Translucency and Characteristics of Newly Developed Polymer-based Dental Tooth Coating Material

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The purpose of this study was to evaluate the translucency and color change of simulated heavily discolored teeth using polymer-based dental tooth coating materials and flowable resin composites. Five shades of coating material and two shades of flowable resin composite were used. Colorimetric values of the materials in different shades were determined using the L*a*b* system of the Commission Internationale de l’Eclairage (CIE). Colorimetric examination was performed on white, black, and shade guide (C4) backgrounds using specimens of various thickness (0.2, 0.3, 0.5, 1.0, and 2.0 mm).

New coating material showed less translucent than flowable resin composites. Moreover the new material showed the potential to improve the appearance of heavily discolored teeth when being applied as a thin first layer.

Key words : Tooth coating material, Translucency, Chroma

INTRODUCTION

Esthetic restorations, such as direct composite restorations1), indirect composite restorations2), ceramic restorations3,4), and laminate veneering5,6) have been widely used in current daily clinical procedure. Besides, there are also many research reports available with regard to esthetic restorations. Generally, these treatments require cutting away a substantial amount of tooth structure using rotary instruments. Namely, these techniques can be called ‘invasive technique’7,8).

Current concept of restorative dentistry focuses on the ‘minimally invasive and/or non-invasive technique’ instead of the ‘invasive technique’7,8) because the less invasive technique appeals to patients. Moreover, treatment is absolutely beneficial to the promotion of oral health of the patients.

The non-invasive technique comprises bleaching and micro-abrasion9). Bleaching is a popular treatment for discolored teeth, because tooth color can be improved without removing sound tooth structure. However, bleaching has many potential problems such as reversion after bleaching, indication limit, tooth sensitivity, and gum irritation10). Since there are advantages and disadvantages with regard to the bleaching treatment, it is thus important to consider other non-invasive techniques as well.

Recently, a polymer-based dental tooth coating material (WHITE COAT, Kuraray Medical Inc., Tokyo, Japan) has been developed11) to meet the rising demand for esthetic improvement, apart from bleaching. This material consists of a self-etching primer solution, light-curing resin coating material (Base Coat), and light-curing surface glazing material (Top Coat). This material can be applied on the enamel surface to improve the esthetic appearance of discolored tooth with a thin layer of resin-based material.

When applying a thin layer of resin-based material on discolored tooth to improve its esthetic appearance, translucency and opacity of the material are important considerations. Translucency parameter (TP) is one criterion used to evaluate the translucency of materials12,13). TP is obtained by calculating the color difference between specimens on white and black backings. When compared with opacity, TP measurement seems to be simpler and easier to understand than that of opacity14).

Clinically, the choice of an esthetic material hinges on its ability to mask discolored teeth5,15). Although TP measurement uses white and black backings, these colors are rare for the color of discolored teeth and inappropriate for clinical use. For the resin-based coating material, its translucency would increase after it is applied in a thin layer. Moreover, its intrinsic color will be influenced by the original tooth color beneath the coatings. Thus, to improve the appearance of a tooth, it must be done in a two-pronged approach that involves both the color of the coating materials as well as the color of the tooth. Against this background, it is necessary to evaluate the color change of simulated, heavily discolored teeth using resin-coating materials. However, not many studies have focused on evaluating the color change of coating materials using tooth-colored backings. Therefore, the purpose of this study was to evaluate the translucency and color change of
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simulated heavily discolored teeth using polymer-based dental tooth coating material.

MATERIALS AND METHODS

Test materials and specimens preparation
Four polymer-based dental tooth coating materials (OB0, OA1, OA2, and OP; WHITE COAT, Kuraray Medical Inc., Tokyo, Japan) and two flowable resin composites (A2, Filtec Flow, 3M Dental Products, St Paul, MN, USA; OA2, FLOW line, Heraeus Kulzer GmbH & Co., KG, Hanau, Germany) were used in this study (Table 1).

Translucent acrylic plates of varying thickness (0.2, 0.3, 0.5, 1.0, 2.0, and 4.0 mm) with 6.0 mm diameter hole were used as molds for the standardized disk-shaped specimens. Each mold was filled with test material (Table 1), covered with a clear celluloid strip on both the top and bottom surfaces, and then pressed between two glass slides to achieve uniform thickness of the disk specimens. The top and bottom surfaces of each specimen were light-cured for 40 seconds using a light-curing unit (Optilix 401, Demetron, Danbury, CT, USA). The specimens were then removed from the molds, stored in an incubator at 37°C and 100% humidity for 24 hours.

