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RESEARCH ARTICLE

Light Transmission of Different Resin Composites at Different Thicknesses

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Composite, filler, indirect composites, light transmission, radiometer.

A B S T R A C T

Objectives: The aim of this study was to evaluate the light transmission of different types and thicknesses of composites.

Materials and Methods: Disk-shaped (N = 240, n = 10 per group) samples of ten direct composites (Aelite-Aesthetic -Enamel, Aelite-LS-Posterior, Aelite-All-Purpose-Body, Clearfil-Majesty-ES-2 Classic, Filtek Ultimate-Enamel, Filtek Z-250 Universal, G-ænial Anterior, Gradia Direct, IPS Empress Direct, and Tetric N-Ceram) and two indirect composites (Estenia C&B and Signum-Ceramis) with diameters of 10 mm and thicknesses of 1 and 2 mm were fabricated. The translucency of each sample was determined with a digital radiometer using the direct transmission method and a 1200 mW/cm2 LED beam as the light source. Measurements were repeated three times for each specimen, and the obtained data were analyzed using ANOVA and Duncan multiple range tests ($\alpha = 0.05$).

Results: The materials with the highest light transmission values included the Filtek Ultimate-Enamel (1 mm: 8.36 lux, 2 mm: 4.62 lux), Gradia Direct (1 mm: 8.57 lux, 2 mm: 4.65 lux), and Tetric N-Ceram, while those with the lowest light transmission values included the Aelite-All-Purpose-Body (1 mm: 2.89 lux, 2 mm: 1.21 lux) and Estenia C&B composites.

Conclusions: The type of composite, as well as the particle size and filler content, significantly affected the light transmission characteristics.

Keywords: Composite, filler, indirect composites, light transmission, radiometer.

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INTRODUCTION

Light-cured dental resin composite restorative materials are widely used in dentistry to create permanent tooth-colored restorations.[1,2] Dental resin composites applied directly or indirectly occupy a paramount position and present acceptable clinical performance with much lower costs than their ceramic counterparts.[3-4] A dental composite resin typically comprises an organic resin matrix, inorganic filler particles, silane coupling agents, and photo-polymerization initiators and activators.[5,6] Dental composites have typically been classified according to their filler characteristics, particularly the particle size. Currently, three categories have been proposed for resin composite filler particles: microfilled composites, microhybrid composites, and nanocomposites (nanofilled or nanohybrid resin composites).[7,8] Microhybrid composites are composed of high density fillller particles of different sizes (15–20 μm and 0.01–0.05 μm) and have good mechanical properties, but relatively poor aesthetic qualities.[8,9] Microfilled composites have been developed to obtain high-quality aesthetic materials, but have relatively poor mechanical properties. The average particle size of these composite filler particles falls in the range 0.01-0.05 μm.[9-11] Nanocomposites or submicroncomposites have increased filler loadings and reduced organic matrix contents, and, consequently, improved mechanical and optical characteristics. Their average particle size falls in the range 20–75 nm. Nanofill is a composite resin that is composed of both nanomers and nanoclusters, whereas a nanohybrid is a hybrid resin composite with a nanofiller in a prepolymerised filler form.[11-13]

Given the aesthetic requirements for different direct and indirect composite systems, light transmission should be considered. Nanometer-sized filler particles improve the optical properties of composite resins because their diameters are much smaller than the wavelength of visible light, and thus they cannot be seen by the human eye.[13,14] When light illuminates a resin composite, it is scattered at the surfaces of the filler particles, diffuses in multiple directions, and can be detected as diffuse transmission and straight-line transmission.[15,16] For composite restorations, particularly those used to restore missing natural enamel, the thickness is also critical, because a slight increase in the thickness may significantly change the light transmission and color value of the restoration.[17,18]

It is important to note that the final results of any restoration depend on the thickness and the degree of light transmission of the composite. Among commercial brands, there is no general agreement on the translucency levels of composite resins or their designations. There have also been no reports in the literature that establish standards for these materials.[17,19,20] The aim of this in vitro study was therefore to evaluate the light transmission of different types and thicknesses of resin composites. It was expected that the amount of transmitted light would differ for both direct and indirect composites with different filler loadings, resin matrices, and thicknesses.

MATERIALS AND METHODS

Specimen preparation

Disk-shaped (N = 240, n = 10 per group) samples of ten direct composites (Aelite Aesthetic Enamel, Aelite LS Posterior, Aelite All-Purpose Body, Clearfil Majesty ES-2 Classic, Filtek Ultimate Enamel, Filtek Z 250 Universal, G-ænial Anterior, Gradia Direct Posterior, IPS Empress

Direct Dentin, and Tetric N-Ceram) and two indirect composites (Estenia C&B and Signum Ceramis) with diameters of 10 mm and thicknesses of 1 and 2 mm were fabricated in shade A2. The tested materials, their chemical compositions, manufacturers, and batch numbers are listed in Table 1.

