent teeth was made with poly vinylsiloxane impression material (Aquasil Ultra digit-XLV Regular Set; Aquasil Monophase; Densply Intl, York, Pa). Type IV die stone (Jade Stone; Whip Mix Corp, Louisville, Ky) was used to pour the impression to fabricate the definitive cast.

The definitive die was scanned, and a restoration site designed with CAD/CAM technology (TurboDent System (TDS); Pou-Yuen Technology Co, Ltd, Fusing Township, Taiwan). Thirty composite resin abutments were milled from composite resin blocks (Paradigm MZ 100; 3M ESPE, St Paul, Minn) with 3 different colors: Aₐ (light color), A₇ (medium color), and A₈ (dark color). Ten composite resin abutments were fabricated for each color. The sample size was determined based on data from a previous study and available resources. No a priori power analysis was performed.

Ten yttria-stabilized zirconia (Y-TZP) veneers were fabricated by using the TDS technique as described: an optical impression of the definitive die was made with a laser scanner, and a restoration was designed and milled from partially sintered zirconia blocks, colored, and sintered to an overall thickness of 0.3 mm. The Y-TZP was layered with the appropriate veneer porcelain (VITA VM9) according to

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the manufacturer’s instructions.

Ten glass-ceramic laminate veneers were machined from IPS e.max CAD HT blocks (Ivoclar Vivadent Inc, Amherst, NY) by using CAD/CAM technology (CEREC 3D CAD/CAM; Sirona Dental Systems LLC, Charlotte, NC). The opaquing powder (IPS Contrast Spray; Ivoclar Vivadent AG) was sprayed to obtain a uniform layer with an optimal thickness of 32 µm to visualize both the internal line angles of the preparation and define the cavosurface margin. An optical impression of the sprayed definitive die was made with a laser scanner and then designed according to the manufacturer’s instructions. The veneers were milled from partially crystallized blocks and then fully sintered according to the manufacturer’s instructions. Another 10 glass-ceramic laminate veneers were fabricated manually with feldspathic porcelain (Noritake Super Ex 3; Noritake Kizai Co, Ltd, Nagoya, Japan) by using conventional refractory techniques.

Each veneer was measured in predetermined regions by using a caliper with accuracy ±0.001 mm (LS Starrett Co, Athol, Mass). The average total thickness, composition, and grain size of bilayer yttria-stabilized zirconia (TurboDent System (TDS); PouYuen Technology Co, Ltd), IPS e.max CAD (Ivoclar Vivadent Inc), and feldspathic porcelain (Noritake Kizai Co, Ltd) laminate veneers are provided in Table I. Veneer thicknesses varied among the 3 ceramic materials. The feldspathic porcelain laminate veneers and layering of feldspathic porcelain on zirconia copings were processed manually in part, whereas IPS e.max CAD veneers were fabricated as a monolayer with a CAD/CAM system.

Four different colors of trial insertion pastes (bleach XL, opaque white, transparent, and yellow) were used to assess the optical effects of the luting cement (Variolink II; Ivoclar Vivadent Inc) on the visual appearance and color coordinates of all the laminate veneers.

A dental spectrophotometer (CrystalEye, Model CE 100-DC/US, v1.3.1.0; Olympus Corp, Shinjuku, Japan) was used in this study to measure CIELAB color coordinates (L*, a*, b*). This device uses 7 light emitting diodes (LEDs) as an illumination source with 45/0-degree geometry. The image capture time was 0.2 seconds. The spectral data were acquired from the captured...
blocks and then fully sintered accord-
mced. The die was made with a laser scanner and
impression of the sprayed definitive
material. The opaquing powder
was utilized in part, whereas IPS e.max
cermets were machined from IPS e.max
CAD HT blocks (Ivoclar Vivadent Inc,
Amherst, NY) by using CAD/CAM
technology (CEREC 3D CAD/CAM;
Sirona Dental Systems LLC, Char-
lotte, NC). The opaquing powder
was used for the rest of the procedure
refractory techniques.29

Table I.

| Characteristics and average thickness at each region of laminate veneer materials |
|---------------------------------|-----------------|-----------------|-----------------|
| Laminate veneer material        | Average veneer mean thickness in mm (± SD) |
| IPS e.max porcelain              | 0.84 ±0.08      |
| Yttria-stabilized zirconia       | 0.54 ±0.08      |
| IPS e.max feldspathic porcelain  | 0.88 ±0.09      |

The mean and standard deviation
(±SD) of ΔΕ for each veneer mater-
ial was calculated and averaged for the
combinations of the composite resin
abutment color and the trial inser-
tion paste color in each veneer region.
Comparisons between tooth regions
were made by using 1-way ANOVA.
When the ANOVA was significant, the Tukey
Honestly Significant Difference (HSD)
test was used to determine which
comparisons were significantly
different.

