Effect of Enamel Shades on Color of Layered Resin Composites

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The purpose of this study was to evaluate the effect of the covering enamel layer of various thicknesses on the color of layered resin composites (LRC). To this end, the CIELAB parameters of the following were evaluated: underlying base (ULB: 2.0 mm of body shade + 3.0 mm of opaque shade), inherent color of the enamel shade (4.0 mm of enamel shade + ULB), and LRC disks (0.5, 1.0, 2.0, 3.0 mm of enamel shade + ULB) of Filtek Supreme (FS, 3M, St. Paul, Mn, USA) and Gradia Direct (GD, GC). To assess the effect of the enamel layer on the color of LRC, color difference between ULB and LRC was calculated. With FS, the enamel layer had no major effect on the color of LRC — regardless of thickness. With GD, the enamel layer had a significant effect on the color of LRC, even if the thickness was only 0.5 mm. The difference in enamel layer effect between the two products could be attributed to the difference in color characteristics of the two enamel shades.

Key words : Resin composite, Color, Translucency

INTRODUCTION

In tandem with their rapid development and vast improvement, direct restorative methods using adhesive systems and resin composites are gaining more and more attention. Indeed, for cases that involve large Class IV cavities or fractured anterior teeth, direct resin composite restorations have become a popular alternative to the more traumatizing prosthetic appliances.

Regarding the optical properties of human teeth such as color and translucency, these properties are known to differ according to the location in a tooth. For example, it was reported that the incisal aspect of natural human teeth appeared bluish, greenish and more translucent than in the cervical area. Hence, to mimic the optical properties of natural teeth, large Class IV cavities or fractured anterior teeth cannot be restored by only a single shade of resin composite: a layering technique seems necessary for a successful restoration in these cases. In the layering technique, a layer of more translucent enamel shade is often applied over the body- or opaque-shade resin composite to help create depth from within the restoration, thereby reducing the color showing only from the surface of the restoration. Nonetheless, as reported by Lee et al., the resultant restoration of this technique is determined by several factors — such as translucency, color and thickness — of each layer. The authors also showed that the covering layer had a greater effect than the underlying layer on the resultant color of layered resin composites. Against this background, the effect of the covering enamel shade on the resultant color of layered resin composites should be thoroughly clarified in order to ensure successful restorations by the layering technique.

However, to date, no information is available concerning the effect of enamel layer on layered resin composites.

As for translucency, it was reported that this optical property was much affected by the thickness of resin composites. In our previous study, it was revealed that the translucency of resin composites increased exponentially as thickness decreased. In particular, the translucency property changed drastically in thinner specimens. As the enamel shade is often used as a thin layer in the layering technique, it is anticipated that a slight change in the thickness of the enamel layer would substantially affect the resultant color of the layered resin composites.

Therefore, the purpose of the present study was to evaluate the effect of the covering enamel layer of various thicknesses on the resultant color of layered resin composites.

MATERIALS AND METHODS

Resin composites for layering technique

In the present study, two resin composite products were used — Filtek Supreme (FS: 3M, St. Paul, Mn, USA) and Gradia Direct (GD: GC, Tokyo, Japan). For Filtek Supreme, the shades used were A2E (Lot No. 4XAJ), A2B (Lot No. 5AKJ), and A2D (Lot No. 4AHJ). For Gradia Direct, the shades used were E1 (Lot No. 0310301), A2 (Lot No. 0406151) and AO2 (Lot No. 0310241).

As the names of shades varied in different products, A2E and E1 shades were given the generic name “enamel shade” in the present study to facilitate comparison and discussion. Similarly, A2B and A2 were described as “body shade”, and A2D and AO2 were described as “opaque shade”.

The authors also showed that the covering layer had a significant effect on the color of LRC, even if the thickness was only 0.5 mm. The difference in enamel layer effect between the two products could be attributed to the difference in color characteristics of the two enamel shades.