Table 1. *Brand names, manufacturers, batch numbers, and types of organic matrices and inorganic filler for the direct and indirect resin composites used in this study (as provided by the manufacturers)*

No.	Brand	Manufacturer (Batch number)	Type (Direct/Indirect)	Organic Matrix	Filler
1	Aelite All-Purpose Body	Bisco Inc., Schaumburg, IL, USA (1300008846)	Microhybrid (Direct)	Ethoxylated bis-DMA, TEGDMA	Glass filler, amorphous silica (76 wt%)
2	Aelita Aesthetic Enamel	Bisco Inc., Schaumburg, IL, USA (1300008896)	Nanohybrid (Direct)	Bis-GMA, Bis-EMA	Glass filler, amorphous silica (73 wt%)
3	Aelite LS Posterior	Bisco Inc. Schaumburg, IL, USA (1300006911)	Hybrid (Direct)	Ethoxylated bis-GMA	Glass filler, amorphous silica (88 wt%)
4	Clearfil Majesty ES-2 Classic	Kuraray Medical Inc., Tokyo, Japan (0014A)	Nanohybrid (Direct)	Bis-GMA, dimethacrylate	Barium glass, silica (78 wt%)
5	Estania C&B	Kuraray Medical Inc. (000433)	Hybrid (Indirect)	UTMA, Methacrylate	Surface treated alumina micro filler, silanated glass ceramic filler (92 wt%)
6	Filtek Ultimate Enamel	3M ESPE, St. Paul, MN, USA (N251021)	Nanohybrid (Direct)	Bis-GMA, UDMA, TEGDMA, Bis-EMA	Silica, zirconia (72,5 wt%)
7	Filtek Z 250 Universal	3M ESPE, St. Paul, MN, USA (N587651)	Microhybrid (Direct)	Bis-GMA, UDMA, Bis-EMA	Silica, zirconia (82 wt%)

bis-DMA: Bisphenol A dimethacrylate; TEGDMA: Triethyleneglycol dimethacrylate; bis-GMA: Bisphenol A diglycidyl methacrylate; ArDMA: Aromatic dimethacrylates UDMA: Urethane dimethacrylate; bis-EMA: Bisphenol A diethoxymethacrylate; TEGMA: Triethylene glycole dimethacrylate; PEGDMA: Polyethylene glycol dimethacrylates; UDMA: Urethane dimethacrylate; UTMA: Urethane tetramethacrylate.

Each specimen was prepared using a stainless steel mold in one step. In order to prevent any voids, a glass plate was gently pressed over the mold, and the composite was photopolymerized using an LED polymerization unit (Elipar Freelight 2, 3M ESPE, St. Paul, USA) for 40 seconds from each direction after removal of the stainless steel mold. Post-polymerization of the indirect composites was performed in a universal laboratory polymerization unit (Blue Thunder, Toei Electric Co., Ltd, Kanagawa-Ken, Japan) at 250 W using 3 halogen lamps at wavelengths ranging from 350–550 nm for 3 min. All specimens were polished using 600 and 1000 grit silicon carbide paper (SiC, Struers GmbH, Willich, Germany) and then cleaned ultrasonically in 70% ethyl alcohol. The thickness of each sample was determined using a digital micrometer (Mitutoyo America Corporation, Aurora, IL, USA) in order to confirm that it remained within the critical tolerance of 0.01 mm. All of the composite specimens were stored dry in the dark at room temperature for 24 hours prior to light transmission analysis.

Light transmission measurements

The translucency of each sample was determined by measuring its direct transmission of a band of light generated by an LED (3M Espe Elipar^{tm} Freelight 2, Germany) with an output power of 1200 mW/cm^2.[21] Each polymerization light had a light guided, 7.4-mm-diameter tip. The power irradiated by the LED without the interposition of the composites and the distances (2 mm and 1 mm) between the light tip of the unit and the digital radiometer (SDI LED Radiometer; SDI Dental Limited Australia; spectral range: 400 to 525 nm) were the same as those for the sample groups. The sample diameter was the same as the distance from the radiometer's optical eye. To avoid any light losses, appropriate silicon impression materials were prepared around the light tips, and the specimens were embedded in silicon (Fig. 1). Each sample was placed on the radiometer and irradiated for 20 s to determine the light transmission. The measurement was repeated three times for each specimen, and the average was value was recorded in units of mW/cm^2. The translucency was repeated for the same material at the second thickness, and then the obtained data were converted to light units (lux).