## RESULTS

The data for color differences of
all veneer materials are shown in Fig-
ure 2. These results combined differ-
et colors of trial insertion paste
(transparent, bleach XL, opaque, yel-
low) with different colors of compos-
ite resin abutments (A1, A2, A3) for dif-
ferent veneer regions (cervical, body,
incisal) and were compared with the
control color (composite resin abut-
ment color (A1) with glycerin). Each
color will be addressed separately.
Furthermore, the effect of color coor-
dinates (L*, a*, b*) on laminate veneer
materials is shown in Table IV.

### Zirconia laminate veneers

The different colors of the com-
posite resin abutments did not cause a
clinically relevant color change (ΔΕ < 3.7) for the yttria-stabilized zirconia laminate veneers when compared in any region. Furthermore, trial insertion paste color did not result in a clinically relevant color change for any region, when they were placed with different composite resin abutment colors (Fig. 2A).
IPS e.max CAD laminate veneers

There was no clinically relevant color change ($\Delta E>3.7$) for any region of the IPS e.max CAD laminate veneers when they were placed on different colors of the composite resin abutment (Fig. 2B). However, the opaque white trial insertion paste caused a substantial color change ($\Delta E>3.7$) when the laminate veneers were placed on the different composite resin abutment colors and compared in the 3 regions. Furthermore, bleach XL trial insertion paste caused a color change ($\Delta E>3.7$) when the laminate veneers were placed on the composite resin abutments with A1 color only when the 3 regions were compared. However, the yellow trial insertion paste did not cause a clinically relevant color change ($\Delta E<3.7$) when the laminate veneers were placed on different composite resin abutment colors in the 3 regions. Opaque white trial insertion paste had a greater effect on the color change of IPS e.max CAD laminate veneers than feldspathic porcelain in the body and incisal regions.

Feldspathic porcelain laminate veneers

A color change ($\Delta E>3.7$) was observed at the cervical region of the feldspathic porcelain laminate veneers when they were placed on the composite resin abutments with A1 color (Fig. 2C) but was decreased by the use of yellow trial insertion paste ($\Delta E>3.7$). A large color change occurred at each region when the laminate veneers were placed on different colors of composite resin abutment with the opaque white trial insertion paste. There was a color change at the cervical region only when the laminate veneers were placed with bleach XL trial insertion paste on the composite resin abutment with A1 color, but no clinically relevant color change at any region was observed when the yellow trial insertion paste was used with the different composite resin abutment colors.
Relationship between color change and ceramic thickness (different regions)

The color change magnitudes (\(\Delta E\)) were averaged for combinations of different composite resin abutment and trial insertion paste colors for each laminate veneer material as shown in Figure 3. It should be noted that the feldspathic porcelain veneers were significantly thinner than IPS e.max CAD and zirconia veneers. There was a statistically significant difference (\(P<.001\)) in the value magnitude of \(\Delta E\) among the 3 regions for each laminate veneer material with an increase of color change from the incisal region to the cervical region, except between the cervical region (\(\Delta E=4.05\pm2.86\)) and the incisal region (\(\Delta E=4.15\pm2.64\)) for IPS e.max CAD veneers. There was a higher magnitude of \(\Delta E\) at each region of the IPS e.max CAD veneers compared with the feldspathic porcelain veneers, except at the cervical region (\(\Delta E=4.05\pm2.86\)) of IPS e.max CAD veneers compared with feldspathic porcelain veneers (\(\Delta E=4.64\pm3.39\)).

**Effect of different trial insertion paste colors on the color coordinates**

As the color of the trial insertion paste color changed from yellow to bleach XL to opaque white, a significant reduction (\(P<.001\)) in the value \(L^*\) (yellow less than bleach less than white) was obtained for all laminate veneer materials, as illustrated in Table III. However, the values of \(a^*\) varied for different veneer materials (yttria-stabilized zirconia: white less than bleach equal to yellow; IPS e.max CAD: white less than bleach less than yellow; feldspathic porcelain: white less than bleach equal to yellow) as did \(b^*\) values (yttria-stabilized zirconia: yellow equal to bleach less than white; IPS e.max CAD: white = bleach less than yellow; feldspathic porcelain: white less than yellow).

