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Original

Color characteristics of resin composites in different color modes and geometries

Yumiko Hosoya[1)], Takanobu Shiraishi[2)], Maki Oshiro[3)], Susumu Ando[3,4)], Masashi Miyazaki[3,4)] and Franklin García-Godoy[5)]

[1)]Department of Pediatric Dentistry, Course of Medical and Dental Science, Nagasaki University Graduate School of Biomedical Sciences, Japan
[2)]Department of Dental and Biomedical Materials Science, Course of Medical and Dental Science, Nagasaki University Graduate School of Biomedical Sciences, Japan
[3)]Department of Operative Dentistry, Nihon University School of Dentistry, Tokyo, Japan
[4)]Division of Biomaterials Science, Dental Research Center, Nihon University School of Dentistry, Tokyo, Japan
[5)]College of Dental Medicine, Nova Southeastern University, USA

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Abstract: **Color characteristics of the shades for different filler type resin composites were compared in the reflectance and transmittance modes, and specular component included (SCI) and specular component excluded (SCE) geometries for reflectance mode. Resin composites and shades used in this study were submicron filled Estelite Σ (Σ: Inc, A2, A3, B3, C2, OA2, OA3) and nanofilled Filtek™ Supreme XT (XT: Clear, A2E, A2B, A3B, C2B, A2D, A3D). Resin disks of 2 mm in thickness and final polish with 2,400-grit silicon carbide paper were kept in 100% humidity. One week after curing, color of the resin disks were measured with a spectrophotometer. Both for Σ and XT, reflectance of each of all shades measured with SCI were significantly higher than those with SCE. Compared to the values with SCI and SCE, the L* with SCI were significantly higher for all shades of Σ and XT, however, a* and b* were depended with brands and shades. Different filler type resin composites showed different color characteristics, reflectance, transmittance and L*a*b* distribution. In some shades, color difference between the measurement with SCI and SCE was visually perceptible level. It would be concluded that the color of resin composite measured with the SCI and SCE geometries differed. (J Oral Sci 51, 123-130, 2009)**

Keywords: color; resin composites; reflectance; transmittance; SCI and SCE geometries.

Correspondence to Dr. Yumiko Hosoya, Department of Pediatric Dentistry, Course of Medical and Dental Science, Nagasaki University Graduate School of Biomedical Sciences, 1-7-1, Sakamoto, Nagasaki 852-8588, Japan
Tel: +81-95-819-7673
Fax: +81-95-819-7676
E-mail: hosoya@nagasaki-u.ac.jp

Introduction

For successful esthetic resin composite restorations, it is important to understand the color characteristics of the resin and restored tooth. The color of teeth is influenced by complex factors such as lighting conditions to the objects, and translucency, opacity, light scattering, and gloss of teeth (1). Characteristics of light transmittance and their influence to the color of various shades of resin composites were evaluated (2), indicating that light transmittance characteristics play an important role in the color of resin composites.

The inherent translucency of resin composites may contribute to shade matching by allowing the shade of the adjacent and underlying tooth structure (3). In cases such as large class III or class IV restorations with proximal or/and incisal cavities, a more grayish aspect is often seen in comparison with the surrounding tooth color, because

Table 1 Main components of resin composites

Resin Composite	Shade	Lot Number	Main Components
Estelite Σ	Inc	W455B1	Filler: 82 wt% silica-zirconia spherical inorganic filler of 0.1-0.3 μm (average, 0.2 μm) and prepolymerized filler of silica-zirconia and copolymer.
	A2	J009	
	A3	J222	
	B3	W7041	
	C2	W803B	Resin: Bis-GMA and TEGDMA
	OA2	W858	
	OA3	W953B1	
Filtek Supreme XT	Clear	20060817	Filler: Translucent shades contain 72.5 wt% non-agglomerated/non-aggregated, 75 nm silica nanofiller and 0.6-1.4 μm agglomerated silica nanocluster. All of the remaining shades contain 78.5 wt% non-agglomerated, non-aggregated, 20 nm nanosilica filler and 0.6-1.4 μm agglomerates of zirconia/silica.
	A2E	20060714	
	A2B	20060728	
	A3B	20060726	
	C2B	20060614	
	A2D	20060628	
	A3D	20060606	Resin: Bis-GMA, Bis-EMA, UDMA and TEGDMA

rather translucent materials are probably affected by the darkness of the oral cavity (4). Thus, it is important to understand the characteristics of the light transmittance of the resin composite to achieve highly esthetic quality resin restorations. However, there is very limited information about the light transmittance of resin composite (5).

