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Author(s)	Kamishima, Naoko; Ikeda, Takatsumi; Sano, Hidehiko
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Title:

Effect of enamel shades on color of layered resin composites.

Authors:

Naoko KAMISHIMA, Takatsumi IKEDA, Hidehiko SANO

Department of Restorative Dentistry, Division of Oral Health Science, Hokkaido

University Graduate School of Dental Medicine, Kita 13 Nishi 7, kita-ku, Sapporo

060-8586, Japan.

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*Corresponding author:

Kamishima Naoko

Hokkaido University Graduate School of Dental Medicine, Kita 13 Nishi 7, kita-ku,

Sapporo 060-8586, Japan; Tel.: +81-11-706-4261;

fax: +81-11-706-4878; E-mail address: kamisima@den.hokudai.ac.jp

SYNOPSIS

The purpose of this study was to evaluate the effect of the covering enamel layer of various thickness on the color of layered resin composites (LRC). The CIELAB parameters of the underlying base (ULB: 2.0mm of body-shade+3.0mm of opaque-shade), inherent color of the enamel-shade (4.0mm of enamel-shade+ULB) and LRC disks (0.5, 1.0, 2.0, 3.0mm of enamel-shade+ULB) of Filtek Supreme (FS,3M) and Gradia Direct (GD,GC) were evaluated. To know the effect of the enamel-layer on the color of the LRC, color difference between the ULB and LRC was calculated. In FS, the enamel layer had no major effect on the color of the LRC, regardless of the thickness. AS for GD, the enamel layer had a significant effect on the color of the LRC, even if the thickness was 0.5mm. The difference between the products might be explained by the characteristics in color of the enamel-shades.

INTRODUCTION

Recently, less traumatized direct restorative methods using adhesive systems and resin composites have been receiving increasing attention. In cases of large class IV cavities or fractured anterior teeth, direct resin composite restorations have become available as an alternative of more traumatize prosthetic appliances through the development and improvement of adhesive systems ^{1,2)} and resin composite materials ³⁾.

Regarding the optical properties such as a translucency or color of human teeth, it was known that the properties were different by the location in a tooth. In the incisal location, natural human teeth showed bluish, greenish and more translucent aspect in comparison with the cervical location ⁴⁾. Hence, to express the optical properties of the natural teeth, the large class IV cavities or fractured anterior teeth cannot be restored by an only shade of resin composite. Therefore, a layering technique seems necessary for a successful restoration in the cases. When using the layering technique, more translucent enamel-shade over an body- or opaque-shade resin composites are often used to create depth from within the restoration, and help to reduce color coming only from a surface of the restoration. The resulting restoration in the technique is determined by several

factors such as translucency, color and thickness of each layer as reported by Lee *et al*⁵⁾. The authors also showed that the covering layer had a larger effect in comparison with the underlying layer on the resulting color of layered resin composites. Therefore, effect of the covering enamel-shade on the resultant color of layered resin composites should be known for the successful restoration by the layering technique. However, there is no information available for the effect of the enamel layer on the layering resin composites.

As for the translucency, it was reported that the optical property was so much affected by the thickness of resin composites⁶⁻⁹⁾. In our previous study, it was revealed that the relation of the thickness and translucency of resin composites was expressed as exponential functions⁹⁾. In the exponential functions, the translucency was changed drastically in thinner specimens. As the enamel shade is often used as a thin layer in the layering technique, it was expected that only a little change in thickness of the enamel layer could 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 thickness on the resultant color of layered resin composites.

MATERIALS AND METHODS

Resin composites for layering techniques

The A2E (lot. 4XAJ), A2B (lot. 5AKJ) and A2D (lot. 4AHJ) shades of Filtek Supreme (FS: 3M, St. Paul, Mn, USA) and E1 (lot. 0310301) and A2 (lot. 0406151) and AO2 (lot. 0310241) shades of Gradia Direct (GD: GC, Tokyo, Japan) were used in the present study. As the names of the shades vary in different products, the A2E and E1 shades were given the generic name "enamel-shade" in the present study for simplicity. Similarly, A2B and A2 were described as "body-shade", and A2D and AO2 were described as "opaque-shade".