**Effect of different laminate veneer materials on the color coordinates**

The color coordinates were measured for composite resin abutment color (\(A^*\)) at the body region for all

![Effect of laminate veneer thickness from cervical region to incisal region on color difference for yttria-stabilized zirconia, IPS e. max CAD HT, and feldspathic porcelain materials.](image)

### Table III. Effect of color coordinates (\(L^*, a^*, b^*\)) on increasing value of trial insertion paste (from yellow to opaque white) for body region and composite resin abutment color (\(A^*\)) of different laminate veneer materials

<table>
<thead>
<tr>
<th>Laminate Veneer</th>
<th>Color Coordinate</th>
<th>Yellow</th>
<th>Bleach XL</th>
<th>Opaque White</th>
<th>F</th>
<th>P</th>
<th>Color Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yttria-stabilized zirconia</td>
<td>(L^*)</td>
<td>74.80 ±0.30</td>
<td>74.60 ±0.40</td>
<td>75.90 ±0.60</td>
<td>40.3</td>
<td>&lt;.001</td>
<td>yellow &lt; bleach &lt; white</td>
</tr>
<tr>
<td></td>
<td>(a^*)</td>
<td>0.11 ±0.19</td>
<td>0.02 ±0.20</td>
<td>0.26 ±0.28</td>
<td>7.2</td>
<td>.003</td>
<td>white &lt; bleach = yellow</td>
</tr>
<tr>
<td></td>
<td>(b^*)</td>
<td>17.40 ±0.40</td>
<td>17.60 ±0.50</td>
<td>18.50 ±0.70</td>
<td>11.4</td>
<td>&lt;.001</td>
<td>yellow = bleach &lt; white</td>
</tr>
<tr>
<td>IPS e.max CAD HT</td>
<td>(L^*)</td>
<td>70.90 ±0.20</td>
<td>73.80 ±0.50</td>
<td>79.80 ±0.80</td>
<td>695</td>
<td>&lt;.001</td>
<td>yellow &lt; bleach &lt; white</td>
</tr>
<tr>
<td></td>
<td>(a^*)</td>
<td>0.53 ±0.08</td>
<td>0.95 ±0.08</td>
<td>1.18 ±0.10</td>
<td>144</td>
<td>&lt;.001</td>
<td>white &lt; bleach &lt; yellow</td>
</tr>
<tr>
<td></td>
<td>(b^*)</td>
<td>13.50 ±0.30</td>
<td>11.60 ±0.40</td>
<td>11.40 ±0.30</td>
<td>117</td>
<td>&lt;.001</td>
<td>white = bleach &lt; yellow</td>
</tr>
<tr>
<td>Feldspathic porcelain</td>
<td>(L^*)</td>
<td>70.50 ±0.70</td>
<td>72.10 ±0.80</td>
<td>77.60 ±1.70</td>
<td>106</td>
<td>&lt;.001</td>
<td>yellow &lt; bleach &lt; white</td>
</tr>
<tr>
<td></td>
<td>(a^*)</td>
<td>0.18 ±0.23</td>
<td>0.35 ±0.21</td>
<td>0.71 ±0.23</td>
<td>15.5</td>
<td>&lt;.001</td>
<td>white &lt; bleach = yellow</td>
</tr>
<tr>
<td></td>
<td>(b^*)</td>
<td>14.80 ±0.30</td>
<td>13.50 ±1.50</td>
<td>12.30 ±2.20</td>
<td>5.2</td>
<td>.012</td>
<td>white &lt; yellow</td>
</tr>
</tbody>
</table>
veneer materials as shown in Table IV. Yttria-stabilized zirconia laminate veneers were the highest (L* = 74.00 ±0.34), but no significant difference (P>0.05) in the L* value between IPS e.max CAD (70.15 ±0.23) and feldspathic porcelain (70.00 ±0.86) laminate veneers was found. IPS e.max CAD laminate veneers had the lowest value of a* (-0.69 ±0.07), while it was higher for zirconia (0.09 ±0.20) than for feldspathic porcelain (-0.28 ±0.20) laminate veneers. Yttria-stabilized zirconia laminate veneers had the highest b* coordinate (b*=17.43 ±0.44), while IPS e.max CAD showed the lowest b* coordinate (11.48 ±0.30) for laminate veneers.