The purpose of this study was to evaluate the effect of the covering enamel layer of various thicknesses on the color of layered resin composites (LRC). To this end, the CIELAB parameters of the following were evaluated: underlying base (ULB: 2.0 mm of body shade + 3.0 mm of opaque shade), inherent color of the enamel shade (4.0 mm of enamel shade + ULB), and LRC disks (0.5, 1.0, 2.0, 3.0 mm of enamel shade + ULB) of Filtek Supreme (FS, 3M, St. Paul, Mn, USA) and Gradia Direct (GD, GC). To assess the effect of the enamel layer on the color of LRC, color difference between ULB and LRC was calculated. With FS, the enamel layer had no major effect on the color of LRC — regardless of thickness. With GD, the enamel layer had a significant effect on the color of LRC, even if the thickness was only 0.5 mm. The difference in enamel layer effect between the two products could be attributed to the difference in color characteristics of the two enamel shades.

Key words : Resin composite, Color, Translucency
Translucency parameters of enamel shade at various thicknesses

Translucent acrylic plates (0.5, 1.0, 2.0, 3.0 and 4.0 mm thick) with 8-mm diameter hole were used as molds for making standardized disk-shaped specimens. Each mold was filled with a resin composite of the enamel shade and covered with clear celluloid strips on the top and bottom surfaces of the hole. The acrylic plate was pressed between two glass slides by finger pressure to achieve uniform thickness of the disk specimen. After removing the glass slides, irradiation was performed through a thin plastic film using an Optilux 401 (Demetron, Danbury, CT, USA). The 60-second irradiation was performed twice — from the top and bottom of the specimen. After light curing, the color of the material against two backings — a black ceramic tile (\(L^* = 29.38, a^* = -0.93, b^* = 0.07\)) followed by a white ceramic tile (\(L^* = 93.56, a^* = -1.97, b^* = 3.53\)) — was measured separately using a colorimeter. For the measurements, five specimens were made from the enamel shade of each product.

Color measurements were carried out using a colorimeter, OFC-300A (Nippon Denshoku, Tokyo, Japan). For the pulsed xenon lamp adopted in the colorimeter, it generated a spectral power distribution of CIE Standard Illuminant D65 — which corresponds to “average” daylight. As for equipment calibration, it was performed immediately before the measurements using a white tile supplied by the manufacturer.

For each color measurement, the values obtained were expressed as CIELAB parameters (\(L^*, a^*\) and \(b^*\)). \(L^*\) represents lightness, where 100 is white and 0 is black. \(a^*\) and \(b^*\) are the red-green and yellow-blue chromatic coordinates, where a positive \(a^*\) or \(b^*\) value indicates a red or yellow shade respectively.

At each thickness, translucency of the enamel shade was calculated by using the following translucency parameter (TP) formula:

\[
TP = [(L_{w} - L_{b})^2 + (a_{w} - a_{b})^2 + (b_{w} - b_{b})^2]^{1/2}
\]

where the subscript “W” refers to the CIELAB value for each specimen on the white backing, and the subscript “B” refers to the corresponding value on the black backing. “TP” is then the color difference of a material of a particular thickness on black and white backings, and which corresponds directly to common visual assessment of translucency. To detect any statistical differences in TP, one-way ANOVA and Games-Howell test were carried out for each group.

Effect of enamel layer of the color of layered resin composites

Fig. 1 illustrates the procedure for evaluating the effect of enamel layer on the color of layered resin composites. For the underlying color base, it comprised the three layers superposed from bottom to top:

- A 4.0 mm thick opaque shade
- A 3.0 mm thick body shade
- A 2.0 mm thick enamel shade

Based on the obtained \(L^*, a^*, b^*\) parameters of the layered resin composites, color difference was calculated in two manners to evaluate the effect of enamel shade at various thicknesses on the color of layered resin composites:

a) \(\Delta E^*\) between the underlying color base and the layered resin composites.

b) \(\Delta E^*\) between the enamel shade and the layered resin composites.
surface in this order: a black ceramic tile ($L^* = 29.38$, $a^* = -0.93$, $b^* = 0.07$), a cured disk of opaque shade (8 mm in diameter, 3 mm in thickness), and a cured disk of body shade (8 mm in diameter, 2 mm in thickness). The layers were simulating dark background color of oral cavity, layered opaque- and body-shade in the layering technique for so called "through and through" cavity. Following which, enamel-shade disks of various thicknesses (8 mm in diameter and 0, 0.5, 1.0, 2.0, 3.0, 4.0 mm in thickness) were placed on the underlying base for color evaluation using the colorimeter (0 mm means no enamel-shade disk, hence only the color of the underlying base itself). Optical contact was achieved by using an optical fluid (refractive index was approximately 1.5) between the resin composite layers – as used by many researchers. For each thickness of the enamel shade, five resin composite-layered specimens were used. Based on the obtained $L^*$, $a^*$, $b^*$ parameters of the layered resin composites, color difference was calculated in two manners to evaluate the effect of enamel shade at various thicknesses on the color of layered resin composites. The two calculations were described below.