Translucency parameter of enamel-shade at various thickness

Translucent acrylic plates (0.5, 1.0, 2.0, 3.0 and 4.0 mm thick) with holes of 8 mm in diameter were used as molds for making standardized disk-shaped specimens. Each mold was filled with the resin composite of the enamel-shade, and covered with clear celluloid strips on the top and bottom of the hole. The acrylic plate was pressed between two glass slides by finger pressure to achieve uniform thickness of the disk specimens. The glass slides were removed, and irradiation was performed through the thin plastic film using an Optilux 401

(Demetron, Danbury, CT, USA). The 60 seconds irradiation was performed twice, from the top and bottom of the specimen. After light curing, the color of the materials was measured separately using a colorimeter, against 2 backings: a black ceramic tile ($L^*=29.38$, $a^*=-0.93$, $b^*=0.07$) and a white ceramic tile ($L^*=93.56$, $a^*=-1.97$, $b^*=3.53$) in this order of measurements. For the measurements, 5 specimens were made from each enamel-shade of the products. 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 CIE illuminant D65, which corresponds to "average" daylight. Calibration of the equipment was performed immediately before the series of 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^* is the 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.

The translucency of the enamel-shade at each thickness was calculated by using the translucency parameter (TP) formula¹⁰⁻¹⁵:

$TP = [(L_W^* - L_B^*)^2 + (a_{W^*} - a_{B^*})^2 + (b_{W^*} - b_{B^*})^2]^{1/2}$, where the subscript "W" refers to CIELAB values for each specimen on the white backing, and the subscript "B" refers to the values for specimens on the black backing. 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. To detect any statistical differences in TP, one-way ANOVA and Games-Howell test were carried out for each group.

The effect of enamel layer on the color of the layered resin composites

Figure 1 illustrates the procedure for evaluating the effect of enamel layer on the color of the layered resin composites. As the underlying color base of the layered resin composites, following three layers were superposed from bottom to surface in order: a black ceramic tile ($L^*=29.38$, $a^*=-0.93$, $b^*=0.07$), a cured disc of opaque-shade (8 mm in diameter, 3 mm in thickness) and a cured disc 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. The various thickness of enamel-shade discs (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 and followed by color

Fig. 1

evaluation using the colorimeter (0 mm means no enamel-shade disc, hence the color of the underlying base itself). Optical contact was achieved by using an optical fluid (refractive index was approximately 1.5), between the layers of the resin composites as used by many researchers¹⁶⁻¹⁸). The number of the layered-resin composite specimens was five for each thickness of the enamel-shade. Based on the obtained L*, a*, b* parameters of the layered resin composites, color differences were calculated in two manners to evaluate the effect of enamel-shade at various thickness on the color of the layered resin composites. The two calculations were described below.

Color difference between the underlying color base and layered resin composites

The color difference between the underlying color base and layered resin composites at various enamel-shade thickness were calculated using the equation:

$$\Delta E^* = [(L_{base^*} - L_{layered^*})^2 + (a_{base^*} - a_{layered^*})^2 + (b_{base^*} - b_{layered^*})^2]^{1/2}, \text{ where } L_{base^*} a_{base^*} b_{base^*} \text{ and } L_{layered^*} a_{layered^*} b_{layered^*} \text{ values are } L^* a^* b^* \text{ values of}$$

underlying color base and layered resin composites of various enamel-shade thickness, respectively. The color differences show the effect of the covering enamel-shade at various thickness on the color of the layered resin composites.

Color difference between the enamel-shade and layered resin composites

In our previous study, it was reported that the enamel-shades of 4 mm thickness were thick enough not to be affected by background color⁹⁾. Therefore, the color of the layered resin composites covered by the enamel-shade of 4 mm thickness could be considered as an inherent color of the enamel-shade. Hence, the color differences were calculated by the following equation to evaluate the similarity in color regarding the inherent color of enamel-shade and layered resin composites covered by the enamel-shade of various thickness.

$$\Delta E^* = [(L_{\text{enamel}^*} - L_{\text{layered}^*})^2 + (a_{\text{enamel}^*} - a_{\text{layered}^*})^2 + (b_{\text{enamel}^*} - b_{\text{layered}^*})^2]^{1/2},$$

where L_{enamel^*} , a_{enamel^*} , b_{enamel^*} and L_{layered^*} , a_{layered^*} , b_{layered^*} values are L^* , a^* , b^* values of inherent color of the enamel-shades and layered resin composites of various enamel-shade thickness, respectively.

