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Change of Color and Translucency by Light Curing in Resin Composites

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Clinical Relevance

For the precise shade matching of resin composite materials, clinicians should always be aware of the color change caused by light curing.

SUMMARY

Objective. This study evaluated color and translucency changes caused by light curing resin composite materials. Methods. The CIELAB parameters (L*, a* and b*) of disks of A2 and opaque A2 shades of Charisma (Heraeus-Kulzer), Solare (GC) and Filtek Supreme (3M) were evaluated on the backings of black, white and the material itself both before and after light curing to evaluate color and translucency changes (by means of calculating ΔE* and the translucency parameter, respectively). Results. Solare and Filtek Supreme showed significantly smaller color changes during light curing than Charisma; however, the value of ΔE* of all the products/shades was still in the clinically unacceptable range. Regarding translucency changes during light curing, the A2 and opaque A2 shades of Charisma showed a statistically significant increase, although no difference was observed in the other products. Conclusions. Solare and Filtek Supreme tended to show less changes in translucency and color during light curing compared to Charisma. Nevertheless, the changes in color during light curing were still in the range of unacceptable color change. Therefore, direct shade matching of these materials for a precise shade match should be performed by using the cured material.

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INTRODUCTION

Shade matching of resin composite restorations is of crucial concern in esthetic dentistry. However, there seems to be several difficulties in shade matching for resin composite restorations. Regarding tooth color, Russel and others revealed that teeth become brighter after drying.[1] Therefore, for filling procedures, all shade matching procedures should be performed before dehydration. When using the Vita Lumin shade guide tab system, it was noted that color differences exist between some composites and the corresponding Vita shades.[2-4] In addition, as each Vita Lumin shade guide tab actually represents a gradation of different shades from the cervical to the incisal aspect,[4] the color varies along the length of the shade tab. Thus, the Vita Lumin shade guide system seemed to be inadequate as a "standard" for precise shade selection of tooth-colored restorative materials. As for individual manufacturers' shade guides, Kim and others reported that the majority of the shade guides do not accurately depict the true shades of resin composites, as the shade guides are often made of acrylic resin.[5] Hence, the authors suggested making custom shade guides from the material itself. The custom shade guide seems to be one of the best solutions for accurate shade selection, but it involves time and material in making the shade guide, which may be inconvenient for clinicians.

An alternative way to accurately shade match is to compare the color of the tooth to be restored with the shade of the paste of the material itself.[5-6] This direct shade matching procedure is as follows: a small amount of resin composite is placed on a tooth to be restored and is polymerized, then shades of the resin and tooth are compared.[6] This procedure seems to be especially beneficial in clinical cases in which the background color has a direct effect on the shade of the restorative resin composite used, as the material contacts the background directly. For example, when restoring shallow, discolored cervical lesions or fractures in the incisal part of anterior teeth, the clinician can estimate the effect of the background color by employing direct shade matching.

In direct shade matching, light curing is necessary, as materials often show perceptible color changes during polymerization.[6-9] One of the problems in direct shade matching is the time wasted with each material placed.[5] However, if the optical properties, such as color and translucency of the resin composites do not change during light curing, direct shade matching can be performed without light curing, resulting in less time spent. Therefore, stability in color and translucency during light curing is an important property in esthetic restorative materials.

This study evaluated color and translucency changes caused by light curing newer restorative resin composite materials. The null hypothesis tested was that the color and translucency of resin composite materials do not change during light curing.

METHODS AND MATERIALS

Tooth-colored Materials

The materials (Table 1) selected for this study were 2 newer resin composites, Solare (GC, Tokyo, Japan) and Filtek Supreme (3M, St Paul, MN, USA) and a resin composite that has been in clinical use for some time, Charisma (Heraeus-Kulzer, Irvine, CA, USA). The A2 and OA2 shades of Charisma, A2 and AO2 shades of Solare and the A2B and A2D shades of Filtek Supreme were used. As the names of the same opaque shades vary in different products, for simplicity, the OA2, AO2 and A2D shades were given the generic name "opaque A2" in this study. Similarly, the A2B of Filtek was described as "A2."

Color Measurement

Translucent acrylic plates (2-mm thick) with holes 8-mm in diameter were used as molds for making standardized disk-shaped specimens (the number of specimens for each group was 10). Each mold was filled with resin composite material, covered with clear celluloid strips on the top and bottom of the hole, and, with the acrylic plate, was pressed between 2 glass slides under a weight to achieve uniform thickness of the disk specimens. After removing the glass slides, the color of the materials was measured separately (using a colorimeter) against 3 backings: a black tile, the material itself (see below) and a white tile, in that order.