A spectrophotometer with an integrating sphere can operate two different measuring geometries. One is the specular component included (SCI) and other is the specular component excluded (SCE). The specular component is the reflected light from the surface such that the angle of reflection equals the angle of incidence (6). There are standards and recommendations that include the measurement geometries defined as *d*/0 and *t*/0, where *d* represents diffuse illumination (SCE) and *t* represents total illumination that included diffuse and the specular component (SCI). The other character represents the incident-viewing angle of the receiver optics as measured from the specimen normal (7). Matte standards are required in reflectance colorimetry to simplify the problem of fully excluding or including the specular component in the measurement, as they diffusely reflect light equally in all directions, to improve the accuracy (8). Specularly reflected components from some kinds of surfaces (paint surfaces, glossy, semi-glossy or matte) were spread over a wide range from the regular direction (9). The surface of dental materials is not totally reflecting or matte. Thus, inclusion or exclusion of the specular component may be important for the color measurement of dental materials. However, limited information of the effects of the differences in the color-measuring geometry of SCI and SCE has been reported (10).

Recently different filler type resin composites have been developed and are on the market. Many of them include both inorganic and organic fillers, and have high esthetics. However, there is no information of color values for newly developed nano-filled or submicron-filled resin composites measured with different color modes and geometries.

The objectives of this study were to compare the color characteristics of two different filler type resin composites in both the reflectance and transmittance modes, and to compare the reflectance and L*a*b* values between measurement with SCI and SCE geometries.

Materials and Methods

Resin composites and shades used in this study were a submicron-filled composite Estelite Σ (Σ: Inc, A2, A3, B3, C2, OA2, OA3; Tokuyama Dental Corp., Tokyo, Japan) and a nanofilled composite Filtek™ Supreme XT (XT: Clear, A2E, A2B, A3B, C2B, A2D, A3D; 3M ESPE, St. Paul, MN, USA). The lot numbers and main components of Σ and XT were as shown in Table 1.

To make a standardized specimen, 3 mm thick acrylic round-box-shaped mold with an 8 mm diameter hole was prepared. Resin composite was filled into the hole with clear plastic film on the top and light irradiated for 30 sec using a light-curing unit (Optilux 501, Kerr, Danbury, CT, USA). Resin disk was taken out from the mold and the bottom-side of the disk was also light irradiated for 30 sec. Both of the top and bottom sides of the resin disks were polished with silicon carbide (SiC) papers until a thickness of 2 mm. Final polishing was done with 2,400-grit SiC paper. The thickness of the disk was measured with a dialverniercaliper (Mitutoyo, Tokyo, Japan). Three disks were prepared for each of the shades. The disks were stored in a 100% wet container and kept in 23 ± 1°C for one week.

Color was measured with a spectrophotometer (CM-3600d, Konica Minolta, Tokyo, Japan) according to the CIE 1976 L*a*b* color scale relative to the standard illuminant D_{65} in the reflectance mode over the white and black backgrounds with the SCI and SCE geometries, and in the transmittance mode. In the CIE 1976 L*a*b* color scale, the L* value determines the psychometric lightness from black to white. The a* and b* values are the psychometric chroma coordinates and indicate hue and chroma factors. The a* axis graphs indicate red on the positive and green on the negative side. The b* axis graphs indicate yellow on the positive and blue on the negative side. The higher the numbers, the stronger the color factors are. The aperture size was 7 mm in diameter for the reflectance measurement and 6 mm in diameter for the transmittance measurement. Illuminating and viewing configurations were CIE diffuse / 8° geometry for the reflectance measurement, and CIE diffuse / 0° geometry for the transmittance measurement (11). Measurements were repeated three times for each specimen in each color-measuring condition and average values for three same-shade specimens (total number of measurements for one shade was nine) were calculated. The software was Spectra-Magic version 2.11 (Konica Minolta, Tokyo, Japan).