To define the relation between ranges of colorimetric differences and the degree of visual color differences, colorimetric differences above "2" were considered as "perceptible differences" in the present study, using the definition by Gross *et al*¹⁹⁾.

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

The inherent color of the enamel-shade as described above were evaluated for

each CIE L*, a*, b* parameter in comparison with the parameters of underlying color bases. The number of the specimens was five for each group. For the comparison, one-way ANOVA and Games-Howell post-hoc test were carried out for the L*, a* and b* values separately to detect statistically significant differences between the groups ($p < 0.05$).

RESULTS

Translucency parameter of enamel-shade at various thickness

The results of TP of enamel-shade at various thickness were illustrated in Figure 2. The correlation between the thickness and TP values was most precisely expressed by exponential functions for the two enamel-shades. The TP values indicated statistically significant decrease in the two products by the reduction of thickness of the specimens (Games-Howell test, $p < 0.05$). In the exponential functions, the TP value were drastically decreased when the thickness of the specimens were thin. Regarding comparison between the two products, the TP values were not statistically different (Games-Howell test, $p > 0.05$), with exception of the 2mm thickness.

Fig. 2

The effect of enamel layer on the color of the layered resin composites

The effect of enamel layer on the color of the layered resin composites was

summarized in Figure 3. Regarding FS, color differences between the underlying base and layered resin composites were always below "2", threshold of distinction for human eyes, with exception of 2mm though the value of TP was 2.06. As for GD, color differences between the underlying base and layered resin composites were always above "2".

Fig. 3

Color difference between the enamel-shade and layered resin composites

The color differences between the enamel-shade and layered resin composites were revealed in Figure 4. Regarding FS, color differences between inherent color of the enamel-shade and layered resin composites were always below "2". As for GD, the color differences were 5.83 and 3.46 for 0 and 0.5 mm of enamel thickness, respectively. The color differences were drastically decreased by the increase of the thickness of enamel layer to the 1 mm and indicated below "2", when the thickness of the enamel layer became above 1 mm.

Fig. 4

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

L*, a*, b* of inherent color of the enamel-shade and underlying color base were indicated in Table 1. Regarding FS, no statistical difference was observed between the enamel-shade and underlying color base in the L*, a*, b* parameters. As for the GD, the L*, a* and b* values of the enamel-shade were

Table 1

always greater compared to the underlying color base.

DISCUSSION

Regarding the color difference between the underlying color base and layered resin composites, FS showed imperceptible color differences regardless of the enamel-layer thickness. Hence, the enamel-shade of this product had no major effect on the resultant color of the layered resin composites. The result could be explained by the similarity in color of the enamel-shade and underlying color base employed in the present study. In GD, the color differences were always above 2, threshold of distinction for the human eyes ¹⁹⁾. Hence, the enamel-shade of the product had a significant effect on the color of the layered resin composites, even when the thickness of the enamel layer was 0.5mm. The fact could be derived from the difference in color between the enamel-shade and underlying layer of this product. As Lee *et al.* reported, the covering layer had a major effect on the resulting color of layered resin composites ⁵⁾. Hence, the thin enamel layer could have a significant effect on the resultant color of the 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. The fact could again be explained by the similarity of

the enamel-shade and underlying base in color. Regarding GD, the color differences were below the threshold of distinction for human eyes, when the thickness of the enamel layer became 1mm. 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 1mm. Hence, the color of the layered resin composites changed drastically in the products by the 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 the different results regarding the effect of the enamel layer on the resultant color of the layered resin composites. Hence, it seems beneficial to alter the direction for use in the two products. Regarding FS, the color of the layered resin composites can not be affected so much by the thickness of the covering enamel layer. Therefore, the product may be suitable for the clinician who has little experience in the layering technique, as the failure arose from an inadequate thickness of the enamel layer may be minimum in the product. However, there exist a concern that the resultant restoration may become monotone in color. Therefore, to express the grayish aspect of the incisal location in a tooth, dark background