**DISCUSSION**

The null hypothesis that there is no effect of composite resin abutment color on the final color of the laminate veneers was partially rejected. There was no measured effect from the composite resin abutment color on the final color of the laminate veneers placed with transparent trial insertion pastes for any region except for feldspathic laminate veneers at the cervical region; these were affected by the composite resin abutment color (A). The color shifted when the yellow trial insertion paste was used because of the thin ceramic (0.45 mm) at the cervical region. The composite resin abutment color (A) in the present study was not dark enough to cause a color shift on the overall color of all laminate veneers.

The null hypothesis that there was no consistent relationship between the color difference and ceramic thickness was rejected for feldspathic porcelain and yttria-stabilized zirconia laminate veneers, but it was not rejected for IPS e.max CAD veneers. As the ceramic thickness increased from the cervical to the incisal region for feldspathic porcelain and yttria-stabilized zirconia laminate veneers, the color difference decreased except for the cervical and body regions of the yttria-stabilized zirconia veneers. This phenomenon can be explained by an increase of incident light absorption at a thicker region that reflects a reduced quantity of light. These results were in agreement with Chaiyabutr et al who reported that as the ceramic thickness increased (from 1.0 to 2.5 mm), the color difference decreased for IPS e.max CAD LT. However, for IPS e.max CAD veneers, the body region was more affected than other regions, and the incisal region was more affected than the cervical region; therefore no consistent relationship between the color difference and ceramic thickness was found. This result can be explained by the different ceramic thicknesses caused by milling the intaglio of the body region of the IPS e.max CAD veneers more than on other regions. These veneers were machined and no layering of veneering porcelain was involved unlike the yttria-stabilized zirconia laminate veneers.

In terms of color difference, the body and incisal regions of IPS e.max CAD veneers were more affected than those of feldspathic porcelain even though the feldspathic porcelain veneers were thinner (0.54 mm) than the IPS e.max CAD veneers (0.85 mm). IPS e.max CAD veneers had a higher magnitude of color change than yttria-stabilized zirconia veneers with similar thickness associated with the presence of a glassy phase. However, the color difference between the feldspathic porcelain and yttria-stabilized zirconia veneers (Fig. 3) is difficult to interpret due to the simultaneous differences in thickness. It is not possible to determine if the change in color is due to veneer thickness or the opacity of zirconia. It was difficult to standardize the thickness of the veneers when they were fabricated with different techniques, and the interpretation of color differences of different materials cannot be tested with standardized flat specimens. Thus testing must be done on restorations to both simulate the geometry of a tooth and the surface texture, which also affects the optical properties.13

The null hypothesis that the opaque white trial insertion paste would not mask a dark composite resin abutment is rejected for zirconia laminate veneers and not rejected for feldspathic porcelain and IPS e.max CAD veneers. The color differences of the yttria-stabilized zirconia laminate veneers were low (0.7 to 1.5) and were lower than the 3.7 perceptible threshold. These results were not affected by any color of the trial insertion paste in any region, which supports the complete opaqueness at this thickness of the yttria-stabilized zirconia veneers. Other studies have shown that a larger color difference was obtained for different types of zirconia, such as 1.99 to 2.89 for DC-Zirkon,9 1.8 to 3.6 for Digident Digizon,24 2.1 to 3.6 for Vita 2000 YZ cubes,24 and 0.9 to 2.1 for Katana.21 These differences can be attributed to different brands of zirconia with minor structural and dimensional differences in the grains and grain boundaries, which yield higher levels of light absorption and scattering, rather than being directly affected by the grain size.22 Dozic et al14 reported that the overall color of 0.6 mm IPS Empress Esthetic (leucite-reinforced glass-ceramic) laminate veneers was not influenced by different shades of resin cement, which were not effective in creating color shifts. This was explained by the limited cement thickness (30 μm). In the present study, the final color of the IPS e.max CAD and feldspathic porcelain veneers was affected more by opaque white than bleach try-in paste of comparable thicknesses (30 to 50 μm).

