Color and Translucency of Resin Composites for Layering Techniques

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The purpose of this study was to evaluate the colors of resin composites used for the layering technique, as well as the translucency at various thickness. For the purpose of calculating the translucency parameter (TP), black and white backings were used to evaluate the CIELAB parameters of Filtek Supreme (3M) and Gradia Direct (GC) disks of various thicknesses (0.5, 1.0, 2.0, 3.0 and 4.0 mm) and of three different shades (enamel-shade, body-shade, and opaque-shade). As for the color of each shade, it was evaluated using 4mm thick specimens on the white backing. Regarding TP, the opaque-shades were less translucent than the other shades. It was also found that translucency increased exponentially as thickness was reduced — regardless of shade. Regarding color, enamel-shades were more bluish (especially in GD) compared to the other shades, and the opaque-shades displayed a brighter and yellowish characteristic. In the layering technique, it is fundamental to have an accurate knowledge about the translucency and colors of the materials/shades used.

Key words : Resin composite, Color, Translucency

INTRODUCTION

Recently, less traumatizing direct restorative methods using adhesive systems and resin composites have received much attention. In cases of large Class IV cavities or fractured anterior teeth, direct resin composite restorations have become available as an alternative to the more traumatizing prosthetic appliances. This is possible through the development and improvement of adhesive systems[1] and resin composite materials[2].

Regarding the esthetic aspect of large Class IV cavities and fractured anterior teeth, there is little or no existing tooth structure to surround the restoration to provide a reflected or transmitted color base. Hence, these so-called “through and through” restorations are especially difficult and extremely challenging to dentists[3]. In these cases, translucent materials may provide relatively poor color matches. More specifically, a grayish shade is often visible against the surrounding tooth structure, because the rather translucent materials are probably affected by the darkness of the oral cavity[4,5]. From this point of view, the translucency of the resin composite must be considered a critical property just like the color of the material itself. Hence, many researchers have evaluated the translucency of resin composites using parameters such as contrast ratio[7-11] or translucency parameter (TP)[4-6,11,12]. Contrast ratio is the ratio of the reflectance of a specimen disk over a black backing to that over a white backing of a known reflectance. It is an estimate of the opacity of 1mm-thick specimens. The TP is the color difference between a uniform thickness of the material on black and white backings, and corresponds directly to common visual assessments of translucency.

For the sake of minimizing the effect of the background color, some opaque-shade resin composites have been utilized as a backing in layering techniques. In the layering technique, a layer of more translucent material is applied over the opaque-shade resin composite in order to create depth from within the restoration, thereby reducing the color coming only from the surface of the restoration. Regarding the thickness to be applied for each layer, it should be changed according to the location within the restoration — depending on whether it is a cervical or incisal area. Therefore, it is crucial to know the relationship between the thickness and translucency of a material to establish a successful color match of the layered restoration. However, very little information is available on the relation between the thickness and translucency of resin composites[7,8,13].

On the other hand, the color of each layer in the layering technique is also a critical factor that determines the esthetical success or failure of a layered restoration. For the resultant color, it is known that the color is influenced not only by the optical properties of the covering layer but also by the color and optical properties of the underlying layer[14]. In this connection, it seems rather difficult to know the inherent color of a resin composite because it can somehow be affected by the background color due to its translucent characteristics. One solution is to estimate the inherent color using a specimen of sufficient thickness such that the resultant color would not be affected by the background color. However, no information is available about the inherent colors of resin composites obtained by this means.

Therefore, the purpose of the present study was
to evaluate the inherent colors of resin composites used for the layering technique and the translucency of these materials at various thickness.

MATERIALS AND METHODS

Resin composites for layering technique

The A2E (Lot No. 4XAJ), A2B (Lot No. 5AKJ) and A2D (Lot No. 4AHJ) shades of Filtek Supreme (FS; 3M, St. Paul, Mn, USA) and El (Lot No. 0310301), A2 (Lot No. 0406151) and AO2 (Lot No. 0310241) shades of Gradia Direct (GD; GC, Tokyo, Japan) were used in the present study. As the names of shades vary in different products, the A2E and El shades were given the generic name "enamel-shade" in the present study to simplify the naming convention. Similarly, A2B and A2 were described as "body-shade" and A2D and AO2 were described as "opaque-shade".

Color measurement

Translucent acrylic plates (0.5, 1.0, 2.0, 3.0 and 4.0 mm thick) with holes of 8mm diameter were used as molds for making standardized disk-shaped specimens.

Each mold was filled with resin composite material 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 specimens. After the glass slides were removed, irradiation was performed twice for 60 seconds – once from the top surface of the specimen and other time from the bottom. After light curing, the color of the material against two backings was measured separately using a colorimeter. A black ceramic tile (L* = 29.38, a* = -0.93, b* = 0.07) was used as the black backing, followed by a white ceramic tile (L* = 93.56, a* = -1.97, b* = 3.53) in this order of measurement. For each color measurement, five specimens from each shade of each product were used.