color should be intentionally utilized by eliminating an opaque-shade from the location in the product. As for GD, the resultant color of the layered resin composites were altered drastically by the tiny change of the thickness of the thin enamel layer. Hence, clinicians should control the thickness of the enamel layer carefully in the product, or too much enamel color will be dominant in the layered resin composites. However, the products have a major point to be able to express the gradation of color in a natural tooth by the very thin enamel layer.

In the present study, the translucency of the enamel-shades and effect of the enamel layer on the color of the layered resin composites were evaluated in various thickness. In an actual restoring procedure, the resin composite materials were used in various thickness. Hence, it seems beneficial to adopt the valuation method employed in the present study for obtaining much more clinical information in the layering technique.

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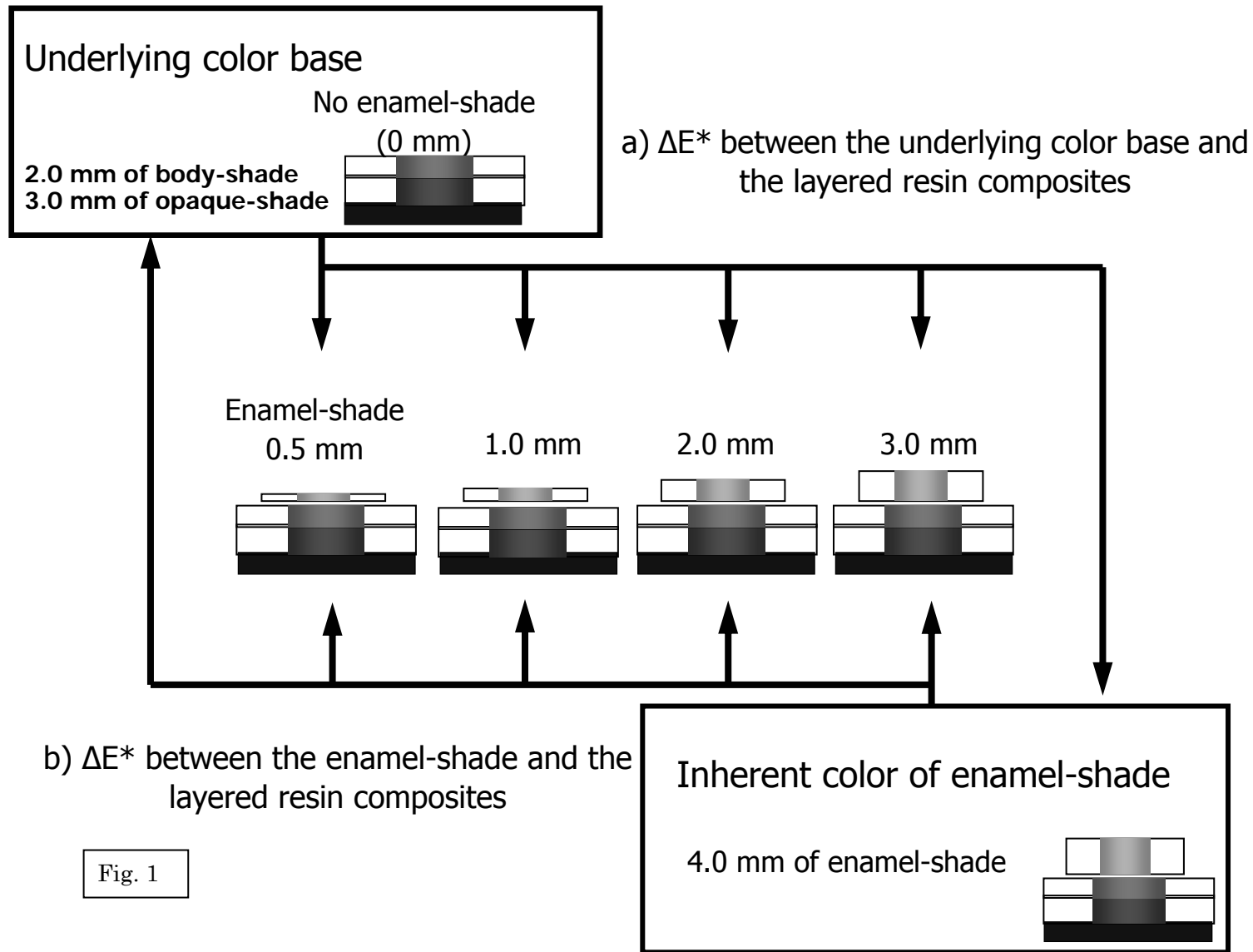
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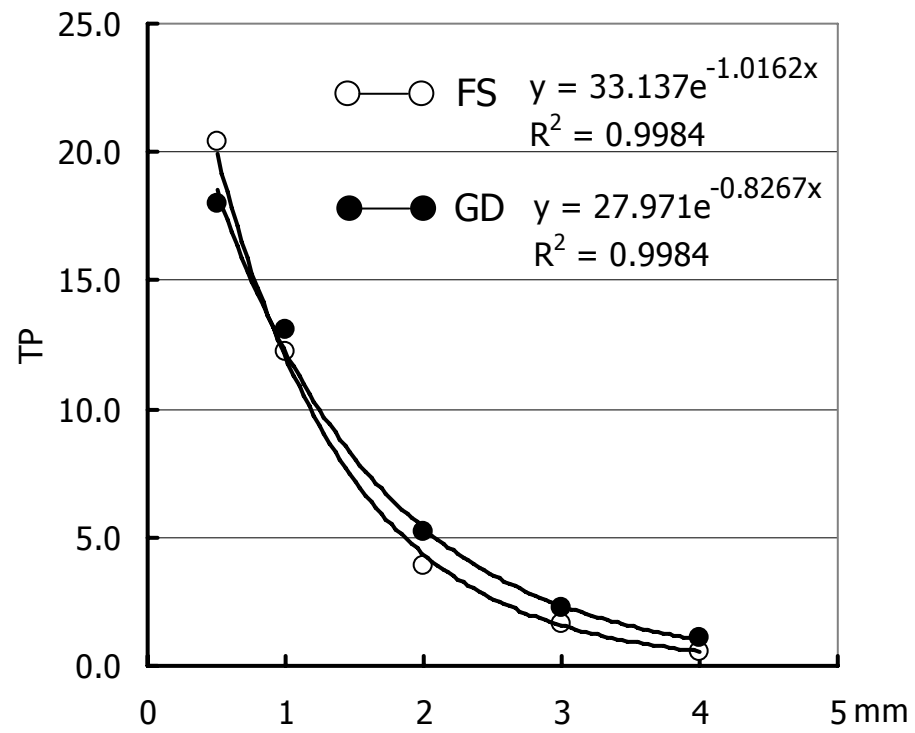


