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Evaluation of Resin Composite Translucency by Two Different Methods

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Clinical Relevance

Composite translucency varies by manufacturer. This information should be considered when selecting materials and clinical techniques to improve clinical performance.

SUMMARY

The purpose of this study was 1) to compare the translucency of seven different types of composite materials and three different shade categories (dentin, enamel, and translucent) by determining the translucency parameter (TP) and light transmittance (%T) and 2) to evaluate the correlation between the results of the two evaluation methods. Three shades (dentin A3, enamel A3, and clear translucent) of seven composite materials (Beautifil II [BF], Denfil [DF], Empress Direct [ED], Estelite Sigma Quick [ES], Gradia Direct [GD], Premise [PR], and Tetric N-Ceram [TC]) from different manufacturers were screened in this study. Ten disk-shaped specimens (10 mm in diameter and 1 mm in thickness) were prepared for each material. For the TP measurements, the colors of each specimen were recorded according to the CIELAB color scale against white and black backgrounds with a colorimeter and used to calculate the TP value. For the %T measurements, the mean direct transmittance through the specimen in the range between 380 and 780 nm was recorded using a spectrometer and computer software. Two-way analysis of variance (ANOVA) tests were performed to compare the TP and %T for the composite materials and shade categories. One-way ANOVA and Tukey tests were used for the seven composite materials per shade category and the three shade categories per composite material. The correlation between the two evaluation methods was determined using the Pearson correlation coefficient. All statistical procedures were performed within a 95% confidence level. TP differed significantly by composite material within each shade category ($p<0.05$) and by shade category within each composite material ($p<0.05$). %T differed significantly by composite material within each shade category ($p<0.05$) and by shade categories within each composite material ($p<0.05$), except for BF and ES. For the two evaluation methods, TP and %T, were positively correlated ($r=0.626$, $p<0.05$). These methods showed strong correlation for each composite

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material except ES (r=0.763-0.992, p<0.05) and moderate correlation for each shade category (r=0.403-0.528, p<0.05).

INTRODUCTION

Light-cured resin composites have been widely used as esthetic restorative materials. However, matching the color of the resin composite to that of the surrounding teeth is difficult because of the differing optical properties of resin composites and natural teeth.

Most color description methods use a three-dimensional coordinate system that includes hue, chroma, and value. In addition to these characteristics, more subtle optical properties are also included, for example, translucency, opacity, opalescence, iridescence, surface gloss, and fluorescence.[1] Of these secondary properties, which are indicators of the quality and quantity of light reflection, translucency and opacity have been regarded as the most important.[2]

The shade and translucency of the composite should be very similar to those of enamel and dentin. Translucency is the ability of a layer of colored substance to allow the appearance of an underlying background to show through.[3] Resin composites are optically translucent because of their structure, which is composed of highly transparent base resin, small filler particles, and other additives. When white incident light travels through the material, it undergoes multiple scattering by the small filler particles within the material before emerging from the material and carries material-specific optical and color information to the detector.

Several manufacturers are now offering expanded lines of shade categories with differing levels of opacity and translucency (ie, dentin, enamel, and translucent). The translucency varies by the manufacturer and shade of the resin composites.[4-8]

The translucency parameter (TP) refers to the color difference for a uniform thickness of a substance against a white or black background.[3] TP is a reliable method for evaluating translucency, and several studies have investigated the TP values of resin composites and dental porcelain.[4-19]

Light transmittance (%T) is defined as the mean percentage of the light spectrum passed through the specimen relative to direct transmittance.[20] Several researchers have measured the light transmission of dental materials and used it as an index of translucency.[20-27]

Although the two methods, TP and %T, have been regarded as reliable methods for evaluating the translucency of tooth-colored materials, their scientific foundations differ. In the case of %T, white incident light travels through the composites and undergoes multiple scattering by the small filler particles. Thetransmitted light is measured. In contrast, the surface reflectivity and internal scattering in composites may be more influential in TP because both light reflected from the sample surface and light reflected from the black and white background, scattered in the composite sample again and then emitted from the sample, are used in TP (Figure 1). Few studies have addressed the correlation between the two methods, especially for nanohybrid-type composites and supra-nano-fill-type composites. The translucency of a composite with nanofiller smaller than 100 nm is high regardless of its refractive index because it cannot scatter visible light (400- to 600-nm wavelength).[28] Furthermore, the refractive index of the resin matrix can be changed without a decrease in translucency if the composite contains nanofiller.[29] The supra-nano-fill-type composite contains fine, uniform, and a relatively large amount of 0.2-μm monodispersing spherical filler.[30] This unique filler may affect the translucency of the composite, the reflection and scattering of light in the composite, and TP and %T.

The purpose of this study was 1) to compare the translucency between seven different types of composite materials and three different shade categories (dentin, enamel, and translucent) by determining TP and %T and 2) to evaluate the correlation between the results of the two evaluation methods.

MATERIALS AND METHODS

Composite Materials

Three shades (dentin A3, enamel A3, and translucent) of seven composite materials (Beautifil II [BF], Denfil [DF], Empress Direct [ED], Estelite Sigma Quick [ES], Gradia Direct [GD], Premise [PR], and Tetric N-Ceram [TC]) from different manufacturers were selected for this study (Table 1). BF, ED, PR, and TC are nanohybrids; DF and GD are microhybrids; and ES is a supra-nano composite (Table 2). The shades of the translucent composites were chosen as those most similar to the T shade of TC using visual inspection because the other composites had their own referring system in translucent shade. The composition of each material is presented in Table 2.