The color of the white background and black background in the SCI and SCE geometries with mean reflectance between 360 and 740 nm under 10 nm intervals were as follows. White background color was (SCI: L* = 95.8, a* = - 0.5 and b* = 1.5) and (SCE: L* = 94.0, a* = - 0.5 and b* = 1.6) respectively. Black background color was (SCI: L* = 26.0, a* = -0.4 and b* = -0.6) and (SCE: L* = 25.1, a* = -1.2 and b* = 0.1) respectively. All of the standard deviations for the L*, a* and b* values of the white and black backgrounds in the SCI and SCE geometries were less than 0.01.

Color difference (ΔE*ab) was calculated by the equation of $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. ΔE*ab was calculated between the values measured with the SCE and SCI geometries for each shades. The ΔE*ab value of 2.5 represents a borderline value recognizable by all people in a color test (12). The opacity % was calculated by the equation of R (B) / R (W) × 100 (%). The R (B) and R (W) are the reflectance % measured with each of the black background and white background. The L*, a* and b* values, and the each of the 10 nm interval reflectance % from 360 to 740 nm were compared between the measurement with SCI and SCE geometries. Data were analyzed using one-way ANOVA and Fisher's PLSD test with $\alpha = 0.05$ (Stat View J-5.0, SAS Institute Inc., Cary, NC, USA).

Results

The means and standard deviations of the thickness of resin shades ranged from 2.02 ± 0.01 (C2) to 2.05 ± 0.01 (OA2) in Σ and 2.01 ± 0.02 (A2D) to 2.04 ± 0.02 (A2E) in XT. There was no significant difference among the thickness of all the shades.

Figures 1a, 1b, 1c and 1d are the reflectance curves of Σ and XT measured with the SCE and SCI geometries in white background. For all the shades of Σ and XT, the reflection % measured with the SCI (Figs. 1b and 1d) was significantly higher than those in the SCE (Figs. 1a and 1c) at all wavelengths. However, both for Σ and XT, the wave patterns of the reflectance curves of the SCI and SCE were similar regardless of the shades. In comparison of the wave patterns among the shades, the Inc shade in Σ and Clear shade in XT differed from other shades. The C2 shade in Σ also differed from other shades at the high wavelength area. For Σ, the reflectance % of all shades except for Incisal shade decreased near the wavelength of 550 nm (green color zone), and showed the sigmoid-like curves.

Figures 2a and 2b show the transmittance curves of Σ and XT, respectively. The transmittance % of Inc in Σ and Clear in XT were significantly higher than those of other shades in the area, in which the wavelengths were over 410 nm. For Σ, the transmittance % of all shades except for Inc decreased near the wavelength of 550 nm, and showed sigmoid-like curves. In the area, in which the wavelengths were over 560 nm, the transmittance % was similar among the A2, A3 and B3 shades, and OA2, OA3 and C2 shades. Both for reflectance and transmittance curves, there was similarity of the wave patterns for all shades except for Inc, and the wave patterns of other shades were flatter in the transmittance mode compared to the reflectance mode. For XT, transmittance curves of all shades except for Clear run almost parallel, like geometric curves. The transmittance % was similar among the A2B, A3B and C2B shades, and between the A2D and A3D shades at all wavelengths. The wave patterns of the transmittance curves differed from the reflectance curves, and were flatter than those of the reflectance curves.

Figure 3 compares the L*and a*b* values of Σ and XT resin composites measured with the SCE and SCI geometries in white background. For all the shades of Σ and XT, the L* with the SCI geometry was significantly higher than that with the SCE geometry (Figs. 3a and 3d). For Σ, there was no significant difference for each of the a* and b* values between the SCE (Fig. 3b) and SCI (Fig. 3c) geometries for all shades except for the a* of the Incisal and OA3 shades, and b* of the B3 and OA3 shades. The a* of the Incisal shade and the b* of the B3 shade with the SCI geometry were significantly higher than those with the SCE geometry. However, the a* and b* of the OA3 shade with the SCI geometry were significantly lower than those with the SCE geometry. For XT, the a* and b*