Measurement of translucency parameter (TP)
Colorimetric measurements were performed with the CIE L*a*b* system for the specimens on a black or white background using a colorimeter (OFC-300A, Nippon Denshoku, Tokyo, Japan). All measurements were repeated five times for each of the three specimens. The translucency of materials at various thickness values was calculated using the translucency parameter (TP) formula:

\[ TP = \left( \frac{L^*_{W} - L^*_{B}}{L^*_{W}} \right)^2 + \left( \frac{a^*_{W} - a^*_{B}}{a^*_{W}} \right)^2 + \left( \frac{b^*_{W} - b^*_{B}}{b^*_{W}} \right)^2 \]

where the subscript “W” refers to CIE L*a*b* value for each specimen on the white backing and the subscript “B” refers to the value for each specimen on the black backing.

Measurement of color change of discolored teeth (MC)
To simulate severely discolored teeth, shade guide (dentin C4, Vita, Zahnfabrik H Rauter GmbH & Co., KG, Bad Sackingen, Germany), in the form of a porcelain plate, was used as a backing for the test specimen. Colorimetric measurements of the specimens - backed with porcelain plate - on a white tile (E_{white}) were conducted in the same manner as described previously. Further, CIE L*a*b* value of each 4.0 mm (E_{4mm}) thick specimen on a white backing was measured as a reference to the material’s original shade. Color change of each material was determined by calculating the color difference between E_{4mm} and E_{white}, according to the following equation:

\[ \Delta E^*_{MC} = \sqrt{\left( L^*_{E_{4mm}} - L^*_{E_{white}} \right)^2 + \left( a^*_{E_{4mm}} - a^*_{E_{white}} \right)^2 + \left( b^*_{E_{4mm}} - b^*_{E_{white}} \right)^2} \]


Table 1 Materials used

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Shade</th>
<th>Code</th>
<th>Batch #</th>
<th>Manufacturer</th>
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<tr>
<td>WHITE COAT™</td>
<td>OA1</td>
<td>OA1</td>
<td>TMX-OA1-3</td>
<td>Kuraray Medical Inc., Tokyo, Japan</td>
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<td>OA2-WC-T02</td>
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<tr>
<td>Filtec™ Flow</td>
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<td>FT</td>
<td>3ACJ</td>
<td>3M Dental Products, St Paul, MN, USA</td>
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<td>FL</td>
<td>010101</td>
<td>Heraeus Kulzer GmbH &amp; Co., KG, Hanau, Germany</td>
</tr>
</tbody>
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Statistical analysis
The correlation between thickness of specimen and translucency parameter or between thickness of specimen and color change was evaluated with Pearson correlation test at 5% level of significance. Color change of 0.2 mm thick specimen was analyzed by one-way ANOVA at 5% significance level. All statistical analyses were done using SPSS Base 10.0 for Windows software (SPSS Japan Inc., Shibuya-ku, Japan).

RESULTS
Regression analysis for each material revealed sig-
significant relationship between TP and thickness of specimen, as shown in Fig. 1 (p<0.05). Table 2 shows the equation used for each specimen, as well as the coefficient of correlation and p value obtained from regression analysis. For all the materials tested in this study, the TP value decreased logarithmically as thickness of the specimen increased. Each regression graph seemed to be divided into three groups. Resin composites (FT and FL) belonged to higher TP value group. Most of WHITE COAT specimens, OA1, OA2, OB0, and OB1, belonged to lower TP value group, while WHITE COAT (OP) was in the lowest TP group. With respect to 1.0 mm specimens, all the TP values of WHITE COAT specimens were below 3, whereas those of composites resins were above 3.

Likewise, regression analysis revealed significant relationship between ΔE*M*C and thickness of specimen, as shown in Fig. 2. Table 3 shows the equation used for each specimen, as well as the coefficient of correlation and p value obtained from regression analysis. For four materials, OA1, OA2, OB0, and OB1, the ΔE*M*C value decreased logarithmically as thickness of the specimens increased (p<0.05). However, OP, FT, and FL failed to show statistically significant correlation between thickness and ΔE*M*C. Each regression graph seemed to be divided into two groups. WHITE COAT (OA2) was in the lowest group whereas other materials belonged to another group (OA1, OB0, and OB1).

With respect to 0.2 mm thick specimens, ΔE*M*C value for the OP shade was below 3, whereas all ΔE*M*C values for the other materials were above 3.5 (Table 4). L* value of each material with 0.2 mm thickness on C4 backing is given in Fig. 3. The values appeared to be divided into two groups. WHITE COAT materials belong to higher L* value group (L*>75), while flowable resins belonged to lower L* group (L*<60).

The change of a*b* values between 0.2 mm and 2.0 mm thickness of each material on C4 backing is shown in Fig. 4. For all 0.2 mm thick specimens, reduced yellowness and increased blueness were noted compared to the 2.0 mm thick specimens. OA1, OA2, and OP indicated reduced redness, whereas OB0 and FT tended to show increased redness in 0.2 mm thick specimens. OB1 and FL showed little change in a* value between 0.2 mm and 2.0 mm specimens.