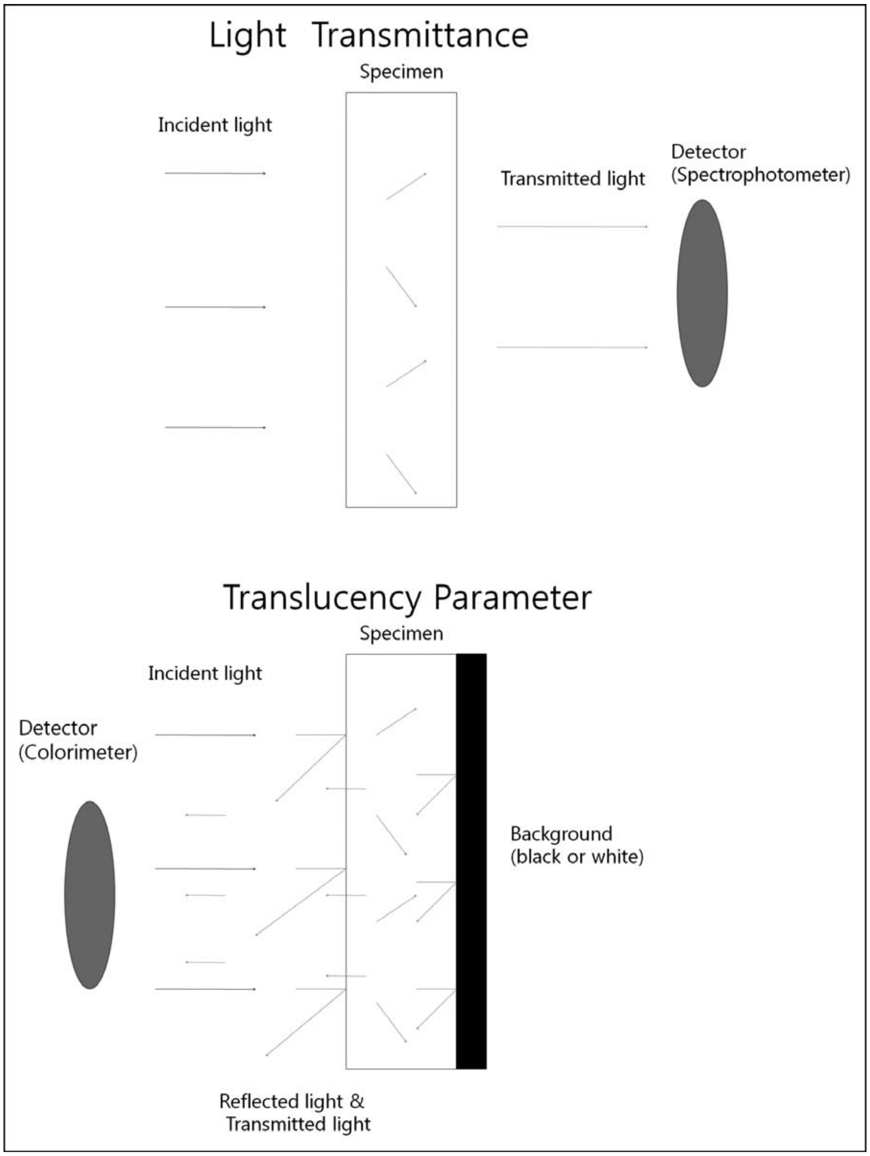

Figure 1. *Comparison of light transmittance (%T) and translucency parameter (TP) in light source detection. In %T, white incident light transmitted through the composites is used for the measurement. In TP, light reflected from the sample surface itself and light reflected from the black and white backgrounds are used for the measurement. In addition, more light scattering occurs in TP measurements.*

Methods

Specimen Preparation—Ten disk-shaped specimens were prepared for each material. Resin composites were packed into a Teflon mold (10 mm in diameter and 1 mm in thickness) on a slide glass. After packing the composite, another slide glass was placed on top of the specimen and pressed for one minute to produce a uniform thickness. Specimens were light cured for 40 seconds on the top and bottom of the mold using a light-curing unit (LED.E, Guilin Woodpecker Medical Instrument Co Ltd, Guilin, Guangxi, China) with an intensity of 400 mW/cm^2. After curing, the specimen was separated, and a digital caliper (500-181, Mitutoyo, Tokyo, Japan) was used to confirm a specimen thickness of 1.0 $\pm$ 0.05 mm. The specimen surface was examined by visual inspection to check for any defects or irregularities. The surface smoothness was measured with a Novo-curve glossmeter (Rhopoint Instrumentation Ltd, East Sussex, UK). Specimens with surface glosses between 85 and 95 GU were included in this study.

Measurement of TP—For TP measurement, the color values of each specimen were recorded

Table 1: *Composite Materials Used in This Study*

Code	Product	Shade		Lot Number	Manufacturer
BF	Beautifil II	Dentin	A3O	091022	Shofu Inc
		Enamel	A3	030804	
		Translucent	Inc	020806	
DF	Denfil	Dentin	A3O	DF0N19533	Vericom
		Enamel	A3	DF9O0363O	
		Translucent	I	DF9D276I	
ED	Empress Direct	Dentin	Dentin A3	M13573	Ivoclar Vivadent
		Enamel	Enamel A3	M14199	
		Translucent	Trans 30	M13042	
ES	Estellite Sigma Quick	Dentin	OA3	E636	Tokuyama Dental
		Enamel	A3	W966	
		Translucent	CE	W463	
GD	Gradia Direct	Dentin	AO3	0808261	GC
		Enamel	A3	0901271	
		Translucent	CT	0809081	
PR	Premise	Dentin	A3O	3035636	Kerr
		Enamel	A3	3195564	
		Translucent	C	2955400	
TC	Tetric N-Ceram	Dentin	A3.5D[a]	L56796	Ivoclar Vivadent
		Enamel	A3	L55382	
		Translucent	T	K08551	

[a] *A3.5D is the brightest in the dentin shade category of Tetric N-Ceram.*

according to a CIELAB color scale relative to the standard illuminant D65 against white (L^*=94.44, a^*=0.26, b^*=1.69) and black (L^*=1.38, a^*=0.00, b^*=0.06) backgrounds using a colorimeter (CR-321, Minolta Co Ltd, Osaka, Japan) and used to calculate the TP values. The colorimeter window size was 3 mm, and each specimen was measured in triplicate.