The series of the color measurements were carried out using a colorimeter: OFC-300A (Nippon Denshoku, Tokyo, Japan). The spectral power distribution of the pulsed xenon lamp adopted in the colorimeter is CIELAB parameters (L*, a* and b*). L* indicates lightness, where 100 is white and 0 is black. a* and b* are the red-green and yellow-blue chromatic coordinates. A positive a* or b* value indicates a red or a yellow shade, respectively.

Calculation of TP

The translucency of each material at various thickness was calculated by using the following TP formula:

$$TP = \left( (L_w^* - L_B^*)^2 + (a_w^* - a_B^*)^2 + (b_w^* - b_B^*)^2 \right)^{1/2}$$

where the subscript “W” refers to the CIELAB value for each specimen on the white backing, and the subscript “B” refers to the value for each specimen on the black backing.

To detect any statistical differences in TP, one-way ANOVA and Games-Howell test were carried out for each group.

RESULTS

The TP values of each shade of each material at 0.5, 1.0, 2.0, 3.0 and 4.0 mm thickness are shown in Table 1. In FS and GD, thicker specimens always showed lower TP values regardless of shade. However, exceptions were found in 3.0 to 4.0 mm of the opaque-shade in both products, and in 3.0 to 4.0 mm of the body-shade in GD.

Among the shades of FS at 0.5 and 1.0 mm thickness (Table 1), groups with the same superscript letter are not significantly different (Games-Howell test, p>0.05).

Table 1 TP (translucency parameter) for each product and its shades at various thickness

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>FS</th>
<th>GD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enamel shade</td>
<td>Body shade</td>
</tr>
<tr>
<td>0.5</td>
<td>20.43 (1.22)</td>
<td>17.11 (0.83)</td>
</tr>
<tr>
<td>1.0</td>
<td>12.25 (0.48)\textsuperscript{a}</td>
<td>10.80 (0.44)\textsuperscript{b}</td>
</tr>
<tr>
<td>2.0</td>
<td>3.93 (0.25)\textsuperscript{c}</td>
<td>3.76 (0.34)\textsuperscript{e}</td>
</tr>
<tr>
<td>3.0</td>
<td>1.65 (0.17)\textsuperscript{d}</td>
<td>1.24 (0.20)\textsuperscript{d}</td>
</tr>
<tr>
<td>4.0</td>
<td>0.57 (0.15)\textsuperscript{e}</td>
<td>0.43 (0.14)\textsuperscript{e}</td>
</tr>
</tbody>
</table>

Mean (SD), n=5

Within each product, groups with the same superscript letter are not significantly different (Games-Howell test, p>0.05).
thickness, the TP values decreased in this descending order: enamel-shade > body-shade > opaque-shade. However, in the thicker specimens of FS at 2.0 and 3.0 mm, no significant difference was found between the enamel and body shades, though the opaque shades indicated significantly lower TP values when compared with the other shades. At 4.0 mm thickness, all the shades showed no significant differences.

Regarding the TP values of GD at 0.5 to 3.0 mm thickness, there were no significant differences between the enamel- and body-shades, though the opaque-shades indicated significantly lower TP values compared with the other shades. At 4.0 mm thickness, all the shades showed no significant differences.

Fig. 1 also shows the TP values at each thickness. To clarify the relationship between thickness and TP value, a correlation analysis was performed for each shade of the products. As a result, the correlation between thickness and TP value was most precisely expressed by an exponential function for each shade of the two products. The calculated correlation coefficients ($R^2$) were also indicated in Fig. 1, and all the values were above 0.9. This meant that there existed a strong exponential relationship between thickness and TP value regardless of product and shade. From the exponential functions, it was plainly shown that for enamel- and body-shades, the TP values decreased drastically as thickness increased as compared to the opaque-shades. Additionally, when the reduction in the thickness was same, the larger increase in the TP value was observed in the thinner part of the exponential function for all products and shades. Further, the exponential function was also used to calculate the thickness at which the TP value became 2.0 — the threshold for color distinction by human eyes$^{15}$. For the enamel-, body- and opaque-shades of FS respectively, the predicted thickness were 2.76, 2.56 and 1.88 mm for the enamel-, body- and opaque-shades of GD respectively.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>L*, a* and b* values of each product and shade at 4 mm thickness on white backing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FS</td>
</tr>
<tr>
<td>Enamel shade</td>
<td>52.00 (0.91)</td>
</tr>
<tr>
<td>Body shade</td>
<td>50.37 (0.39)</td>
</tr>
<tr>
<td>Opaque shade</td>
<td>60.24 (0.24)</td>
</tr>
</tbody>
</table>

Mean (SD), n=5
Within each CIELAB parameter, groups with the same superscript letter are not significantly different (Games-Howell test, p>0.05)
opaque-shades of FS, the predicted thickness were 2.76, 2.56 and 1.88 mm respectively. For the enamel-, body- and opaque-shades of GD, the predicted thicknesses were 3.19, 3.04, and 2.69 mm respectively.