The color coordinates of the laminate veneers were affected by a different value of trial insertion paste color. The color coordinates were higher (higher L*), but a* and b* varied (Table III). This result indicated that the L* of the trial insertion paste overcame the optical properties imparted by different veneer materials to cause constant L* changes and that they have a direct influence on the overall color of the laminate veneers. Therefore, the overall color of the veneer
can be changed by using different colors of trial insertion paste to minimize ΔΕ with adjacent natural teeth and thereby best match color. This finding was in agreement with Azer et al. who reported that when comparing different shades of composite resin core material or resin luting agents, no statistically significant difference for CIE L*a*b* color parameters was found among the various ceramic specimen combinations regarding color change. This can be explained by the thickness of the specimens (1 mm). Shokry et al. demonstrated that increasing the ceramic thickness reduced the brightness and increased the reddish and yellowish appearance of ceramic specimens.

The null hypothesis that the color coordinates would not be different for each laminate veneer material was rejected. The results in this study showed different color coordinates (Table IV) for different veneer materials. The IPS e.max CAD was the most translucent material because it showed the greatest color difference even though the veneers were thicker than feldspathic porcelain and demonstrated a more bluish color (b* = 11.48 ±0.30) than feldspathic porcelain (b* = 13.86 ±1.08). The color coordinates of the teeth should be measured before preparation and the appropriate material selected in order to match the color coordinates of natural teeth. Furthermore, the shade of the prepared tooth (dentin) should be selected and replicated as closely as possible by using a tooth colored die when the definitive restoration is fabricated. The color difference between the abutment and prepared tooth should be corrected by the color of the luting cement for feldspathic porcelain and IPS e.max CAD veneers. The opacity of yttria-stabilized zirconia veneers, as shown in the present study, is advantageous for masking dark substrates. The color difference between the yttria-stabilized zirconia core and the adjacent natural tooth should be reduced through layering techniques for the veneering porcelain. Using a spectrophotometer to measure color coordinates and calculating the color difference to determine the magnitude of value decrease showed that modifying the veneering porcelain can minimize the color difference with adjacent teeth and provide an overall esthetic restoration that matches the adjacent natural teeth.14,26

The limitations of correlations between in vitro simulations of intraoral function are recognized. In this study, the simulations did not include light aging. However, the data on zirconia laminate veneers provide an initial step to better understand the optical properties of zirconia as a laminate veneer restoration. Further in vivo studies should be conducted to determine how long the yttria-stabilized zirconia laminate veneers and their color stability in the oral environment.

CONCLUSIONS

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

1. The underlying color of the test-

| permeated laminate pastes caused color change (ΔΕ >3.7) for different regions for IPS e.max CAD (3 regions) and for feldspathic porcelain laminate veneers.

2. The IPS e.max CAD laminate veneers with lower glass content were more significantly affected by trial insertion paste color than feldspathic porcelain laminate veneers.

3. The yttria-stabilized zirconia laminate veneers with relative opacity were not significantly affected by the color of the trial insertion paste or the composite resin abutment color.

4. No significant effect of the color of the composite resin abutment was observed on the overall color of all the laminate veneers, except in the cervical region for feldspathic porcelain laminate veneers.

5. Different colors of trial insertion paste affected the color coordinates of the overall color for all the laminate veneers in which L* increased, while a* and b* varied.

6. The yttria-stabilized zirconia laminate veneers were brighter (higher L*), more yellowish (higher b*), and more reddish (higher a*) than the IPS e.max CAD and feldspathic porcelain laminate veneers.

7. The IPS e.max CAD laminate veneers demonstrated the same brightness as feldspathic porcelain laminate veneers but were more greenish (lower a*) and more bluish (lower b*) than the feldspathic porcelain laminate veneers.

REFERENCES


TABLE IV. Effect of color coordinates (L* a* b*) on laminate veneer material for body region and composite resin abutment color (A4) with glycerin using 1-way ANOVA.

<table>
<thead>
<tr>
<th>Veneer Material</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yttria-stabilized zirconia</td>
<td>74.00 ±0.34</td>
<td>0.09 ±0.20</td>
<td>17.43 ±0.44</td>
</tr>
<tr>
<td>IPS e.max CAD HT</td>
<td>70.15 ±0.23</td>
<td>-0.69 ±0.07</td>
<td>11.48 ±0.30</td>
</tr>
<tr>
<td>Feldspathic porcelain</td>
<td>70.00 ±0.86</td>
<td>-0.28 ±0.20</td>
<td>13.86 ±1.08</td>
</tr>
<tr>
<td>F</td>
<td>170</td>
<td>53.10</td>
<td>184</td>
</tr>
<tr>
<td>P</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>


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