Table 2: *Composition of Composite Materials*[a]

Code	Product		Composition
BF	Beautifil II	Filler (nanohybrid)	Multifunctional glass filler and S-PRG filler based on fluoroboroaluminosilicate glass
		Filler loading	83.3 wt% (68.6 vol%)
		Particle size	0.01-4.0 μm (mean 0.8 μm) including 10-20 nm nanofiller
		Base resin	Bis-GMA/TEGDMA (<12.5%)
DF	Denfil	Filler (microhybrid)	Barium aluminoslicate, fumed silica
		Filler loading	80 wt%
		Particle size	Barium ≤1 μm, fumed silica 0.04 μm
		Base resin	Bis-GMA/TEGDMA (8%-12%)
ED	Empress Direct	Filler (nanohybrid)	Barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide, copolymer
		Filler loading	75-79 wt% (52-59 vol%)
		Particle size	40-3000 nm (mean 550 nm)
		Base resin	Dimethacrylates (<22%)
ES	Estellite Sigma Quick	Filler (suprananofill)	Silica-zirconia and composite filler Spherical submicron filler
		Filler loading	82 wt% (71 vol%)
		Particle size	0.1-0.3 μm (mean 0.2 μm)
		Base resin	Bis-GMA/TEGDMA (5%-20%)
GD	Gradia Direct	Filler (microhybrid)	Microhybrid filler/no barium glass
		Filler loading	73 wt% (64 vol%)
		Particle size	Mean 0.85 μm
		Base resin	UDMA (20%-30%)
PR	Premise	Filler (nanohybrid)	Prepolymerized filler (PPF), barium glass, silica filler
		Filler loading	84 wt% (70 vol%)
		Particle size	PPF 30-50 μm, barium 0.4 μm, silica 0.02 μm
		Base resin	Bis-EMA/TEGDMA (20%-35%)

Table 2: Continued.

Code	Product	Composition	
TC	Tetric N-Ceram	Filler (nanohybrid)	Barium glass, ytterbium trifluoride, mixed oxide, copolymer
		Filler loading	80.5 wt% (55-57 vol%)
		Particle size	40-3000 nm
		Base resin	Bis-GMA/UDMA (<22%)

Abbreviations: Bis-EMA, ethoxylated bisphenol-A-dimethacrylate; Bis-GMA, bisphenol-A-glycidyl dimethacrylate; S-PRG, surface prereacted glass ionomer; TEGDMA, triethyleneglycol dimethacrylate; UDMA, urethane dimethacrylate.
[a] From manufacturer's information.

TP was obtained by calculating the color difference between the specimen against the white and black backgrounds according to the formula

$$TP = [(L_W^* - L_B^*)^2 + (a_W^* - a_B^*)^2 + (b_W^* - b_B^*)^2]^{1/2}$$

where $_W$ is against the white background and $_B$ is against the black background.

Measurement of %T—The %T of each specimen was recorded using a spectrometer (USB4000-VIS-NIR, Ocean Optics, Dunedin, FL, USA) and computer software (SpectraSuite, Ocean Optics; Figure 2). An attenuating polytetrafluoroethylene disc was used to diminish the radiation intensity of the tungsten-halogen light source (LS-1, Ocean Optics), which emitted in the wavelength range of 360-2000 nm. The light was delivered to the spectrometer by two optical fibers with 600-μm diameters (QP600-1-VIS-NIR, Ocean Optics). A lens holder (74-ACH, Ocean Optics) was located between the two optical fibers to hold the specimen. The direct light spectrum with no specimen was recorded as the 100% light transmittance spectrum. The transmission spectrum for each specimen was obtained by the spectrometer and converted into a relative %T plot using computer software. The mean direct transmittance for wavelengths between 380 and 780 nm was calculated using Microsoft Excel to determine the mean %T. The entire process was performed in a darkroom.

Statistical Analysis—The TP and %T data were analyzed using two-way analysis of variance (ANOVA) followed by Tukey test to compare the translucency of the seven composite materials and three shade categories. One-way ANOVA and Tukey test were used for the seven composite materials per

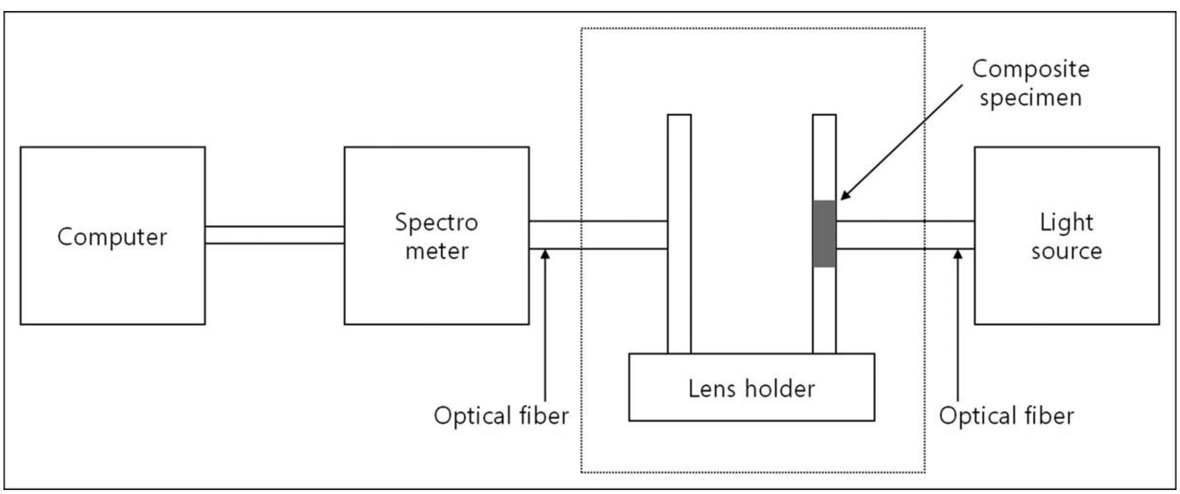

Figure 2. *Schematic diagram of the apparatus for measuring light transmittance.*

Table 3: *Result of Two-Way Analysis of Variance (Translucency Parameter)*

Source	Sum of Squares	*df*	Mean Square	*F*	Significance
Composite	1942.242	6	323.707	292.704	<0.001
Shade category	5768.028	2	2884.014	2607.801	<0.001
Interaction	2384.911	12	198.743	179.708	<0.001
Error	209.018	189	1.106		
Total	76990.499	210			

shade category and the three shade categories per composite material, respectively, to compare the translucency in each shade category and for each composite material.