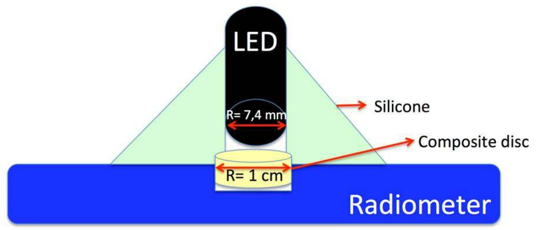

Fig.1. *Schematic diagram of the experimental setup for light transmission determination using a radiometer.*

Statistical analysis

All statistical analyses were performed using SAS version 9.3. To obtain descriptive statistics and normality tests, results were expressed as Proc Means and Proc Univarite commands, respectively. Factorial ANOVA was used to compare the mean results for the twelve groups of samples with different thicknesses in order to determine whether they differed significantly from one another ($p < 0.05$). Duncan's test was used for multiple comparisons. To compare thickness means within each group was used two independent sample t test method with Proc TTEST. One-way ANOVA was used to analyze the means of the translucency ratios of the groups. The factorial ANOVA, One-way ANOVA, and Duncan results were analyzed using Proc GLM in SAS.

RESULTS

Table 2 lists the light transmission data (means and standard deviations) for the 1- and 2-nm-thick samples of the investigated materials. Light transmission was significantly affected by the composite type ($p < 0.05$) and thickness ($p < 0.001$). Interaction between these two factors was also significant ($p < 0.001$). Furthermore, for both thicknesses, there were statistically significant differences ($p < 0.05$) between the direct composite group (1 mm: 2.82 lux–8.57; 2 mm: 1.21–4.75 lux) and the indirect composite group (1 mm: 3.6–5.89 lux; 2 mm: 1.31–2.81 lux).

Table 2. *Light transmission values (means and standard deviations (SD)) for the resin composite samples used in this study. Different lowercase letters in the same column indicate significant differences (p < 0.05). Different uppercase letter in same row indicate significant differecences at p < 0.05 level.*

No.	Materials	Mean± (SD)(lx) 1 mm.	Mean± (SD)(lx) 2 mm.	(Mean1-Mean2) Difference±SD	Percentage change(%)
1	Aelite All-Purpose Body	2.89 ± 0.22^{h}	1.21 ± 0.06^{f}	$1.68\pm0.16^{**}$	57 ± 0.04^{b}
2	Aelite Aesthetic Enamel	4.25 ± 0.27^{f}	1.79 ± 0.09^{e}	$2.46\pm0.20^{**}$	57 ± 0.03^{b}
3	Aelite LS Posterior	2.82 ± 0.24^{h}	1.81 ± 0.14^{e}	$1.01\pm0.20^{**}$	35 ± 0.05^{h}
4	Clearfil Majesty ES-2 Classic	6.35 ± 0.22^{d}	3.14 ± 0.31^{c}	$3.21\pm0.27^{**}$	$50\pm0.04^{c.d}$
5	Estania C&B	3.60 ± 0.19^{g}	1.31 ± 0.16^{f}	$2.29\pm0.18^{**}$	63 ± 0.06^{a}
6	Filtek Ultimate Enamel	$8.36\pm0.43^{a.b}$	4.62 ± 0.26^{a}	$3.74\pm0.36^{**}$	$44\pm0.03^{g.f}$
7	Filtek Z 250 Universal	7.11 ± 0.23^{c}	$3.69\pm0.0.1^{b}$	$3.41\pm0.29^{**}$	$47\pm0.05^{d.e.f}$
8	G-ænial Anterior	7.21 ± 0.33^{c}	3.67 ± 0.21^{b}	$3.54\pm0.28^{**}$	$49\pm0.02^{d.c.e}$
9	Gradia Direct	8.57 ± 0.41^{a}	4.65 ± 0.25^{a}	$3.92\pm0.34^{**}$	$45\pm0.03^{f.e}$
10	IPS Empress Direct Dentin	4.24 ± 0.17^{f}	1.86 ± 0.11^{e}	$2.38\pm0.14^{**}$	56 ± 0.03^{b}
11	Signum Ceramis	5.89 ± 0.31^{e}	2.81 ± 0.27^{d}	$3.08\pm0.29^{**}$	52 ± 0.03^{c}
12	Tetric N-Ceram	8.14 ± 0.44^{b}	4.75 ± 0.24^{a}	$3.38\pm0.35^{**}$	41 ± 0.03^{g}
	Total	5.78 ± 2.08^{A}	2.94 ± 1.30^{B}	$2.84\pm1.71^{**}$	50 ± 0.08

**: $p<0.0001$ (p value from independent samples t test)

The light transmission values for all of the 1-mm-thick specimens were higher than those for the 2-mm-thick specimens. ($p<0.0001$).