Difference in chroma values (ΔC*) of each material between 0.2 mm and 2.0 mm thickness on C4 backing is shown in Fig. 5. The values appeared to be divided into two groups. Four materials (OA1, OA2, OB0, and OB1) belonged to higher ΔC* value group (ΔC*>4), and other materials (OP, FT, and FL) belonged to lower ΔC* group (ΔC*<2.5).
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Table 4 \( \Delta E^*_{MC} \) values of 0.2 mm thick specimens

<table>
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<tr>
<th></th>
<th>OA1</th>
<th>OA2</th>
<th>OB0</th>
<th>OB1</th>
<th>OP</th>
<th>FT</th>
<th>FL</th>
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<tr>
<td>0.2</td>
<td>8.55</td>
<td>5.40</td>
<td>8.30</td>
<td>8.95</td>
<td>2.31</td>
<td>4.82</td>
<td>3.61</td>
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</table>

Fig. 3 \( L^* \) value of 0.2 mm thick specimen.

DISCUSSION

Translucency or opacity and shade matching are important criteria for esthetic restorations, such as coating discolored teeth with resin-based materials. This study evaluated the translucency parameter (TP) and color change of simulated discolored teeth using WHITE COAT materials.

The translucency parameter (TP) was obtained by calculating the color difference between specimens on white and black backings. The translucency parameter is difficult to interpret for clinical use. Generally, a higher-value translucency parameter is indicative of greater translucency or less opacity\(^\text{12}\). However, translucency parameter is specific for a given material thickness and backing used in the evaluation. It is therefore important to evaluate the relationship between thickness and translucency parameter for translucent materials\(^\text{16}\).

In the present study, when the translucency parameter values were compared among the products, WHITE COAT materials showed a lower value than those of flowable resin composites (Fig.1). This finding meant that WHITE COAT materials were less translucent than flowable resin composites. Among the WHITE COAT materials, OP shade exhibited the lowest translucency.

When considering the thickness of each specimen, there was a greater variation of TP values among the thinner specimens. It was reported that color difference less than 3 to 3.3 CIE \( L^*a^*b^* \) units was clinically acceptable\(^\text{19-22}\). For this study, any value less than 3.3 was considered clinically acceptable. For flowable resin composites, the TP values of all specimens exceeded 4. It meant that translucency of flowable resins was above the clinically acceptable threshold value. For WHITE COAT, TP values of OB0, OA2, and OP shades among the 1.0 mm thick specimens were less than 3; but for 0.5 mm thick specimens, only OP shade indicated a value below 3. However, TP measurement using white and black backings seems to be impractical for clinical situations.

In this study, therefore, measurement of color change was performed using a shade guide to simulate severely discolored teeth (Fig.2). As for the CIE \( L^*a^*b^* \) color difference (\( \Delta E^*_{MC} \)) of the specimens on C4 backing and on the material itself, significant correlation was observed in four materials (OA1, OA2, OB0, and OB1). On the other hand, flowable resins and OP failed to show significant correlation between \( \Delta E^*_{MC} \) and material thickness. Flowable resins — incorporated with fillers — showed greater TP values. This might be the reason for the lack of relationship. Likewise, the OP shade seemed to be unaffected by material thickness. Moreover, there was a trend of the OP shade to yield the smallest \( \Delta E^*_{MC} \) values compared with other shades. This
could be explained by the smallest translucency parameter of the OP shade (Fig. 1). In other words, OP shade could mask dark background color effectively, as compared to other materials. This also meant that OP shade has a high potential for masking discolored teeth with a very thin layer (0.2 mm). Leveraging on this potential, it may be possible to mask heavily discolored teeth by applying OP shade as a thin first layer followed by another shade. Besides, OP shade might even be able to mask restorations with metal color. Future study is needed to evaluate the effect of dual coating technique that is able to mask both severely discolored teeth and metal color.

As for the L* values measured in the present study, WHITE COAT materials indicated a greater value than those of flowable resins (Fig. 3). This meant that material with a brighter color would satisfy a patient’s desire for brighter, whiter tooth color.

Chroma characteristics of a material are just as important too2). Interestingly, chroma values measured for a thin layer of each material showed different characteristics (Figs. 4 and 5). When comparing the change of chroma (ΔC*) between 0.2 mm and 2.0 mm, the materials were divided into two groups: greater ΔC* group and smaller ΔC* group. The greater ΔC* group (OA1, OA2, OB0, and OB1) appeared to be affected by the color of the C4 backing. On the other hand, materials of the smaller ΔC* group (OP, FT, and FL) seemed unaffected by the color of the backing. Further study is needed to evaluate the masking effect of other shade guides which simulate slightly discolored tooth color, such as A3 and/or B3 shades.

If WHITE COAT materials are properly utilized in clinical situation, these materials should have a high potential of meeting the esthetic demands of patients. Future study is needed to evaluate the satisfaction level of patients after using WHITE COAT materials in clinics.

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