The correlation between the two evaluation methods was determined by the Pearson correlation coefficient.

All statistical procedures were performed based on a 95% confidence level using PASW Statistics version 18.0 (SPSS Inc, Chicago, IL).

RESULTS

TP

The TP values differed significantly between the composite materials and between shade categories ($p<0.05$; Table 3), and the interaction between the composite materials and between shade categories was significant ($p<0.05$; Table 3). The TP exhibited the following trend: GD, ED>DF>ES≥TC≥BF≥PR and translucent>enamel>dentin shade ($p<0.05$; Table 4).

The TP values were 10.1-15.6 for the dentin shade, 13.2-21.1 for the enamel shade, and 19.2-37.9 for the translucent shade. The TP values differed significantly between composites in each shade category according to the following trend: DF>ES>GD>ED>TC≥BF≥PR for the dentin shade; ED>DF, TC, GD>ES, BF, PR for the enamel shade; and GD>ED>ES≥BF≥PR≥DF≥TC for the translucent shade ($p<0.05$; Figure 3).

There were significant differences in the TP values between the dentin, enamel, and translucent shades for each composite material ($p<0.05$; Figure 4).

%T

The %T values differed significantly by composite material and by shade category ($p<0.05$; Table 5), and the interaction between composite material and

Table 4: *Translucency Parameter of Composite Materials (N=10)[a]*

Code	Dentin Shade		Enamel Shade		Translucent Shade		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BF	10.577	0.970	14.063	0.462	21.011	0.865	15.217[ab]	4.476
DF	15.630	0.311	17.738	1.308	19.601	0.788	17.656[d]	1.864
ED	11.717	0.288	21.054	2.920	34.228	1.569	22.333[e]	9.573
ES	13.644	0.472	14.417	0.776	21.289	0.482	16.450[c]	3.541
GD	12.692	0.742	16.937	0.705	37.874	1.588	22.501[e]	11.245
PR	10.114	0.467	13.154	0.546	20.482	0.896	14.584[a]	4.472
TC	10.925	0.396	17.907	0.488	19.168	1.216	16.000[bc]	3.765
Total	12.186[A]	1.903	16.467[B]	2.869	24.807[C]	7.341	17.820	7.022

[a] *Data were analyzed by two-way analysis of variance and Tukey test. Different capital letters denote statistically significant difference between shade categories ($p<0.05$). Different lowercase letters denote statistically significant difference between composite materials ($p<0.05$).*

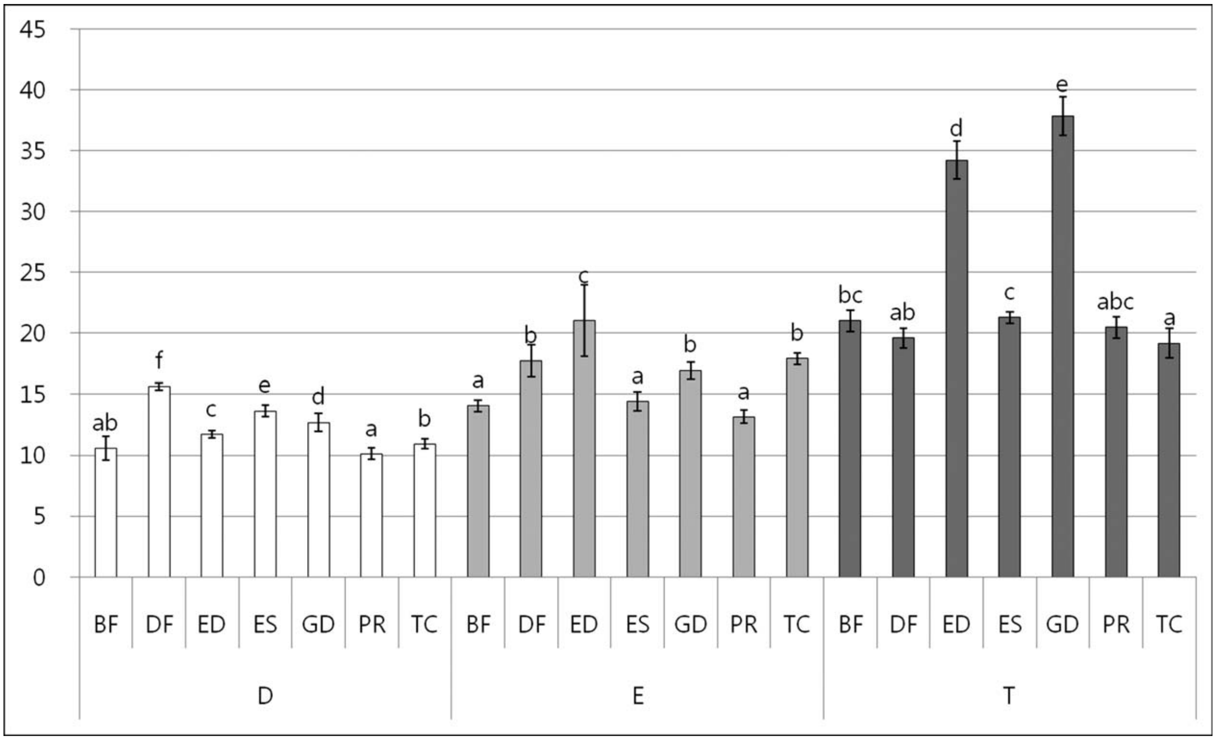

Figure 3. *Translucency parameter of composite materials. Data were analyzed using a one-way analysis of variance and Tukey test for the seven composite groups within each shade category. Different letters denote statistically significant differences (*$p<0.05$*).*