Table 1

Products	Filler Composition and Size	Color/Batch #	Manufacturer
Charisma	65 vol% (76 wt%) barium aluminum fluoride glass filler of 0.02-2 µm, 5 vol% pyrogenic silicon dioxide filler of 0.02-0.07 µm	A2 010052 Opaque A2 010079	Heraeus-Kulzer, Irvine, CA, USA
Solare	64vol% (73wt%) pre-polymerized filler of 16 µm*, silica glass of 0.85 µm*, fumed silica of 16 µm*	A2 0402163 Opaque A2 0306191	GC, Tokyo, Japan
Filtek Supreme	58-60 vol% (78.5 wt%) aggregated zirconia/silica cluster filler with primary particle size of 5-20 nm, non-agglomerated/non-aggregated 20 nm silica filler	A2 3ACJ Opaque A2 3AAJ	3M, St Paul, MN, USA

**Average particle size*

The series of these 3 color measurements per disk was carried out using a colorimeter: OFC-300A (Nippon Denshoku, Tokyo, Japan). The spectral power distribution of the pulsed xenon lamp in the colorimeter was derived from a 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* refers to lightness, where 100 is white and 0 is black, a* and b* are the red-green and yellow-blue chromatic coordinates and a positive a* or b* value indicates a red or a yellow shade, respectively.

To determine the inherent color of each material, measurement was made using a disk (10-mm in diameter and 2-mm thick) of the cured material (of the same shade) as a backing. For example, to measure the color of the A2 shade of Charisma, the corresponding backing was the cured A2 shade of Charisma. The white and black backings employed in this study were a white ceramic tile (L*=93.00, a*=-0.136, b*=2.65) and a black ceramic tile (L*=25.20, a*=0.23, b*=0.51).

After the initial series of color measurements of each uncured disk, irradiation was performed through thin plastic film, using an Optilux 401 (Demetron, Danbury, CT, USA) at ≥400mW/cm^2 for 60 seconds. The color measurements were then repeated for each cured disk.

Calculation of the Translucency Parameter

The translucency of the materials 2-mm thick before and after light curing was calculated using the translucency parameter (TP) formula[10-12]:

$TP_{(D=2mm)}=[(L_W^* - L_B^*)^2 + (a_W^* - a_B^*)^2 + (b_W^* - b_B^*)^2]^{1/2}$, where the subscript “W” refers to the CIELAB values for each 2-mm thick specimen on a white backing and the subscript “B” refers to the values for specimens on a black backing. 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.[10-12]

This calculation of TP was performed for the values obtained before and after light curing. To detect any statistical changes in TP during light curing, as primary factors, 2-way ANOVA and Tukey’s post-hoc test were carried out regarding materials/shades and before or after light curing. When this analysis revealed interaction of any of the primary factors, 1-way ANOVA and Tukey’s post-hoc tests were employed to detect statistically significant differences between groups (p<0.05).

Calculation and Evaluation of Color Differences (ΔE*) During Light Curing

The color change of each specimen (ΔE*) during light curing was calculated using the equation:

$\Delta E^* = [(L^*_{after} - L^*_{before})\ 2 + (a^*_{after} - a^*_{before})\ 2 + (b^*_{after} - b^*_{before})^2]^{1/2}$, where L^*_{after}, a^*_{after}, and b^*_{after} were CIELAB values of each specimen evaluated on the backing of the material itself after light curing and L^*_{before}, a^*_{before}, and b^*_{before} were those values of each specimen evaluated on the backing of the material itself before light curing.

The averages of ΔE* during light curing were statistically analyzed using 2-way ANOVA, considering the products and shades were primary parameters. When this analysis revealed interaction of any of the primary factors, 1-way ANOVA and Tukey’s post-hoc tests were employed to detect statistically significant differences between groups (p<0.05).

The L*, a* and b* changes during light curing were also evaluated statistically.

RESULTS

The values for TP before and after light curing are indicated in Table 2. Statistical analysis was performed using 1-way ANOVA, and Tukey’s post-hoc tests, as an interaction between the 2 primary factors, was detected in the 2-way ANOVA.