The highest light transmission values were observed for the Gradia Direct (1 mm: 8.57 lux., 2 mm:4.65 lux.), Filtek Ultimate Enamel (1 mm:8.36 lux., 2 mm: 4.62 lux.), and Tetric N-Ceram (1 mm:8.14 lux., 2 mm:4.75 lux.). Aelite All-Purpose Body (1 mm 2.89 lux., 2 mm:1.21 lux.) and Estenia C&B (1mm 3.6 lux., 2 mm:1.31 lux.), resin composites had the lowest light transmission values. Furthermore, the Estenia C&B and Aelite LS Posterior samples exhibited the least change in the maximum percent light transmittance when the thickness was increased (0.63 and 0.35, respectively; $p < 0.05$).

DISCUSSION

In the present study, the light transmission of direct and indirect composites with different chemical compositions was investigated as a function of composite thickness using digital radiometer measurements. Because the results were significantly affected by the composite type, the null hypothesis could be rejected. Typical dentin composites are constructed using high-opacity composite resins with a translucency close to that of natural dentin. Other composites are composed of composite resins that have translucency, opacity, and chromaticity values similar to those of natural dental enamel. There are also composite resins referred to as enamel or incisal composites that have higher than normal translucencies for matching the high translucency areas in restorations.[20-23] In the present study, the Filtek Ultimate Enamel composite, an enamel composite, exhibited one of the highest light transmission values. The other enamel composite, the Aelita Aesthetic Enamel, was found to have a relatively low light transmission value, but its light transmission was still greater than that of the Aelite All-Purpose Body and Aelite LS Posterior materials, which are made by the same company. The IPS Empress Direct Dentin composite exhibited a very low light transmission value, below those of materials in the enamel composite group. Friebel et al.[(24)] recommended the use of a dentin composite for front teeth in order to mask the dark background of the oral cavity. They also suggested the inclusion of a 1–2 mm translucent edge at the crown of the tooth using a layering technique with translucent enamel shades in order to make the reconstruction appear more natural.

In recent years, nanomaterials have captured increasing attention because of their unique structures and properties. Nanohybrid resin composites have been reported to have high translucency because the particles are smaller than the wavelength of light and cause minimal or zero scattering of photons.[25,26] In fact, in the present study, similar results were obtained. Among the indirect composites, the Signum Ceramis hybrid-type composite specimens exhibited significantly higher light transmission than the Estenia C&B hybrid-type composite at both thicknesses.

The optical properties of a composite resin comprising different transparent base monomers and filler particles are characterized by the differences in the optical properties of the resin matrix and the filler particles. Furthermore, the filler causes changes in the physical characteristics of light transmittance that influenced the color of resin composites.[27,28] The fact that the Estenia C&B indirect composite, which is a hybrid composite, exhibited the lowest light transmission values at both thicknesses can be attributed to the higher percentage of ceramic microfillers (92 wt%) with a particle size of 2 µm.

The depth of cure of a composite resin is affected by the amount of light that reaches the photoinitiator. The intensity of the light decreases as it passes through the material. Fillers and pigments strongly influence the intensity of the incident light, limiting the depth of cure.[29] Furthermore, as emphasized by Vichi et al.,[30] thickness is a crucial factor affecting the final aesthetic result. Thus, to achieve the effective reproduction of the aesthetic aspects of natural teeth, texture, thickness, opacity, and translucency are important characteristics that must be considered. The present outcomes revealed that the decrease in light transmission was dependent on the composite thickness, confirming the tested hypothesis. Thus, the thickness of the composite materials used must be taken into consideration during treatment in order to obtain the desired light transmission.

Some researchers have indicated that blue light-curing units with a minimum power irradiance of 300 mW/cm^2 are effective for the photoactivation of composite materials.[31-32].The ISO 4049 standard does not have any standard for the minimum light intensity for photoactivation, but does recommend that manufacturers' instructions should be followed.[31-33] The power irradiance of the light-curing unit used in the present study was 1200 mW/cm^2, which is higher than the minimum indicated in previous studies.

This in vitro study on composite translucency may be limited due to lack of clear clinical relevance. The esthetic appearance of the transluecency can be altered by the thickness, color, surface texture, adesiv and base material of composite resin restorations. Further studies will be required to investigate the variations in light transmission properties between resin composite and tooth structure.

CONCLUSION

Based on the results of the present study, the following conclusions can be drawn:

1. Light transmission was affected by the composite type, filler particles, volume, and contents.

2. Light transmission through the composite resins was significantly reduced as the specimen thickness increased as measured using an LED polymerization unit.

3. Among the composite resins investigated the direct nanohybrid Filtek Ultimate Enamel and the indirect hybrid composite Estenia C&B exhibited the highest and lowest light transmission values, respectively.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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