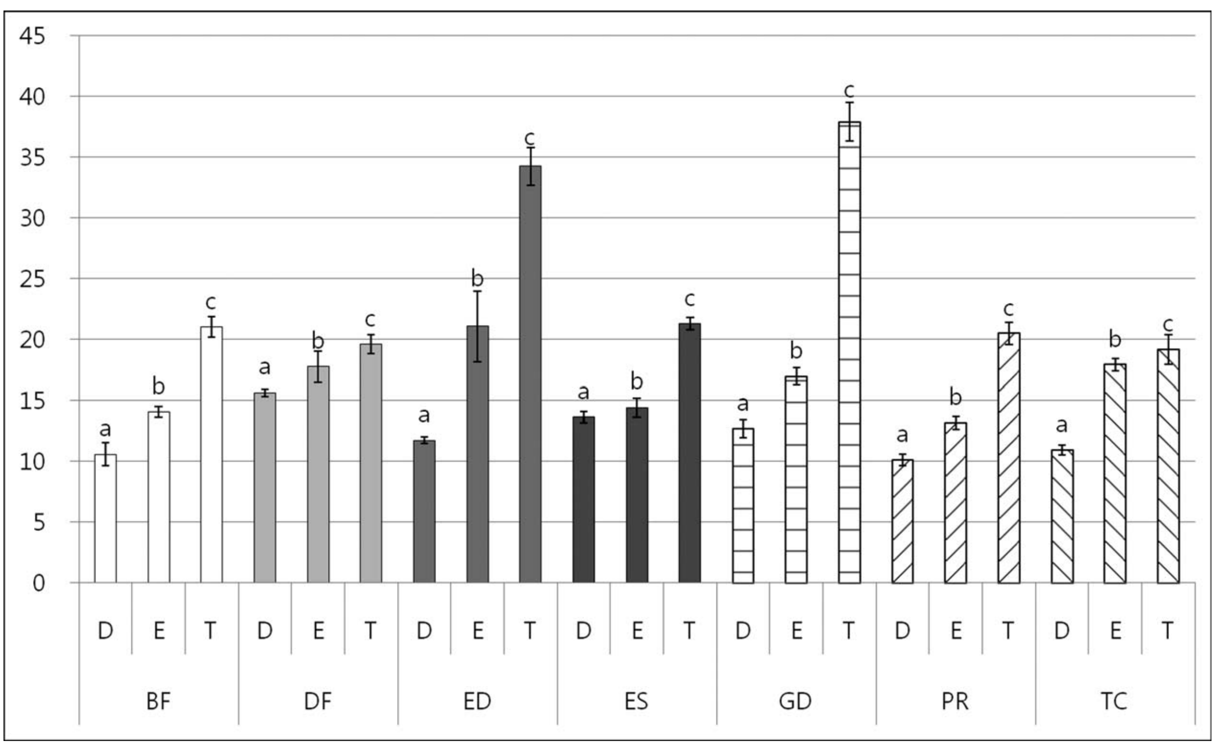

Figure 4. *Translucency parameter of shade categories. Data were analyzed using a one-way analysis of variance and Tukey test for the three shade categories within each composite material category. Different letters denote statistically significant differences (*$p<0.05$*).*

Table 5: *Result of Two-Way Analysis of Variance (Light Transmittance)*

Source	Sum of Squares	*df*	Mean Square	*F*	Significance
Composite	213.818	6	35.636	491.074	<0.001
Shade category	184.905	2	92.452	1274.004	<0.001
Interaction	218.592	12	18.216	251.019	<0.001
Error	13.715	189	0.073		
Total	941.765	210			

by shade category was significant ($p<0.05$; Table 5). The %T values exhibited the following trends: ED, DF>TC, PR, GD>ES, BF and translucent> enamel>dentin shade ($p<0.05$; Table 6).

The %T values for each group are presented in Table 6.

The %T values were 0.12-1.00 for the dentin shade, 0.10-2.30 for the enamel shade, and 0.27-7.14 for the translucent shade.

The %T values differed significantly between composites per shade category: DF>PR>TC≥ED≥GD>ES, BF for the dentin shade; DF>ED≥PR≥TC≥GD≥ES≥BF for the enamel shade; and ED>DF>GD, TC, PR>BF, ES for the translucent shade ($p<0.05$; Figure 5).

The %T values differed significantly by shade in the DF, ED, GD, PR, and TC groups ($p<0.05$; Figure 6). However, there was no significant difference between the dentin and enamel shades in the BF group or between the enamel and translucent shades in the ES group (Figure 6).

Correlation Analysis Between Two Evaluation Methods

Correlation Analysis—The Pearson correlation coefficient for the two evaluation methods, TP and %T, for all 210 specimens was 0.626 ($p<0.05$; Table 7). A scatterplot of the results is presented in Figure 7.

Correlation Within Each Composite Material Group

The Pearson correlation coefficients for the two methods within each composite material group are listed in Table 7.