**Color difference between underlying color base and layered resin composites**

Color difference between the underlying color base and layered resin composites at various thicknesses of enamel shade was calculated using the following equation:

$$\Delta E^* = \left( (L^*_{\text{base}} - L^*_{\text{layered}})^2 + (a^*_{\text{base}} - a^*_{\text{layered}})^2 + (b^*_{\text{base}} - b^*_{\text{layered}})^2 \right)^{1/2}$$

where $L^*_{\text{base}}$, $a^*_{\text{base}}$, $b^*_{\text{base}}$ and $L^*_{\text{layered}}$, $a^*_{\text{layered}}$, $b^*_{\text{layered}}$ values are $L^*$, $a^*$, $b^*$ values of the underlying color base and layered resin composites at various enamel shade thicknesses respectively. The color difference showed the effect of the covering enamel shade at various thicknesses on the color of layered resin composites.

**Color difference between enamel shade and layered resin composites**

In our previous study, it was reported that an enamel shade of 4-mm thickness was sufficient to keep out the influence of the background color. Therefore, the color of layered resin composites covered by an enamel shade of 4-mm thickness could be considered as the inherent color of the enamel shade. Hence, color difference was calculated by the following equation to evaluate the similarity in color between the inherent color of enamel shade and the layered resin composites when covered by enamel shade of various thicknesses.

$$\Delta E^* = \left( (L^*_{\text{enamel}} - L^*_{\text{layered}})^2 + (a^*_{\text{enamel}} - a^*_{\text{layered}})^2 + (b^*_{\text{enamel}} - b^*_{\text{layered}})^2 \right)^{1/2}$$

where $L^*_{\text{enamel}}$, $a^*_{\text{enamel}}$, $b^*_{\text{enamel}}$ and $L^*_{\text{layered}}$, $a^*_{\text{layered}}$, $b^*_{\text{layered}}$ values are $L^*$, $a^*$, $b^*$ values of the inherent color of enamel shade and layered resin composites at various enamel shade thicknesses respectively.

To define the relation between a range of colorimetric differences and the degree of visual scaling of color differences, colorimetric differences above 2 were considered as “perceptible differences” in the present study, using the definition by Gross et al.

$L^*$, $a^*$, $b^*$ of the inherent color of enamel shade and the underlying color base

The inherent color of the enamel shade as described above was evaluated in terms of CIE $L^*$, $a^*$, $b^*$ parameters and compared with those of the underlying color base. The number of specimens was five for each CIELAB parameter group. To detect statistically significant differences between the groups ($p < 0.05$), one-way ANOVA and Games-Howell post-hoc test were carried out separately for the $L^*$, $a^*$ and $b^*$ values.

**RESULTS**

**Translucency parameters of enamel shade at various thicknesses**

Fig. 2 illustrates the TP results of the enamel shade at various thicknesses. The correlation between thickness and TP value was most precisely expressed by the exponential functions for the two enamel
shades. The TP values indicated a statistically significant decrease in the two products as the thickness of the specimens was increased (Games-Howell test, p<0.05). In the exponential functions, the TP value decreased drastically when the thickness of the specimens became large. When comparison was made between the two products, the TP values were not statistically different (Games-Howell test, p>0.05), with exception at 2-mm thickness.

**Effect of enamel layer on the color of layered resin composites**

Fig. 3 summarizes the effect of enamel layer on the color of layered resin composites. With FS, the color difference between the underlying base and layered resin composites was always below “2” — threshold of distinction for human eyes, with exception at 1 mm when the value of TP was 2.06. As for GD, the color difference between the underlying base and layered resin composites was always above “2”.