Fig. 2

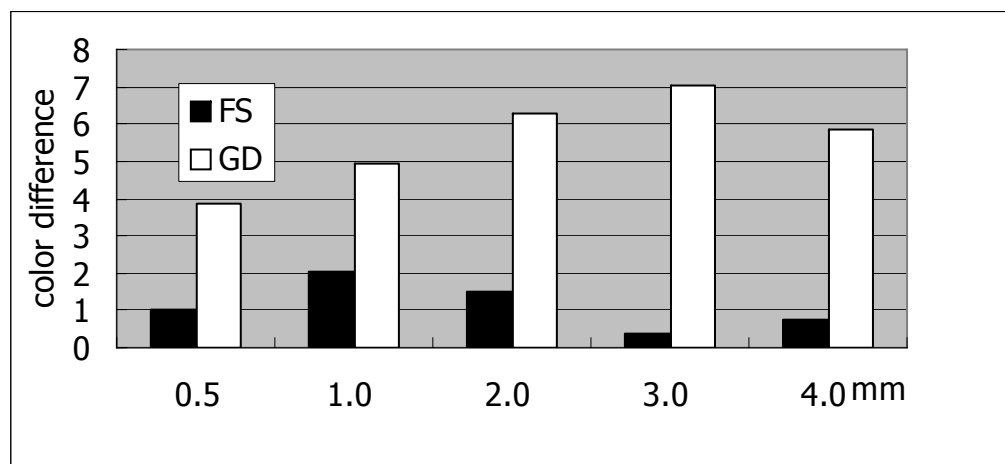


Fig. 3

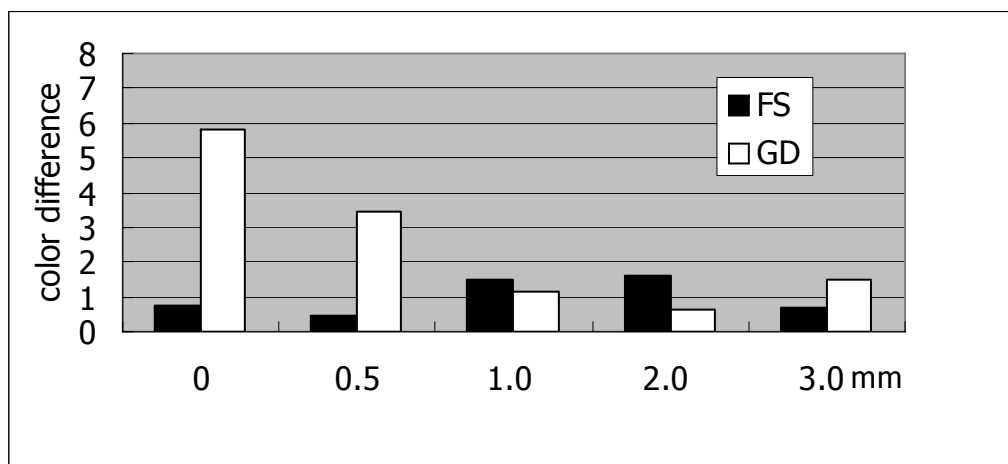


Fig. 4

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

	L*		a*		b*	
	FS	GD	FS	GD	FS	GD
Enamel-shade	50.59 ^a (0.63)	50.06 ^a (0.48)	-3.60 ^A (0.09)	-4.90 (0.08)	1.92 ^a (0.30)	-2.54 (0.61)
Underlying base	50.11 ^a (0.67)	52.28 (0.94)	-3.54 ^A (0.16)	-3.42 ^A (0.09)	2.50 ^a (0.90)	2.51 ^a (0.55)

Mean (SD), n=5

Within each CIELAB parameters, groups with the same superscript letters are not significantly different (Games-Howell test p>0.05).

Caption for Fig 1.

Based on the obtained L^* , a^* , b^* parameters of the layered resin composites, color differences were calculated in two manners to evaluate the effect of enamel-shade at various thickness on the color of the layered resin composites.

- a) ΔE^* between the underlying color base and the layered resin composites
- b) ΔE^* between the enamel-shade and the layered resin composites

Caption for Fig 2.

The results of TP of enamel-shade at various thickness were illustrated. The correlation between the thickness and TP values was most precisely expressed by exponential functions for the two enamel-shades. The TP values indicated statistically significant decrease in the two products by the reduction of thickness of the specimens (Games-Howell test, $p < 0.05$). Regarding comparison between the two products, the TP values were not statistically different with exception of the 2mm thickness (Games-Howell test, $p > 0.05$).

Caption for Fig 3.

The effect of enamel layer on the color of the layered resin composites was summarized. Regarding FS, color differences between the underlying base and layered resin composites were always below "2", threshold of distinction for human eyes, with exception of 2mm though the value of TP was 2.06. As for GD, color differences between the underlying base and layered resin composites were always above "2".

Caption for Fig 4.

The color differences between the enamel-shade and layered resin composites were revealed. Regarding FS, color differences between inherent color of the enamel-shade and layered resin composites were always below "2". As for GD, the color differences were 5.83 and 3.46 for 0 and 0.5 mm of enamel thickness, respectively. The color differences were drastically decreased by the increase of the thickness of enamel layer to the 1 mm and indicated below "2", when the thickness of the enamel layer became above 1 mm.