Table 6: *Mean Light Transmittance of Composition Materials (N=10)*[a]

Code	Dentin Shade		Enamel Shade		Translucent Shade		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BF	0.121	0.025	0.098	0.020	0.356	0.033	0.192[a]	0.121
DF	1.004	0.056	2.299	0.375	4.942	0.542	2.749[c]	1.707
ED	0.217	0.035	0.923	0.100	7.144	0.976	2.761[c]	3.212
ES	0.129	0.039	0.311	0.066	0.271	0.024	0.237[a]	0.091
GD	0.189	0.036	0.468	0.074	1.868	0.177	0.842[b]	0.755
PR	0.526	0.027	0.728	0.060	1.286	0.180	0.846[b]	0.344
TC	0.258	0.037	0.635	0.073	1.772	0.182	0.888[b]	0.664
Total	0.349[A]	0.300	0.780[B]	0.690	2.520[C]	2.429	1.216	1.738

[a] *Data were analyzed by two-way analysis of variance and Tukey test. Different capital letters denote statistically significant difference between shade categories (p<0.05). Different lowercase letters denote statistically significant difference between composite materials (p<0.05).*

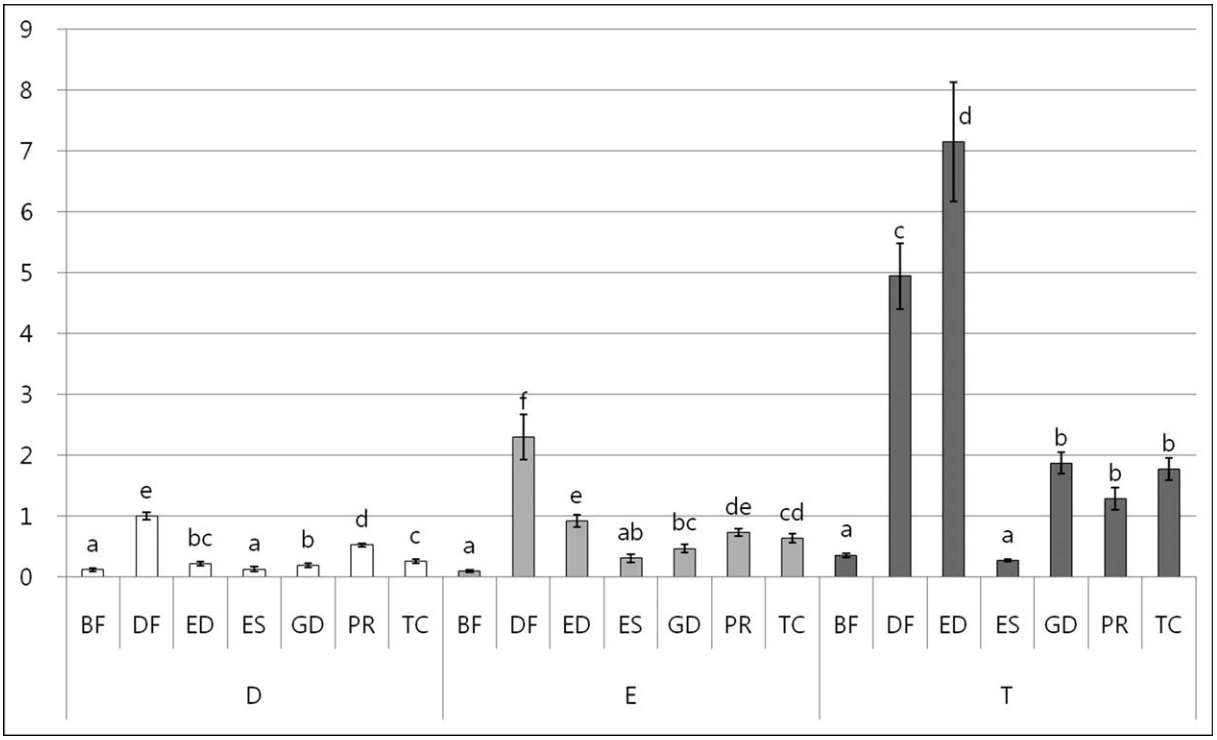

Figure 5. *Light transmittance of composite materials. Data were analyzed using a one-way analysis of variance and Tukey test for the seven composite groups within each shade category. Different letters denote statistically significant differences (*$p < 0.05$*).*

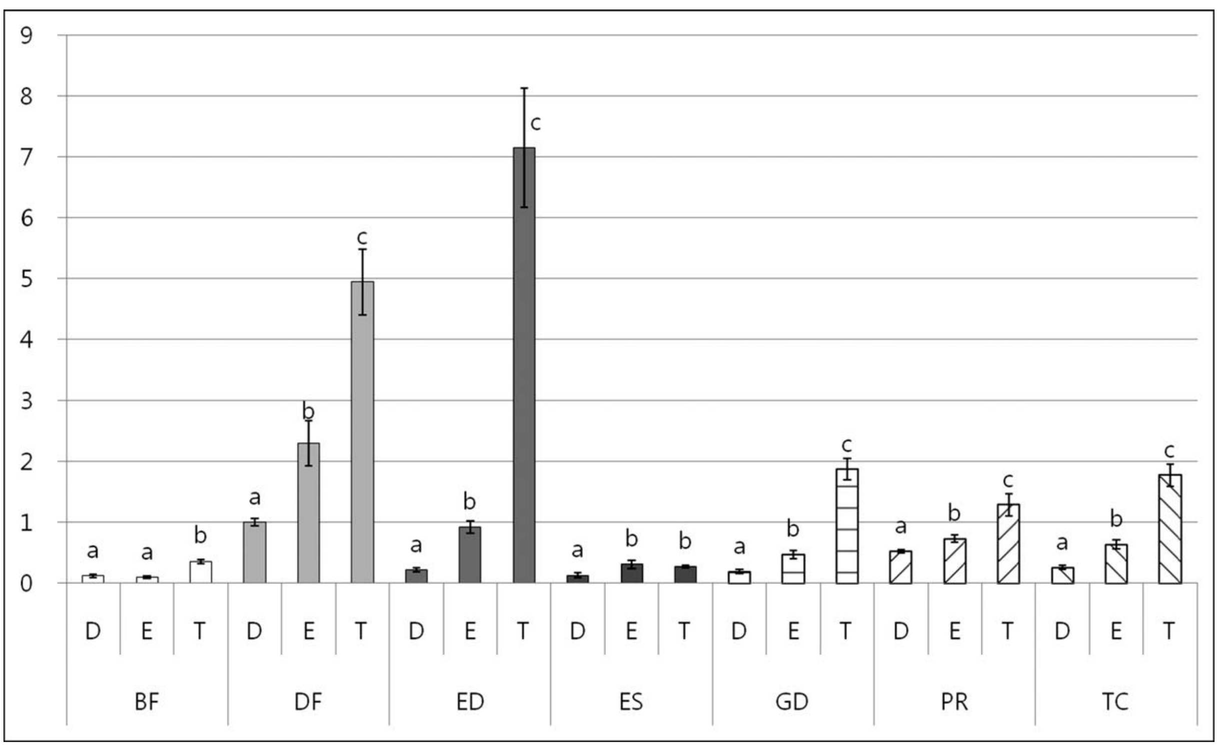

Figure 6. *Light transmittance of shade categories. Data were analyzed using a one-way analysis of variance and Tukey test for the three shade categories within each composite material category. Different letters denote statistically significant differences (*$p < 0.05$*).*