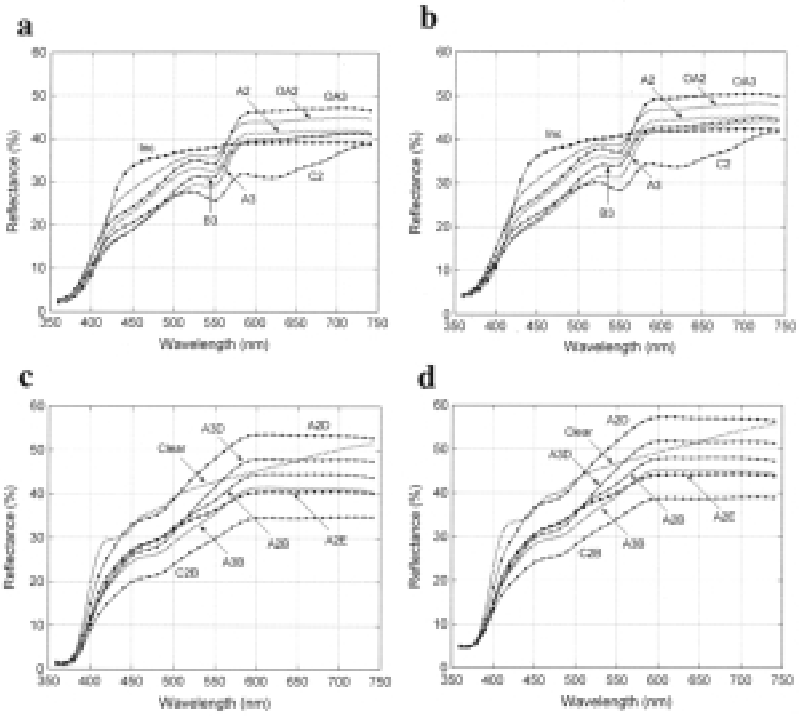

Fig. 1 a. Reflectance of Estelite Σ measured with SCE geometry, b. Reflectance of Estelite Σ measured with SCI geometry, c. Reflectance of Filtek Supreme XT measured with SCE geometry, d. Reflectance of Filtek Supreme XT measured with SCI geometry.

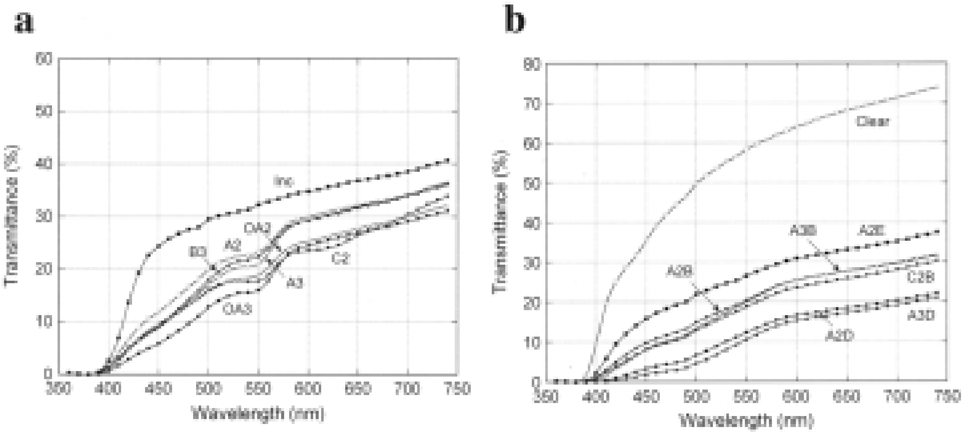

Fig. 2 a. Transmittance of Estelite Σ, b. Transmittance of Filtek Supreme XT.

values of all shades measured with the SCE geometry (Fig. 3e) were significantly higher than those with the SCI geometry (Fig. 3f) except for the a* of the A2E shade, and the a* and b* of the Clear shade. There was no significant difference of the a* of the A2E shade and the a* and b* of the Clear shade between the SCE and SCI