Regarding TP changes during light curing, the A2 and opaque A2 shades of Charisma showed a statistically significant increase, although no difference was observed in the other products. As for the TP value after light curing, the opaque A2 shade of Charisma revealed a higher TP compared to the opaque A2 of the other 2 materials, although no significant difference was observed in the A2 shade among the 3 products.

Table 3 summarizes the results in color differences (ΔE*) during light curing. The ΔE* of A2 shade was a significantly greater value compared with the opaque

Table 2: *Translucency Parameters Before and After Light Curing*

	Before Light Curing	After Light Curing
Charisma		
A2	2.85 (0.77)[ace]	5.08 (1.58)[b]
Opaque A2	2.76 (1.19)[ace]	4.85 (1.82)[bd]
Solare		
A2	4.45 (1.77)[abd]	3.59 (1.19)[abcde]
Opaque A2	2.23 (0.83)[ce]	2.58 (1.51)[ace]
Filtek Supreme		
A2	3.12 (1.05)[acde]	1.73 (0.84)[e]
Opaque A2	4.13 (1.27)[abcd]	1.74 (0.86)[e]

Mean (SD), n=10
Same superscripts show no statistically significant differences.
(One-way ANOVA and Tukey’s post-hoc test: p<0.05)

A2 shade. As for the products, Charisma showed significantly greater color changes during light curing than Solare and Filtek Supreme.

Changes in L*, a* and b* values are indicated in Table 4. A 2-way ANOVA was attempted for each parameter; however, interactions were detected in all parameters. In addition, the hypothesis of homogeneity of variance was rejected in the Levene test. Hence, 1-way ANOVA and the Games-Howell tests were performed for each parameter.

Comparing the L* values before and after light curing, no significant differences were detected except for the opaque A2 shade of Filtek Supreme. No significant differences were observed in the a* values except for the A2 shade of Solare. However, regarding the parameter of b*, statistically significant decreases were indicated in all products and shades.

DISCUSSION

The inherent translucency of resin composites may contribute to shade matching with a tooth by allowing the shade of the adjacent and underlying tooth structure to shine through. Clinicians have commonly observed this "chameleon" effect of resin composites.[13]

However, in situations where there is no tooth structure to provide a backing for the restoration, such as in a large Class III or IV cavities, translucent materials may provide relatively poor color matches. More specifically, a grayish shade is often seen in comparison with the surrounding tooth structure, as relatively translucent materials are probably affected by the darkness of the oral cavity. In such situations, opaque-shade resin composites have been utilized.[12,14-15]

Charisma was selected in this study because, in a previous study, this product showed a relatively small change in TP and color during light curing,[10] while the remainder of the products are newer resin composites. In this study, the A2 and opaque A2 shades of Charisma showed a statistically significant increase in TP. Hence, the null hypothesis on translucency was rejected for this product. This increase in TP may result in a more grayish shade after light curing when used in large Class III and IV cavities. Therefore, direct shade matching for a large Class III or IV cavity using uncured paste may be inadequate in this product. Furthermore, the TP of the opaque A2 shade in this product after light curing showed a statistically greater value than that of the other 2 products. The greater TP value might be a disadvantage against the dark background of the oral cavity.

As for the TP and color change of Charisma, the TP values before and after light curing were smaller, and the color change during light curing was greater in this study compared with that of another study.[10] The reason for the differences may be due to differences in methodology, such as in specimen preparation and the colorimeter employed.

It was previously reported that color differences of less than 3.3 CIELAB units were clinically acceptable to match tooth structure.[16] This implies that the opaque A2 shades of Solare and Filtek Supreme may help to mask a dark background color more effectively. However, as too much opacity of resin composite may be less desirable against relatively translucent

Table 3: *Color Change (ΔE*) During Light Curing*

	A2	Opaque A2
Charisma	10.52 (0.99)	8.44 (1.00)
Solare	5.63 (1.04)	4.85 (0.68)
Filtek Supreme	6.11 (2.76)	4.44 (1.17)

Mean (SD), n=10
A 2-way ANOVA indicates statistically significant differences in the factors products and shades (p<0.05).
Tukey's post-hoc test revealed significantly larger color change in Charisma compared with 2 other products (p<0.05).