Table 7: *Pearson Correlation Coefficient Between Translucency Parameter and Light Transmittance*

Total (*N*=210)	Correlation Coefficient	Significance
	0.626*	<0.001
Composite (*N*=30)		
BF	0.888*	<0.001
DF	0.927*	<0.001
ED	0.929*	<0.001
ES	0.356	0.054
GD	0.992*	<0.001
PR	0.977*	<0.001
TC	0.763*	<0.001
Shade category (*N*=70)		
Dentin	0.528*	<0.001
Enamel	0.403*	<0.001
Translucent	0.407*	<0.001

* *Correlation is statistically significant.*

The methods showed strong correlation for all composite materials except ES (r=0.763-0.992, p<0.05).

Correlation Within Each Shade Category

The Pearson correlation coefficients for the two methods within each shade category are listed in Table 7.

The methods exhibited moderate correlation within each shade category (r=0.403-0.528, p<0.05).

DISCUSSION

Based on the results of this study, the nanohybrid composites (BF, ED, PR, TC) and microhybrid composites (DF, GD; Tables 2 and 4, Figures 3-6) do not differ in translucency. This finding is consistent with that of a previous study.[23] This property seems to be more material specific than the type of composites.

The main cause of the different translucencies for different materials might be the color difference between the materials. The actual color of each product varies despite the use of the same shades (A3) for all materials. The shades of the translucent composites were chosen as those most similar to the T shade of TC using visual inspection because the other composites had their own referring system in translucent shade. This procedural detail may have contributed to the color differences and might have resulted in larger translucency differences for the translucent shade than the enamel and dentin shades.

According to the manufacturer's instruction, the enamel shade can be used for single-layer restoration and, if necessary, translucent or dentin (opaque) resin can be used as addition in BF, DF, ES, GD, PR, and TC. In contrast, ED is more of a pure layering composite. The difference in the TP and %T values between the dentin, enamel, and translucent shades was greater for ED than for the other materials (Figure 4 and 6). ED exhibited relatively low translucency (TP and %T) for the dentin shade but very high translucency for the enamel shade (highest among all composites in terms of the TP value [Figure 3] and second highest in terms of the %T value [Figure 5]). In other composites, the translucency values in enamel seem to have been lowered for general use.

In class IV or large class III restorations, both dentin and enamel shade resins are usually used, and, if necessary, translucent resins are added in the incisal area to increase the esthetic effect. The dentin shade resins are used in the core or lingual area to mimic the shade of dentin and reduce the light transmission, whereas enamel shades are placed on the labial side to increase the light transmission and mimic the tooth enamel shade. In this sense, the sum of the enamel and dentin translucency may strongly influence clinical performance. If this combined translucency is too high, the dark oral cavity may make the restoration look dark. If the translucency is too low, the restoration may look unnatural. In this study, the sum of the enamel and dentin translucencies is summarized in Table 8. BF had the lowest translucency in terms of both TP and %T. When using BF, the enamel shade should be thicker and the dentin shade thinner to improve the restoration. The sum of translucency was high in DF and ED in terms of TP and DF, ED, and PR in terms of %T. The translucency of the dentin shade in DF was highest and that of the enamel shade was also fairly high. In contrast, ED had a much lower