The L* values of each material and shade at 4 mm thickness on white backing are shown in Table 2. According to the L* value, the opaque-shades showed higher values than the enamel- and body-shades of both products. When comparing the L* values between FS and GD, the opaque-shade of GD showed a higher value in comparison with that of FS. Regarding the a* value, the enamel-shade of FS and the body-shade of both products showed no statistical differences. Moreover, these values were greater than the other shades of both products. Regarding the b* value, it increased in this ascending order for both products: enamel-shade < body-shade < opaque-shade. When comparing the b* values between FS and GD, GD revealed a smaller value than FS in enamel-shade, though the b* values of both body- and opaque-shades showed no statistical differences between the products.

**DISCUSSION**

Whenever a so-called “through and through” restoration is encountered, it is essential that filling materials — with limited thickness — can avoid an unfavorable color change due to the dark background color of the oral cavity. Based on the present study, it was found that opaque-shade resin composites could effectively minimize the effect of the dark background color of the oral cavity, because the shade was less translucent than the other shades.

Based on the TP-thickness exponential curves shown in Fig. 1, the predicted thickness at which TP became 2.0 — the threshold of color distinction by human eyes — were 2.76, 2.56, and 1.88 mm for the enamel-, body- and opaque-shades of FS respectively, and 3.19, 3.04 and 2.69 mm for the enamel-, body- and opaque-shades of GD respectively. This predicted thickness seemed to be the minimum thickness at which each shade can avoid an unfavorable color change by the dark background color of the oral cavity. As the predicted thickness of the opaque-shades was the lowest for both products, clinicians should use the opaque-shade when the clinically available thickness for minimizing of the effect of the dark background color is limited. The thickness values obtained from the exponential curves in the present study could give an indication to the thickness of the opaque layer to be used, which is required to mask the dark background color in the layering technique.

The translucency of the enamel-shade is also a crucial property that affects the resultant color of a layered restoration, because the color of a more translucent covering layer is easily affected by the color of the underlying layer. Based on the TP-thickness exponential curves in the present study, the more translucent enamel-shade seemed to be more easily affected by change in thickness compared with the other shades. In addition, translucency change was larger in the thinner part of the exponential curves. Clinically, the superficial enamel-shade is often applied as a thin layer in the layering technique. Hence, a minute difference in thickness of the covering enamel-shade might have a significant effect on the color of the layered restoration. However, very little information is available on the relation between the thickness of the covering enamel-shade and the resultant color of the layered restoration. Therefore, future studies are needed to investigate the color shifts of layered restorations with respect to change of thickness of the covering enamel layer.

In the present study, the inherent colors of the resin composites were evaluated by using 4 mm thick specimens. For all the 4 mm thick specimens, their TP values were always below 1.1, regardless of shade. These TP values fall within the imperceptible range by human visual sense. Therefore, the colors of the 4 mm thick specimens could be considered as the inherent colors of the resin composites not affected by the background color. In the inherent colors, the b* values of the enamel-shades, especially in GD, were smaller (more bluish) than that of the other shades. Such a characteristic of b* values in the enamel-shades of the resin composites would seem beneficial for simulating a blue shift of the dentin color by the effect of an enamel-color in natural teeth.

Regarding the opaque-shade, larger L* and b* values were observed in comparison with the other shades. Hence, the opaque-shade may serve to add brightness and yellowish characteristics — alongside opacity — to a layered resin composite restoration. However, the effect of the underlying opaque-shade on the resultant color of a layered restoration remains much to be known. Therefore, more detailed studies should be conducted to clarify the extent to which the opaque-shade affects the color of layered restorations.

In conclusion, the opaque-shades were less translucent in comparison with the other shades. Further, translucency was found to increase exponentially with reduction in thickness, regardless of shade. As for the color itself, the enamel-shades were more bluish (especially in GD) compared to the other shades, and the opaque-shades indicated brighter and yellowish characteristics in comparison with the other shades.

For all the filling materials used in the present study, it was revealed that each shade of both resin composites had different optical properties. Hence, in layering restoration, an accurate knowledge about the differences in the translucency and color of the materials used seems to be fundamental, together
with the accumulated experience of the individual clinician. However, very little information is available on the resultant color after layering the selected shades. Therefore, future studies are needed to investigate the effect of parameters such as color, translucency and thickness of each layer on the resultant color of layered restorations.

REFERENCES