Fig. 3-A

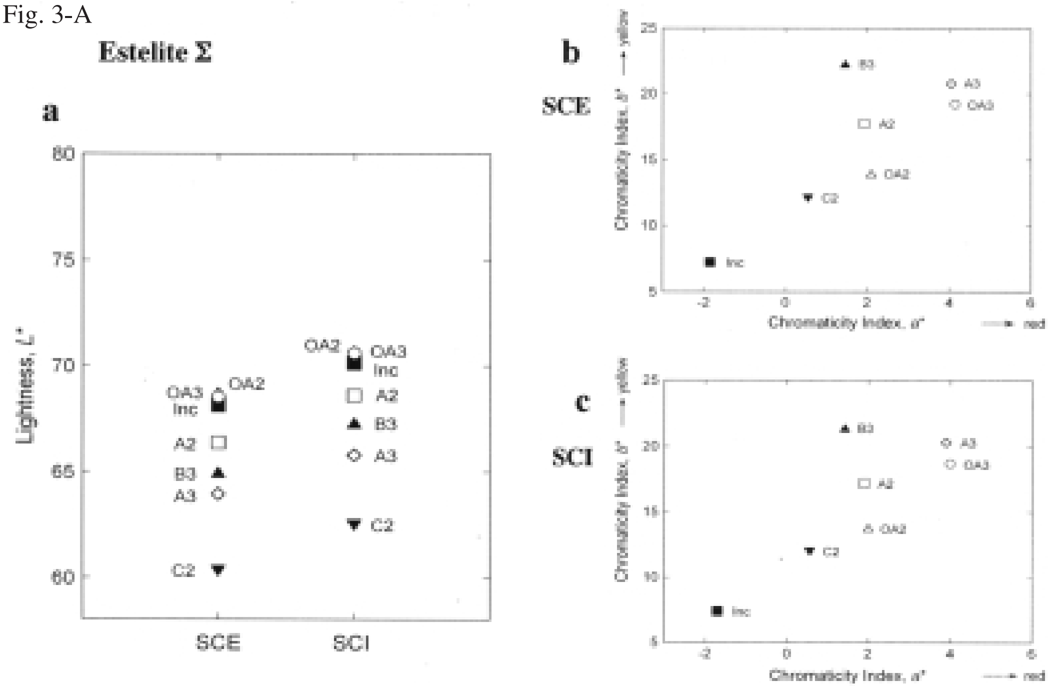

Fig. 3-B

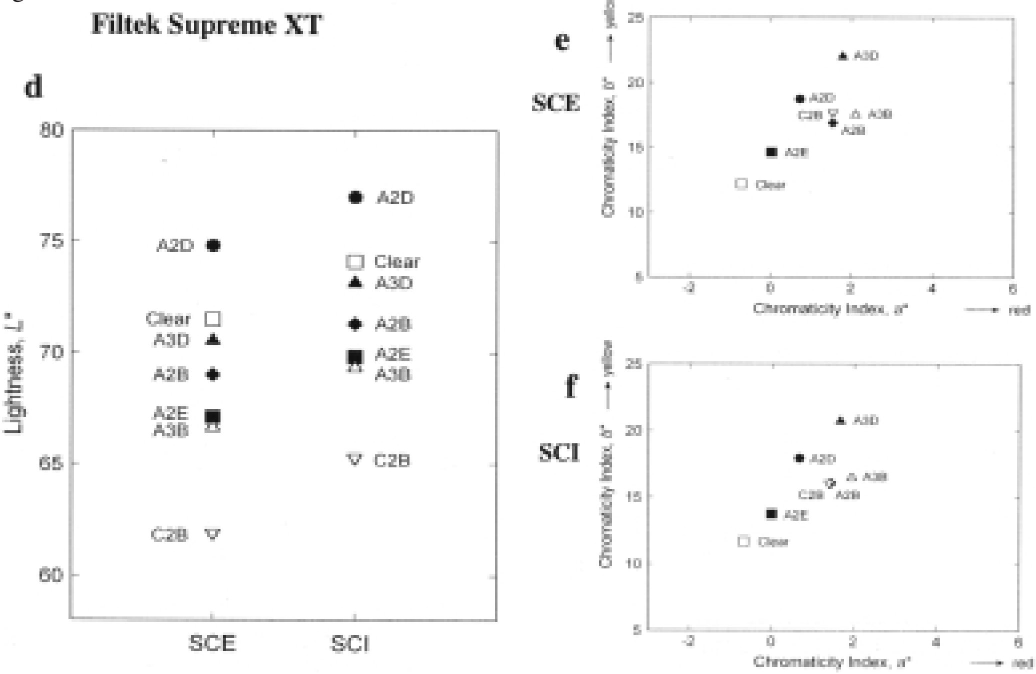

Fig. 3 L*a*b* distributions of Estelite Σ (Fig. 3-A) and Filtek Supreme XT (Fig. 3-B) measured with SCE and SCI geometries in white background. a. L* of Σ in SCE and SCI geometries, b. a*b* of Σ in SCE geometry, c. a*b* of Σ in SCI geometry, d. L* of XT in SCE and SCI geometries, e. a*b* of XT in SCE geometry, f. a*b* of XT in SCI geometry.

geometries.