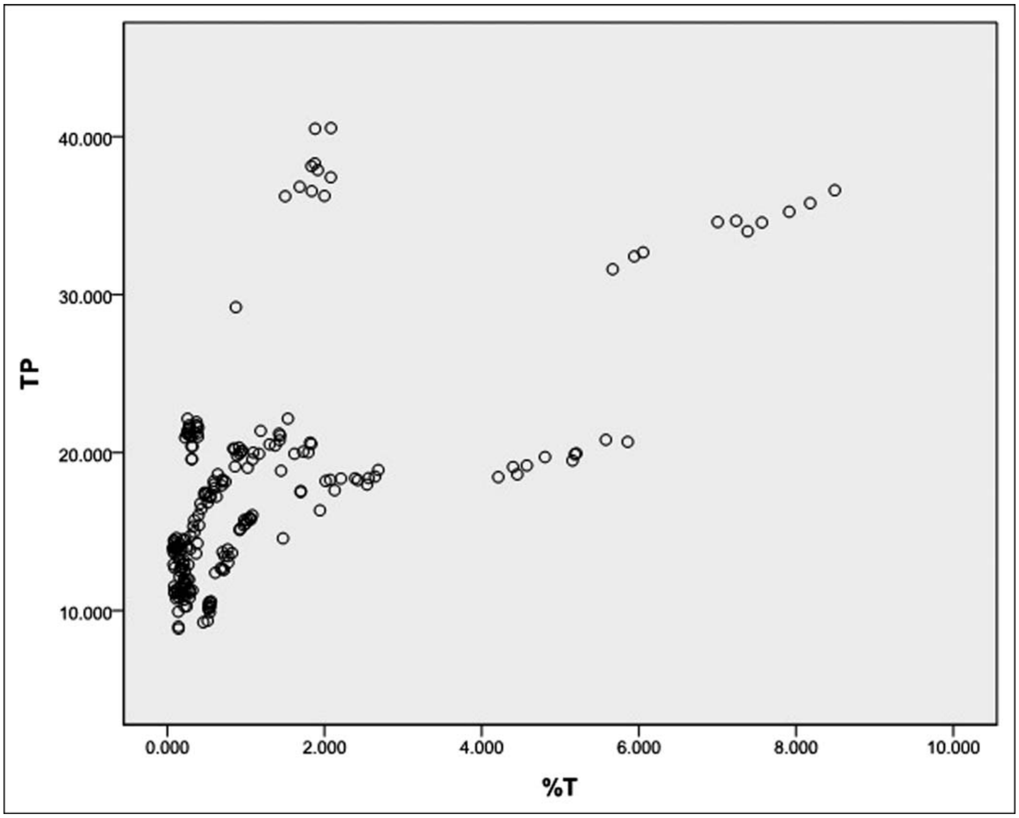

Figure 7. *Correlation between translucency parameter and light transmittance based on all composite specimens.*

translucency for the dentin shade but the highest (TP value, Figure 2) or second highest (%T value Figure 3 and 5) for the enamel shade. Therefore, when using DF, the dentin shade should be thicker and the enamel shade thinner when layering to reduce the total translucency. ED seems to be better optimized for a true layering technique.

The translucency of composite resin is also influenced by the matrix and filler compositions.[5,10,11,31,32] In this study, differences in translucency could be explained by differences in the matrix and filler composition. Azzorpardi and others[27] reported that the amount of Bis-GMA used in the resin matrix had a significant effect on the translucency of silica-filler–containing dental composites. They reported a linear correlation between the percentage of Bis-GMA in the matrix and the total diffuse translucency. Lee[33] reported that TP decreased as the amount of filler increased for a given filler size.

BF, which contains <12.5% resin matrix, less than other products, exhibited relatively low TP and %T. The low resin matrix content might explain the low translucency in BF. ED exhibited intermediate TP and %T for the dentin shade and high TP and %T for the enamel and translucent shades. ED has the least filler of the studied composites (52%-59% filler). The low filler content and the existence of nanofiller might cause the high translucency in ED, especially in the enamel and translucent shades. PR revealed low TP and intermediate %T in all three shade categories. This composite's translucency could be affected by its relatively high filler content (70%) or the presence of prepolymerized filler. TC had low TP for the dentin and translucent shades, high TP for the enamel shade, and intermediate %T for all three shades. Previous reports indicated that the material translucency was high when the refractive indexes of the resin matrix and filler were similar.[34] In TC, barium glass and ytterbium trifluoride provide the radiopacity, with refractive indexes of 1.98 and 1.53, respectively. As the refractive indexes of the resin monomer are between 1.49 and 1.56, the resin monomer is more similar to ytterbium trifluoride than barium glass in terms of refractive index. The use of ytterbium trifluoride would increase the translucency of the composites relative to the use of barium glass alone.[34]

Arikawa and others[35] reported that materials with small, irregularly-shaped fillers showed greater %T

Table 8: *Total Translucency (Enamel Shade + Dentin Shade)*

	Translucency Parameter Value	Light Transmittance Value
BF	24.64	0.22
DF	33.368	3.304
ED	32.77	1.14
ES	28.062	0.22
GD	29.63	0.658
PR	29.168	1.254
TC	28.832	0.894

than those with large, spherically-shaped fillers. Dos Santos and others[25] reported that a composite containing 20 nm filler showed greater %T than that containing 0.6 μm filler. ES is the only composite with relatively large, uniform fillers (not hybrid-type), which may explain its low %T values for the three shade categories. However, the TP of ES was intermediate for the dentin and translucent shades and high for the enamel shade. ES was the only material that did not show a significant correlation between the TP and %T results (Table 7). This lack of correlation seems to be caused by the difference in the translucency shade between TP and %T. The reason for this difference is not clear, but the unique filler morphology in ES might affect the light transmission, reflection, and scattering, which affected the translucency of this composite differently from that of other composites in TP measurement. This issue requires further research.

DF, a microhybrid-type composite, contains the fillers barium silicate (≤1 μm) and fumed silica (0.04 μm). The TP for DF was high for the dentin shade, intermediate for the enamel shade, and low for the translucent shade. The %T results were highest for enamel and dentin and second highest for the translucent shade.

In GD, microhybrid, average filler size is 0.85 μm (Table 1). TP was intermediate for the dentin and enamel shades and high for the translucent shade. %T was low for the dentin shade and intermediate for the enamel and translucent shades. GD is the only product that does not contain radiopaque fillers and appears radiolucent. Whereas this lack of radiopacity might increase the composite translucency because most fillers with radiopacity tend to decrease it, its relative large filler size and microhybrid trait would act in the opposite direction. The result would be a combination of these two opposing factors.

When color is measured using an instrument with a relatively small window of a few millimeters in diameter, a considerable fraction of the light entering the specimen is lost because it emerges at the surface outside of the window of measurement.[36] This edge-loss effect could affect the accuracy of the measurement.[37] A method to minimize the edge-loss effect by the use of plasticine was introduced,[38] producing higher TP values than those obtained by the conventional method.[39] In this study, as the specimen size was much larger than the colorimeter window, the edge-loss effect could be ignored.

Although the TP measurement methodology has been introduced in several studies, there are no background standards for TP measurement. As TP values could be affected by the reflectance of the background material, this method should be standardized more specifically.

In this study, the two methods showed much stronger correlation when analyzed by composite material than when analyzed by shade category, indicating that the translucency was measured more accurately and consistently by both methods when the composite compositions were more similar. However, there was no correlation in ES, which had a unique filler morphology. As composites are developing very rapidly and becoming much more diverse, it will be necessary to develop more advanced methods for the translucency measurement of dental composites.

CONCLUSIONS

Although there was a positive correlation in the translucency measurements of composites using the TP and %T, it is necessary to develop more advanced methods for this measurement because the two evaluation methods did not match well in some composites.

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Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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