Table 4: *L*, a*, b* Before and After Light Curing*

	L* Before	L* After	a* Before	a* After	b* Before	b* After
Charisma						
A2	52.39 (0.90)	53.37 (2.03)	-3.11 (0.76)	-2.27 (0.37)	7.57 (1.08)	-2.74 (0.69)
Opaque A2	56.97 (1.48)	56.70 (2.03)	-2.29 (0.23)	-2.36 (0.22)	10.23 (0.98)	1.99 (0.44)
Solare						
A2	57.71 (2.47)	56.92 (4.14)	-2.59 (0.67)	-1.58 (0.35)	4.89 (1.30)	1.04 (0.67)
Opaque A2	63.85 (1.36)	63.65 (0.80)	-2.86 (1.29)	-2.42 (0.18)	9.85 (1.35)	5.42 (0.21)
Filtek Supreme						
A2	55.92 (2.61)	51.60 (2.68)	-2.97 (0.51)	-2.57 (0.24)	4.63 (0.62)	2.24 (0.76)
Opaque A2	63.04 (1.29)	59.65 (1.28)	-3.78 (0.99)	-3.39 (0.09)	7.90 (0.39)	5.63 (0.48)

Mean (SD), n=10
Games-Howell test were performed on L, a* and b*, respectively.*
The values connected with a horizontal line indicate no statistical difference (p>0.05)

natural teeth, there is a case for the layering technique, as recommended by the manufacturer of Filtek Supreme.

There are numerous reports about factors that contribute to the opacity of resin composites. Inokoshi and others[17] stated that, the greater the difference between the refractive indices of inorganic particles and the matrix phase of resin composites, the greater the opacity of the materials, due to multiple reflection and refraction at the matrix particle interfaces. Campbell, Johnson and O'Brien[18] stated that, in experimental PMMA resin composites, the efficiency of light scattering for a quartz filler decreased as the size of the filler increased. Kawaguchi, Fukushima and Miyazaki[15] mentioned that certain types of hybrid resin composites could show smaller transmission coefficients because of the wide range of particle size. Johnston and Reisbick[10] insisted that the color and translucency of esthetic restorative materials is determined not only by more macroscopic phenomena, such as matrix and filler composition as well as filler content, but also by relatively minor pigment additions and potentially by all other chemical components of these materials. In this study, the relatively small translucency changes in the newer materials, Solare and Filtek Supreme, may be due to minimal change in differences between the refractive index of the glass filler and that of the resin matrix during light curing.

Regarding the TP change observed in Charisma in this study, it is likely that light curing brought about a change in the optical characteristics of the resin matrix. Hence, the TP increase observed could be caused by a corresponding decrease in the refractive index difference between the inorganic particles and the matrix phase of the resin composite.

As for the color change (ΔE^*) values during light curing, a significantly smaller ΔE^* was observed in Solare and Filtek Supreme compared to Charisma. However, all the ΔE^* values were above 3.3, which was considered a clinically unacceptable color difference as mentioned above.[16] Therefore, direct shade matching using uncured resin composites seemed inadequate for these products. This study has highlighted the fact that, in order to get a precise shade match, direct shade matching of these materials should be performed by using the cured material.

In terms of the L^*, a^* and b^* change during light curing, no statistical change was indicated, except for the opaque A2 of Filtek Supreme in L^* change and the A2 of Solare in a^* change, though all the products/shades showed a significant decrease in b^* value. The same phenomenon, in terms of a decrease in b^* values, was also reported by Seghi and others.[7] These authors explained that the reason for the color change was due to a decrease in absorption of blue light by photo initiators, such as camphoroquinone, after light curing.[7] Although Johnston and others[10] attached importance to the L^* value as an indicator of color change, in this study, the b^* values appeared to reflect color changes, which agrees with Seghi and others.[7]

The technique employed in this study generated considerable data to evaluate color and translucency change during light curing. One of the advantages of the technique is that the CIELAB parameters on the 3 backings before and after light curing can be obtained from the same specimen in order to make the data "paired data." As a result, in this study, statistical analysis of TP and color change during light curing became possible. In addition, the authors could evaluate inherent colors of the specimens by means of the estimation on the backing of the material itself. As resin composites are more or less translucent, evaluation on the backing of the material itself may minimize the influence of the backing color in the evaluation of inherent color of the materials.

CONCLUSIONS

This study showed that, depending on the irradiation; newer restorative resin composite products tend to show less change in TP and color during light curing. However, changes in color during light curing may still be within the range of unacceptable color change. Therefore, for precise shade matching, direct shade matching of these materials should be performed using cured paste or a shade guide made with the resin composite itself.

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