Table 2 compared the color differences of shades measured with the SCE and SCI geometries in white background. For Σ, there was no shade in which the ΔE*ab value was over 2.5. However, for XT, the ΔE*ab values of all the shades were over 2.5 except for the A2D shade.

Figure 4 compares the opacity (%) among the shades. Both for Σ and XT, the opacity of the shades could be divided into three groups except for the Clear shade in XT. The opacity of the Clear shade was considerably lower than that of the other shades.

Discussion

Reflection of light from surfaces can be classified into

Table 2 Color differences between the SCE and SCI geometries for shades in white background

	Shade	ΔL*	Δa*	Δb*	ΔE*ab
Estelite Σ	Inc	-2.00	-0.11	-0.15	2.01
	A2	-2.21	0.08	0.57	2.28
	A3	-1.86	0.12	0.50	1.93
	B3	-2.30	0.02	0.92	2.48
	C2	-2.22	-0.03	0.17	2.23
	OA2	-2.21	0.09	0.06	2.21
	OA3	-2.03	0.15	0.50	2.10
Filtek Supreme XT	Clear	-2.57	-0.05	0.52	2.62
	A2E	-2.67	0.03	0.88	2.81
	A2B	-2.37	0.09	0.83	2.51
	A3B	-2.69	0.19	1.08	2.90
	A2D	-2.23	0.09	0.83	2.38
	A3D	-2.57	0.10	1.32	2.89
	C2B	-3.41	0.14	1.64	3.79

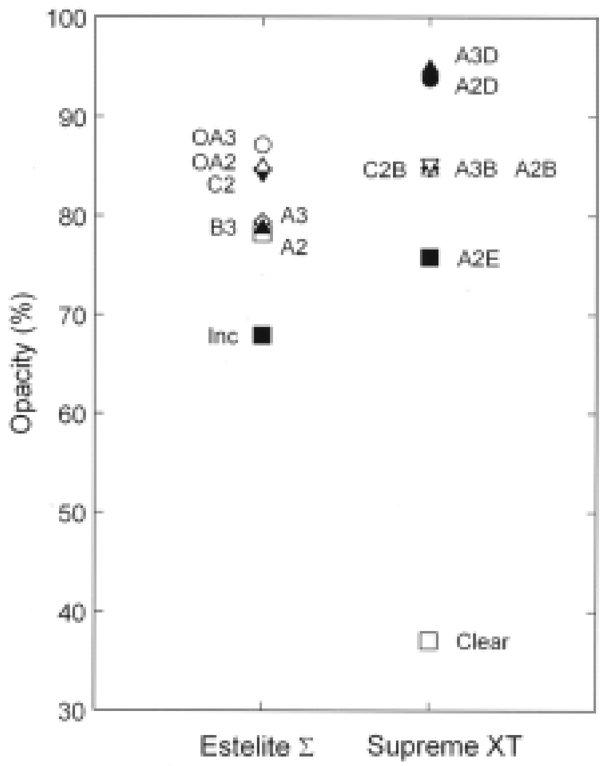

Fig. 4 Opacity of Estelite Σ and Supreme XT.

two broad categories. The diffuse component results from light penetration to the surface, undergoing multiple reflections and refractions, and reemerging again at the surface. The specular component is a surface phenomenon, and it can be expressed as a function of the incidence angle and the refractive index of the material, the surface roughness, and a geometrical shadowing function (13).

Most color-measuring spectrophotometers cannot separate or compensate for several types of residual or confounded differences between instruments. The sources of these differences include specular part effects, nonuniformities in integrating sphere illumination, nonlinearities in the photometric scale, and the translucent blurring effect found in translucent materials (14). In this study, the influence of the color measuring modes (reflectance and transmittancee) and geometries (SCE and SCI) on the color of polished resin composites were determined with the use of one instrument. One of the reasons of the wave pattern differences between the reflectance and transmittance, that was more significant in XT than in Σ, can be caused by filler type difference (Table 1). Size of filler of Σ is larger than that of XT, and shape of filler of these resin composites is different. As shown in Figs. 2, the transparencies of Σ were higher than that of XT except for Clear of XT. These differences might be mainly caused by the filler difference. However, differences of pigment and matrix including monomer also can influence the transparency differences.