Table 1 **L*, a*, b* values of the enamel shade and underlying base**

<table>
<thead>
<tr>
<th></th>
<th>FS</th>
<th>GD</th>
<th>FS</th>
<th>GD</th>
<th>FS</th>
<th>GD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enamel shade</strong></td>
<td>50.59*</td>
<td>50.06*</td>
<td>−3.60A</td>
<td>−4.90</td>
<td>1.92α</td>
<td>−2.54</td>
</tr>
<tr>
<td></td>
<td>(0.63)</td>
<td>(0.48)</td>
<td>(0.09)</td>
<td>(0.08)</td>
<td>(0.30)</td>
<td>(0.61)</td>
</tr>
<tr>
<td><strong>Underlying base</strong></td>
<td>50.11*</td>
<td>52.28*</td>
<td>−3.54A</td>
<td>−3.42A</td>
<td>2.50α</td>
<td>2.51α</td>
</tr>
<tr>
<td></td>
<td>(0.67)</td>
<td>(0.94)</td>
<td>(0.16)</td>
<td>(0.09)</td>
<td>(0.90)</td>
<td>(0.55)</td>
</tr>
</tbody>
</table>

Within each CIELAB parameter group, values with the same superscript letter are not significantly different (Games – Howell test, p>0.05).
DISCUSSION

The thickness values of the opaque and body shades employed in the present study for the underlying color base were determined by the data of our previous study9. In the previous study, the minimum thickness at which the opaque layer of the two products could mask the dark background color were 1.88 and 2.69 mm for FS and GD respectively. In this manner, the effect of the underlying black tile was eliminated through the underlying color base. In addition, the color differences calculated between the inherent color of the body shade obtained in the previous study9 and the underlying color base in the present study were only 0.47 and 0.43 for FS and GD, respectively (the two studies were performed using the same lot, hence the above calculation was possible). Based on the calculation, the color of the underlying base was almost the same as the inherent color of the body shade.

Regarding the color difference between the underlying color base and layered resin composites, FS showed imperceptible color differences regardless of the thickness of enamel layer. Hence, the enamel shade of this product had no major effect on the resultant color of layered resin composites. The result could be explained by the similarity in color of the enamel shade and the underlying color base employed in the present study. With GD, the color difference was always above 2—the threshold of distinction for the human eye10. Hence, the enamel shade of this product had a significant effect on the resultant color of layered resin composites, even when the thickness of the enamel layer was merely 0.5 mm. Such a significant influence could be attributed to the color difference between the enamel shade and the underlying layer of this product. As Lee et al. reported, the covering layer had a major effect on the resultant color of layered resin composites9. Hence, a thin enamel layer could have a significant effect on the resultant color of layered resin composites.

As for the color difference between the enamel shade and layered resin composites, FS always revealed color differences below the threshold of distinction for human eyes. This result could be explained by the similarity in color of the enamel shade and the underlying base. With GD, the color difference fell below the threshold of distinction for human eyes when the thickness of the enamel layer increased to 1 mm and above. In other words, the resultant color of the layered resin composites became similar to the color of the enamel shade when the thickness of the enamel layer increased to 1 mm. Hence, the resultant color of layered resin composites changed drastically for the product by a thin enamel layer. The fact could be explained by the sharp decline in the translucency of the enamel shade caused by the reduction of the thickness.

The two products employed in the present study showed different results regarding the effect of enamel layer on the resultant color of layered resin composites. Hence, it seems beneficial to modify the direction for use concerning the two products. With FS, the color of layered resin composites was not much affected by the thickness of the covering enamel layer. Therefore, this product may be suitable for clinicians who have little experience in the layering technique, so that failures arising from an inadequate thickness of the enamel layer would be minimal when using this product. However, there exist a concern that the resultant restoration may become monotone in color. Therefore, to express the grayish shade in the incisal area of a tooth, dark background color of the oral cavity should be intentionally utilized by eliminating an opaque shade of the product from the incisal area. As for GD, the resultant color of layered resin composites was altered drastically by a slight change in the thickness of the enamel layer. Hence, clinicians should control the thickness of the enamel layer carefully when using this product; otherwise, too much enamel color will be dominant in the resultant color of the layered resin composites. Nevertheless, this product possess this advantage: it is able to mimic the gradation of color in a natural tooth by a very thin enamel layer.

In the present study, the translucency of two enamel shades and the effect of the enamel layer on the color of layered resin composites were evaluated at various thicknesses. In an actual restoration procedure, resin composite materials were used in various thicknesses. Hence, it seems beneficial to adopt the evaluation method employed in the present study to obtain more clinical information.

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