A previous study (15) stated that the higher the refractive index difference between inorganic fillers and matrix phase of resin composites, the greater the opacity of the materials, due to multiple reflection and refraction at the matrix filler interfaces. Another study (16) insisted that the color and translucency of esthetic restorative materials is determined not only by more macroscopic phenomena, such as matrix and filler composition and filler content, but also by relatively minor pigment additions and potentially by all other chemical components of these materials.

In this study, the a* value for each of the A3, OA3 and OA2 shades in Σ was significantly higher than the a* for each of the A3B, A3D and A2D shades in XT, respectively (Fig. 3). These higher a* values for some of the Σ shades is one of the apparent characteristics of this resin composite, and could be mainly caused by the pigmented and chemical components. Lower reflectance at 550 nm wavelength area that locates in the green zone of color spectral could influence the higher a* values in Σ (Fig. 1). Both for Σ and XT with the SCI geometry for each of the shades, the L* was significantly higher than that with the SCE geometry (Fig. 3) and agreed with the previous study (10). However, in comparing the values measured with the SCE and SCI geometries, different results of the a* and b* were obtained between Σ and XT resin composites (Fig. 3). The a* and b* values of many shades in Σ showed no significant difference, however, the a* and b* values of many shades in XT with SCE were significantly higher than those with SCI. Specular component can increase the reflectance % (Fig. 1) at all wavelengths, and led to higher lightness (L*) with the SCI geometry (Fig. 3). Other complex factors might also influence the a* and b* values.

The L*a*b* of XT shades were arranged in order to adjust the L*a*b* of Vita shade guides. Thus, Filtek Supreme XT can be useful for clinicians who use Vita shade guide for shade matching. Estelite Σ has the shades that are not included in Vita shade guides, and can broadly cover the tooth color. A similar trend was observed in the results of transmittance (Fig. 2) in Σ. Many dentists are familiar with the L*a*b* values obtained from reflectance mode, but have less knowledge of the transmittance mode. As shown in the results of this study and a previous study (16), the transmittance of resin composites is an important factor to understand the character of resin composites and success of the esthetic restorations especially for restoration of enamel and influence of the glass fiber used for frameworks of esthetic veneers. Transmittance influences the opacity % or translucency parameter (TP) values (17), and is used to estimate the covering ability of resin composites.

The accepted theory in color science is that the SCE geometry approximates to the view with the naked eye, and the SCI geometry is adequate to analyze the intrinsic color of objects. However, to our knowledge, no information is available to demonstrate the theory for esthetic dental treatment including resin composite. Generally, the spectrophotometer with an integrating sphere and developed for the laboratory studies can measure the color both in the transmittance and reflectance modes and the latter can be measured both with the SCE and SCI geometries. The spectrophotometer mainly developed for *in vivo* measurement, such as tooth color or skin color, has fiber-optic head and can directly touch and measure the object color but can only measure the reflectance. Normally, this type of spectrophotometer has a light-trap or filter to exclude specular component, and can be used with SCE geometry. Although it is unclear which geometry reflects clinical situations, because of the above mentioned reasons, for clinical study the SCE geometry may be preferable at the present time. However, when the correlations between the color and properties of resin composites, color and gloss or surface roughness of resin composites are to be compared, the SCI geometry might be useful.

The different filler type of the resin composites Σ and

XT had unique color characteristics, and showed different reflectance and transmittance curves, and CIE L*a*b* distributions. Not only reflectance but also transmittance is useful to analyze the color of resin composites. In some shades, color difference between the SCE and SCI geometries was visually perceptible level (Table 2). Thus reflectance should be measured both with the SCE and SCI geometries, and correlations between the reflectance measured with each of the geometry and the visual colorimetry including sensory test should be compared in future studies.

It was found that different filler type resin composites showed different color characteristics, reflectance, transmittance and L*a*b* distribution. In some shades, color difference between the measurement with SCE and SCI geometries was visually perceptible. It should be understood that the color of resin composite measured with the SCE and SCI geometries differed.

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